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GEOLOGY OF THE TULLOCK CREEK COAL FIELD

ROSEBUD AND BIG HORN COUNTIES MONTANA

BY

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AND
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GEOLOGY OF THE TULLOCK CREEK COAL FIELD, ROSEBUD AND BIG HORN COUNTIES, MONTANA.

By G. Sherburne Rogers and Wallace Lee.

INTRODUCTION.

SCOPE OF REPORT.

The field work on which this report is based occupied two seasons. Although most of the time was spent in examining and mapping the coal beds, considerable information concerning the general geology was also gathered. The strata are well exposed in this field, and in most localities 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 writers. 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 make this report fairly complete.

The report is divided into two parts—a general geologic description of the field and 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 Tullock Creek coal field (Fig. 1), as defined for the purposes of this report, lies on the east side of Big Horn River, Mont., in the angle formed by its junction with the Yellowstone. The district examined, which comprises 900 square miles, extends on the east to about the center of R. 38 E. and is approximately bounded on the south by the Montana base line. The coal is contained in the Lance and Fort Union formations. In the Lance it occurs in beds less than 5 feet thick, but in the Fort Union some beds are over 20 feet

thick. The heating value of the coal in the two formations is about the same, approximately 10,000 British thermal units.

Although time was not available for continuing the examination farther south and east, it is known that the same coal-bearing strata extend far beyond the limits of the field in these directions. West of the Tullock Creek field, however, lower strata, barren of coal, constitute the surface rocks for a long distance, except within a small outlying area about 8 miles west of Big Horn River, known as Pine Ridge. The Tullock Creek field thus occupies a position on the western edge of the great Powder River and Fort Union coal regions, which extend practically without a break from Big Horn River to points several hundred miles east of the Dakota line. The coal is

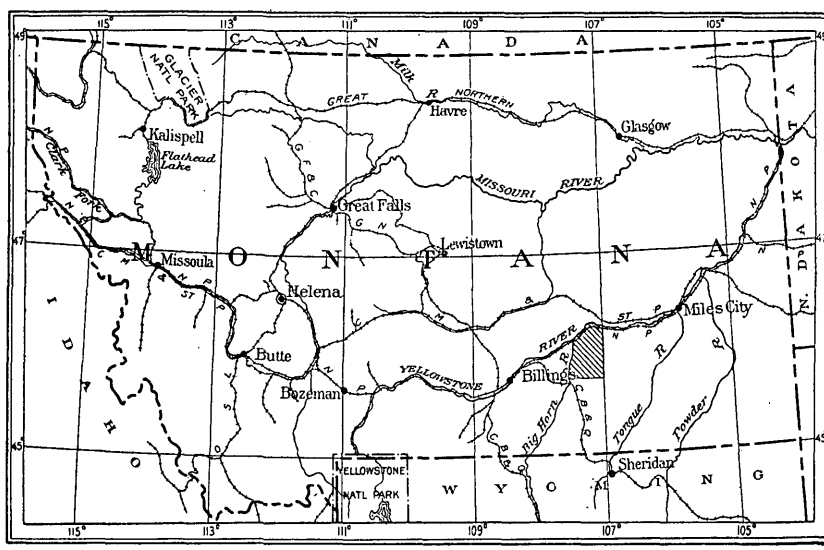


FIGURE 1.—Index map showing location of Tullock Creek coal field, Mont.

not uniform in quality throughout this great area, however, but grades imperceptibly from a brownish lignite in the Dakotas to a black lignite in the extreme eastern part of Montana and finally to a true subbituminous coal along the western margin of the area. The subbituminous coal of the Tullock Creek field is thus of higher rank than that found in near-by fields to the east, and compares favorably with the commercial varieties now sold in neighboring markets and derived mostly from isolated fields still farther west.

The geographic relations of the Tullock Creek coal field are shown on the accompanying index map (Fig. 1). The field consists of the part of the lands ceded to the Government by the Crow Indians in 1904 lying east of Big Horn River, an area of 900 square miles. The eastern boundary of the field is the east line of the original reserva-

tion, and its southern boundary a line drawn east from the northeast corner of the Fort Custer Military Reservation. The township subdivisions comprised in whole or in part are Tps. 1 S., 1, 2, 3, 4, 5, and 6 N., Rs. 35, 36, 37, and 38 E.; Tps. 1 S., 1, 2, 3, 4, and 5 N., R. 34 E.; and Tps. 1 S., 1, 2, and 3 N., R. 33 E., Montana principal meridian. The area originally lay entirely within Rosebud County, but a part of it was included in Big Horn County, organized in 1913.

STATUS OF THE LAND.

The Crow Indian Reservation, as originally defined by treaty with the Crow Indians, concluded and ratified by Congress in 1868,[1] consisted of a roughly triangular area lying between the 107th meridian, the southern boundary of Montana, and Yellowstone River. By a subsequent treaty this area was considerably enlarged, but by still later treaties it has been successively reduced, principally on the south and west. In 1899 an agreement with the Indians was reached for the cession of the northern part of the reservation to the Government in consideration of an expenditure of $1,150,000 on irrigation projects, stock, fences, schools, etc., for the Indians. This agreement was ratified by Congress April 27, 1904, and in October, 1910, a part of the ceded land was thrown open for sale in accordance with this act. The remainder, which comprised those parts lying within the ceded areas of Tps. 1 S., 1, 2, 3, 4, and 5 N., R. 36 E., and Tps. 1 S., 1, 2, 3, and 4 N., Rs. 37 and 38 E., had previously been withdrawn from entry as possible coal lands and reserved for special examination.

On July 13, 1912, on the recommendation of the United States Geological Survey, parts of Tps. 1 to 4 N., Rs. 34 and 35 E., not yet sold (the land adjoining on the west that previously withdrawn) were ordered withheld from sale until examined for coal. During the summer of 1912 a party in charge of G. Sherburne Rogers examined this land and classified it as to its mineral character. In October of the same year a sale of the noncoal land classified during the summer, together with the lands not formally withdrawn or previously sold, was ordered, and at this time most of the noncoal land west of Tullock Creek passed into private hands. During the summer of 1913 the lands affected by the formal withdrawal were examined, so that now all the land in the ceded portion of the Crow Indian Reservation has been definitely classified.

Of the 575,881 acres included in the Tullock Creek field, 117,301 acres, or about 20 per cent, has been classified as coal land.

[1] U. S. Stat. L., vol. 15, p. 649.

FIELD WORK.

The Tullock Creek field, as implied above, was examined primarily for the purpose of land classification, and the field work was therefore sufficiently detailed and accurate to satisfy the exacting requirements of this work. The land was first thoroughly prospected for coal, all beds 18 inches or more in thickness being considered of sufficient value to mine at the present time. Sections of the coal beds were measured at intervals of about half a mile along the outcrop where possible, although these intervals were, of course, varied to meet local conditions. Thus it was generally not practicable to obtain complete sections of the very thick coal beds of the Fort Union formation at such intervals, as complete exposures of the beds are rare, and a considerable amount of digging is usually necessary to expose the coal. The outcrops of all beds more than 18 inches thick were meandered by plane-table and stadia methods, and the traverses were tied to land corners. The use of the plane-table and telescopic alidade also permitted carrying lines of altitudes from the Northern Pacific Railway along the northern edge of the field to all its parts. These altitude lines are not necessarily accurate when carried for long distances, and those in the southern part of the field may be as much as 50 feet in error, but they were nevertheless of inestimable value in correlating the coal beds and other strata from point to point and in working out the details of the structure. In carrying these altitude lines across noncoal-bearing areas in the field it was also possible at the same time to map the boundaries of the geologic formations with an accuracy scarcely less than that attained for the coal beds.

The Fort Custer quadrangle, of which a contour map was published by the United States Geological Survey in 1894, includes a small area in the southwestern part of the field. Owing partly to the small scale of this map (1:125,000) but chiefly to the fact that it could not be satisfactorily tied to the land lines, which were surveyed at a later date, it was not used either in the field or in the preparation of the maps accompanying this report.

In accordance with the act of October 15, 1904, already referred to, the ceded lands were subdivided by the General Land Office in 1904 and 1905. All the surveys made by the writers in connection with the geologic field work were tied to the section corners placed at that time, and, in so far as a check was thus afforded, the land survey seems to be accurate and reliable. Practically every corner stone searched for was found, and all stones are well marked.

The field work was in charge of G. S. Rogers. During the season of 1912 he was assisted by H. M. Robinson, W. C. Mansfield, and A. H. Sloan; in 1913 by Wallace Lee, R. C. Moore, and A. H. Sloan.

PREVIOUS WORK.

In 1906 N. H. Darton described the geology of the Big Horn Mountains and gave a detailed account of the stratigraphy of the area,[2] which is only 30 miles south of the Tullock Creek coal field. Detailed work was done in the Bull Mountain coal field in 1907 by L. H. Woolsey,[3] in 1908 by R. W. Richards,[4] and in 1909 by C. T. Lupton.[5] The southeast corner of that field is only 15 miles northwest of the Tullock Creek field, and the stratigraphic sections observed in the two areas are essentially the same. In 1911 G. S. Rogers[6] examined the Little Sheep Mountain coal field, 23 miles to the northeast, where similar beds were found to outcrop. In 1913, as a continuation of the work in the Tullock Creek field, the party in charge of Mr. Rogers examined an area of 125 square miles in the western angle formed by Yellowstone and Big Horn rivers. Owing to the fact that only a part of the coal land on the west side of the Big Horn was examined the report on this area was published separately.[7] Other fields containing coal at the same stratigraphic horizon farther south, east, and north have been examined but on account of their distance do not immediately concern this area.

GEOGRAPHY.

LAND FORMS.

This region is in a broad way a maturely dissected plateau, across which Yellowstone and Big Horn rivers have cut wide valleys. The Tullock Creek field is to a certain extent a natural unit, being bounded on the west by Big Horn River, on the north by the Yellowstone, and on the east in a general way by the divide that separates roughly the drainage basins of Big Horn and Tongue rivers. This divide in T. 1 N., R. 38 E., is high and rough and is known as Wolf Mountain; north of this field it is considerably lower, or about equal in height to the ridges between the smaller creeks.

The altitude of the town of Sanders, on Yellowstone River near the mouth of Sarpy Creek, is 2,598 feet, and that of the town of Big Horn, near the mouth of Big Horn River, 2,692 feet. The forked end of the divide between Tullock and Sarpy creeks rises rather

[2] Darton, N. H., Geology of the Big Horn Mountains: U. S. Geol. Survey Prof. Paper 51, 1906.

[3] Woolsey, L. H., The Bull Mountain coal field, Mont.: U. S. Geol. Survey Bull. 341, pp. 22–77, 1909.

[4] Richards, R. W., The central part of the Bull Mountain coal field, Mont.: U. S. Geol. Survey Bull. 381, pp. 60–81, 1910.

[5] Lupton, C. T., The eastern part of the Bull Mountain coal field, Mont.: U. S. Geol. Survey Bull. 431, pp. 163–189, 1911.

[6] Rogers, G. S., The Little Sheep Mountain coal field, Mont.: U. S. Geol. Survey Bull. 531, pp. 159–228, 1913.

[7] Rogers, G. S., Geology and coal resources of the area southwest of Custer, Yellowstone and Big Horn counties, Mont.: U. S. Geol. Surv. Bull. 541, pp. 316–328, 1914.

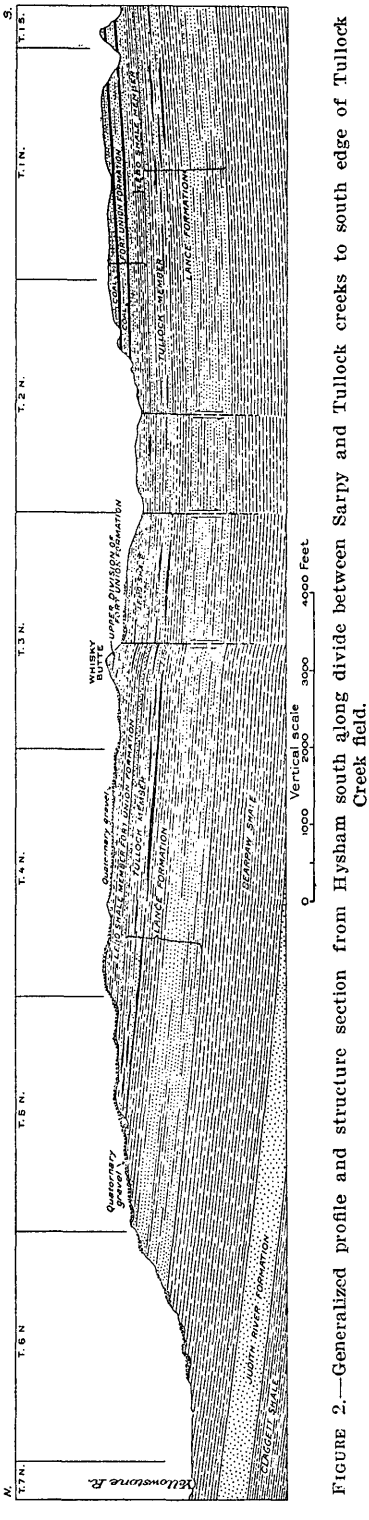


FIGURE 2.—Generalized profile and structure section from Hysham south along divide between Sarpy and Tullock creeks to south edge of Tullock Creek field.

steeply from the flat river flood plain and attains within about 12 miles a height of 900 to 1,000 feet above the river, or 3,600 to 3,700 feet above sea level. This and the other large divides maintain about this altitude throughout the field, rising to the south only about 100 feet more in the next 25 miles. (See Fig. 2.) The interstream divides also rise sharply from the creek bottoms and are in general broad, flat, and well grassed; the geologic reason for this condition is discussed below. Wolf Mountain, which lies in T. 1 N., R. 38 E., about 3 miles east of the field, rises some 500 feet above the highest point in the field. In the northern part of the field the relief between the stream valleys and the nearest points on the crests of their divides is as much as 800 feet, but toward the south it decreases to about 500 feet.

Throughout the field a more or less striking difference was observed between the character of the south and west slopes of the hills and the north and east slopes. (See Pl. V, *A*.) The south and west slopes receive the greater part of the sun's heat, which in the spring causes rapid melting of the snow, with consequent washing and gullying, and which operates again in the summer to absorb the moisture and retard the growth of trees and grasses. These slopes are therefore generally bare of soil, and their drains are steeply graded, so that erosion is rapid. On the north and east slopes there is less gullying, and conditions are more favorable to plant growth; these slopes are therefore generally grassed over and are decidedly more gentle.

DRAINAGE AND WATER SUPPLY.

The field is drained by Yellowstone and Big Horn rivers and their tributary creeks. (See map, Pl. X, in pocket.) The largest of these streams, Tullock and Sarpy creeks, flow in a general northerly direction, and drain the western and eastern parts of the field, respectively. The north end of the divide between these two main drainage lines is dissected by several smaller northward-flowing creeks, among which are Unknown and Box Elder creeks and Forty-four Coulee. The western edge of the field is drained by a number of small creeks that flow roughly at right angles to the main drainage lines and empty into Big Horn River. From south to north the chief valleys are those of Ninemile Creek, Cottonwood Creek, Eighteenmile Creek, and Pocket Creek.

Tullock Creek is a perennial stream about 50 miles long, which within the field flows slightly west of north and empties into Big Horn River about 2 miles above its junction with the Yellowstone. West Burnt Creek, Meadow Creek, Lazyman Creek, and West Cabin Creek, named in order from north to south, enter Tullock Creek from the west side, and Lightning Creek, East Burnt Creek, Cottonwood Creek, Plum Creek, and East Cabin Creek enter it from the east. None of these tributaries are more than 5 miles long, and all of them are intermittent streams. Sarpy Creek, which drains the eastern part of the field, has an almost straight course northward through the center of R. 37 E. to its junction with Yellowstone River. Of its tributaries, West Corral Creek, West Bear Creek, West Beaver Creek, West Passage Creek, Rainwater Creek, Pleasant Creek, and Spring Creek, named in the order of their distance from its mouth, enter it from the west. East Corral Creek, East Bear Creek, East Beaver Creek, East Passage Creek, Horse Creek, and East Sarpy Creek enter in the same order from the east. None of these streams are more than 5 or 6 miles long except East Sarpy Creek, which is a perennial stream extending some distance outside the field. Tullock and Sarpy creeks have made flood plains ranging in width from three-quarters of a mile to 1½ miles, and along their tributaries there are many small flat bottoms or flood plains.

The flood plains of Yellowstone and Big Horn rivers average nearly 5 miles in width, but the rivers meander sharply from side to side and confine the bottom land to small areas alternately arranged on the opposite banks. The largest area of bottom land is that extending from Myers to the eastern border of the field, a distance of 16 miles. This tract is about 4 miles wide near Hysham. Between Myers and the mouth of Unknown Creek Guy's Bluffs rise sheer above the Yellowstone to heights of from 150 to 350 feet. Extending from Unknown Creek to the mouth of the Big Horn is the

plain on which the town of Big Horn stands. Big Horn River generally flows in this region near the east side of its flood plain, so that its eastern bank is generally steep. However, at Mission Bottom, at Oldhorn Bottom, and near the mouth of Ninemile Creek small areas of alluvium lie in the old meanders of the river.

Tullock and Sarpy creeks are practically perennial streams and afford a small supply of water throughout the year, although the flow almost ceases in the dry season. The water is sufficient for grazing and domestic purposes, and on the lower courses of these creeks small areas of land are under irrigation. The water of Tullock Creek is fairly good for drinking, but that of Sarpy is decidedly more alkaline, and many of the settlers in this valley derive their drinking water by melting ice cut and stored in the winter. Springs are not uncommon throughout the field, but all the water is more or less alkaline.

The distribution of the springs is notably affected by the character of the underlying rocks. Thus a particularly favorable horizon is the base of the sandstone that forms the cap rock of the Lance formation (see Pl. X), and seepages or springs occur in nearly every coulee that cuts back into this bed. On the other hand, in the Lebo shale member of the Fort Union formation springs are rare, and the value of those known is diminished by the chalybeate character of the water. The so-called Iron Springs, near the edge of T. 2 N., R. 37 E., are good examples. The water probably derives its iron from the numerous limonite concretions characteristic of the Lebo beds. In the upper division of the Fort Union the distribution of the seepages is influenced by the coal beds, the horizon of bed M being particularly favorable. In the lower part of the Lance formation the distribution of the springs is irregular, and in the areas underlain by the Bearpaw, Judith River, and Claggett formations the few known springs are small and the water is strongly alkaline. The structure of the rocks also influences the movement of the underground water, which tends to flow down the dip; thus, on the west side of the Tullock-Big Horn divide, in which the strata dip slightly to the east, there are few springs, whereas on the east side springs are relatively numerous. The same is true to a lesser degree of the Sarpy-Tullock divide, and the influence on the underground water of many of the other structural features described below may be detected in the distribution of the springs. Although there are not many strong natural springs of good water in the Tullock Creek field, very few places in the field are more than 2 miles from water, and there is no doubt that water can be obtained in shallow wells sunk in the small coulees almost anywhere in the field.

TIMBER.

The distribution of timber throughout the field is irregular and is controlled largely by the geology. In the areas underlain by the Bearpaw and Claggett formations and the Lebo shale (see Pl. X) there are practically no trees except a few cottonwoods along the creeks. In the areas underlain by the Lance formation, which contains many sandstone beds, small pine trees are plentiful, being especially abundant on the slopes. In the district underlain by the upper division of the Fort Union, however, the heaviest growths of timber occur, and there are many sections in T. 1 N., Rs. 37 and 38 E., that may properly be described as forested. Nearly all the trees on the upland slopes are pines, cedars being rare and cottonwoods being confined to the creek bottoms. Most of the pine is valuable only for mine timber or other rough lumber or for firewood, as few of the trees attain a diameter greater than 18 inches at the butt.

The field as a whole is fairly well grassed, with the exception of the districts underlain by the Bearpaw and Claggett formations and the Lebo shale. These strata, which consist chiefly of shale and are therefore relatively impervious to surface drainage, contain a considerable amount of alkali and give rise to an infertile soil. The soil formed by the Lance formation and the sandstones of the Fort Union is suitable for dry farming, though much of the land is badly broken and very rough. At the time of the examination no attempt had been made to cultivate any of the uplands. Practically all the bottom land along the rivers and in the valleys of Tullock and Sarpy creeks, however, is under cultivation.

COMMERCIAL RELATIONS.

The Northern Pacific Railway follows the meanders of Yellowstone River along the north border of the field and crosses Big Horn River near its mouth, in T. 5 N., R. 34 E. The four small towns located on the railway within the field, named in order from east to west, are Sanders, Hysham, Myers, and Big Horn. Sanders, which is one of the old stations, is near the mouth of Sarpy Creek. It consists only of a store, a post office, and cattle pens. Most of the trade of Sarpy Valley goes to the newly established town of Hysham, which is on the broad river flood plain in sec. 9, T. 6 N., R. 36 E. The station and post office of Myers lies in sec. 23, T. 6 N., R. 35 E., where a bridge crosses the river and affords communication with the broad, fertile Pease Bottom, on the north side. The town of Big Horn is at the mouth of Big Horn River in T. 5 N., R. 34 E., and is the trading center for the surrounding river bottom. However, owing to the isolation of this bottom, which is almost inclosed by impassable badlands, the town draws no trade from the outside,

except a little from the lower part of Tullock Creek valley. Most of the settlers in the valleys of Tullock Creek and Big Horn River are supplied either at Custer, which lies on the Northern Pacific Railway about 4 miles west of the Big Horn, or at Hysham.

The Chicago, Burlington & Quincy Railroad, which connects with the Northern Pacific at Huntley, passes around the south end of Pine Ridge, crosses the Big Horn in T. 1 S., R. 33 E., and follows the valley of the Little Big Horn to the south. The railroad thus does not enter the field, but it passes within 3 miles of the southwest corner. The thriving town of Hardin, on the railroad near the point at which it crosses Big Horn River, draws some trade from the southern part of the field.

Before the great coal resources of the southern part of the Tullock Creek field and the area to the south and east can be exploited adequate railroad connection is essential. A spur road from the Northern Pacific at Sanders, following Sarpy Creek, would be the cheapest solution of this difficulty. In addition to rendering the rich coal beds in the southern part of the field accessible, it would further the development of the important beds in the northern part and would open up a considerable area of fairly rich farm land.

The two main roads through the field follow Tullock and Sarpy creeks. The Sarpy Creek road is used by the stage line running from Hysham to the town of Sarpy, a small agricultural settlement on East Sarpy Creek a few miles outside of the field. In addition to these main thoroughfares there are several east-west trails which cross the Sarpy-Tullock and Tullock-Big Horn divides. Travel is more or less restricted by the very rough character of most of the country outside of the creek bottoms, and all the ranches in the field are situated either in these creek valleys or on the patches of bottom land scattered along the rivers.

STRATIGRAPHY.

GENERAL SECTION.

The outcropping rocks in the Tullock Creek field belong to the Cretaceous, Tertiary, and Quaternary systems. The Cretaceous is represented by some 1,800 feet of the Montana group, which is separable into the Claggett, Judith River, and Bearpaw formations. The top of the Bearpaw is marked by a small erosional unconformity, upon which rests the Lance formation, the upper part of which contains the lower group of coal beds that crop out in this field. The Fort Union overlies the Lance and contains the upper group of coal beds. All these formations are covered in certain localities by river gravel, which is probably of Quaternary age. The identification of these formations is based on fossils collected by G. S. Rogers in 1912

and determined by T. W. Stanton, F. H. Knowlton, and C. W. Gilmore.

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

Composite geologic section of the Tullock Creek coal field.

System and series.	Group and formation.		Character.	Thickness.
Quaternary.			Coarse gravel, sand, and silt.	*Feet.* 0–90
Tertiary (Eocene series).	Fort Union formation.		*Upper division.* Sandy shale and clay shale, with considerable sandstone in thick and prominent layers; prevailingly yellow; contains several thick coal beds which have almost everywhere burned and reddened the overlying strata.	0–675+
			Lebo shale member. Soft shale with some sandy shale and with abundant hard concretions in certain beds; gray to dark gray; forms gentle barren slopes and diminutive badlands; contains little good coal.	25–155
Tertiary (?) (Eocene (?) series).	Lance formation.		*Tullock member.* Shale, yellow to yellow-gray, with abundant yellow or brown sandstone, closely resembling the yellow sandstone of the Fort Union; contains many thin coal beds, which at no place are extensively burned.	300
			Lower division. Shale, light greenish to yellow, with many heavy yellow sandstone beds, especially in the lower half; contains no coal.	800
Cretaceous (Upper Cretaceous series).	Montana group.	Bearpaw shale.	Shale, dark gray to greenish gray, with abundant calcareous and richly fossiliferous concretions; giving rise to an infertile soil.	1,000±
		Judith River formation.	Yellow to white sandstone, partly of fresh or brackish water and partly of marine origin, separated by a considerable thickness of dark-gray marine shale.	400?
		Claggett shale.	Shale, dark gray to greenish gray, similar to the Bearpaw shale.	400±

CRETACEOUS SYSTEM.

MONTANA GROUP.

DIVISIBILITY OF THE GROUP.

The Montana group is divisible in this field into three formations—the Claggett, Judith River, and Bearpaw. The Bearpaw and as much of the upper part of the Claggett as is exposed in this field consist entirely of dark-gray to greenish-gray marine shale. The Judith River is apparently made up of two sandstone beds separated by about 200 feet of shale similar to that of the Bearpaw and Claggett.

Although the boundaries of these formations were mapped in the field, it was at first believed from paleontologic evidence that they should be considered as a unit, under the name Pierre shale, inasmuch as they represent the time interval of the Pierre. The few fossils found in the sandstones were not considered sufficient to warrant calling them Judith River, although they suggest this correlation;

moreover, although the marine faunas found above and below these sandstones are distinct from each other and resemble the Bearpaw and Claggett faunas, respectively, it was held that these names are not applicable in an area in which the Judith River formation is not developed as such. During the season of 1913, however, C. F. Bowen [8] examined the area directly north of this field and traced the outcrop of the sandstones in question to a point at which their correlation with the Judith River could no longer be considered doubtful. Although the sandstone that crops out in the southwest corner of the Tullock Creek field is probably twice as thick as that exposed in the area north of the field, according to Bowen's measurements, there is no doubt that they are the same. The name Judith River is therefore used in this report to designate the sandstones and the intervening shale, and the name Bearpaw is applied to the overlying marine shale. Reconnaissance studies by T. W. Stanton indicate that the Eagle sandstone, which normally separates the Claggett from the underlying Colorado shale, disappears some distance west of this field. The propriety of using the term Claggett in an area in which Eagle sandstone is probably absent and in which the Claggett is therefore lithologically indistinguishable from the Colorado may be questioned; but inasmuch as the Colorado does not crop out in this field, the problem does not directly concern this discussion, and the name Claggett is therefore employed.

At the top of the Bearpaw shale, as described below, there is an inconspicuous zone of thin-bedded sandstone, on the eroded top of which rests the massive fresh-water sandstone beds of the Lance formation. This thin-bedded sandstone appears to grade down into the marine shale of the Bearpaw, and no sharp line can be drawn between them. It seems probable that this zone represents the closing or shore facies of the marine Cretaceous and as such is directly comparable with the Fox Hills sandstone of other areas. No fossils were found in it, however, and Mr. Stanton reports that many of the collections made in the underlying Bearpaw shale contain fossils that also range up into the Fox Hills. Because of the lack of fossil evidence to justify the separation of this zone, and because of its thinness and its lack of a definite base, which preclude mapping it as a separate formation, it is here treated as part of the Bearpaw shale, though considered broadly it is probably equivalent to the Fox Hills.

CLAGGETT SHALE.

Only the upper part of the Claggett formation is exposed in this field. This part is made up almost entirely of dark-gray shale containing many orange-brown calcareous concretions. These concre-

[8] Bowen, C. F., Possibilities of oil in the Porcupine dome, Rosebud County, Mont.: U. S. Geol. Survey Bull. 621, pp. 61–70, 1915.

tions are commonly arranged in layers; some of them are fossiliferous, but they do not contain the wide range of invertebrate life that characterizes the similar concretions of the Bearpaw shale. In one or two localities small, thin lenses of shaly sandstone were noticed, but the formation in this field is made up almost entirely of shale.

Owing to the absence of distinct bedding planes, it is impossible to measure the dip of these beds except along their contact with Judith River sandstone. The thickness of that portion of the Claggett exposed within the field is therefore not susceptible of accurate measurement, but it is believed to be about 400 feet. The position of the top of the Claggett is somewhat doubtful, as discussed below under "Judith River formation."

The following fossils from these beds were determined by T. W. Stanton, who states that the fauna represented is somewhat distinct from that of the Bearpaw and is rather characteristic of the Claggett, though most of the species have an extended vertical range:

No. 35. NW. ¼ sec. 1, T. 1 S., R. 34 E. From concretions about 150 feet below base of lowest exposed Judith River sandstone:

Inoceramus sagensis Owen.
Baculites ovatus Say ?

No. 37. SE. ¼ sec. 23, T. 1 N., R. 33 E. From concretions 50 to 100 feet below base of lowest exposed Judith River sandstone:

Baculites ovatus Say ?

No. 40. SE. ¼ sec. 23, T. 1 N., R. 33 E. From concretions 25 feet below base of lowest exposed Judith River sandstone:

Syncyclonema sp.
Inoceramus barabini Morton.
Baculites ovatus Say.

JUDITH RIVER FORMATION.

GENERAL FEATURES.

The Judith River formation in this field is apparently made up of two sandstone beds, each 75 to 100 feet thick, separated by 200 feet or more of dark-gray shale resembling the shale of the Claggett and Bearpaw formations. In places, also, the sandstone beds contain lenses of shale. The only good exposure of the Judith River formation in this field is at the Brandt ranch, near the mouth of Ninemile Creek, where the following sections were measured:

Section of Judith River formation at mouth of Ninemile Creek, in sec. 15, T. 1 N., R. 33 E.

	Feet.
Bearpaw shale.	
Sandstone, yellow to brown, thin-bedded	12
Sandstone, yellow, massive	27
Shale, green and brown	18
Sandstone, yellow, massive	20
Shale (Claggett ?).	
	77

Section of Judith River formation on Brandt ranch, at east quarter corner of sec. 22, T. 1 N., R. 33 E.

Bearpaw shale.	Feet.
Sandstone, yellow, hard	3
Sandstone, white, massive, shattered, containing brown concretions	47
Sandstone, white, thin-bedded, and generally cross-bedded	5
Sandstone, white, massive, shattered	24
Sandstone, yellow, hard	1
Sandstone, white, massive, shattered, containing brown concretions	23
Shale (Claggett?).	
	103

These sections were measured at two exposures about half a mile apart. At the first locality the strata dip 12° N. 30° W., and at the second about 11° N. 20° E., though the sandstone at this outcrop is much shattered and these observations may not be accurate. Between the two exposures the dark-gray shale seems to dip about 20° NW., but owing to its lack of distinct bedding planes and to the fact that its outcrop is obscured by gravel, the apparent attitude of the shale throws little light on the relations of the two sandstone exposures. At this locality, however, the lithologic differences and also the difference in the thickness of sandstone exposed at the two points seem to indicate two sandstone beds, separated by about 200 feet of shale. On the other hand, the discrepancy in direction of dip is difficult to explain, and at no point along the sandstone outcrop to the east is there direct evidence of the existence of two sandstones. In this district the surface of the ground is covered by river gravel, exposures are poor, and the shale outcrops give no clue to the exact structure. As shown in Plate X, the sandstone outcrops are distributed irregularly and may be considered either as belonging to one sandstone bed set over by faults or as belonging to two sandstone beds which do not happen to crop out in any one section. In this district, therefore, the evidence is not conclusive; and if three normal faults are postulated, all the known outcrops may be referred to one bed. Most of the exposures mapped are very inconspicuous, but the general sandstone zone may be followed by the hogback that it forms. (See Pl. I, *A*.)

On Yellowstone River about 2 miles east of Sanders a sandstone bed crops out which resembles the one described in the first section given above. Reasonably accurate measurements made in the two districts indicate that both sandstones are about 1,000 feet below the top of the Bearpaw shale, and there seems to be no doubt that these exposures are of the same bed. In the locality on Yellowstone River only about 39 feet of the sandstone is exposed, its base being concealed by alluvium; but on the north bank of the river, directly op-

posite, a thickness of about 75 feet is exposed. This sandstone was traced by C. F. Bowen [9] from this point several hundred miles to the north and west and was found by him to be the upper of two sandstone beds separated by gray shale, the three members together constituting the Judith River formation. There is no doubt that the upper sandstone of the Judith River north of the Yellowstone is identical with the sandstone that crops out at the mouth of Ninemile Creek and is described above; and in view of the lack of evidence in regard to the relations of the sandstone at that locality, it seems best to consider this bed as the upper of two sandstones separated by shale. Unfortunately, the validity of this assumption can be determined only by an examination of the areas to the south and southwest of this field.

LITHOLOGIC CHARACTER.

For the reasons set forth above, it is assumed tentatively that the sandstone which crops out at the mouth of Ninemile Creek represents the upper part of the Judith River formation, and that it is separated by about 200 feet of shale from the sandstone which crops out at the Brandt ranch, in sec. 22, and which is taken to represent the basal part of the formation. The upper sandstone is yellow, arkosic, and for the most part thick bedded and closely resembles the thick sandstone beds of the lower part of the Lance formation. It exhibits decided cross-bedding, both regular and irregular; it contains conglomeratic swirls suggestive of fresh-water origin; and it carries fragments of leaves, plant stems in a vertical position, and bone fragments, some sharp-edged and others waterworn. This sandstone is believed to be identical with the one that crops out on Yellowstone River, which is a light-yellow thick-bedded arkosic sandstone containing many thin, hard lenses and characterized by a pitted surface. It carries some small fragments of bone and a few shark teeth. No diagnostic fossils could be found in the upper sandstone at either locality, nor were any collected from the shale that separates it from the lower sandstone. This shale is dark gray and is indistinguishable from the Bearpaw and Claggett shales; it is doubtless of marine origin. The lower sandstone bed differs from the upper in being white rather than yellow and in consisting more largely of quartz. Cross-bedding is rare, and only the regular type was observed.

PALEONTOLOGIC CHARACTER.

In the SW. ¼ sec. 23, T. 1 N., R. 33 E., the lower sandstone carries dark-red limonite concretions that contain leaf impressions, but none that were recognizable. At this locality, however, a small collection

[9] Op. cit.

of invertebrate shells was made, which are described by Mr. Stanton as follows:

No. 36. Sec. 23, T. 1 N., R. 33 E.:
Lingula sp.
Liopistha undata Meek and Hayden.
Fragment of sandstone containing Sphaerium, Physa, and other fresh-water shells in the form of casts.

The first two forms named are marine species not distinctive of any restricted horizon in the Montana group. The fresh-water shells occurred in a single hand specimen, which is probably a concretion but which may be a boulder derived from some older formation. No recognizable fossils were collected from the upper sandstone at this point, but its lithologic character, together with the presence of bone fragments and plant stems, indicates that it is largely of fresh-water origin. The upper sandstone on Yellowstone River, however, contains shark teeth, which imply a marine origin.

These apparently conflicting observations are in accord with those of C. F. Bowen in the district north of Yellowstone River. On the west side of the so-called Porcupine dome, or everywhere west of the 108th meridian, the Judith River is a fresh-water formation; on the east side of this dome, or along the 107th meridian, it is of marine origin. The transition zone, according to Bowen, lies between these lines, and probably about halfway between; this is almost exactly the longitude of the Judith River area in the southwestern part of the Tullock Creek field. As stated above, the fossils collected from the lower sandstone in that locality are about equally divided between fresh-water and marine types, while the upper sandstone is believed to be largely of fresh-water origin; the exposure on Yellowstone River, which is near the 108th meridian, yielded only marine shark teeth. The fossil evidence in this field is meager, though corroborated by the lithologic evidence; but both are consonant with the more extended observations of Bowen in the area to the north. It may therefore be concluded that during Judith River time the sea retreated east about as far as the center of this field, but that the strand line oscillated back and forth across the western boundary and that much of the sediment deposited in that locality was laid down under marine conditions.

BEARPAW SHALE.

GENERAL CHARACTER.

The Bearpaw is made up almost entirely of dark-gray marine shale with an abundance of orange-brown calcareous concretions. These concretions, which are commonly arranged in irregular layers, are highly fossiliferous and contain a wide range of invertebrate life. At one or two places small, thin lenses of shaly sandstones

were observed, but these are relatively inconspicuous. At the top of the Bearpaw is a zone of thin-bedded sandstone ranging in thickness from 20 to 50 feet. This zone evidently represents the closing or shore facies of the marine Cretaceous and as such is comparable with the Fox Hills, though for the reasons given above it was mapped as part of the Bearpaw.

The country underlain by the Bearpaw in the southwestern part of the field is fairly rough, although the total relief is not great. It is possible that the resistant sandstones of the Lance were removed by erosion in this area only at a comparatively recent date and that the present erosion of the soft Bearpaw shale has not yet progressed far enough to lend the country the flat appearance which is characteristic of the formation in other areas. (See Pl. I, *A*.) Along the Yellowstone the relief is low and the hills are rounded, but the surface becomes steeper and rougher as the dissected edge of the Lance beds is approached. The districts underlain by the Bearpaw and Claggett formations are marked off sharply from the Lance areas by their lack of trees and their general sterility.

THICKNESS AND LIMITS.

The thickness of the Bearpaw shale is about 1,000 feet, as shown by measurements made in both the southwestern and northeastern parts of the field. Conditions are not favorable for accurate measurement, however, at either place. Notwithstanding the thickness of the Bearpaw, its outcrop in the southwestern part of the field is limited to a narrow zone, owing to the steep dip of the strata. On the Yellowstone the formation is brought to the surface by a dip of less than 3°, and its outcrop in this area does not extend more than 4 miles south of the edge of the bottom land.

The base of the Bearpaw is marked by the top of the upper sandstone of the Judith River formation. The top of the Bearpaw is here considered the top of the zone of thin-bedded sandstone, or the base of the Lance formation. The contact of this zone of thin-bedded sandstone with the basal sandstone beds of the Lance, though somewhat obscure because of the general lithologic similarity of the two, appears to be irregular. Thus near the mouth of Boxelder Creek there is an exposure showing the basal sandstone of the Lance filling what seems to be an erosion channel in the top of the Bearpaw. Along the railroad tracks in secs. 21 and 29, T. 6 N., R. 35 E., there are several places at which the Lance seems to rest on an indented surface. The relief of this old surface, however, is not more than 20 or 30 feet at any point observed. At Oldhorn bottom, in T. 2 N., R. 33 E., the Lance seems to rest on a somewhat irregular surface, and in this locality a discrepancy in dip of 1° or 2° was noticed.

PALEONTOLOGIC CHARACTER.

The fossils found in this formation constitute a typical Bearpaw fauna. The following fossils were collected from the Bearpaw at the localities and horizons noted and were identified by T. W. Stanton:

No. 3. Sec. 5, T. 1 S., R. 35 E., near middle of formation:
Baculites compressus Say.

No. 4. Sec. 6, T. 1 S., R. 35 E., about 300 feet above base of formation:
Inoceramus barabini Morton.
Trigonarca (Breviarca) exigua Meek and Hayden.
Nucula subplana Meek and Hayden ?
Leda scitula Meek and Hayden.
Leda sp.
Lucina occidentalis (Morton).
Mactra gracilis Meek and Hayden.
Nautilus dekayi Morton.
Scaphites nodosus Owen.
Placenticeras intercalare Meek and Hayden.

No. 5. Sec. 31, T. 1 N., R. 35 E., about 300 feet below top of formation:
Inoceramus barabini Morton.

No. 24. Three-fourths mile west of Myers, Mont., from shale about 30 feet below base of Lance formation:
Nucula cancellata Meek and Hayden.
Protocardia subquadrata (Evans and Shumard).
Mactra? sp.
Pholadomya sp.

No. 34. Sec. 26, T. 1 N., R. 34 E., from concretion at about middle of Bearpaw:
Ostrea sp.
Leda sp.
Mactra gracilis Meek and Hayden.
Anchura americana (Evans and Shumard)?
Baculites compressus Say.
Placenticeras sp.

No. 38. SE. ¼ sec. 26, T. 1 N., R. 34 E., from concretions about 150 feet above base of Bearpaw:
Inoceramus barabini Morton.
Mactra gracilis Meek and Hayden.
Cerithium? sp.
Amauropsis paludinaeformis (Hall and Meek).
Scaphites nodosus Owen.

No. 39. Sec. 26, T. 1 N., R. 34 E., from concretions about 300 feet above base of Bearpaw:
Micrabacia americana Meek and Hayden.
Chlamys nebrascensis Meek and Hayden.
Syncyclonema rigida (Hall and Meek).
Trigonarca (Breviarca) exigua Meek and Hayden.
Leda scitula Meek and Hayden.
Nucula subplana Meek and Hayden.
Lucina subundata Hall and Meek.
Mactra gracilis Meek and Hayden.

Cuspidaria moreauensis Meek and Hayden?
Corbula sp.
Dentalium sp.
Lunatia occidentalis Meek and Hayden?
Xenophora sp.
Anchura sp.
Actaeon? sp.
Haminea? sp.
Cylichna sp.
Baculites compressus Say.
Scaphites nodosus Owen.

TERTIARY (?) SYSTEM.

LANCE FORMATION.

AGE AND DIVISIBILITY OF THE FORMATION.

There has long been doubt as to whether the Lance formation should be considered the initial formation of the Tertiary system or the last formation of the Cretaceous. A review of the evidence in 1914 resulted in the decision by the United States Geological Survey to refer it tentatively to the Tertiary.

The Lance formation in the Tullock Creek field is divisible into two parts—an upper coal-bearing member about 300 feet thick, to which the name Tullock member is here applied, and a lower undifferentiated portion about 800 feet thick. The absence of coal in the lower part of the Lance constitutes the most striking difference between the two divisions, the other lithologic distinctions, though constant through the field, being less conspicuous. In addition, fossils are much more rare in the Tullock member than they are in the lower part of the Lance, and such fossils as were found indicate a slightly different form of fauna.

LOWER PART OF THE LANCE FORMATION.

GENERAL CHARACTER.

The lower part of the Lance formation is made up of sandstone and shale having a general yellowish to greenish-yellow color. This part contains no coal, though lenses of black carbonaceous shale have been found in it. The strata are calcareous in many places, and nearly all the specimens collected react more or less strongly with acid, though no true limestone was observed. The sandstone beds of the lower part of the Lance resemble in a general way those of the Tullock member, but the shale has a distinctly greenish-gray tint, whereas the shale of the Tullock member is commonly yellow with

many brown carbonaceous streaks. The general greenish cast of the lower part of the Lance, though faint, is yet sufficient to enable the observer to distinguish it from the overlying Tullock member at a distance of several miles.

The districts in which the lower part of the Lance formation outcrops are generally rough, and some of them are almost impassable to a man on horseback. Examples of this extremely broken country are the district between Myers and the mouth of Unknown Creek and the area known as the Devils Pocket, in T. 2 N., R. 34 E. The roughness of these areas, however, is due to their intricate dissection rather than to actual relief, and when viewed from the bold escarpment of the Tullock member of the Lance they appear almost flat. An exception to the common physiographic expression of the lower part of the Lance is found on Tullock Creek in the southern part of the field, where the districts in which these beds crop out are for the most part gently sloping and grass covered.

THICKNESS AND LIMITS.

The areal distribution of the lower part of the Lance formation is greater than that of any of the other units mapped. (See Pl. X.) The entire thickness of these beds is not exposed in any accurately measurable section. Levels were carried from the base of the Tullock member at the head of East Corral Creek to the contact of the Lance with the Bearpaw shale 3 miles farther north, and corrections were made for the dip. These calculations show the lower part of the Lance to have a thickness of 810 feet, which is believed to be very nearly correct.

The top of the lower part of the Lance is the base of coal bed A, the lowest coal bed in the field. This bed is persistent and easily recognizable in the middle and western parts of the field, but east of Sarpy Creek it is very thin or absent and its horizon is not easy to locate. In this part of the field, therefore, the top of the lower part of the Lance is considered to be 35 feet below coal bed C, which is persistent in this district, or at the approximate horizon of bed A. The absence of bed A in the eastern part of the field may indicate that the lower or non coal-bearing portion of the Lance becomes thicker to the east, but it was thought best to disregard this possibility and to map its top at the same stratigraphic level throughout the field.

The base of the Lance formation is not conspicuous at any locality in the field, being obscured by a zone of thin-bedded sandstone that forms a lithologic transition to the Bearpaw shale below. It is believed, however, that this thin-bedded sandstone represents the shore facies of the marine Cretaceous, and the line mapped at the

base of the Lance is therefore the top of this zone, which is usually overlain by yellow thick-bedded fresh-water sandstones. As already stated (p. 12), an erosional unconformity at this horizon was noted in the northern part of the field, and there appears to be also a slight angular unconformity in the southwestern part.

LITHOLOGIC CHARACTER.

In the northwestern part of the field, especially on Unknown Creek, in T. 5 N., R. 35 E., the 300 feet of strata immediately underlying the Tullock member are chiefly shale, whereas in the basal 500 feet of the formation sandstone is very prominent. Typical views of these two divisions are shown in Plate II. The shale of the upper division is greenish gray, resembling in a general way the Bearpaw shale, and the few sandstone beds in this part of the formation are thin and lenticular and generally do not crop out. Fossil collections 17, 18, 21, and 26, described below, were made in this shale and consist entirely of fresh-water shells. In the basal part of the formation fossils are more abundant (see collections 14 to 16, 25, 27 to 32) and comprise not only shells but bone fragments. The sandstone beds of the lower division, which are thick and form prominent outcrops, are strikingly cross-bedded in many places and also exhibit conglomeratic swirls. In one or two places small lenses of coal an inch or two thick were observed. The sandstone layers are interbedded with shale, which is generally greenish gray, though yellowish and even reddish beds are not uncommon. These facts seem to indicate that during the deposition of the lower part of the formation fresh-water conditions alternated with subaerial conditions, and that during the deposition of the upper 300 feet more uniform fresh-water conditions prevailed. The differences between the two divisions are so striking in the district around Unknown Creek, where the geologic mapping was started, that an attempt was made to map them as separate members of the Lance formation, but it was found that the distinctions noted there do not hold in other parts of the field. In fact, conditions are reversed locally in the southern part of the field, as shown by the partial stratigraphic sections in the descriptions of Tps. 2 and 3 N., R. 34 E. The basal part in that locality is shaly, and the upper part more sandy. The Lance strata below the Tullock member are therefore shown as a unit.

The great predominance of shale in the upper 300 feet of the lower part of the Lance is shown in the following detailed section,[10] measured on Unknown Creek. The second section was measured near

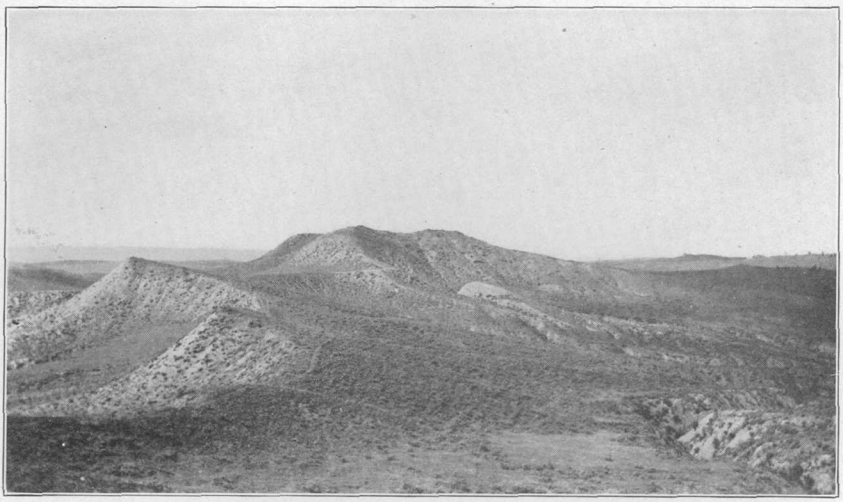
[10] An additional partial section of these beds is given in the detailed description of T. 4 N., R. 35 E., pp. 113–114.

Myers and shows the basal part of the Lance formation. Inasmuch as the lower part of the Lance is 810 feet thick, these two sections overlap, the lower 320 feet of the first being presumably identical with the upper part of the second.

Stratigraphic section of lower part of Lance formation measured along Unknown Creek in secs. 7 and 21.

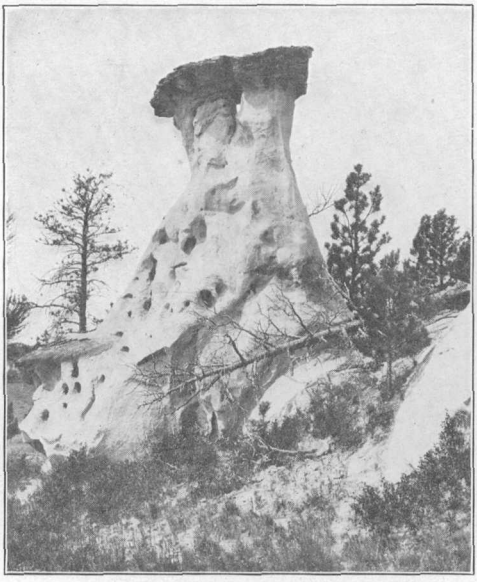
[For lists of fossil collections see pp. 26–29.]

	Feet.
Coal bed A (base of Tullock member of Lance formation).	
Shale, yellowish gray, sandy	24
Sandstone, white	10
Shale, white, gray, green, and brown, variegated	82
Shale, yellow-brown, calcareous, concretionary	2
Shale, white	4
Sandstone, white, soft, massive	11
Shale, grayish green	32
Sandstone, white, massive, with brown sandstone layer on top (collection 18, at top)	10
Shale, gray and greenish (collection 17)	17
Concealed, probably all shale (collection 21, near middle)	95
Shale, gray and green, with several brown sandstone lenses, 1 to 2 feet thick	31
Shale, gray and green, mostly covered	20
Sandstone, yellow, massive, cross-bedded. About 8 feet from bottom is a 1-foot layer of conglomerate (sandstone and shale pebbles, rounded to subangular, as much as 4 inches in diameter. Collection 14, at base)	28
Shale, greenish, sandy, with 1-foot carbonaceous streak at top	12
Sandstone, yellow, soft	5
Shale, yellowish, sandy, with lenses of soft yellow sandstone	34
Sandstone, yellowish, shaly	6
Shale, greenish to yellowish, sandy	17
Shale, gray, concretionary, calcareous	12
Shale, green to gray, sandy to pure (collection 15)	19
Sandstone, brown, hard, thin-bedded	2
Sandstone, yellow, soft, massive, with lens of hard brown sandstone 2 feet above base (collection 16, 2 feet above base)	11
Shale, gray, sandy	23
Shale, green	3
Shale, reddish brown	2
Shale, gray, sandy	6
Sandstone, yellow, soft, mostly massive, with some hard thin-bedded brown layers	30
Shale, gray, with several thin sandstone lenses	32
Sandstone, yellow, soft, massive	16
Sandstone, brown, hard, thin-bedded, cross-bedded	2
Sandstone, yellow, fairly hard, thin-bedded, cross-bedded	10
Bottom, alluvium of Unknown Creek.	
	608

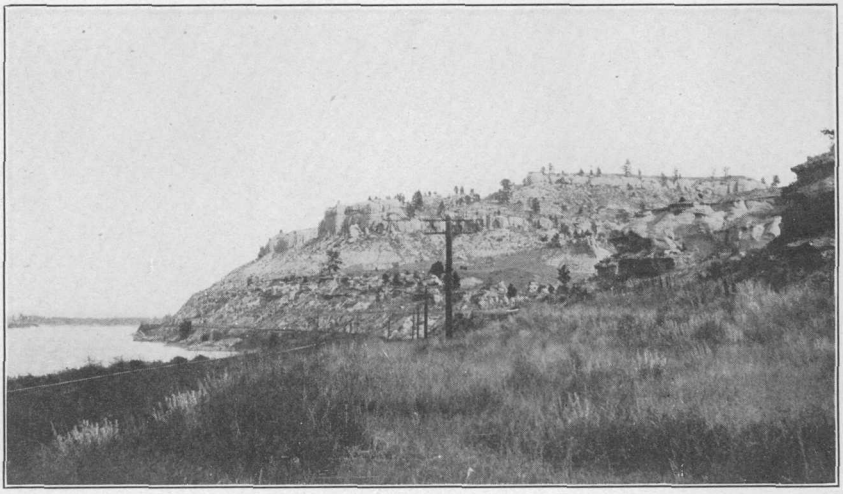


A. HOGBACK FORMED BY SANDSTONE OF THE JUDITH RIVER FORMATION.

Looking northwest from sec. 22, T. 1 N., R. 34 E.

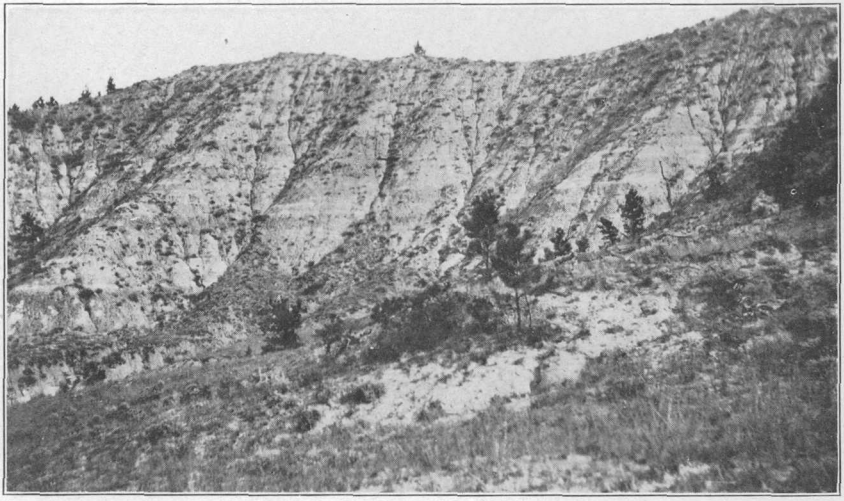


B. SCULPTURING OF SOFT WHITE SANDSTONE CAPPED BY HARD BROWN CONCRETIONARY LAYER, OVERLYING COAL BED D IN THE TULLOCK MEMBER OF THE LANCE FORMATION, WEST BEAR CREEK, SEC. 12, T. 4 N., R. 36E.



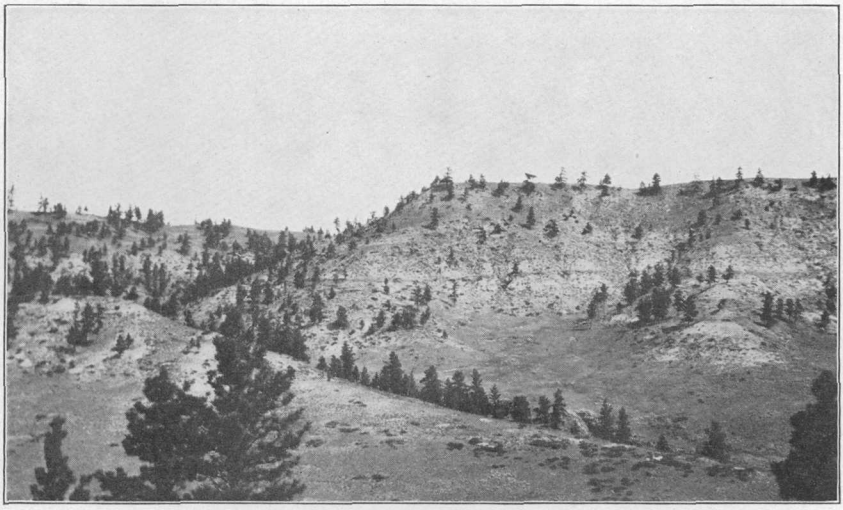
A. GUY'S BLUFFS, ON YELLOWSTONE RIVER 4 MILES NORTH OF BIG HORN.

Showing the abundance of sandstone strata in the basal part of the Lance formation. (Compare Pl. II, *B.*)



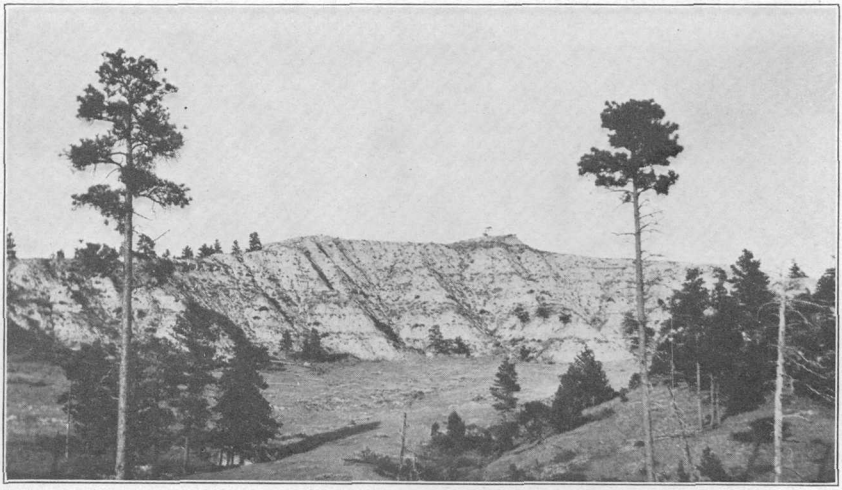
B. MIDDLE PORTION OF LANCE FORMATION 3 MILES ABOVE MOUTH OF UNKNOWN CREEK, SEC. 15, T. 5 N., R. 35 E.

Showing almost entire absence of sandstone. (Compare Pl. II, *A.*)



A. TYPICAL ESCARPMENT FORMED BY THE TULLOCK MEMBER OF THE LANCE FORMATION ON WEST CORRAL CREEK, SEC. 33, T. 5 N., R. 36 E.

(Compare Pl. III, *B*.)



B. BUTTE FORMED BY THE UPPER DIVISION OF THE FORT UNION FORMATION AT THE HEAD OF PASSAGE CREEK, SEC. 32, T. 3 N., R. 38 E.

In this locality these strata contain only thin coal beds, which are not burned on the outcrop. Note their great similarity to the beds of the Tullock member of the Lance formation, as shown in Plate III, *A*, and compare also with Plate V, *A*, showing the upper division of the Fort Union in the southern part of the field.

Stratigraphic section of lower part of the Lance formation on bluff a quarter of a mile southeast of Myers, in sec. 14, T. 6 N., R. 35 E.

	Feet.
Shale, greenish	30
Sandstone, yellow, massive	60
Shale, greenish gray	118
Sandstone, yellow, massive, with brown lenses	10
Shale, gray, sandy	16
Sandstone, yellow, massive, with brown cap	12
Sandstone, gray, soft, shaly	5
Shale, gray	10
Sandstone, yellow, fine-grained, hard	1
Shale, variegated, gray, green, brown, and yellow	10
Sandstone, yellow, massive, with brown cap	9
Sandstone, yellow, massive	15
Shale, yellow, gray, sandy	25
Sandstone, massive	20
Shale, yellow	35
Sandstone, yellow, massive, with 1-foot harder cap	51
Shale, gray	47
Sandstone, yellowish, bedded	18
Shale, yellow	17
Sandstone, yellow, massive	10
Bearpaw shale, with 20 to 30 feet of thin-bedded sandstone at top.	
	519

The sandstone of the lower part of the Lance is, for the most part, soft and yellow, occurring in beds from 1 to 50 feet thick. All the sandstone is arkosic, most of it containing a large proportion of feldspar. Thin sections of the rock from several typical beds revealed the general angular or subangular character of the grains. Some of the feldspar is almost entirely fresh, though generally it is more or less kaolinized. Some of the beds also contain a large amount of biotite and hornblende, and these minerals are so conspicuous in places that they give the sandstone the appearance of a weathered granite. Most of the sandstone beds contain irregular swirls of conglomerate, in which the pebbles are mostly of yellow sandstone and generally subangular or rounded. These pebbles are not highly indurated, and most of them are probably no older than the Cretaceous. Many of the Lance sandstone beds have an irregular layer of the same kind of conglomerate at the base.

Through the soft yellow sandstone beds are scattered numerous lenses of hard gray sandstone which on weathering tend to stand out prominently. In wind-eroded columns these lenses form the "mushroom heads" common in semiarid regions (see Pl. I, *B*). In most places, also, the Lance sandstone beds are characterized by the formation of rim rocks or cap rocks. The upper few feet of a thick sandstone bed, or the whole of a thinner layer, becomes case-

hardened by some process of weathering, possibly the solution of silica by ground water and its precipation by evaporation at the outcrop. Wind erosion then cuts back the underlying softer layers, leaving a hard projecting cap rock. At some horizons, however, this condition is so prominent and so general as to suggest that it is due partly to the hardening of the surface by exposure before it was covered by the succeeding bed. Some beds of sandy shale have been subjected to similar hardening, with the production of the same but less pronounced phenomena. The process of formation is probably different in different localities, but the development of cap rocks is so common as to be characteristic of the whole Lance formation.

The cap rocks in certain localities are very persistent, and in conjunction with the soft yellow sandstone beneath they form prominent escarpments that are impassable for considerable distances. Such a condition prevails near the mouth of Unknown Creek, in T. 5 N., R. 35 E., and also in many other parts of the field. In general, however, the sandstone beds appear lenticular and can be traced only 2 or 3 miles, and in many places a sandstone 30 or 40 feet thick disappears within 300 feet. This appearance of discontinuity, however, is not always borne out on close examination; it may be due primarily to the lithologic character of the sandstone and the effect on it of weathering. Most of the sandstone is decidedly arkosic and contains a considerable proportion of feldspar and mica. Most of the quartz grains are very fine. Under certain conditions of weathering the sandstone stands out prominently and the character of the bed is clearly evident, but under other conditions, as where the bed is not protected by a cap rock, it is washed down in talus slopes. The feldspar then weathers to clay, and the fine quartz sand is generally so inconspicuous that the derivation of this material from a sandstone is not apparent. In some places these two forms of weathering may be observed in sharp contact, as on opposite sides of a small gully, so that a fault is strongly suggested. On the other hand, there are many examples of such differences which can be explained only on the ground that the sandstone is actually lenticular. Such variations in the character of the beds are probably produced chiefly by the interpolation of thin lenses of different material rather than by sharp gradation from pure sand to pure shale throughout the thickness of the thick beds. Plate IX, *A*, shows a thick sandstone bed partly replaced by thin-bedded sandstone and shale within a very short distance; although this particular sandstone is in the Tullock member of the Lance, the irregularity shown is typical of the whole formation. However, though there can be no doubt that some beds actually grade from sand to shale within short distances, this is thought to be the exception rather than the rule.

That the apparent discontinuity of some of the sandstones is due to weathering is indicated by a study of the general conditions of outcrop throughout the field. As already explained (p. 6), plant growth is generally scanty on the southern and western slopes of the hills, and exposures are therefore good. Erosion is so rapid on these slopes that even the softer sandstone beds tend to form cliffs, the products of disintegration being removed before they accumulate as talus slopes. The northern and eastern slopes, however, are generally grassed over, and if sandstone is exposed at all its outcrop is usually inconspicuous. For this reason the steep southern and western slopes have the appearance of being decidedly more arenaceous than those facing the north and east, but this is really not the case. As another instance of the same process, it may be mentioned that sandstone beds exposed near the tops of the ridges resist weathering to a greater degree than those occupying positions on the lower slopes, owing in part at least to the accumulation of débris on the lower slopes, which tends to prevent the surface hardening of the sandstone. This condition is well displayed in the lower valley of Sarpy Creek. Any given sandstone bed near the top of the ridge crops out prominently, but as the southerly dip carries this bed to lower levels, conditions of weathering become less favorable to a strong outcrop and the bed when viewed from a distance appears to pinch out. All the formations that crop out in the field are, of course, subject to these rules, but because of the abundance of soft sandstone in the Lance, these conditions are most strikingly developed in that formation.

Much of the sandstone of the Lance formation is strikingly cross-bedded and contains numerous conglomeratic swirls. In places, however, the sandstone laminae are so steeply upturned—locally even contorted—that it is difficult or impossible to account for the phenomenon as being due to cross-bedding. A typical example of this kind is shown in Plate VI, *A*, which shows a sandstone 75 feet below the base of the Tullock member. A local thrust, due possibly to slumping before the consolidation of the beds, might be postulated to explain this condition in isolated localities, but the phenomenon is common and widespread. In a sandstone that crops out in a cut bank on West Bear Creek the writers observed a condition which seemed to throw light on the problem. The sandstone at this place is distinctly cross-bedded, but the cross-bedding is regular and at an angle of 30°. In the lower part of the bed, however, traversing the true cross-bedding and practically obliterating it, are undulating bands or fine parallel sheets of iron-stained and cemented sand grains less than one-eighth of an inch thick. These are distinctly a secondary development, and, in fact, their formation at this point is probably still in progress. Although the bands

are merely undulatory and not highly contorted and weathered into prominence, as in the sandstone shown in Plate VI, *A*, it is believed that their mode of formation is identical. To this pseudo cross-bedding, so common in the Lance sandstone beds, is thus assigned a concretionary origin, though it is only where the process is still going on that its nature can be definitely worked out.

PALEONTOLOGIC CHARACTER.

The lower part of the Lance formation contains many fossils, chiefly fresh-water shells but in the basal part of the formation many bone fragments as well. The shells were examined by T. W. Stanton, who says: "The collections numbered 17, 26, and 30 contain species that are believed to be characteristic of the Lance fauna, and all the other lots are believed to indicate the same general fauna, although they do not include such definitely characteristic species." The following lists give the forms recognized in each lot and the approximate location and horizon of each:

No. 2. Northeast corner of sec. 36, T. 1 N., R. 35 E., from shale bed about 400 feet below base of Tullock member:

Sphaerium sp.
Physa sp.
Goniobasis tenuicarinata Meek and Hayden.

No. 6. NE. ¼ sec. 12, T. 1 N., R. 34 E., from shale bed about 25 feet below base of Tullock member:

Unio sp.
Sphaerium sp.
Physa sp.
Limnaea? sp.
Viviparus sp.
Goniobasis tenuicarinata Meek and Hayden.

No. 8. Sec. 28, T. 2 N., R. 34 E., from sandstone about 75 feet below base of Tullock member:

Sphaerium sp.

No. 10. SE. ¼ sec. 7, T. 3 N., R. 35 E., from conglomerate about 60 feet below base of Tullock member:

Limnaea sp.
Physa sp., related to P. copei White.
Goniobasis tenuicarinata Meek and Hayden.
Viviparus sp.

No. 11. SW. ¼ sec. 10, T. 4 N., R. 35 E., from bluish shale about 100 feet below base of Tullock member:

Sphaerium sp.
Goniobasis tenuicarinata Meek and Hayden.

No. 12. SE. ¼ sec. 9, T. 4 N., R. 35 E., from dark shale about 200 feet below base of Tullock member:

Sphaerium sp.
Physa sp.
Columna? sp.
Viviparus? sp.
Goniobasis tenuicarinata Meek and Hayden.

No. 14. SE. ¼ sec. 12, T. 5 N., R. 34 E., from conglomerate at base of heavy sandstone 365 feet below base of Tullock member. Sandstone contains bone fragments also:

Unio sp.
Sphaerium sp.
Campeloma?
Viviparus sp.
Goniobasis tenuicarinata Meek and Hayden.

No. 15. Sec. 12, T. 5 N., R. 34 E., from dark shale 450 feet below base of Tullock member:

Sphaerium sp.
Physa sp.
Planorbis sp.
Columna? sp.
Goniobasis tenuicarinata Meek and Hayden.

No. 16. Sec 12, T. 5 N., R. 34 E., from sandstone 480 feet below base of Tullock member. (See also collection 28, listed below.)

Sphaerium sp.
Viviparus sp.
Goniobasis tenuicarinata Meek and Hayden.

No. 17. Sec. 7, T. 5 N., R. 35 E., from cap rock of heavy-bedded yellow sandstone 190 feet below base of Tullock member:

Sphaerium sp.
Unio sp., casts of two or more species of Lance types.
Campeloma multilineata Meek and Hayden.
Goniobasis tenuicarinata Meek and Hayden.
Tulotoma thompsoni White.

No. 18. Sec. 21, T. 5 N., R. 35 E., from sandstone 175 feet below base of Tullock member:

Unio sp.
Sphaerium sp.
Physa sp.
Limnaea sp.
Campeloma? sp.
Goniobasis tenuicarinata Meek and Hayden.

No. 21. Sec. 27, T. 5 N., R. 35 E., from bluish shale about 250 feet below base of Tullock member.

Unio sp.
Sphaerium sp.
Viviparus sp.
Columna? sp.
Helix? sp.
Goniobasis tenuicarinata Meek and Hayden.

No. 25. Three-fourths of a mile west of Myers, Mont., from base of sandstone about 200 feet above base of Lance formation:

Sphaerium sp.
Goniobasis tenuicarinata Meek and Hayden.

No. 26. Sec. 17, T. 5 N., R. 35 E., from conglomerate about 275 below base of Tullock member:

Unio sp., short form.
Sphaerium sp.
Campeloma multilineata Meek and Hayden.
Tulotoma thompsoni White.

No. 27. NW. ¼ sec. 28, T. 6 N., R. 35 E., from base of sandstone which yielded collection 25, about 200 feet above base of Lance formation.

Sphaerium sp.
Viviparus sp.
Goniobasis tenuicarinata Meek and Hayden.

No. 28. Sec. 12, T. 5 N., R. 34 E., from sandstone which yielded collection 16, 480 feet below base of Tullock member. This bed also contains bone fragments (see below).

Unio sp.
Sphaerium sp.
Physa sp.
Campeloma multilineata Meek and Hayden?
Goniobasis tenuicarinata Meek and Hayden.

No. 29. Near west quarter corner sec. 7., T. 5 N., R. 35 E., from sandstone which yielded collection 14, 365 feet below base of Tullock member. This bed contains bone fragments also.

Unio sp. cf. U. stantoni White.
Campeloma multilineata Meek and Hayden.
Goniobasis tenuicarinata Meek and Hayden.

No. 30. NE. ¼ sec. 13, T. 5 N., R. 34 E., from sandstone about 300 feet below base of Tullock member. This bed carries bone fragments also.

Unio verrucosiformis Whitfield.
Unio percorrugata Whitfield?
Unio holmesianus White.
Unio sp.
Sphaerium sp.
Physa sp.
Limnaea? sp.
Viviparus sp.
Campeloma multilineata Meek and Hayden.
Tulotoma thompsoni White.

No. 32. NE. ¼ sec. 28, T. 4 N., R. 34 E., from shale bed about 450 feet below base of Tullock member:

Sphaerium sp.
Physa sp.
Goniobasis tenuicarinata Meek and Hayden.

No. 33. SE. ¼ sec. 14, T. 4 N., R. 34 E., from shale bed about 60 feet below base of Tullock member:

Unio sp.
Sphaerium sp.
Physa sp.
Viviparus sp.
Goniobasis tenuicarinata Meek and Hayden.

The sandstone beds near the base of the Lance contain many fragments of bone, most of which are unrecognizable. The following collections were examined and identified by C. W. Gilmore:

No. 7. NW. ¼ sec. 17, T. 1 N., R. 35 E.. from shale lens in sandstone, about 50 feet below base of Tullock member:

Horn core and other fragments of the skull of a ceratopsian, probably Triceratops.

No. 14. Sec. 18, T. 5 N., R. 35 E., from sandstone about 325 feet below base of Tullock member:

Fragments of fossil bone, not determinable.

A worn fragment of a tooth which is doubtfully regarded as pertaining to a ceratopsian.

No. 28. SW. ¼ sec. 7, T. 5 N., R. 35 E., from base of sandstone, about 480 feet below base of Tullock member. (This sandstone also yielded collection 16, listed above.)

Tooth of a ceratopsian.

Fragmentary limb bone of Champsosaurus.

Fragment of turtle shell, not determinable.

In addition to the above-named fossils, several specimens of a rare plant form were collected from the bed that yielded collection 7. This fossil was found in close association with the horn core and other fragments of the skull of the ceratopsian. F. H. Knowlton identified these specimens as the fruits of a species of *Ficus*,[11] to which he has given the name *F. ceratops*. This fossil was hitherto known only at the type locality in Converse County, Wyo., where it is associated with the remains of *Triceratops*. A very closely related species, *F. russelli*, has, however, been found at Forsyth, about 25 miles northeast of the locality at which collection 7 was made. Both of these species are regarded as diagnostic fossils of the Lance formation.

TULLOCK MEMBER.

GENERAL CHARACTER.

The upper member of the Lance formation—herein named Tullock member, from its exposures in the valley of Tullock Creek—is made up of yellowish sandstone and shale and contains ten more or less lenticular coal beds. The rocks resemble the lower portion of the Lance in a general way, but certain differences are apparent on close examination. Although the sandstone is lithologically similar to that in the lower part of the formation, it commonly occurs in beds less than 20 feet thick. These beds, however, seem to be more persistent than the thicker ones that are common in the lower part of the Lance. Much of the sandstone and shale is more or less calcareous, but true limestone was observed at only one point. The shale is for the most part yellowish gray to brownish, and the faint greenish tint so characteristic of the shale in the lower part of the Lance is very uncommon. Many bands of carbonaceous shale are present in the Tullock member, and these also help to give it a brownish-yellow cast. The bare western and southern slopes of the buttes formed by these beds are sometimes referred to by the settlers as "buckskin hills," a term which very aptly describes their color. Plate III, *A*, shows a typical exposure of the Tullock member.

[11] Knowlton, F. H., Description of two new fossil figs from Wyoming and Montana: Torrey Bot. Club Bull., vol. 38, pp. 389–392, 1911.

The outcrop of this member is generally marked by a steep escarpment. Apparently the rocks are much more resistant than those in the lower portion of the Lance, especially that predominantly shaly portion which in many localities immediately underlies it. The Tullock member is overlain by the relatively soft Lebo shale member of the Fort Union, which weathers down to gentle slopes, and in many places in the field erosion has reached the stage at which practically the whole thickness of the Tullock member is exposed within a zone 1,500 feet wide. (See Pl. X.) This stage has been reached along the west side of the Tullock-Big Horn divide, where the escarpment formed by this member is very bold and striking. Along Sarpy and Tullock creeks the escarpment has been more or less dissected by the tributary streams and is somewhat less conspicuous. On the north ends of the main divides the outcrop of the Tullock member is obscured by a heavy mantle of river gravel and is only moderately steep.

THICKNESS AND LIMITS.

The thickness of the Tullock member is remarkably uniform throughout the area, despite the existence within it of a number of more or less well-marked local unconformities. A large number of hand-leveled sections of the member were made, some of which are shown on Plate IV; and the thickness of the member was also determined instrumentally at several points. In the northern part of the field the thickness so measured is 299 feet on Boxelder Creek and 296 feet on West Bear Creek. In the eastern part, as shown by a complete section on East Beaver Creek, the thickness is 294 feet, and in the southern part a section measured in sec. 6, T. 1 N., R. 36 E., shows a thickness of 289 feet. The calculated thickness of the member in the central part of the field just west of Whiskey Butte is 313 feet, but measurement in this locality is complicated by faults.

The top of the Tullock member is marked by a thin but very persistent sandstone which everywhere weathers to a well-defined rim rock. This sandstone is overlain by the soft beds of the Lebo shale member of the Fort Union, and the physiographic contrast produced by weathering along this contact is very striking. In several localities a sandstone 29 feet above the base of the Lebo closely simulates the rim rock marking the top of the Tullock. It was generally found possible to distinguish the two by noting the character of the soil immediately above, the top sandstone of the Tullock being thinly covered by white glistening clay washed from the basal stratum of the Lebo, which is absent above the Lebo. (See stratigraphic section of Lebo member, pp. 37–38.)

The base of the Tullock member is considered to be the base of coal bed A, the lowest in the Lance formation in this field. (See Pl. IX.) Bed A is fairly persistent through the western and central parts of the

field and is generally thicker than 18 inches in these districts. It is very thin or absent on the west side of the Tullock-Big Horn divide north of Pocket Creek, but in Pine Ridge, 10 miles west of Big Horn River, a coal bed occupying the same stratigraphic position was found. In both the Pine Ridge and the Tullock Creek fields the bed may be recognized by a thin brown parting resembling carbonaceous sandstone, which is present in nearly every exposure examined. (See p. 33.) At several places a coal bed about a foot thick was found some 20 feet below bed A, but this lower bed is not at all persistent and is of no economic importance. Nearly everywhere along Tullock Creek bed A is underlain at a distance of 10 to 25 feet by a massive yellow sandstone from 10 to 50 feet thick, which rests on greenish gray shale characteristic of the lower part of the Lance. This sandstone-shale contact was at first considered to mark the base of the Tullock member, but it was later found to be probably not a definite plane nor as easily recognizable as coal bed A. In cases of doubt, however, the identification of this coal bed may often be confirmed by finding the sandstone-shale contact below. In much of the district east of Sarpy Creek coal bed A is absent, but bed C, which is 35 feet higher, is persistent. In this district, however, for the sake of uniformity, the base of the Tullock member was mapped at the horizon of bed A.

LITHOLOGIC CHARACTER.

The general composition of the Tullock member has already been described. Its sandstone beds do not differ greatly from those of the lower part of the Lance, and the detailed descriptions of those sandstones apply almost equally well to these. The sandstone beds of the Tullock member, however, are generally thinner and more regular, and few of them exhibit the basal conglomerate or the conglomeratic swirls that are common in the lower beds. They are generally made up very largely of quartz and feldspar, with a little muscovite; biotite and hornblende are not present in large quantity.

The coal contained in the Tullock member is found at ten general horizons. Bed A, the base of the member, is the most persistent coal bed in the field. Beds C, H, and I, all occurring in the lower half of the member, are also present in most localities, but the remaining beds are lenticular. These beds are designated by letters in order to furnish a means of reference and to indicate their relative positions, but it is really the horizons that should be so designated, for the beds themselves are not continuous throughout the field. Thus, a bed found on Tullock Creek in T. 2 N., R. 35 E., is called bed C, and a bed that crops out on Sarpy Creek in T. 4 N., R. 37 E., is also called bed C; this is done merely to show that they occupy the same stratigraphic position and were therefore deposited at about the same time. The time equivalence of beds designated by the same

letter is probably only approximate, however, as the intervals between the several beds are not absolutely constant throughout the field. A striking example of this condition, shown in Figure 5 (p. 162), is found in T. 4 N., R. 37 E., where the interval between beds C and D decreases from 15 feet to 4 feet in about 2 miles. In several localities a coal bed is replaced by black shale, or by a sandstone, and the shale and sandstone beds are also very lenticular. At a number of points small erosional unconformities were observed, but the hiatus represented is probably very small, and such irregularities are to be expected in continental deposition of this type. Furthermore, they do not affect the thickness of the member as a whole, and the rim rock marking the top of the member and coal bed A at its base occupy the same relative positions throughout the field.

A number of hand-leveled sections of the Tullock member are shown in Plate IV. These sections are correlated as far as possible on bed A, which is the most convenient datum plane in the field and which is used as a base for the structure-contour map described on page 49 (Pl. X). The sections show the intervals between the coal beds and the approximate thickness of each bed.

In order to show the lithology of the other strata in more detail, the following section is presented. This section was measured in the eastern part of the field, where coal bed A is absent or not recognizable, but from the rim rock at the top down as far as bed B the section is typical.

Section of Tullock member of the Lance formation in sec. 35, T. 4 N., R. 37 E.

	Ft.	in.
Lebo shale member of the Fort Union formation.		
Tullock member of the Lance formation:		
Sandstone, hard rim rock	4	
Shale, sandy, with lenses of hard sandstone	38	
Bone and black shale (representing bed J)	4	
Shale, gray	17	
Sandstone, hard	5	
Shale, white, sandy, soft	6	
Coal, impure		10
Shale, carbonaceous	3	
Shale, gray	2	
Shale, carbonaceous	2	
Sandstone, hard	4	
Shale, sandy	8	
Bone		9
Coal, impure		3
Bone		2
Coal		3
Shale, carbonaceous		3
Shale, yellow, sandy	17	
Coal		3
Shale, gray	11	

SECTIONS OF TULLOCK MEMBER OF LANCE FORMATION

SECTIONS OF UPPER DIVISION OF FORT UNION FORMATION

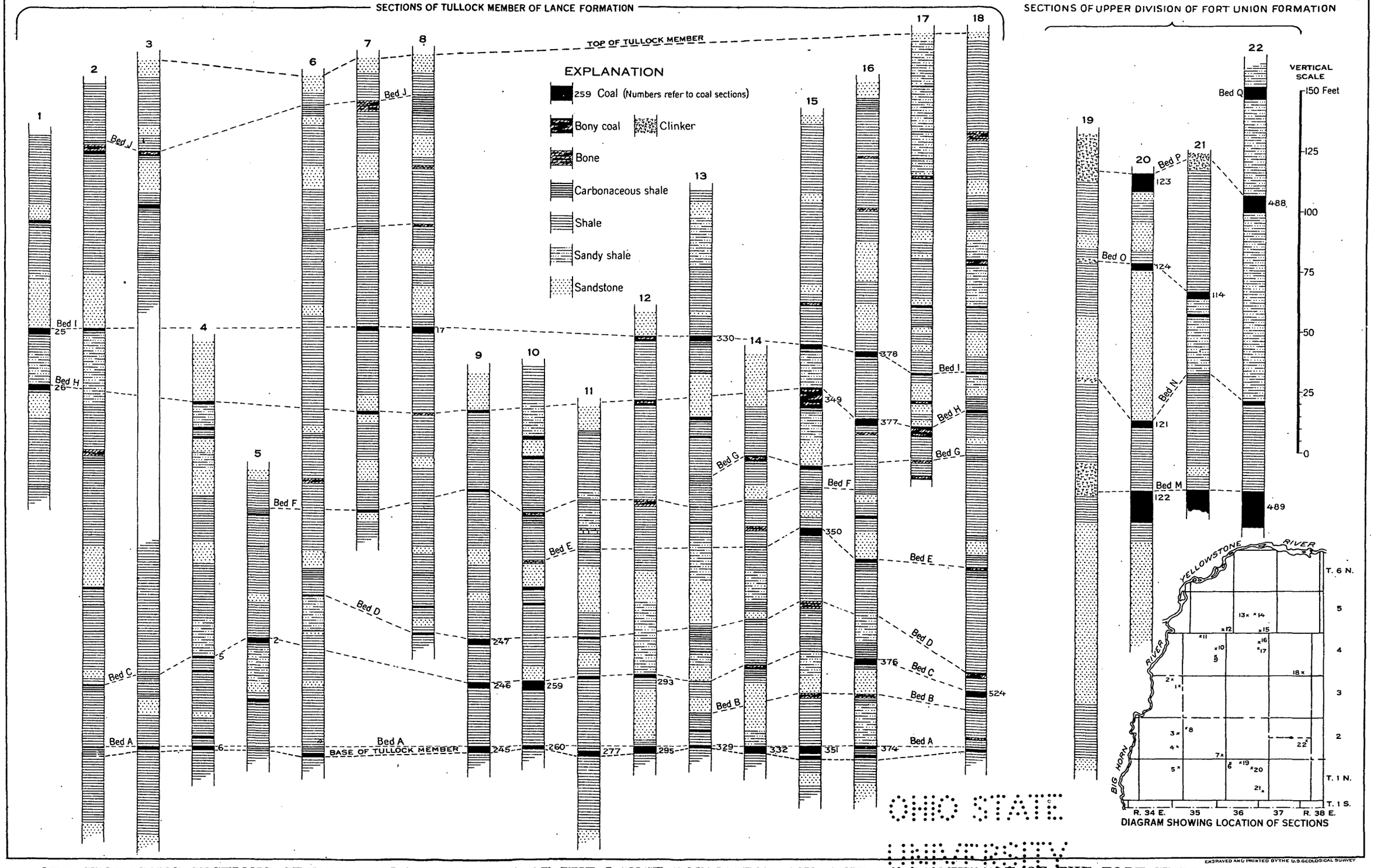


DIAGRAM SHOWING LOCATION OF SECTIONS

ENGRAVED AND PRINTED BY THE U.S. GEOLOGICAL SURVEY

STRATIGRAPHIC SECTIONS OF THE TULLOCK MEMBER OF THE LANCE FORMATION AND THE UPPER DIVISION OF THE FORT UNION FORMATION

Tullock member of the Lance formation—Continued.	Ft.	in.
Sandstone, white, soft	3	
Sandstone, gray, hard	6	
Shale, gray	7	
Coal		4
Shale, sandy	6	
Sandstone, soft	3	
Shale, carbonaceous	7	
Coal		5
Shale, carbonaceous	1	6
Shale, gray	9	
Sandstone, shaly, thin-bedded	2	
Shale, gray	2	
Shale, brown	3	
Shale, black	1	8
Shale, brown, carbonaceous	1	3
Shale, buff	30	
Shale, carbonaceous	2	
Sandstone, soft yellow	6	
Shale, carbonaceous	2	
Shale, yellow	3	
Coal bed E:		
Coal, impure		8
Bone		3
Coal		5
Shale, black	1	6
Shale, gray to yellow	40	
Coal bed D:		
Coal		6
Sandstone, carbonaceous		1
Coal		10
Shale, carbonaceous		6
Shale, gray	4	
Shale, carbonaceous	1	
Coal bed C:		
Coal	1	9
Shale, gray	6	
Shale, carbonaceous	1	
Shale, gray	4	
Shale, hard, slaty	2	
Shale, gray	4	
Coal bed B:		
Coal, impure		6
Shale, gray	3	
Shale, carbonaceous	1	
Coal bed A:		
Bone		3
Shale, carbonaceous		2
Coal		3
	293	7

PALEONTOLOGIC CHARACTER.

Fossils are not so abundant in the Tullock member as in the lower part of the Lance formation, and the invertebrates found are considered by T. W. Stanton to represent a slightly different facies of the typical Lance fauna. Most of the fossils found were leaves, but a single fragment of bone and a few fresh-water shells were collected. The invertebrates identified by Mr. Stanton are as follows:

No. 13. SW. ¼ sec. 36, T. 4 N., R. 35 E., associated with leaves in shale about 200 feet above coal bed A:

Physa sp., smaller than the Physa of preceding collections and probably a different species.

No. 19. Sec. 22, T. 5 N., R. 35 E., from shale about 50 feet above coal bed A:

Unio sp.
Sphaerium sp.
Campeloma multilineata Meek and Hayden.

The single bone fragment found was identified by C. W. Gilmore as a section of a supraorbital horn core of a ceratopsian, probably *Triceratops*. This fossil, which was collected in sec. 22, T. 5 N., R. 35 E., was found associated with other bone fragments on the surface of a steep slope about 50 feet above the base of the Tullock member.

Four collections of fossil leaves were made in the Tullock member. Inasmuch as the plant species found in the Lance also range up into the Fort Union, fossil plants are generally of no value in distinguishing between these formations. The following forms were identified by F. H. Knowlton:

No. 9. SE. ¼ sec. 13, T. 2 N., R. 34 E., from sandstone about 75 feet above coal bed A:

Populus cuneata Newberry.
Pterospermites cf. P. whitei Ward.
Celastrus curvinervis Ward.

No. 13. SW. ¼ sec. 306, T. 4 N., R. 35 E., associated with Physa sp. in shale about 200 feet above coal bed A:

Onoclea sensibilis fossilis Newberry.
Populus amblyrhyncha? Ward.
Sapindus grandifoliolus Ward.
Populus daphnogenoides? Ward.

No. 20. Sec. 34, T. 4 N., R. 35 E., in shaly sandstone 30 feet above coal bed A:

Leguminosites arachioides Lesquereux.
Populus amblyrhyncha Ward.
Platanus, probably P. raynoldsii.

No. 22. Sec. 34, T. 5 N., R. 35 E., in sandstone 10 feet above coal bed A:

Cocculus haydenianus Ward.
Populus sp.

TERTIARY SYSTEM.

FORT UNION FORMATION.

DIVISIBILITY OF THE FORMATION.

The Fort Union formation in this district is separable into two divisions—a basal member 150 feet thick, composed of dark shale and known as the Lebo shale member, and an overlying series of shales and sandstones, which are normally yellow but which over large areas have been changed by the heat from burning coal beds to a brick-red or reddish-brown color. Although there is no paleontologic evidence for distinguishing the Lebo as a separate member, its peculiarities in color and lithology are sufficiently striking to warrant the separation. The relations of this member are more fully described below.

LEBO SHALE MEMBER.

GENERAL CHARACTER.

The Lebo shale member, the basal member of the Fort Union, consists of dark-gray to olive-gray and drab shale interbedded with a few beds of gray or yellow sandstone. Lenses of bone and carbonaceous shale are not uncommon, and there are two horizons at which coal occurs in beds over 18 inches in thickness. Some of the sandstone beds are fairly resistant and tend to form rim rocks, but the member as a whole is soft and suffers rapid erosion. Some of the beds carry brown ironstone nodules in great abundance; these range from a quarter of an inch to a foot in diameter and on weathering generally slump down and thickly strew the whole surface. The smaller nodules, which resemble coffee grains, are especially abundant and characteristic. The member as a whole has a dark and somber aspect and is thus easily distinguishable from the light-yellow strata above and below it.

In addition to the generally somber color of the Lebo, its physiographic expression is very characteristic. The Lebo is overlain by the yellow sandstones of the Fort Union, which have been removed by erosion in the northern part and most of the central part of the field, and is underlain by the resistant Tullock member of the Lance formation, which extends well out on the north ends of the divides. Hence the outcrop of the Lebo member generally forms a broad zone, and owing to its softness and its position immediately above the highly resistant cap rock of the Lance formation, it is generally eroded down into long, gentle slopes or forms a practically flat plain. (See Pl. VII, *B*.) Although the Lebo, as shown in Plate X, crops out over a considerable part of the field, in most of the exposure only 25 feet or so of the basal portion of the member remains, and erosion would have removed still more had it not been

materially retarded by the Lance cap rock below. In a few localities almost the entire thickness of the Lebo is exposed in a fairly narrow zone, and here, because of the softness of most of the beds and the infertile character of the soil produced, a typical badland topography is developed. However, owing to the small thickness of the member in this field, these badlands are not so conspicuous a feature of the topography as in some areas to the north and east.

THICKNESS AND LIMITS.

The Lebo member generally covers a wide zone, and accurate measurements of its thickness are difficult to make. In T. 4 N., R. 36 E., its thickness as measured with a hand level is 155 feet; in the next township to the south it is 135 feet; and in the southern part of the field, in T. 1 N., R. 36 E., it is 139 feet. Several calculations made from altitudes determined on the top and base of the member in T. 3 N., R. 38 E., indicated a thickness of 140 to 150 feet. It is very possible, however, that the thickness of the Lebo is not as uniform as these measurements suggest.

The base of the Lebo is the top of the resistant sandstone that caps the Lance formation, as described above. The top of the Lebo apparently is not marked by any very conspicuous stratum, though the character of the material changes sharply within a vertical distance of 25 to 30 feet. In some districts the color contrast and the character of the topography are the chief guides. In most localities, however, the lowest stratum of the upper division of the Fort Union is a thick, massive sandstone (see Pl. V), and the base of this sandstone is considered the top of the Lebo.

LITHOLOGIC CHARACTER.

The Lebo is made up very largely of shale and fine sandy shale, with generally lenticular beds of fine arkosic sandstone. Except for the numerous irregular and discontinuous layers of hard ferruginous concretions mentioned above and for a few thin sandstones, these beds are soft and practically incoherent. Much of the shale is too fine for microscopic examination, though most of it contains a considerable percentage of quartz in very fine grains. Much of the sandstone, however, when examined in thin section, is seen to contain from 30 to 50 per cent of brown volcanic glass, generally considerably altered and devitrified. The remainder of the rock consists chiefly of quartz with some feldspar, generally kaolinized, and chlorite. The brown concretions so characteristic of the Lebo doubtless owe their ferruginous composition to the considerable percentage of ferric oxide that these beds originally contained.

A number of hand-level sections of a part or the whole of the Lebo were made, and some are given below.

Sections of Lebo shale member of the Fort Union formation.

Sec. 23, T. 3 N., R. 36 E.

Upper division of the Fort Union formation.

Lebo shale member:	Ft.	in.
Sandstone, yellowish, forms rim rock locally		6
Shale, gray to white	4	
Shale, friable, carbonaceous, forming purple band (not everywhere conspicuous)	1	6
Shale, gray	6	
Shale, yellowish	5	
Coal bed L: Coal and bone	2	
Shale, carbonaceous, weathering purple	2	
Shale, gray, crumbly; includes several layers containing abundant coarse ironstone nodules	22	
Sandstone, coarse, arkosic, gray to white when fresh, yellowish when weathered; prolific source of ironstone nodules; probably lenticular	19	
Shale, carbonaceous	2	
Coal bed K: Coal and bone	1	
Shale, carbonaceous	4	
Sandstone, gray, fine, arkosic, more or less carbonaceous, weathering like shale; shows root marks of fossil plants	6	
Ferruginous nodules		3
Sandstone, gray when fresh, yellowish brown when weathered, arkosic, medium coarse grained, laminated, and platy; forms rim rock locally; contains root marks of fossil plants	1	
Shale, crumbly	4	6
Shale, carbonaceous; forms conspicuous band	1	
Shale, yellowish gray	16	
Shale, carbonaceous; forms inconspicuous blue-gray band	1	
Talus, probably shale	2	
Sandstone, yellow, platy, medium coarse; forms broken blocky rim rock which in some localities resembles the cap rock of the Lance formation	1	6
Shale, dark; weathers bluish gray	5	
Shale, dark, gritty, weathering yellow; brownish band near center carries numerous large ironstone nodules	6	
Shale, gritty; weathers white; washes down to a glistening white soil	5	
Sandstone with carbonaceous bands (base of Fort Union formation)	11	
	135	3

Rim rock of Tullock member of Lance formation.

Sec. 5, T. 4 N., R. 36 E.

Upper division of the Fort Union formation.

Lebo shale member:	Ft.	in.
Sand, gray, tuffaceous	10	
Shale, gray, containing an abundance of brown ironstone concretions	30	
Sandstone, yellow, hard	3	
Sandstone, white, friable, tuffaceous	20	
Sandstone, yellow, hard, concretionary	1	
Sandstone, white, friable, tuffaceous	7	
Shale, gray, containing an abundance of brown ironstone concretions	12	
Shale, dark gray, containing carbonaceous matter	4	
Shale, gray, containing dark brown ironstone concretions	21	
Bone		6
Shale, dark gray	6	
Shale, carbonaceous	8	
Shale, white, sandy	4	
Sandstone, brown, thin-bedded	1	
Shale, dark gray	10	
Sandstone, yellow, thin-bedded (base of Fort Union formation)	2	
	139	6

Sec. 17, T. 4 N., R. 36 E.

Upper division of the Fort Union formation.

Lebo shale member:	Ft.	in.
Shale, hard, black, sandy	1	
Shale, gray, very many orange concretions	22	
Sandstone, orange-brown	1	
Sandstone, dark gray, concretions at top	37	
Sandstone, gray-white	11	
Sandstone, gray; dark-brown concretions at top	3	
Coal, dirty		6
Sandstone, gray	8	
Sandstone, carbonaceous	2	
Sandstone, light gray	15	
Sandstone, hard, yellow		6
Sandstone, light gray, lenticular	5	
Shale, concretionary, light yellow	1	
Shale, light gray, with concretions, sandy at top	22	
Bone		10
Shale, dark gray, with concretions (base of Fort Union formation)	30	
	169	10

The two coal beds of the Lebo member, which are about 20 and 70 feet below the top, are of little economic importance. The horizons at which these beds occur are generally marked by layers of carbonaceous shale and bone 2 to 7 feet thick, and these layers

are remarkably persistent and recognizable almost everywhere in the field. It is only in a few very small areas, however, that these carbonaceous layers carry more than 18 inches of even moderately clean coal. Carbonaceous material occurs at another prominent horizon 30 feet above the base of the member (see section above), but although this material generally carries some coal, it was not found to contain more than 15 inches at any point examined. The sandstone beds of the Lebo are lenticular and, with the exception of the thin sandstone 29 feet above the base, do not form conspicuous outcrops. This sandstone was observed at a number of places; in some localities it closely resembles the rim rock marking the top of the Lance formation, and in others it forms on weathering ellipsoidal masses of sandstone several feet in diameter. The only other widely recognizable horizon in the Lebo is one somewhat below the center carrying silicified wood, the float of which is very widespread.

RELATIONS AND AGE.

The Lebo member was first described from its occurrence in the vicinity of the Crazy Mountains, about 125 miles west of the Tullock Creek field, where it is appropriately called the Lebo andesitic member.[12] It was interpreted as an outfingering of the Livingston formation, which is composed of andesitic detrital and tuffaceous material. A mass of dark shale at the same horizon in the Bull Mountain field was described by Lupton [13] as the Lebo shale member, and in the Little Sheep Mountain field similar dark shale which was found to carry a considerable percentage of andesitic ash was mapped by the senior writer [14] under the same name. The name Lebo is used in the Tullock Creek field on the basis of the lithology and stratigraphic position of the beds, no fossils having been found. The age of the Lebo in the Crazy Mountains was determined as Fort Union by the presence of Torrejon mammal remains near its top, but in that locality the member is some 2,000 feet thick and no diagnostic fossils were found in the lower portion; and in other localities only leaves or shells that are of little value in distinguishing between the Fort Union and Lance have been collected. The name Lebo has therefore been extended to eastern Montana areas, chiefly on the basis of lithology and stratigraphic position. On this basis the Lebo was recognized by Lupton in a reconnaissance on Rosebud Creek about halfway between the Tullock Creek field and Miles City, and it can also be distinguished in the Miles City section. In the

[12] Stone, R. W., and Calvert, W. R., Stratigraphic relations of the Livingston formation of Montana: Econ. Geology, vol. 5, pp. 752 et seq., 1910.

[13] Lupton, C. T., The eastern part of the Bull Mountain coal field, Mont.: U. S. Geol. Survey Bull. 431, pp. 163–189, 1911.

[14] Rogers, G. S., The Little Sheep Mountain coal field, Mont.: U. S. Geol. Survey Bull. 531, pp. 159–228, 1913.

eastern part of the Little Sheep Mountain field the dark shale mapped as Lebo pinches out, leaving the yellow beds of the Fort Union resting directly on the Lance. It is known, however, that a considerable thickness of dark shale at about this horizon extends far to the east, and in North Dakota it has been mapped as Lance. In the present state of our knowledge concerning the criteria available for distinguishing Fort Union from Lance, it seems probable to the writers that the line drawn between the two in North Dakota is higher than that drawn in the Tullock Creek field, and that the Lebo member in this locality may be equivalent to the upper part of the Lance in areas to the east. It is true that there is a considerable variation in thickness throughout this area, that there is at least one place where the shale pinches out entirely, and that the shale becomes more notably coal-bearing toward the east; but C. F. Bowen states that even in the area between the Bull Mountain and Little Sheep Mountain fields, where the correlation can not be doubted, the Lebo becomes much thinner and probably pinches out to the north. Unfortunately, petrographic methods have not been applied in the eastern areas, and it is not known whether the dark shale there contains andesitic material or not. More field work is needed to determine the relations of the shale here called Lebo, on the one hand, to the Lebo andesitic member in the Crazy Mountains, and, on the other, to the dark shale beds mapped as Lance in areas to the east; but it is certain that in the vicinity of the Tullock Creek field the lithologic contrast between the Lebo and the adjoining strata fully justifies its recognition as a separate member.

UPPER DIVISION OF THE FORT UNION FORMATION.

GENERAL CHARACTER.

The upper division of the Fort Union in this district is composed of well-consolidated material consisting of arkosic sandstone, more or less sandy shale, carbonaceous shale, and coal. Many of the beds are calcareous, though no limestone was observed. The color of this part of the Fort Union is normally yellow, but the thick coal beds have burned along the outcrop and baked the overlying strata to a strong brick-red to reddish-brown color, and in the southern part of the field the lower 300 feet is prevailingly red. In T. 3 N., R. 38 E., however, the coal beds are thin and have burned only locally, and in this district the yellow beds can be distinguished from the Lance formation only by their relations to the Lebo shale. The yellow color of the beds, the cross-bedded and arkosic character of the sandstone, the way in which the sandstone yields to wind erosion, the scattered growth of trees, and the topographic forms are entirely similar in the two formations. This is illustrated in Plate III,

which shows a typical view of the Tullock member of the Lance and a view of the yellow beds of the Fort Union.

The yellow beds of the Fort Union are considerably more resistant than those of the Lebo shale member and commonly rise steeply from the gently sloping Lebo plain. (See Pl. V.) In the district where the coal is not burned the yellow beds are highly dissected and tend to form a badland topography. Where the coal has baked or fused the overlying strata, however, their resistance to erosion is greatly increased, and in the southern part of the field the beds form a bold escarpment. The clinkers formed by the burning of these coal beds, especially beds P and Q, tend to protect the underlying rock, which makes the interstream divides more or less flat topped. The isolated buttes on the face of the escarpment are generally protected at the top of the clinker of bed P, and some of them are thus eroded to a strikingly symmetrical shape (Pl. V, *B*). In this area the streams flow through comparatively narrow gorges, and although the relief does not exceed 300 feet, travel across the drainage lines is very difficult. However, a good loose soil is produced by the weathering of the baked shale and sandstone, and the flat tops of the divides are well grassed and in some places heavily timbered. In the extreme southeast corner of the field, where yellow beds above the burned zone crop out, the topography is more gentle, and practically the whole surface is grass covered.

THICKNESS AND LIMITS.

No accurate measurement of the thickness of the upper part of the formation exposed in this field was made, but on the basis of altitudes determined on the higher coal beds it is estimated at about 675 feet. Fully 600 feet more of these beds, including several thick coal beds, is exposed in Wolf Mountain, within 3 miles of the eastern edge of the field.

The base of this part of the formation, which is generally covered by sand wash and therefore difficult to study, is apparently not a definite line. The drab and somber shale of the Lebo grades within 25 feet into the massive arkosic sandstone in the lower part of the upper division, but there is no sharp change in the character of the materials except at the base of the sandstone, and hence this line was taken as marking the base of the upper portion. In some localities this sandstone is broken by lenses of yellow sandy shale and becomes a sandy zone rather than a single bed, but in either case the horizon is easily recognizable everywhere in the field. (See Pl. V, *A*.)

LITHOLOGIC CHARACTER.

Owing to the baked and altered condition of the lower 300 feet of the upper division, and to the fact that the higher strata are not

well exposed in this field, no good stratigraphic sections were measured. The clinker or slag produced by the burning of the three thick lower coal beds has in places coalesced, and even where this has not occurred, the upper clinkers slump down and greatly obscure the underlying beds. The only datum planes that could be followed in the field with any success were therefore the coal beds themselves, and as their unburned outcrops are generally confined to the heads of the youngest coulees, even the intervals between the coal beds are very difficult to work out. The outcrop of a burned bed may of course be traced roughly by its clinker, but this is of no value in exact measurements, for the baking extends not only above but below the bed. Another factor that militates against accurate work is the disturbance of the strata caused by the burning. When a coal bed 20 feet or so thick is burned and in the course of its combustion largely dissipated, the space previously occupied by the coal must be taken by the slumping of the overlying strata. Inasmuch as in the southern part of the field 15 per cent of the lower 300 feet of the upper division is composed of coal, this process is obviously of no mean importance.

Even if due weight is given to the above-stated considerations, however, it is difficult to escape the conviction that the upper beds were deposited very irregularly. The intervals between the coal beds vary considerably from place to place, and bed M, the lowest and most persistent coal, is channeled or abruptly replaced by black shale at several localities on Sarpy Creek. The strata between beds M and P contain smaller coal beds, which seem to be very lenticular. Although the basal sandstone of the upper division is a prominent and persistent stratum, neither its top nor its base is thought to be a definite plane. Some of these facts are shown in the following composite section, which is supplemented by the more detailed measurements given in Plate IV.

General composite section of the upper division of the Fort Union formation.

	Feet.
Shale and massive sandstone	100+
Coal bed R	5
Shale and thin sandstone beds	300
Coal bed Q	1–11
Sandstone and shale, thinning southward	10–50
Coal bed P	1–24½
Shale and massive sandstone, thinning to the southeast, with thin local coal lenses	80–140
Coal bed M	1–23
Sandstone, massive, cross-bedded, locally containing shale lenses	75–130

The most prominent sandstone in this section is that at the base, which is found not only in the southern part of the field but also north of Whiskey Butte, on the Sarpy-Tullock divide, where it constitutes the sole remnant of the yellow beds unremoved by erosion. It is arkosic in character, and the grains are generally coarse enough to permit the identification of quartz and feldspar with a hand lens. Irregular swirls of conglomerate, though uncommon, are not lacking in places, and the bed also contains a few lenses of harder material, which stand out on weathering. In some localities pyrite concretions are abundant at this horizon and on weathering out leave a pitted surface. As a rule, however, the sandstone is massive and fairly homogeneous and weathers to a smooth rounded surface; neither the bedding planes nor the cross-bedding stands out. The sandstone is almost everywhere characterized by cross-bedding, and Plate VI, *B*, shows a typical exposure. A thick sandstone lithologically similar to that of the base generally occurs 25 to 50 feet above coal bed M, and many other thick but more or less lenticular sandstone beds are contained in the lower 300 feet. Between beds Q and R the strata consist largely of shale and contain only thin sandstones, but above bed R another thick, massive sandstone crops out prominently. However, the character of the section varies considerably from place to place. It is considered in more detail under the township descriptions given below.

PALEONTOLOGIC CHARACTER.

These beds are correlated with the yellow beds of the Fort Union formation in the Little Sheep Mountain field, to the east, and the Bull Mountain field, to the northwest, chiefly on the basis of their lithology and their stratigraphic position above the Lebo shale, which is widely recognizable by its lithologic and physiographic characteristics. Only a few fossil leaves were obtained in this part of the formation, and although these indicate the Tertiary age of the beds, they do not alone demonstrate that they are of Fort Union age. The following fossils were identified by F. H. Knowlton:

No. 1. Sec. 21, T. 1 N., R. 37 E., from sandstone about 25 feet above coal bed M:

Virburnum erectum Ward.
Viburnum tilioides Ward.
Sapindus grandifoliolus Ward.
Populus cuneata Newberry.
Viburnum limpidum Ward.
Onoclea sensibilis fossilis Newberry.

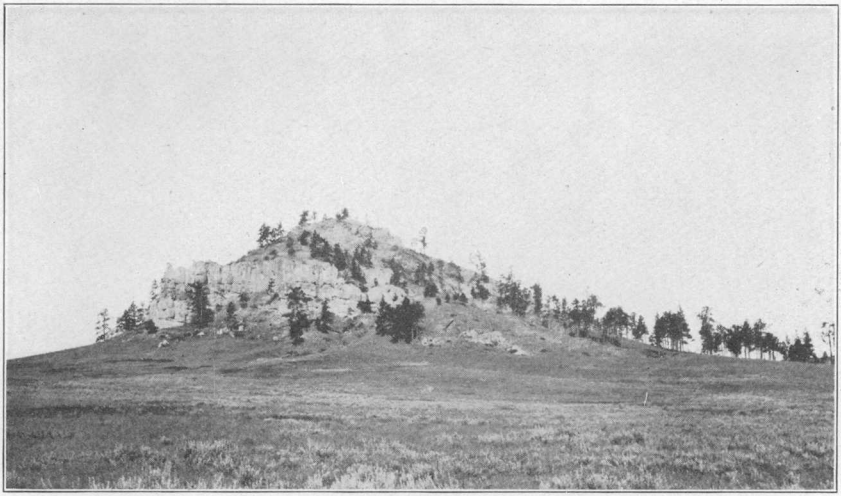
QUATERNARY SYSTEM.

PLEISTOCENE GRAVEL.

GENERAL CHARACTER.

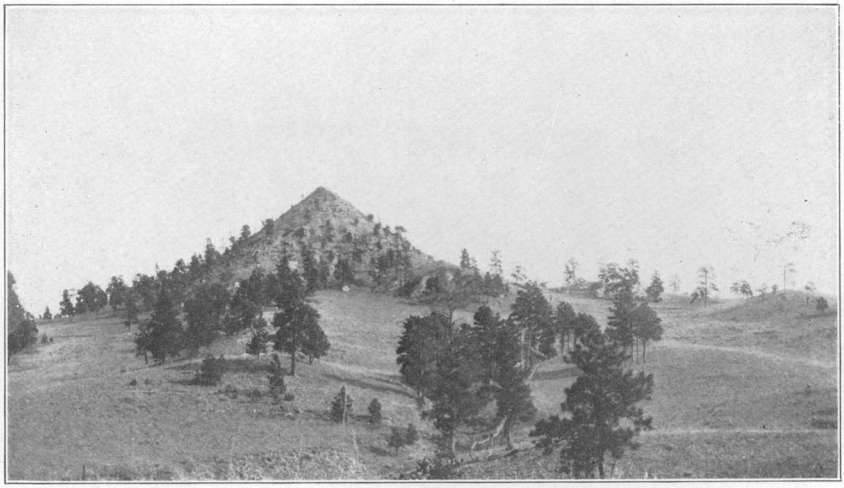
A more or less irregular mantle of gravel ranging in thickness from a few inches to 90 feet covers the outcrops of the older rocks in the northern and western parts of the field. The variation in thickness is irregular and probably is due in part to recent reworking, as the average thickness of the material is not more than 20 feet. In some localities within 5 miles of the rivers only a few scattered pebbles are found, but in some districts along the southern margin of the gravel-covered area the deposit is 25 feet or more thick. Where the gravel is more than 5 feet thick it is generally cemented to a more or less compact conglomerate, in which the cement is calcareous and the interstitial filling is the sand associated with the gravel. (See Pl. VII, *A*.) The rock thus formed does not make sharp outcrops, however, and constantly slumps down; hence on casual examination the material appears unconsolidated.

Because of the peculiarly uniform way in which the gravel yields to erosive agencies, it tends to develop a characteristic rounded type of topography. This is due to the homogeneous character of the gravel itself but is naturally most striking in the areas in which the gravel rests on soft shale. As the Lebo shale covers the divides in the gravel-covered area, it is on the divides that this type of topography is best developed. A monotonous series of bare, rounded, though fairly steep hills is formed, each hill resembling every other, so that landmarks are entirely lacking. A similar topography results where the gravel rests on the Bearpaw shale. It is well developed in the southwestern part of the field and along Yellowstone River in the zone between the edge of the bottom land and the outcrop of the base of the Lance formation. Where the gravel overlies the tilted sandstone of the Judith River formation a smooth hogback topography is produced (see Pl. I, *A*), but the Claggett shale area is characterized by the more rounded hills. Where the gravel rests on the Lance formation this characteristic topography is only locally developed, owing to the abundance of ledge-forming sandstone. Only the thick basal sandstone of the upper division of the Fort Union crops out within the gravel-covered area, but this sandstone is so homogeneous that where covered with gravel it gives rise to a topography similar to that of the soft Lebo shale. Where the gravel rests on this sandstone or on the sandy Lance formation, the slopes are generally timbered, but where it covers a shale formation the surface is practically treeless.



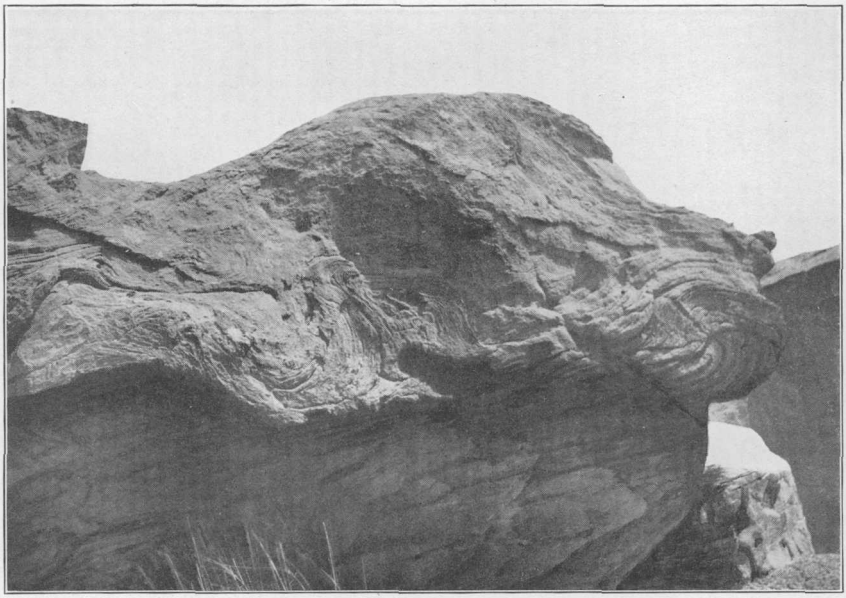
A. TYPICAL BUTTE OF THE BASAL PART OF THE UPPER DIVISION OF THE FORT UNION FORMATION ON PLUM CREEK IN SEC. 9, T. 1 N., R. 36 E., LOOKING NORTH.

These beds are marked by the heavy sandstone shown in the view. The grass-covered foreground is underlain by the soft Lebo shale member of the Fort Union. Note abrupt western slope and gentle, grass-covered eastern slope.



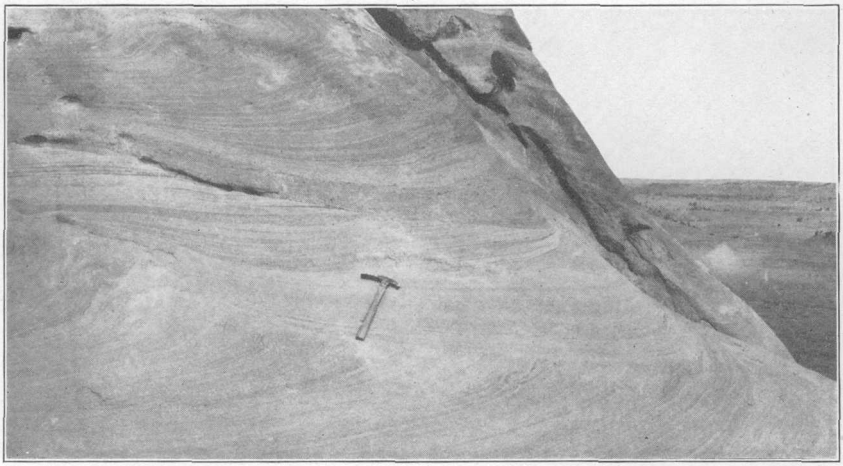
B. BUTTE OF UPPER DIVISION OF THE FORT UNION FORMATION RISING ABRUPTLY FROM THE FLAT LEBO SHALE PLAIN ON PLUM CREEK IN SEC. 5, T. 1 N., R. 36 E.

The strikingly symmetrical shape of this butte is due to its hard cap of baked rock formed by the burning of coal bed P.

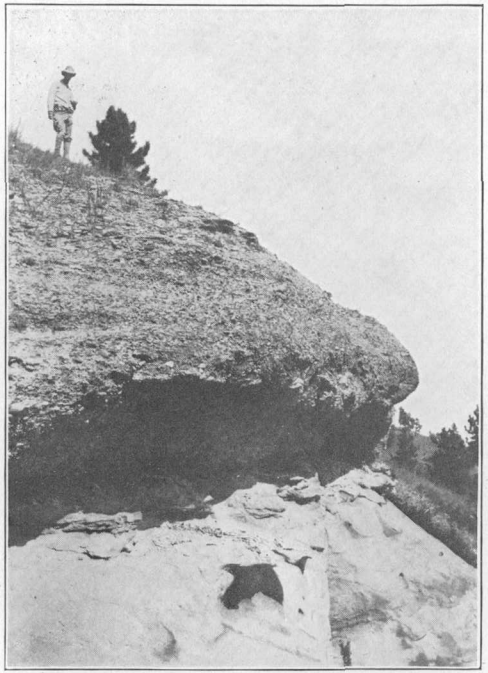


A. CONTORTED LAMINAE IN FLAT-LYING SANDSTONE LAYER IN THE LANCE FORMATION IN SEC. 4, T. 4 N., R. 35 E.

Sandstone is 75 feet below the base of the Tullock member. The apparent crumpling is probably due to concretionary action. (See text.)

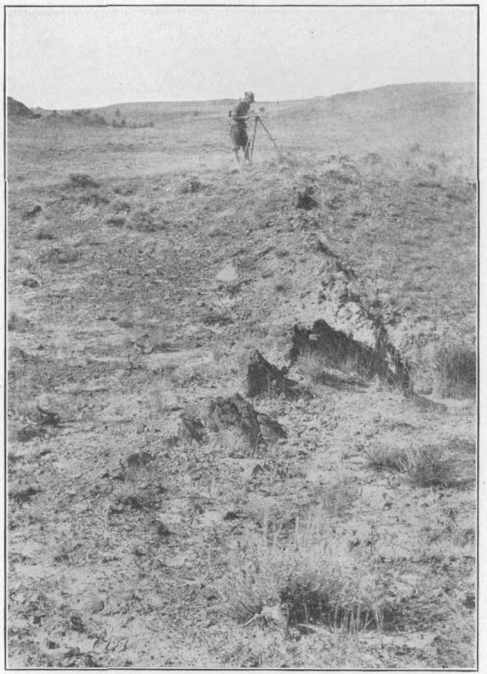


B. DETAIL OF CROSS-BEDDING IN THE SOFT BASAL SANDSTONE OF THE UPPER DIVISION OF THE FORT UNION FORMATION IN SEC. 9, T. 3 N., R. 36 E.



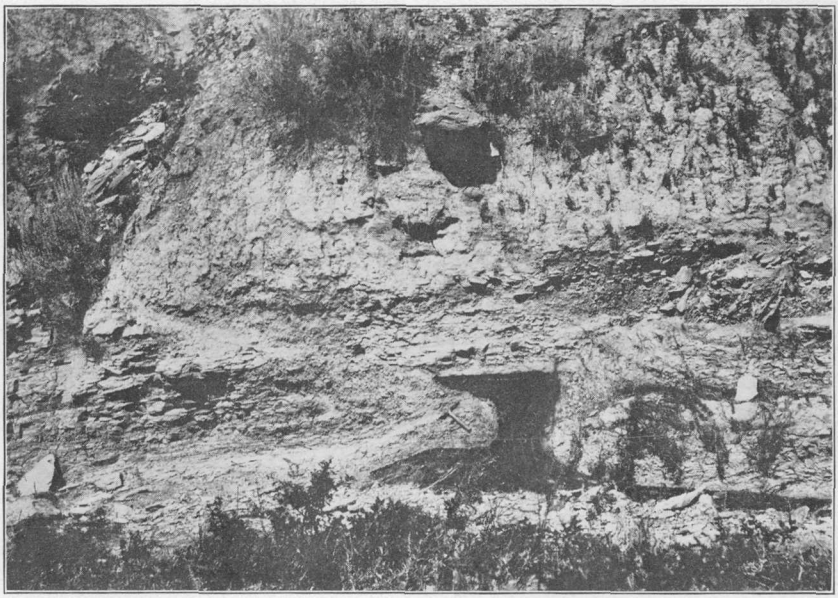
A. QUATERNARY GRAVEL RESTING ON ERODED SURFACE OF THE LOWER PART OF THE TULLOCK MEMBER OF THE LANCE FORMATION ON BOX ELDER CREEK, SEC. 13, T. 5 N., R. 35 E.

This gravel covers the main divides and higher hills in the northern part of the Tullock Creek field, where it reaches a maximum thickness of 90 feet. Though unconsolidated in some localities, in others it is a conglomerate, as shown in this view.

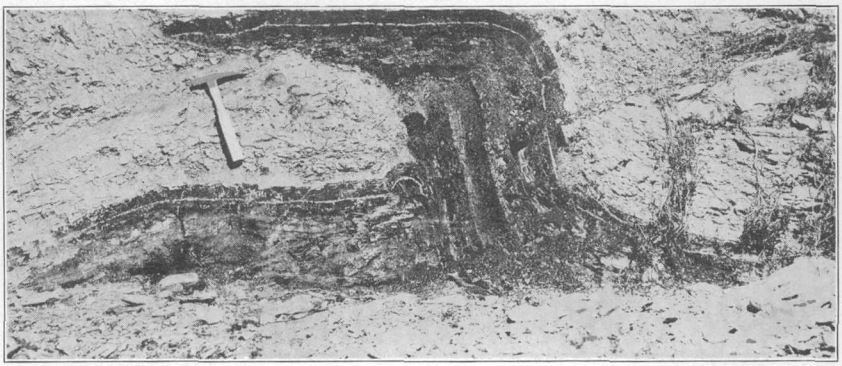


B. TRACE OF FAULT IN NEARLY FLAT-LYING BEDS OF THE LEBO SHALE MEMBER OF THE FORT UNION FORMATION, SEC. 22, T. 2 N., R. 36 E.

Showing also the type of country underlain by the Lebo member. The small hogback marking the fault is formed of shale hardened and compacted by the friction and pressure along the fault plane.



A. OVERTHRUST FAULT CUTTING COAL BED C, SEC. 3, T. 2 N., R. 35 E.
The strata in this vicinity are nearly flat. (See Pl. X.)



B. CLOSER VIEW OF FAULT, SHOWING DETAILS OF FOLDING.

ORIGINAL AND PRESENT DISTRIBUTION.

The gravel does not extend more than 23 miles south of Yellowstone River except on the western edge of the field, where it is found also in a zone extending about 10 miles back from the Big Horn. Within these limits, however, its distribution is somewhat irregular. On the divide east of Sarpy Creek the most southerly gravel deposit is in sec. 20, T. 3 N., R. 38 E., 23 miles south of the Yellowstone. On the Sarpy-Tullock divide gravel is found as far south as the southern part of T. 3 N., R. 36 E., which is about the same distance from the river. On the Tullock-Big Horn divide, however, gravel is not abundant, and even at its north end there are considerable areas in which only scattered pebbles are found. The gravel is also very thin and inconspicuous on much of the western flank of this divide, though in places fairly thick beds are found. Gravel is found on the crest of this divide in T. 2 N., R. 35 E., however, and forms a thick cover over most of the surface in the southwestern part of the field. Thus it seems to be confined to the general zones along Yellowstone and Big Horn rivers, though it may be noted that the angle between these zones is not sharp, as gravel occurs in the valley of Tullock Creek in the northeastern part of T. 2 N., R. 35 E. No gravel or even isolated pebbles were found in the area south and east of these general limits, and it is believed that the gravel was never deposited there. There is no marked increase in the altitude of the land on the border of the gravel area, but it seems probable that there must have been some confining slope at the time the gravel was deposited.

The general altitude of the highest gravel is from 3,700 to 3,800 feet, or about 1,100 feet above the river. In the lower valleys of Tullock and Sarpy creeks and on the north ends of the main divides there are also several well-marked benches at lower altitudes. There appears to be an abundance of material on which to work out the Pleistocene history of this region, but the subject is one that demands broad study, in which a good topographic base map is essential.

The significance of many of the lower beds of gravel is obscured, however, by the probability that they have been reworked, perhaps many times. The present streams are constantly carrying gravel down and depositing it at lower levels, and if it happens to be laid down in a fairly thin deposit on a natural rock beneath, it may be very difficult to distinguish from a primary gravel terrace. If, on the other hand, the deposit is fairly thick, subsequent stream cutting may be diverted to the lateral contact between the gravel and the older beds, which seems to be a plane of weakness. One striking result of this process, noticed in several localities, is the formation of gravel hills

at the forks of secondary drains. The gravel apparently represents an accumulation at the old head of an originally straight valley; but when cutting was resumed, the stream followed the contacts of the gravel with the old sides of the drain, leaving most of the gravel as a hill between two channels, which join farther down.

Another instance of what is probably reworking of this gravel at a very early date was noticed at the end of the ridge between Boxelder and Sarpy creeks. In sec. 16, T. 5 N., R. 36 E., there is an east-west channel over 90 feet deep extending directly across the end of the present divide and cutting out coal bed A. The base of the gravel in this channel is about 350 feet below the highest point at which gravel is known. It does not seem at all likely that the gravel was originally laid down on a surface whose relief was 350 feet; and the only alternative hypothesis is that the channel was cut and filled by reworked gravel at a comparatively early stage in the dissection of the old peneplain represented by the present ridge top.

LITHOLOGIC CHARACTER.

The gravel is composed of pebbles representing a wide range of rock types. Quartzite is one of the most common, a fact which is no doubt due more to its greater hardness than to its preponderance in the original series of rocks from which the gravel is derived. Jasper and quartz are common, and chalcedony is also found. Pebbles of very dense fossiliferous limestone are present, and crinoid stems were noted in one pebble. Of igneous rocks a fairly complete series is present, the types ranging in composition from basalt to granite and in texture from porphyritic to granitic. Sandstone of the type common in the Cretaceous and Tertiary rocks of the region was rarely found.

The pebbles are for the most part smoothly rounded and are ovoid to flattish in shape. They are fairly well sorted locally, the average diameter being 2 to 3 inches. Pebbles 6 inches in diameter are common, however, and a few boulders 10 to 14 inches in diameter are found. The interstitial material is chiefly quartz, generally in angular grains; very little clay is associated with the gravel.

AGE AND RELATIONS.

The gravel contains no fossil remains, and the age of the oldest deposits can not be worked out in the study of a small area. It is certain that the lower deposits are of Pleistocene age, but if the higher deposits also are assigned to this epoch, about 1,100 feet of stream cutting must have been effected since the beginning of the Pleistocene.

It must be remembered, however, that both Yellowstone and Big Horn rivers rise in the mountains and that this area is situated

fairly close to their sources. W. C. Alden,[15] who has worked out the Pleistocene geology of a part of northwestern Montana, states that Milk River, which rises in the plains and derives practically no water from the mountains, has, since the formation of the oldest glacial deposits, cut a valley which is over 700 feet deep well up toward its head and that mountain streams in the same region have effected more than 1,200 feet of cutting. Furthermore, the oldest gravel in the Tullock Creek field resembles in every way the lower deposits, which are undoubtedly Pleistocene; it seems probable, therefore, that all this gravel may be assigned to the Pleistocene.

The oldest gravel in this field is equivalent to that on Pine Ridge, 10 miles to the west, which stands 1,100 feet above the Yellowstone. A terrace that stands 200 feet above the rivers in that district is also recognized in the Tullock Creek field. A terrace is found in the Little Sheep Mountain field, 60 miles to the northeast, at approximately 1,000 feet above the river. The altitude of this terrace was not accurately determined, however, but as the character of the material is similar to that in the oldest deposits in the Tullock Creek field, they may be provisionally correlated.

The gravel in the northern part of the field was derived from the mountains in which the forerunner of the present Yellowstone had its source. The terraces in this part of the field do not correspond in altitude with those on the flanks of the Big Horn Mountains described by N. H. Darton, nor is the material similar. However, the gravel in the southwestern part of the field contains a somewhat greater proportion of granite, which is the predominant rock in the Big Horn terraces, and this gravel is probably derived mostly from the Big Horn and Pryor mountains.

RECENT ALLUVIUM.

The most recent deposit in this area is the alluvium that is now being laid down in the flood plains of the Yellowstone and its tributaries. The flood plains of Yellowstone and Big Horn rivers average about 3 miles in width, but the meandering of the rivers has divided the bottom land into comparatively small areas alternately arranged on the opposite banks. The location and extent of these areas is indicated on Plate X. Corresponding deposits extend in narrowing branches into the valleys of Tullock, Sarpy, and other northward-flowing creeks and ramify also into those of their tributaries. Along the lower courses of the smaller creeks, such as Boxelder Creek, the flood plain has a width of only 300 or 400 feet, but along Tullock and Sarpy creeks it is nearly half a mile wide.

[15] Alden, W. C., and Stebinger, Eugene, Pre-Wisconsin glacial drift in the region of Glacier National Park, Mont.: Geol. Soc. America Bull., vol. 24, pp. 529–572, 1913.

The material deposited in the flood plains of the Yellowstone and Big Horn is composed largely of sand and silt, with subordinate amounts of gravel and rubble. In their tributaries, however, the material is coarser, and as the heads of these streams are approached, the coarse materials predominate. At the heads of the tributary valleys coarse material is washed into the drains so much faster than the intermittent streams can convey it riverward that even in times of flood they are fully loaded and exhibit the anomaly of sharply meandering streams occupying steeply graded valleys.

STRUCTURE.

RELATIONS AND CHARACTER.

The Tullock Creek field lies within an area in which the broad, shallow syncline connecting the Bull Mountain and Powder River basins is crossed by a structural upwarp that connects the Porcupine dome and an anticlinal spur of the Big Horn Mountains. The Lake Basin fault zone, which has been traced more than 100 miles through the Lake Basin and Huntley fields, extends into the southwest corner of the Tullock Creek field and rather probably is underlain by a deep-seated fault separating the Big Horn-Pryor uplift from the Big Snowy anticline, of which the Porcupine dome is believed to be a part. Although the mechanics of the Rocky Mountain structure are not yet fully understood, it seems probable that uplift, or radial movement, has played a much larger part than direct tangential thrust in the development of the structural features of central and southern Montana.[16]

Considered structurally, the Tullock field may be divided into three areas. In the northern part the strata dip gently to the south, in the southern part they are tilted more steeply to the north and east, and in a zone extending across the center of the field and widening at the southeast they are very gently warped and are faulted to some extent. The steep tilting in the southwest corner is due to the Big Horn uplift, locally modified by the structural line of the Lake Basin fault zone, which terminates in a domelike feature or plunging anticline near the the southeast corner of the field. The strata in the northern part of the field rest on the lower flanks of the Porcupine dome, whose center is about 25 miles north of the field. The zone of structural depression that crosses the field in a southeasterly direction corresponds closely in both direction and alinement with the synclinal axis traversing the Bull

[16] The relation of such radial uplift to the thrust faulting of the eastern Cordillera in Montana has been suggested in a recent paper by W. T. Thom, 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), and he further suggests that the principal structural features of central Montana have been produced by the differential elevation or rotation of crustal blocks, bounded by deep-seated faults.

Mountain field, which has been traced almost to the foot of the Big Snowy Mountains. It therefore seems probable that the structure in the northern part of the field is connected primarily with the Big Snowy uplift, and that in the southern part of the field with the Big Horn uplift, the intermediate zone representing the boundary between the areas in which these uplifts entirely control the structure.

USE OF STRUCTURE CONTOURS.

The structure of a gently folded bed can be adequately depicted only by the use of structure contours. A structure contour on any particular stratum is an imaginary line connecting all points at which the stratum is the same distance above sea level. By interpolation between the lines shown, the altitude of the stratum at any point may be estimated and the complete shape or contour of the top of the folded bed may be seen at a glance.

A structure-contour map is made by determining numerous altitudes on the top or bottom of the bed chosen as the datum plane, plotting these altitudes on the map and connecting by lines the points of equal altitude. Altitudes determined on other beds whose stratigraphic distance above or below the key bed is known may also be used after this distance is added or subtracted, although if the intervals between these other beds and the key bed are not constant this method may introduce some errors. In this field a great many altitudes were determined on the coal beds and on the rim rock at the top of the Lance formation, and these were all reduced to the plane of coal bed A, which was used as the key bed in preparing the map (Pl. X). Within the area bounded by the lowest coal bed, therefore, the contours are probably reasonably correct and should be of value in the development of the coal resources of the field. Outside of this area the general course of the contour lines is known from dip and strike observations, but the spacing of the lines as shown is based only on a rough estimate. This is particularly true in the southwest corner of the field, where in places the dip is as high as 30°. It should be remembered, moreover, that there may be considerable error in altitudes determined by long vertical-angle traverse lines, and that although the altitudes in the northern part of the field, where the lines were started, are nearly correct, those in the southern part may be as much as 50 feet in error. However, this error does not affect the value of the calculations within a small area and becomes apparent only when altitudes of widely separated points are compared. Within the coal-bearing area, therefore, the contours may be relied upon, especially within small districts; for the territory outside of the coal-bearing area the map is of little exact or quantitative value and is to be considered merely as a pictorial representation of the structure.

FOLDS.

The following summary is based on the structure-contour map (Pl. X), to which the reader is referred for more detailed information. In most of the fields the strata are tilted at angles so low that they can not be read with a clinometer and are determinable only by plotting the altitude of the beds at many points. There are, however, numerous sharp irregularities in the dip, even in districts where the strata lie practically flat; many of these are too localized to be indicated on the map, but their significance is discussed under "Faults." It is a rule in most of the field that where the dip is steep enough to record with a clinometer it does not represent the average inclination of the beds. In other words, the average dip is not steep enough to simplify the outcrop lines but is sufficiently steep and irregular to render difficult the exact correlation of isolated exposures.

The strongest tilting in the field is in the southwest corner, where dips as great as 30° were measured on the outcrop of Judith River sandstone. The strike is practically east near Big Horn River but changes gradually until in T. 1 S., R. 35 E., it is north. The dip can not be measured in the Bearpaw shale or Claggett shale, but is believed to flatten on either side of the outcrop of the Judith River formation. It is strong enough, however, as far north as T. 2 N., R. 35 E., to exercise a general effect on the outcrop of the formations. Thus, on the Tullock-Big Horn divide the outcrop of the Tullock member of the Lance is abruptly terminated on the south by the northeast dip, and the outcrop of these beds extends much farther down the east slope than the west. The dip is about equal to the gradient of the eastward-flowing streams, so that the lower part of the Lance crops out for a long distance above their mouths.

The structural depression lying between the two uplifts trends in outcrop of Judith River standstone in T. 6 N., R. 37 E., which is also the highest structural point on Yellowstone River east of Huntley. The Judith River is brought to the surface by a northerly rise of about 2°, but it is also folded in a gentle anticline, the western limb of which dips under the alluvium at an angle of 2° and the eastern limb at a slightly smaller angle.

The structure here is similar in kind to that in the southwestern part of the field, though not nearly so steep; in both localities the outcrop of the Judith River is apparently folded on the flanks of domes whose centers lie without the field. The northern uplift is much more gentle than the other and appears to be modified by rather obscure cross-warping in a general north-south direction. The only strongly marked north-south fold is a small syncline in Tps. 4 and 5 N., R. 36 E., which dies out at the base of the structural slope. This general uplift influences the outcrops of the formations through-

out the northern part of the field, but its effects, being gentle and uniform, are not locally noticeable.

The structural depression lying between the two uplifts trends in a northwesterly direction across the center of the field. It is perhaps 5 miles wide on Big Horn River and somewhat narrower on Tullock Creek, but it broadens greatly to the southeast and covers most of that part of the field. Near its intersection with Tullock Creek it is crossed by a low anticline which divides it into two troughs plunging in opposite directions. This anticline may mark the point of contact between the peripheries of the two areas of uplift, or it may be the result of more recent warping. Within the whole trough the strata are gently warped in a series of small and not very distinctly related anticlines and synclines. The dip is generally low but is irregular, and the zone is characterized by small faults, as described below. The depressed area southeast of the anticline is folded into two synclines separated by a low anticline trending and pitching to the southeast. The southern syncline of these two is the better defined and may be observed on Sarpy Creek in T. 1 N., R. 37 E. The beds in the depressed area northwest of the anticline are warped into a syncline that conforms rather closely in direction and position to the more prominent of the two on the southeast but pitches in the opposite direction. The anticline separating these areas resembles a drainage divide, meandering irregularly between the overlapping ends of the pitching troughs.

FAULTS.

Small faults were observed in every quarter of the field, though a majority of them occur in a zone roughly coincident with that of structural depression, as described above. All the faults observed are shown on the geologic map (Pl. X) and are described in detail in the township descriptions below. However, in studying the distribution of the faults shown on the map, it must be remembered that the field work was much more detailed in the coal-bearing areas and also that field conditions are most favorable to the detection of faults in areas in which the Tullock member of the Lance crops out. In the lower part of the Lance and in the underlying beds there are doubtless many faults that were not observed, and probably some in the Fort Union formation also escaped detection because of the extent to which the outcrops are obscured by clinker.

A great many faults occur in a very well defined belt 3 miles wide that trends in an easterly direction across the Sarpy-Tullock divide at Whiskey Butte. The strike of the faults in this belt ranges from N. 60° W. to S. 70° W. The displacement is generally small but in one or two places slightly exceeds 100 feet. One fault was traced for 3½

miles, and several for 2 miles, but many are probably very local. An apparently normal fault with a displacement of 70 feet was observed also on West Burnt Creek in T. 3 N., R. 35 E., slightly to the north of the main belt. The continuation of this general zone was studied by the writers on Pine Ridge, 8 miles west of Big Horn River.

The faults in this zone are of two kinds. Many on the east side of the divide are apparently normal block faults with a maximum displacement of 100 feet. Although on the west side of the ridge the faults appear to be of the same nature, there has been displacement on only one side, the stress on the other side of the block having been taken up by deformation—in other words, in the vicinity of the fault the general southerly dip increases sharply, and at the fault the upthrow is about sufficient to compensate for this steepening in local dip. The exposures do not in general permit accurate measurement of the hade, but it is apparently small, as in a normal fault. These

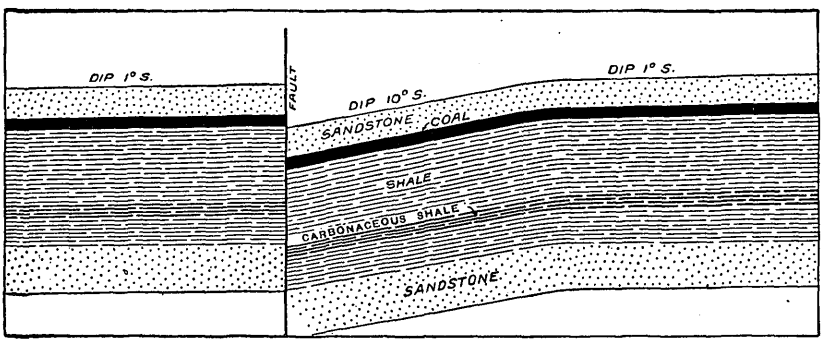


FIGURE 3.—Diagram to illustrate type of faults common in parts of the Tullock coal field.

relations are shown diagrammatically in Figure 3. The occurrence of a fault on a dip slope with the upthrow constituting a partial recovery from the dip is unusual and suggests that the fault is not due to simple tension. In sec. 3, T. 2 N., R. 35 E., a small though undoubted overthrust fault is clearly exposed, as shown in Plate VIII. The total displacement is only 29 inches, but its occurrence in nearly flat strata is interesting and it also indicates the possibility of true overthrusting elsewhere in the field.

The fact that all these faults are associated with a sharp dip is also important, for dips of this kind were observed at many places in the field where exposures are too poor to allow working out their relations and significance. Furthermore, there are many observed dips of 5° or more that do not appear at all on the structure-contour map, which is compiled from determinations of altitude; this indicates that these dips are either very local or are compensated in some way. It seems probable that the compensation has in many places been effected by faulting, as in the district near Whiskey Butte, and therefore many of the sharp dips observed in

the zone of structural depression and mentioned in the township descriptions below may be taken to indicate the presence of a small fault near by.

In sec. 22, T. 2 N., R. 36 E., the trace of a fault in the almost flat-lying beds of the Lebo shale member of the Fort Union was observed. (See Pl. VII, *B*.) This fault trends northeast and is believed to terminate the outcrop of the upper division of the Fort Union in sec. 23. Two miles to the north another fault, between which and the one last mentioned a downthrown block is thought to be inclosed, was mapped inferentially on the basis of rather poor exposures. Two small and probably local normal faults are well exposed in secs. 31 and 32, T. 2 N., R. 37 E. In T. 1 N., R. 36 E., a fault of 105 feet with downthrow to the south displaces the coal outcrops. On the southern edge of the field, in T. 1 S., R. 36 E., a fault having a displacement of 250 feet or more is believed to cause a repetition of nearly the whole of the Tullock member of the Lance. North of the main belt of faulting only a few small faults were observed—two in T. 5 N., R. 34 E., and one in T. 4 N., R. 38 E.

GEOLOGIC HISTORY.

The present features of the land surface, its hills, valleys, and plains, record changes that have taken place within comparatively recent geologic time; the relations of the underlying formations, their composition, and their fossils constitute a chronicle of more ancient events. From these records some idea can be gained of the former geography of the country, of the course of great earth movements, of the climatic conditions that formerly existed, and of the animals and plants that once flourished. All the events recorded are due to general processes such as deformation, erosion, and deposition, which modified the geography and climate and gradually produced changes in living organisms. Only disconnected parts of the geologic record can be deciphered in a small area such as the Tullock Creek field, and our still fragmentary knowledge of the geology of the surrounding region is drawn upon in the brief outline of geologic history given below.

CRETACEOUS PERIOD.

The lowest formation exposed in this field is the Claggett, a shale formation of marine origin. During the time represented by this formation and probably for a long time previously the sea covered this field and a great area to the southeast and east. The shore line was 125 miles or so to the west, and the sediment deposited in this area was therefore practically all mud. The depth of this sea and the position of the shore line were not constant, however, and several periods of shallower-water deposition are indicated by

the few thin sandstone beds occurring in the Claggett. A fauna consisting of univalve shell forms inhabited these waters and contributed to the deposit a small amount of lime.

The changes in the shore line, though irregular, brought it farther and farther east until it reached the central part of the Tullock Creek field. As it approached this field the deposition of fine sediment was interrupted here but was continued farther to the east, and in this field the coarser, near-shore sediment, or sand, now known as the Judith River, was laid down. The shore itself was probably low-lying, and much of this same coarse sediment brought down from the higher land to the west never reached the sea but was deposited in lakes, lagoons, and brackish-water marshes on the flat-lying coastal plain. Thus, in the western part of the field the Judith River formation is partly of fresh-water origin, whereas in the eastern part it is wholly of marine origin, showing that the ancient shore line rested for a time between these points. Though the shore line did not advance farther east, it probably receded to the west temporarily a number of times, for even in the western part of the field the Judith River formation contains some marine layers. The thickest of these layers, if the writers' conclusions are correct, consists of some 200 feet of marine shale. This represents a retreat of the shore line to a point many miles to the west and the maintenance of this position for a considerable time. Its next advance brought it again near the Tullock Creek field and resulted in the deposition of the upper sandstone of the Judith River formation.

At the end of this epoch the sea again advanced from the east and covered this area for a very long time, during which the Bearpaw shale was laid down. During this epoch the shore line stood 100 miles or more to the west and probably remained nearly stationary. Moderately deep water undisturbed by strong currents covered the field, and only fine sediment was carried to this distance from the shore. The general conditions were thus similar to those that prevailed during Claggett time, and the fauna, though more varied than that of the Claggett, resembles it in a general way.

After a lapse of time represented by the deposition of 1,000 feet of shale, the shore line again advanced toward the east and the water in this area became shallower. Sand was deposited in the shallow near-shore zone, mingling with the finer sediment farther out. The shoaling was probably very gradual, however, as shown by the gradation from the typical Bearpaw shale to the sandy beds at the top of the formation. The proportion of fine sediment became smaller and smaller as the shore line approached, until almost pure sand was deposited; finally this area emerged from the sea and became a land surface. The shore line continued to advance to the east until practically all of Montana and much of the Dakotas became land.

LANCE EPOCH (TERTIARY?).

After this field became land, at the end of the Bearpaw epoch, it probably remained as a low-lying coastal plain for some time. During this period it was exposed to moderate erosion and became somewhat dissected. This is not apparent everywhere in this region, however, and it is probable that the erosion was rather local and that no very great amount of material was removed. The surface in what is now the Tullock Creek field remained in this condition long enough to allow the formation of stream channels 30 feet deep.

This neutral period, in which the newly raised land surface was not very greatly affected by either erosional or depositional agencies, was succeeded by one of deposition. This was due to the elevation of the land to the west, a movement which continued for a long time and finally culminated in the formation of the Rocky Mountain ranges. The streams rising in the mountains began to erode more vigorously and to bring down great quantities of sediment, most of which was laid down on the flat-lying coastal plain. Thus, the basal sandstone of the Lance formation shows evidence of having been deposited by river action, or in shallow water moving in strong currents. After some time lakes were formed in which beds of finer sediment were laid down. Conditions varied from place to place; deposits were being formed simultaneously in river flood plains and deltas and in fresh-water lakes and small swamps, and in some areas subaerial conditions prevailed and erosion took place. During this time the whole surface was slowly but constantly sinking, for although continually being built up by sediment it seems to have remained a fairly low-lying plain. Many species of fresh-water shellfish inhabited the ponds and rivers, and trees and plants flourished on the shores. Reptiles of various types also existed; one of the common forms was the horned dinosaur. These varied conditions continued until 800 feet of sand, sandy mud, and mud had accumulated. In the northern part of the field, however, conditions were somewhat more uniform during the deposition of the upper 300 feet, which consists chiefly of shale.

At the end of this period deposition, with possibly minor erosion, had operated to produce a fairly level surface. This plain was perhaps not dissimilar to that existing on the coast of North and South Carolina to-day. The supply of sediment from the higher land to the west and southwest then practically ceased for a time, the streams became sluggish, and swampy conditions prevailed in the central part of the field. In these swamps vegetal matter accumulated, which was later compacted to form coal bed A. The location and shape of some of the swamps existing at this time are

shown in Plate XIV. This map, the construction of which is explained on pages 68–70, does not show the entire swampy area but only that portion of it in which accumulation continued long enough to cause the formation of 18 inches or more of coal. The relations of the coal lenses formed at this time are discussed below.

This period of vegetal accumulation was terminated by the arrival of more sediment and its deposition in the swamps. After some 15 feet of sediment, consisting of sand in some places and mud in others, had been laid down, a swampy condition again prevailed in parts of the field. In these local swamps peat accumulated which gave rise to coal bed B. After about 20 feet more of sediment had been laid down there was a recurrence of swampy conditions through much of the field. These conditions continued long enough in places to result in the formation of coal bed C, the distribution of which is shown in Plate XV. This cycle of events continued until 300 feet of strata, including many thin coal beds, has accumulated. Most of the coal beds represent only local swamps, but at the time of the formation of coal bed I swampy conditions again prevailed over much of the field (Pl. XVI). The last stratum deposited during this epoch was the sandy bed forming the rim rock that marks the top of the Lance formation. This stratum is very persistent, and the conditions under which it was formed existed practically everywhere in the field.

TERTIARY PERIOD.

Apparently no epoch of deformation or erosion separated the Lance and Fort Union epochs in this field, and there was no material change in the conditions of sedimentation. At some time prior to this, however, there had been a volcanic eruption, with probably later renewals of activity, near the Crazy Mountains, about 125 miles to the west, which produced great quantities of volcanic ash or tuff. A part of this material now began to mingle with the sediment being transported from the west, and a marked change in the color and composition of the beds laid down in this field was produced. However, river, lake, and swamp conditions alternated as before, though perhaps even more irregularly. The silicified stumps of trees have been found in these beds at a number of places indicating that subaerial conditions occasionally prevailed. The Lebo shale is succeeded by sandstone and shale essentially similar to those of the Lance. The change, though marked, is not sharp and appears to represent merely a gradual decrease and final cessation of the supply of volcanic material. This may have been due to the exhaustion of such material, but was more probably due to a change in drainage conditions in the region to the west and the consequent diversion of the

volcanic material to other areas, for the Lebo is known to vary rather irregularly in thickness.

For some reason, then, the supply of basic ferruginous material ceased, and the sediment brought down was chiefly coarse, was yellow in color, contained little iron, and was derived from the disintegration of a more acidic series of rocks. After the deposition of about 100 feet of this material a swampy condition was produced in the southeastern part of the field that led to the formation of coal bed M (Pl. XIV). This swamp lasted much longer than any that had formed in the Lance epoch, and conditions were more favorable to the accumulation of pure vegetal matter free from sediment. The old drainage channels through this swamp, which gradually became filled with black shale, were observed at several localities on Sarpy Creek in T. 1 N., R. 37 E. Swamp conditions were terminated by a further influx of sediment and recurred only locally during the deposition of the next hundred feet or so of strata. They then developed again in the same area, and the center of this new swamp was located almost directly above that of the older one (Pl. XV). The organic matter that accumulated in this basin formed coal bed P, which generally consists of two benches of coal 10 feet or more thick, separated by about 5 feet of shale. A thickness of 10 to 50 feet of sediment was then deposited before swamp conditions again prevailed in this field. The areal extent of the third swamp, in which bed Q accumulated, was also roughly coincident with that of the two earlier ones (Pl. XVI). After the formation of bed Q about 300 feet of sediment, mostly mud, was deposited, and it was not until the end of the time thus represented that coal bed R was formed. At least 700 feet more of Fort Union material, including several thick coal beds, was deposited in this field but has since been removed by erosion.

At some subsequent time in the Tertiary period all these strata were deformed. As described in more detail under the heading "Structure," it is believed that the chief centers of disturbance in this region were in what are now the Big Horn Mountains and the Big Snowy Mountains. The strata in those localities are tilted steeply, but the intensity of folding decreases with distance from the mountains until in the Tullock Creek field the beds lie at comparatively low angles. The structure within this field is controlled by the formation of domes to the north and southwest, which are probably minor features of the two great uplifts. The strata in the structural trough betweeen them are irregularly warped and slightly faulted, doubtless as a result of stresses in opposite directions. There is also a suggestion of secondary warping along a north-south axis, which may be due to the same cause or which may indicate that the for-

mation of the two domes was not entirely synchronous, one lagging slightly behind the other. At about this time also a general elevation of the land took place, and all this region was raised high above sea level.

This general elevation caused the streams to cease depositing and to start eroding. It is possible that the forerunner of the Yellowstone during this time cut a very wide, flat valley and in conjunction with other rivers reduced much of the country to a practically flat plain. This is suggested by the facts that Wolf Mountain rises 1,700 or 1,800 feet above the Yellowstone and that Eldridge Mesa, the highest point in the Bull Mountains, has a similar height above the river. Little Sheep Mountain, which is one of the highest points on the Yellowstone-Missouri divide east of the Bull Mountains, is believed to be about 1,600 or 1,700 feet above the river. Though suggestive, these figures are only approximate, and the altitudes of many high points must be accurately determined before the existence of an old base level at this altitude can be assumed. In any event, it is probable that a great deal of erosion took place in late Tertiary time, and it is possible that local or even widespread base leveling was effected several times.

QUATERNARY PERIOD.

STREAM DEPOSITION.

At about the beginning of the Quaternary period the Yellowstone had cut a fairly flat valley some 50 miles wide, the floor of which was at the general level of the present top of the Sarpy-Tullock divide. A change in the gradient of the stream then took place, probably because of the elevation of the land to the southwest and west, which caused the stream to erode more rapidly in those regions. The Yellowstone thus became heavily loaded, and as it meandered across its wide valley in this lower lying district at the foot of the mountains it deposited a great quantity of sediment. This was therefore the first clearly marked period of deposition in this area since late Tertiary time, and a great change in the character of the sediment had taken place. In Tertiary time the land was lower lying, and the rivers were more sluggish and brought down chiefly sand and mud, products of the fairly complete disintegration of older rocks. During the Pleistocene epoch, however, erosion on the higher land was much more rapid, and much of the material brought down consisted of pebbles or even boulders of scarcely altered rock.

After this period of deposition, which was very brief in comparison to those of the Tertiary, a further elevation caused the river to

cease depositing and resume cutting. After a period of cutting conditions were again reversed and another but less extensive gravel bed was formed. This alternation of long periods of cutting with short periods of deposition continued throughout the Pleistocene epoch, during which the Yellowstone deepened its valley floor 1,100 feet below the level at which it stood at the beginning of the epoch. The Pleistocene erosion removed much of the earlier gravel sheet as well as the underlying rocks, but some of the gravel was redeposited during later epochs of deposition, and the remnants of the later flood plains now form gravel-covered terraces on the lower valley slopes.

In comparatively recent time Yellowstone and Big Horn rivers have ceased cutting and built up the present bottom land. The streams now flow in shallow channels slightly below the level of this plain and are cutting only laterally. The channels are not being deepened, as shown by the shifting sand bars so common in both rivers, and the present is therefore a time of moderate deposition.

DEVELOPMENT OF PRESENT SURFACE FEATURES.

In the description of the formations given above an attempt has been made to indicate the manner in which each yields to erosion and thus to show the contribution that each has made to the development of the present land forms of the field. Although the broader features of the land forms—as, for example, the level character of the divide tops—are due to the processes described above, going on outside the field, many of the details are largely due to the character of the formation themselves.

In the absence of an accurate contour map, a profile and structure section across the field (Fig. 2, p. 6) has been prepared to illustrate the character of the surface and its relation to the geology. This section is necessarily somewhat generalized, and the vertical scale, including the dip of the strata, is exaggerated about ten times.

At the left or north end of Figure 2 is shown the flat bottom land of Yellowstone River, underlain by Bearpaw shale. At the foot of the slope this formation crops out, forming characteristic low, rounded, gravel-covered hills. Above the Bearpaw the Lance formation constitutes the surface rock, and the slope is broken into a number of benches, some of them covered with gravel and others merely the product of the differential erosion of hard and soft layers. In this locality the steep escarpment that generally marks the outcrop of the Tullock member of the Lance is largely obscured by the gravel, and an old stream channel, referred to above, cuts out the base of the

member. The Lebo member of the Fort Union rests on the Lance and is overlain by the basal sandstone of the upper division of the Fort Union, but these strata are everywhere covered with a thick mantle of gravel and give rise to bare, rounded hills. Whiskey Butte rises some 200 feet above the general level of the divide, and little gravel remains on its slopes. The low gravel-covered hills terminate less than 2 miles south of this butte, and no gravel was observed beyond that place. If this represents the southern limit of the gravel and therefore the edge of the old river flood plain, there must have been at one time a rise in the surface at this point to confine the river on the south. Instead of a rise, however, there is now a marked depression, due to the fact that the Lebo shale where unprotected by the gravel yields rapidly to erosion. To the south of this low saddle the upper division of the Fort Union, baked and hardened by the burning of its coal, rises in a steep and abrupt escarpment about 300 feet high. Back of this escarpment the character of the surface is largely controlled by the resistant clinker of coal bed P; it is therefore fairly flat but rises slightly to the south at about the angle at which the strata rise. At the southern edge of the field the outcrop of the upper division is bounded by another steep escarpment, at the foot of which the softer Lebo shale is exposed. The physiographic influence of the several formations and of their structure may thus be directly traced, and the manner in which the gravel has affected the weathering of the Lebo shale is especially striking.

The surface features on the eastern divide of Sarpy Creek are essentially similar to those described above, but on the Tullock-Big Horn divide all of the upper division of the Fort Union and nearly all of the Lebo shale have been removed. Except in the southern part of the field, the rim rock at the top of the Lance formation forms the top of much of this divide, and its flatness is therefore even more striking. On the top of this divide there are still several undrained areas in which water collects, but most of the field is well drained, and the general topography is at the stage of early maturity.

ECONOMIC GEOLOGY.

COAL.

The coal in the Tullock Creek field is of subbituminous rank and occurs in the Fort Union formation and in the upper or Tullock member of the Lance. The coal of the Tullock member occurs in beds less than 5 feet thick, but beds thicker than 18 inches were found at ten horizons. These beds are broken by many thin part-

ings of shale and bone, and much of the coal itself contains a rather high percentage of ash. The coal of the Lebo member of the Fort Union is of very little importance; there are three thick beds of carbonaceous material in this member, but at only one or two localities were they found to contain more than 18 inches of coal. The coal contained in the upper division of the Fort Union occurs in six beds from 1 to 24 feet thick. In the four thickest of these beds much of the coal is in thick benches unbroken by partings, and most of it is probably lower in ash than that of the Lance formation.

PHYSICAL AND CHEMICAL CHARACTER.

Most of the coal in the Tullock Creek field has no visible woody structure and is black in color. It is brittle when fresh, has a bright vitreous luster, and weathers in the platy manner characteristic of subbituminous coal. Associated with this coal, especially in the Fort Union coal beds, are a few small seams that exhibit the woody structure, the brown streak, and the characteristic weathering of lignite. Notwithstanding the presence of some lignite, which is of high grade, the great bulk of the coal is subbituminous. Selenite, generally in small quantity, constitutes the common impurity in the Lance coal, and selenite and pyrite both occur in the Fort Union coal.

Subbituminous coal has a tendency to slack on exposure to the air, owing to the fact that it contains considerable water, which evaporates on exposure, causing shrinkage and the development of an irregular network of cracks. There are no mines in this field, and the writers had little opportunity of observing the behavior of perfectly fresh coal from this field when exposed to the air. Specimens of the Lance coal taken from a fresh cut 8 feet deep were allowed to lie in the sun for about 10 days, and at the end of this time, though checked, they had not fallen to pieces. In fact, this first checking rather tended to form a protective coating around a core of unchecked material, which was not affected for several months. It is believed from the rather meager chemical data presented below that the Fort Union coal contains a somewhat higher percentage of moisture than the Lance coal. For this reason its stocking qualities may be somewhat lower, but doubtless there is no great difference between the two. If proper precautions are observed in moving the coal, either type should form a fairly satisfactory fuel.

Owing to the lack of development work in this field, the writers were unable to obtain fresh samples of coal for analysis. Two samples of more or less weathered coal were collected, one from bed

C in the Lance formation and the other from bed P in the upper division of the Fort Union. The sample from bed C (No. 14755 in the table of analyses given below) was obtained by blasting 8 feet back under a heavy sandstone bed. This sample is therefore reasonably fresh, though it can not be compared with samples collected in working mines several hundred feet below the surface. The section of the bed at the point of sampling and the parts represented by the sample are shown graphically by No. 293 in Plate XIII. The sample from bed P (No. 17711) was collected in an old cut 5 feet deep. About a foot of coal was cleaned off before cutting the sample, but the coal collected, though apparently fresh, was doubtless considerably weathered. Only the upper part of bed P is exposed at this point, and only 7 feet in the upper part of the bed, which consists of clear coal, was included in the sample. (See section 474, p. 170.)

The analyses of these two samples are shown in the table below. In order to afford some measure of comparison between this coal and other coal with which it must compete in the market, analyses of representative samples of coal of the Miles City, Bull Mountain, Bear Creek, and Sand Coulee fields, Mont., and the Sheridan field, Wyo., are also given. In studying this table it must be borne in mind that the analyses of the products of the other fields represent perfectly fresh coal, whereas those of the Tullock Creek coal represent material that was considerably weathered.

In the table the analyses are given in four forms, marked A, B, C, and D. Analysis A represents the sample as it is received in the laboratory. This form is not well suited for comparison because the amount of moisture in the coal as collected is largely a matter of accident and may vary widely. Analysis B represents the sample after it has been dried at a temperature of 30° to 35° C. until its weight becomes constant. This form of analysis is best adapted to general purposes of comparison. Analysis C represents the theoretical condition of the coal after all the moisture has been eliminated, and analysis D its composition after all moisture and ash have been theoretically removed. This is supposed to represent the true coal substance, free from the most significant impurities. Forms C and D, which represent conditions that do not actually exist, are derived from the others by recalculation. They are of value in certain scientific studies and in some engineering calculations but should not be used in comparisons of the actual working efficiency of coal from different fields.

Analyses of coal samples from the Tullock Creek field and of representative samples from possibly competing fields.

[Made by the U. S. Geological Survey and the Bureau of Mines.]

Laboratory No.		Reference.	Air-drying loss.	Form of analysis.	Moisture.	Volatile matter.	Fixed carbon.	Ash.	Sulphur.	Heating value.	
										Calories.	British thermal units.
14755	Prospect on coal bed C (Lance formation), sec. 2, T. 4 N., R. 35 E.	293, Pl. XIII.	8.5	A	19.8	30.7	35.2	14.3	1.50	4,765	8,580
				B	12.3	33.5	38.5	15.7	1.64	5,210	9,380
				C	.....	38.2	43.9	17.9	1.87	5,940	10,700
				D	.....	46.6	53.4	.....	2.28	7,235	13,030
17711	Prospect on coal bed P, sec. 30, T. 1 N., R. 38 E.	474, p. 170.	3.7	A	22.6	31.9	39.5	6.0	.51	4,895	8,810
				B	19.6	33.1	41.1	6.2	.53	5,085	9,150
				C	.....	41.2	51.1	7.7	.66	6,325	11,380
				D	.....	44.6	55.4	.....	.72	6,855	12,340
5694	Miles City, Kircher bed	.....	24.9	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	12,930
3701	Miles City, Weaver bed	.....	16.5	A	29.1	25.4	30.5	15.0	.55	3,700	6,660
				B	15.1	30.3	36.6	18.0	.66	4,430	7,980
				C	.....	35.7	43.1	21.1	.78	5,220	9,400
				D	.....	45.4	54.6	.....	.98	6,630	11,930
19009	Sheridan, Wyo	.....	13.4	A	23.3	33.9	38.9	3.9	.52	5,275	9,490
				B	11.5	39.1	44.9	4.5	.60	6,090	10,960
				C	.....	44.2	50.8	5.0	.68	6,880	12,680
				D	.....	46.5	53.5	.....	.72	7,245	13,040
29004	Roundup, Mont	.....	3.5	A	13.6	32.9	45.5	8.0	.70	5,935	10,690
				B	10.5	34.0	47.2	8.3	.72	6,150	11,070
				C	.....	38.0	52.7	9.3	.81	6,870	12,360
				D	.....	41.9	58.1	.....	.89	7,575	13,630
29466	Red Lodge, Mont	.....	6.3	A	11.3	33.6	44.5	10.6	.72	5,795	10,440
				B	5.3	35.9	47.5	11.3	.77	6,185	11,140
				C	.....	37.9	50.2	11.9	.81	6,535	11,760
				D	.....	43.0	57.0	.....	.92	7,420	13,360
15130	Bear Creek, Mont	.....	3.0	A	10.0	33.9	44.8	11.3	2.26	5,885	10,590
				B	7.2	35.0	46.2	11.6	2.33	6,065	10,920
				C	.....	37.7	49.8	12.5	2.51	6,535	11,760
				D	.....	43.1	56.9	.....	2.87	7,475	13,450
4115	Sand Coulee, Mont	.....	2.4	A	6.0	28.4	51.4	14.2	2.38	6,195	11,150
				B	3.7	29.1	52.7	14.5	2.44	6,350	11,430
				C	.....	30.3	54.7	15.0	2.53	6,590	11,870
				D	.....	35.6	64.4	.....	2.98	7,760	13,970

The analysis of the Fort Union coal (No. 17711) shows a very low air-drying loss, thus indicating that the sample was badly weathered and that exact comparisons are impossible. However, it is probable that even if the sample had been fresh the moisture would be higher than that of the Lance coal of this field, though lower than in the coal of the Miles City field. The ash and sulphur are remarkably low, and the heating value is nearly equal to that of the Lance coal. The factor that lowers the heating value in this sample is therefore the moisture, which is due partly to the fact that the sample is weathered; if the sample had been fresh it would probably have about the same heating value as that of the coal of the Sheridan field and somewhat less than that of the Bull Mountain field. The theoretical heating value of the coal in the ash and moisture free

condition is interesting, being considerably lower than that of the Lance coal of this field and about equal to that of the coal in the Sheridan field.

The analysis of the Lance coal (No. 14755) shows that nearly half of the moisture in the sample as received is given off on air-drying, indicating that the coal is comparatively fresh and that the high original moisture is largely a matter of accident. The percentage of moisture still retained is fairly high, though lower than that of the coals of the Miles City field. The percentage of ash is high, as it is in many of the other coals of Montana. This factor, however, probably varies in different beds; the coal in bed A

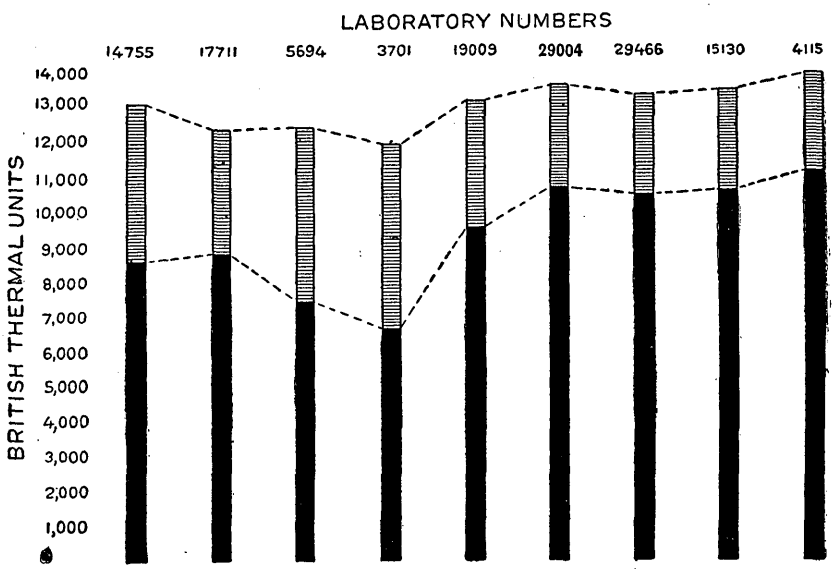


FIGURE 4.—Graph showing the comparative heating value of Tullock Creek and competing coals.

seems to be in general cleaner than that in bed C, whereas that in bed I is dirtier. The sulphur in this coal is higher than in any other except the Bear Creek and Sand Coulee coal.

The chemical composition of the coal, as shown in the table of analyses, is very important, but after all the chief interest lies in the heating value. In order to afford a ready comparison of the heating value of the several coals Figure 4 has been prepared. From this graph it is apparent that the coal in the Tullock Creek field is nearly as good as that of Sheridan, Wyo., but the coal as mined makes a very much poorer showing, in part doubtless owing to the weathered condition of the Tullock Creek coals but in part perhaps the result of their lesser metamorphism due to their greater distance from the uplifted mass of the Big Horn Mountains.

The graph shows that of the coals with which the Tullock Creek coals are likely to come into competition those of Bear Creek, Red Lodge, Roundup, and Sand Coulee are the best. The comparative heating value of these coals can easily be stated in terms of dollars and cents, which will enable anyone to determine which is the cheapest, all things considered. Thus if the coal represented by sample 14755 is assumed to be worth $5 a ton the relative value of the other coals would be as follows:

14755 ---------- $5.00	3701 ---------- $3.88	29466 ---------- $6.08
17711 ---------- 5.13	19009 ---------- 5.53	15130 ---------- 6.11
5694 ---------- 4.36	29004 ---------- 6.23	4115 ---------- 6.50

To sum up these comparisons, the Lance coal of this field has reached a fairly high stage of devolatilization, and if it can be found cleaner or freer from ash than the sample analyzed it will compete in the market with any coal mined in the eastern or central parts of the State; but if the single analysis shown is representative of all this coal, it will be greatly handicapped because of its high percentage of ash. The Fort Union coal in an unweathered condition is a good, clean fuel and will probably be able to compete with the coals of the Sheridan and Bull Mountain fields, though owing to its fairly high percentage of moisture its stocking quality is probably poorer than that of those coals. Both the Lance and the Fort Union coals are of higher grade than that from Miles City but of somewhat lower grade than that from the Bear Creek field. Either the Fort Union or the Lance coal should form a satisfactory domestic fuel and is fairly well adapted for use in stationary engines. It is probably somewhat "light" for a good forced-draft steam coal, though it can doubtless be used in this way also. If this coal ever commands a distant market, however, it is probable that closed cars will be needed for shipment.

In addition to the careful analyses made by the Bureau of Mines, a few supplementary tests were made with a small portable outfit during the course of the field work. This work was done by C. E. Lesher, of the United States Geological Survey, in September, 1912. Only ash and loss of moisture in air drying were determined in these tests, and all the samples were collected from the Lance coal beds in the northern part of the field.

The chief purpose and value of Mr. Lesher's work in this field was to standardize the writers' terminology of the several grades of carbonaceous material. Thus, for purposes of land classification it is arbitrarily assumed that coal does not contain more than 33 per cent of ash, and if the percentage is higher and the material otherwise similar it is called bone. In this field the writers also distinguished as impure coal a coal that contains from 20 to 33

per cent of ash. Coal, impure coal, and bone, if typical, can easily be distinguished by their appearance, but as they grade into one another, material near the border lines is often encountered which is very difficult to classify decisively with the eye alone. It is, therefore, very desirable to have for reference and comparison a series of specimens of known grades of purity. The purest material analyzed in this field contains 6 per cent of ash, but this of course does not represent the average of any whole bed. An example of the kind of work done is shown in the following section of bed C, in which each bench was sampled and tested:

Section No. 293 of bed C, showing partial analysis of each bench.

Material (field name).	Thickness.	Air-drying loss.	Ash.	Color of ash.	Luster and weathering.
	Ft. in.	*Per cent.*	*Per cent.*		
Sandstone and shale.	2 1	.....	.....	.....	
Bone.....	2	10	50	White.....	Uneven fracture, dull luster, no cleavage.
Coal.....	8	19	10	Gray.....	Bright luster, conchoidal fracture.
Bone.....	1¾	14	61	Dark gray.	In thin laminae, dull luster.
Coal, good.....	8	16	6	Gray.....	Bright luster, conchoidal fracture.
Coal, impure.....	3	.....	27	.....	Luster uneven, bright and dull.
Coal, good.....	1 2½	16	6	Gray.....	Bright luster.
Shale.					

Mr. Lesher's work also established the presence of a small proportion of lignite interbedded with the ordinary subbituminous coal. It was found that small lenses of material in some of the beds yielded as much as 33 per cent of moisture on air drying. This material weathers into cubical blocks and is distinctly brownish in streak.

GENERAL CHARACTER AND DISTRIBUTION OF THE COAL BEDS.

MAPPING AND DESIGNATIONS.

The coal of the Tullock Creek field is believed to have a heating value of about 9,500 British thermal units in the unweathered condition, and a bed 18 inches thick of this grade of coal is considered, in this paper, as eventually worth mining. It is possible that at some future time, or under certain present conditions, beds thinner than 18 inches can be mined at a profit. In the writers' field work all outcropping beds 18 inches or more thick were examined and mapped, and many thinner beds were also examined and some of them mapped for short distances. The outcrops of the beds are shown on Plate XI, and many representative sections are shown in Plates XII and XIII. No drilling has been done within the field, and this report is based entirely on data gathered along the outcrop. It is very possible that the lower coal-bearing strata in the southern part of the field contain lenses of coal over 18 inches in thickness which do not crop out and concerning which, therefore, the writers have no information.

The coal outcrop lines shown on Plate XI were mapped by plane-table and stadia methods, and the traverses were based on the land survey. The points at which sections were measured, shown on the map by numbers, were accurately located, together with many other points along the outcrop. The mapping of the outcrops of the Lance coal beds is believed to be in general as accurate as the scale of the map permits. The outcrops of coal beds in the yellow Fort Union strata are somewhat less accurately shown, owing to poor exposures; and as these beds are nearly everywhere burned on the outcrop the exact location of the edge of the unburned coal is generally impossible to determine. Some allowance for this has been made on Plate XI, and certain isolated buttes or long necks of land under which the coal is entirely burned out are not shown on the map. No distinction is made on Plate XI between "outcrop exposed" and "outcrop inferred," as in the Fort Union area a great majority of all the exposures are indicated by locality numbers, and in the Lance area probably half of the good exposures are so indicated, though on the southern and western slopes many of the Lance beds may easily be followed with the eye for some distance. In this field, therefore, it is thought to be more important to show at a glance the approximate thickness of the coal at all points along the outcrop, and this is done by the use of different patterns on the map. The determination of points at which one pattern, indicating, say, from 18 to 30 inches of coal, changes to another is of course a matter of estimate; it is here based on the procedure followed in land classification, which involves the use of lines of equal thickness as described below.

Coal beds over 18 inches thick occur at eighteen general horizons—ten in the Tullock member of the Lance, two in the Lebo member of the Fort Union, and six in the upper division of the Fort Union. Portions of all these beds are lenticular, and some of the lenses are of very slight extent, though it is probable that if the field work had included the examination of beds down to 6 inches thick, most of the lenses would have been found to be connected. At some horizons only one lens was found, whereas others carry lenses over 18 inches thick in various parts of the field. For purposes of discussion and reference all these lenses occurring at the same horizon are here designated by the same letter, A being assigned to all lenses at the lowest horizon and R to all lenses at the highest. The term "bed D," therefore, does not necessarily imply a single bed continuous throughout the field but is used to designate several widely separated lenses whose stratigraphic distances above or below certain prominent key rocks are the same. The lenses referred to some of the beds, notably beds A, C, H, and I, are believed to be connected—that is, these beds are believed to be actually continuous, though thicker than 18 inches only in certain parts of the field; the lenses referred to some of the other

beds are probably isolated, though occurring at the same horizon. Letters are assigned only to the beds or lenses thicker than 18 inches; many other beds containing a foot or less of coal were examined at numerous places but are not considered in this report.

USE OF LINES OF EQUAL THICKNESS.

The most convenient method of summarizing all the known data concerning the thickness of a coal bed is furnished by the use of lines of equal thickness,[17] or imaginary lines each connecting all the points at which a coal bed is believed to be of the same thickness. Inasmuch as all the coal in this field occurs in lenses, the lines of equal thickness on these beds are roughly concentric or close on themselves. The outermost line drawn is the 18-inch line and shows at a glance the position and the shape of the lens of coal over 18 inches thick.

As many coal beds are split by bone or shale partings, which are not only worthless but actually detrimental, it is first necessary to express the sections of such beds in terms of usable coal—that is, the split bed must be evaluated before it can fairly be compared with an unbroken bed. According to the broad rule adopted by the United States Geological Survey, "any parting or bench of bone included in a bed injures the value of the coal of the bed in amount equal to the thickness of the parting."[18] The cost of removing a parting, in other words, is assumed to be about equal to the profit on the same thickness of coal. For example, if the bed consists of two benches of coal, each 3 feet thick, separated by 1 foot of shale, this bed is considered the economic equivalent of one consisting of 5 feet of unbroken coal. Or, if the upper bench of this bed is only 1 foot or less thick, the value of that bench is held to be nullified by the cost of mining the 1-foot parting, and the bed is considered for practical purposes to be only as thick as the lower bench. If the bed consists of a number of benches separated by partings the best bench is selected and given full value, and the thickness of the adjoining benches minus that of the intervening partings is then added, any bench that is thinner than the contiguous parting being of course omitted. A bench of impure coal, or coal whose ash content is between 20 and 33 per cent, is considered to have a value one-half to two-thirds of its measured thickness.

After all the sections have been standardized according to this method, the calculated thicknesses are plotted on the map. In this field lines of equal thickness for each variation of 6 inches in thickness were drawn on the Lance coal beds, and for each 2 feet on the coal

[17] Rogers, G. S., and Lesher, C. E., The use of thickness contours in the valuation of lenticular coal beds: Econ. Geology, vol. 9, pp. 707–729, 1914.

[18] Smith, G. O., and others, The classification of the public lands: U. S. Geol. Survey Bull. 537, p. 70, 1913.

beds of the upper division of the Fort Union. After the calculated thicknesses have been plotted, points are established by grading between them at which the coal is thought to be 18, 24, and 30 inches thick, and so on. This is done on the broad assumption that the variation in thickness is comparatively regular—that is, if two sections measured a mile apart show the coal to be 18 and 30 inches thick at those points, it is assumed that the coal is 24 inches thick at a point halfway between them. When as many as possible of these points, obtained either by actual measurement or by grading between measurements, have been established, they are connected by the lines. Thus at all points along the 30-inch line the coal bed is believed to be 30 inches thick (proper allowance having been made for partings), and in the area between the 30 and 36 inch lines the bed is believed to be between 30 and 36 inches thick and to average 33 inches.

The value and reliability of lines of equal thickness depends not only on the number but also on the distribution of the field measurements on which they are based. Topographic conditions in this field admit of making many and well-distributed measurements, for the practically flat-lying coal beds crop out on highly dissected hillsides. The measurements are therefore not all located along one line but are so distributed as to show the variations in thickness in all directions. At a few places abrupt variations in thickness that appear to be due to channeling and to have no influence on the broad variation in thickness of the bed were observed, and these have not been taken into account in drawing the lines. In general, however, the coal appears to vary regularly in thickness, and the conditions are therefore well adapted to the use of thickness lines.

In the course of classifying the coal land in this field lines of equal thickness were drawn on all coal beds or lenses that are more than 18 inches thick at any point. The lines were used as a basis for the tonnage estimates given below, which govern the prices fixed for each tract of coal land.[19] Maps showing the thickness of six of the most valuable coal beds in the field are reproduced in this report, in order to illustrate the following descriptions of the distribution and thickness of the beds. (See Pls. XIV, XV, and XVI.) To avoid confusion, therefore, the thickness figures given in the text, unless otherwise stated, will be the standardized or net figures shown on the contour maps. The detailed sections as actually measured are shown on Plates XII and XIII or are given in the township descriptions below.

In order properly to correlate and to bring out the significance of all thickness measurements, it is generally advisable to make a com-

[19] This statement does not apply to the coal-leasing law now in effect.

plete map regardless of the fact that recent erosion has removed the coal in certain areas. The shape and extent of the valleys in the present surface have no relation to the distribution or the thickness of the coal deposited in the ancient swamp, though of course they materially affect the shape of the areas of coal remaining at the present time. The thickness lines should therefore be drawn irrespective of the present topography. On the maps accompanying this report the outcrop lines and the localities where measurements of thickness were obtained are shown, but the lines of equal thickness are drawn to represent the shape of the original coal lens and are therefore continued across valleys from which the coal is known to have been removed.

COAL IN THE UPPER OR TULLOCK MEMBER OF THE LANCE FORMATION.

Coal beds thicker than 18 inches occur at ten general horizons in the Tullock member of the Lance. For purposes of description these beds are designated by letters of the alphabet; bed A is the lowest. The outcrops of these beds are shown on Plate XI, and representative sections in Plate XIII. Maps showing the thickness of beds A, C, and I form Plates XIV to XVI.

The following generalized section of the Tullock member shows the relative positions of the beds and the average distances between them. As stated above in the description of the Tullock member, the intervals are not constant throughout the field and may vary 15 feet from the figures here given. These figures are averaged from specific measurements given in the township descriptions. It will be noted that nine of the ten beds occur in the lower half of the member.

Section of Tullock member of Lance formation showing relative position of the coal beds and average thickness of the intervals between them.

	Feet.
Fort Union formation.	
Tullock member of Lance formation:	
Sandstone	30
Bed J	0–2
Shale and sandstone	100
Bed I	0–3
Shale and sandstone	26
Bed H	0–3
Shale and sandstone	27
Bed G	0–2
Shale and sandstone	9
Bed F	0–2
Shale and sandstone	17
Bed E	0–2
Shale and sandstone	33
Bed D	0–2
Shale and sandstone	10
Bed C	0–5

Tullock member of Lance formation—Continued.	Feet.
Shale and sandstone	20
Bed B	0–2
Shale and sandstone	15
Bed A	0–4
Lower part of Lance formation.	

Bed A is the lowest coal found in the field and marks the base of the Tullock member. Along the eastern edge of the field this bed is less than 18 inches thick and was not positively identified, but on Tullock Creek and on the north end of the Sarpy-Tullock divide it is well developed. A characteristic exposure of this bed is shown in Plate IX, *A*. The bed attains a maximum thickness of 47 inches in sec. 25, T. 3 N., R. 35 E., but is commonly less than 30 inches thick. The lower part of the bed usually consists of clear coal, but the upper part is generally broken by partings of shale and bone. (See Pl. XIII.)

The stratigraphic relations of this bed, by which it may generally be recognized, are described on pages 30–31. A valuable auxiliary in identifying it is the almost invariable presence of a brownish parting in the upper half of the bed. (See Pl. IX, *B*.) This parting generally ranges in thickness betwen three-quarters of an inch and 1½ inches, though in some places it is as much as 3 inches thick. It is generally present even where the coal bed itself is only 6 inches thick. The parting contains some carbonaceous matter, including vertical roots and plant stems. It has a granular appearance and resembles a fine carbonaceous sandstone, but closer examination shows that it is a crystalline aggregate. The small crystals have well-marked cleavage faces and are soft enough to be scratched with the finger nail. Under the microscope the crystals suggest the rare mineral leverrierite, but chemical analysis shows the material to be a hydrous aluminum silicate and indicates that it may be merely kaolin. Whatever the identity of this material, which has been described in more detail elsewhere,[20] it was evidently precipitated from the swamp waters at the time the coal was formed. No other hypothesis adequately explains the crystallization of the material, its wide distribution, and the small but constant thickness of the deposit. It was presumably carried by the swamp waters in the form of colloidal silica and alumina and was precipitated either by the action of organic acids or by simple evaporation during a period of drought. The second alternative is perhaps the more plausible, as it accounts for the fact that plant growth was checked but not entirely killed during the deposition of the material and also

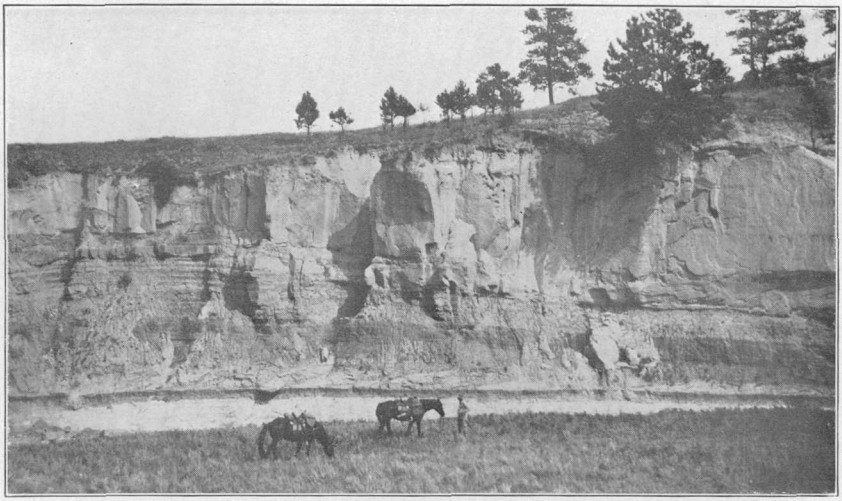
[20] Rogers, G. S., The occurrence and genesis of a persistent parting in the coal bed of the Lance formation: Am. Jour. Sci., 4th ser., vol. 37, pp. 299–304, April, 1914.

explains, without postulating special conditions in each case, the presence of similar partings in other beds.

Bed A consists of three large, well-defined lenses and one small lens. (See Pl. XIV.) The small lens, which has a maximum thickness of 30 inches, underlies the south-central part of T. 1 N., R. 36 E., and is less than 3 square miles in extent. One of the larger lenses extends across the valley of Tullock Creek from the northwest corner of T. 1 N., R. 35 E., underlying the southeastern part of T. 2 N., R. 35 E., and the western margin of T. 2 N., R. 36 E. This lens attains its maximum thickness of 34 inches in the southeast corner of T. 2 N., R. 35 E. The third lens is V-shaped and in reality consists of two smaller well-defined lenses connected by a narrow strip in which the coal is less than 24 inches thick. One of these subsidiary lenses underlies the central part of T. 3 N., R. 35 E., where its greatest observed thickness is 37 inches. The other underlies the eastern part of the same township and the western part of T. 3 N., R. 36 E., and also extends into the two townships adjoining on the north. It has a maximum thickness of 48 inches in the southeast corner of T. 3 N., R. 35 E., and its average thickness is over 24 inches. The fourth lens lies chiefly in Tps. 4 and 5 N., R. 35 E., but is extended eastward by a narrow neck of barely workable coal, which expands into a subsidiary lens in T. 5 N., R. 36 E. The average thickness of this smaller lens is less than 30 inches, but near its southern margin the coal abruptly thickens to nearly 3½ feet, and within a short distance to the south it falls to 18 inches. Along Sarpy Creek south of West Corral Creek bed A is thin and identifiable only with difficulty, as the peculiar sandy parting is not everywhere present, and in some localities the bed is probably absent.

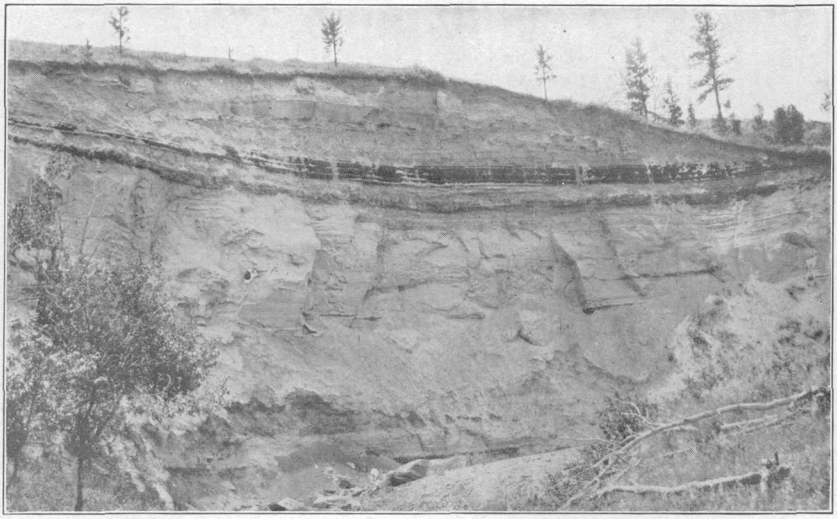
Bed B is a thin bed of little value 12 to 15 feet above bed A. It is more than 18 inches thick in a small area in the northwest corner of T. 1 N., R. 35 E., but elsewhere it is thinner. The bed was recognized at a few other localities but generally contains less than a foot of coal. A thin bed thought to represent bed B was found at the head of West Bear Creek.

Bed C is one of the most valuable of the Lance coal beds, being rather widely distributed and attaining at one point a thickness of 59 inches. (See Pl. XV.) In many places on Sarpy Creek the bed is associated with considerable carbonaceous shale, both above and below, which may increase its total thickness to 9 feet or more. The coal itself in some places occurs in one or two clear benches, but in many localities it is broken by a number of very thin shale and bone partings (some less than a quarter of an inch thick), which materially affect its value. Bed C underlies a small area in the northern part of T. 2 N., Rs. 34 and 35 E. Another and larger lens of bed C underlies the northeast quarter of T. 2 N., R. 35 E.; its maximum



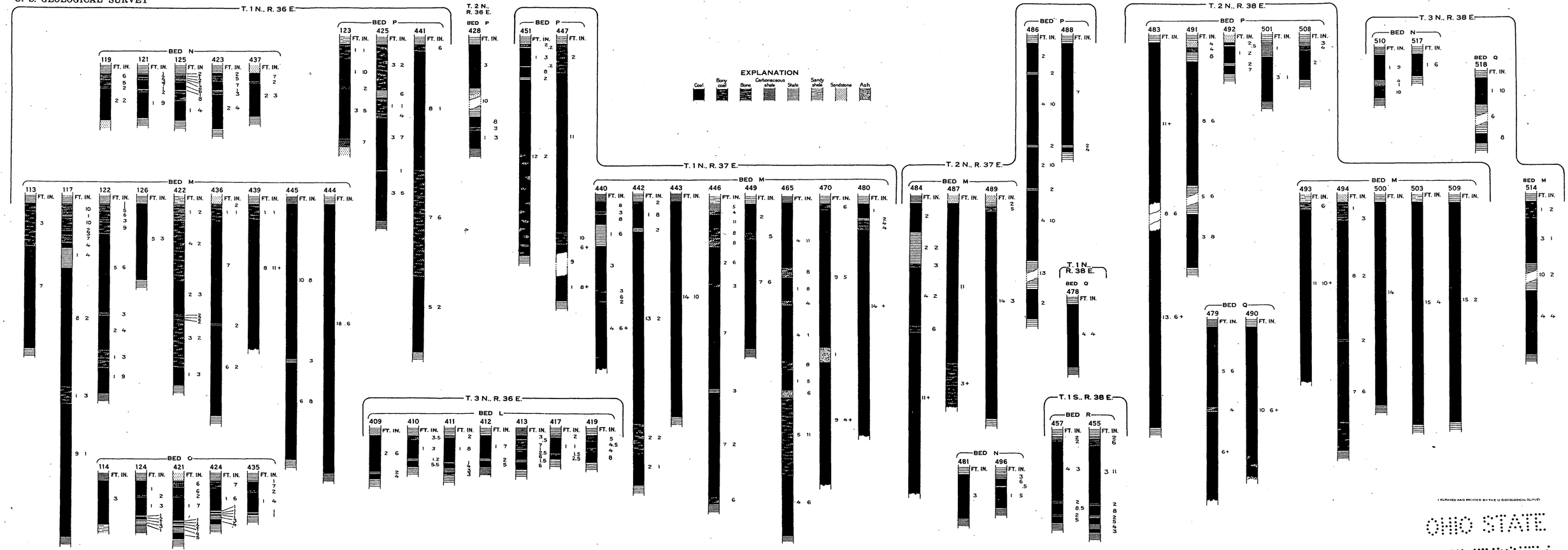
A. COAL BED A, THE BASE OF THE TULLOCK MEMBER OF THE LANCE FORMATION, EXPOSED NEAR HEAD OF UNKNOWN CREEK IN SEC. 34, T. 5 N., R. 35 E.

The manner in which the heavy sandstone bed overlying the coal to the right is partly replaced by thin-bedded sandstone and shale within a short distance well illustrates the irregularities in stratification characteristic of the Lance formation.

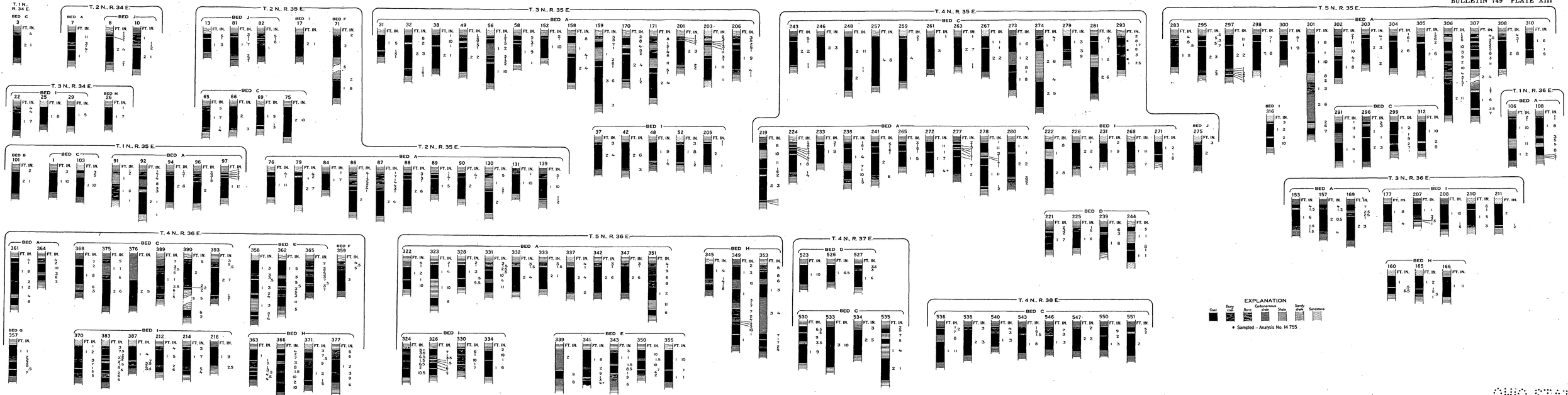


B. COAL BED A, THE BASE OF THE TULLOCK MEMBER OF THE LANCE FORMATION, EXPOSED ON WEST CORRAL CREEK IN SEC. 2, T. 4 N., R. 36 E.

The characteristic thin sandy parting is shown near the top of the bed.



SECTIONS OF COAL BEDS OF THE FORT UNION FORMATION IN THE TULLOCK CREEK COAL FIELD, MONTANA



SECTIONS OF COAL BEDS OF THE TULLOCK MEMBER OF THE LANCE FORMATION IN THE TULLOCK CREEK COAL FIELD, MONTANA

ENGRAVED AND PRINTED BY THE U.S.GEOLOGICAL SURVEY.

thickness is 32 inches. The third and largest lens, assigned to bed C, underlies nearly the entire east half of T. 4 N., R. 35 E., as well as the adjacent parts of the townships to the north and east. This is the thickest lens of coal in the Lance formation, attaining a thickness of 59 inches in sec. 13, T. 4 N., R. 35 E., and averaging well above 30 inches. The fourth lens extends from T. 4 N., R. 36 E., almost to the eastern edge of the field, but the greater part of the coal has been removed by the erosion of Sarpy Creek valley. The western edge of this lens underlies a narrow strip of land along West Bear Creek, and the eastern edge a somewhat greater area on the divide east of Sarpy Creek. In the latter locality the bed attains a thickness of 46 inches, but in the former only the thin edge of the lens is still unremoved by erosion. A lens that may be connected with this large one underlies the northern part of T. 4 N., R. 38 E., and extends out of the field to the east. A small and apparently isolated lens underlies parts of secs. 29 and 32, T. 4 N., R. 36 E.

Bed D was recognized at a number of localities, but it is generally too thin to be of value and does not exceed 24 inches in thickness at any point. The coal seems to be of fair quality, however, and the bed does not contain many partings. Bed D is thicker than 18 inches only in two very small areas in T. 4 N., R. 37 E., and in an area of several square miles in the southeastern part of T. 4 N., R. 35 E.

The interval between beds C and D varies considerably, as shown in Figure 5 (p. 162), which is compiled from measurements made in secs. 33, 34, and 35, T. 4 N., R. 37 E. In these localities the interval between these beds decreases from 15 feet to 4 feet within about 2 miles, and there is no means of telling from the data at hand whether both beds are inclined with regard to the general stratification or whether one is parallel and the other inclined. This discrepancy may be due to the gentle warping of the old surface between the times of deposition of the two beds but is probably to be regarded merely as an irregularity in deposition.

Bed E, which was recognized at a number of localities, generally consists chiefly of bone and carbonaceous shale. However, in an area of about 5 square miles on Corral Creek, in Tps. 4 and 5 N., R. 36 E., it contains more than 18 inches of coal, and in sec. 34, T. 5 N., R. 36 E., it attains a thickness of 34 inches.

Bed F is of only minor importance. It is thicker than 18 inches in a very small area in sec. 3, T. 4 N., R. 36 E., and it attains a maximum thickness of 26 inches in two small areas in T. 2 N., R. 35 E.

Bed G was recognized only in T. 4 N., R. 36 E., though it probably occurs elsewhere as a band of carbonaceous shale. It contains more than 18 inches of coal only in a small area in sec. 3 of that township.

Bed H is slightly greater than 18 inches in several parts of the field, but such areas are all comparatively small. The bed is thicker than 18 inches in a very small area in sec. 2, T. 4 N., R. 35 E., where it reaches a maximum of 21 inches. Two similar lenses underlie parts of secs. 19 and 29, T. 3 N., R. 36 E. The only important lens assigned to bed H is on the line between Tps. 4 and 5 N., R. 36 E., and this lens is divided into two areas by the valley of Corral Creek. North of the creek the bed attains a maximum net thickness of 36 inches and south of the creek a maximum of 33 inches.

Bed I consists of one large elongated lens and six small lenses. Although this bed underlies a considerable area its thickness does not exceed 32 inches at any point and is generally much smaller. The bed itself is exceedingly variable in quality but generally contains a great deal of impure coal and many bone and shale partings. The large lens extends from the head of Pocket Creek in T. 2 N., R. 35 E., to the head of Lightning Creek in T. 4 N., R. 36 E. (See Pl. XVI.) Much of the coal originally contained in this lens has of course been removed by the erosion of Tullock Creek and its tributaries. Except within a small area in T. 4 N., R. 35 E., the bed is less than 28 inches thick. This lens may extend under the Sarpy-Tullock divide and connect with a small lens on West Bear Creek and possibly with two other small lenses in T. 5 N., R. 36 E., but this is considered improbable, owing to the variable character of the bed. There are two other small lenses a short distance west of Whiskey Butte, and a third lens, which is doubtfully referred to this horizon, in the southwestern part of T. 2 N., R. 36 E. None of these small lenses are as much as 24 inches thick.

Bed J is well defined, particularly in the southern part of the field, but the bed is of workable thickness at only a few points. It underlies about 4 square miles near the top of the ridge between Tullock Creek and Big Horn River in T. 2 N., Rs. 34 and 35 E., where it attains a maximum thickness of 21 inches. A single section showing 24 inches of coal was measured in sec. 2, T. 4 N., R. 35 E., but elsewhere the bed is too thin or impure to be of value.

COAL BEDS OF THE FORT UNION FORMATION.

LEBO SHALE MEMBER.

The coal in the Lebo member of the Fort Union is generally associated with considerable bone and carbonaceous shale and thus forms beds that are conspicuous but have little actual value. Coal thicker than 18 inches was found at only two localities. These beds are very irregular, however, and as the Lebo in many localities is not well exposed, it is possible that there are other small lenses of coal more than 18 inches thick that were not observed by the writers.

Bed K, which is 70 feet below the top of the Lebo, consists chiefly of bone and carbonaceous shale, but in sec. 21, T. 2 N., R. 36 E., it carries 23 inches of coal. This is a very small lens, however, and is believed to underlie less than a quarter of a square mile.

Bed L, which is 20 feet below the top of the Lebo, underlies an area of 2 or 3 square miles on the crest of the divide near Whiskey Butte. This bed is thinner and less conspicuous than bed K but at one place carries 28 inches of coal.

UPPER DIVISION OF FORT UNION FORMATION.

Four thick and well-defined coal beds are contained in the upper division of the Fort Union and are here designated beds M, P, Q, and R. In addition to these, two thin beds, N and O, were observed in several localities. The relations and thickness of all these beds are obscured by the fact that they are burned almost everywhere on the outcrop, and some of the apparent variation in the intervals between them may doubtless be ascribed to this fact. The variation in thickness of beds M, P, and Q is shown on Plates XIV, XV, and XVI, the interval used being 2 feet instead of 6 inches, as for the Lance beds. As shown by the measured sections in Plate XII, these beds are not badly broken by partings and consist largely of clear coal.

Beds M, P, Q, and R do not occur as small scattered lenses, like the Lance coal beds, but each forms a single large and comparatively symmetrical lens. The greater apparent regularity of these lenses is due in part to the fact that they are based on fewer measurements and that the contour interval used is four times as great, but the suggestion of greater regularity in the habit of the beds themselves is probably well founded.

The following generalized section shows the relations of the beds and the variability of the intervals between them:

Generalized section of the upper division of the Fort Union formation.

[See also Pl. IV.]

	Feet.
Shale and massive sandstone	100+
Coal bed R	5
Shale and thin sandstone	300
Bed Q	1–11
Sandstone and shale, thinning southward	10–50
Bed P	1–24½
Shale and sandstone	35–50
Bed O	0–3
Shale and sandstone	30–65
Bed N	0–3
Shale and sandstone	25–40
Bed M	1–23
Sandstone, massive, cross-bedded, with locally some shale	75–130

Bed M forms a large and fairly symmetrical lens, which was originally somewhat greater in extent than the present area of the formation in this field. (See Pl. XIV.) The maximum thickness of bed M is found in sec. 14, T. 1 N., R. 37 E., where it contains 23 feet of coal, of which 6 feet is dirty. In sec. 19 of the same township the bed is 18½ feet thick, and in all directions from a line joining these points the bed gradually becomes thinner. The western edge of the lens seems to be rather abrupt, the coal thinning from 18 feet to 5 feet in a distance of 4 miles. However, the measurements in the northwestern part of T. 1 N, R. 36 E., are greatly obscured by the burning of the coal and may not represent the total thickness of the bed. From the central part of T. 1 N., R. 37 E., the bed thins gradually to the north as far as Horse Creek. North of this locality it decreases very abruptly in thickness, and in sec. 31, T. 3 N., R. 38 E., it is split into two benches that decrease in thickness toward the north and become less than 18 inches thick near the northern extremity of the area in which this part of the formation crops out. The northwestern part of the lens probably once extended well into T. 2 N., R. 36 E., but it has been removed by erosion. The only land to the north sufficiently high to contain the horizon of bed M is Whiskey Butte, on top of which a coal bed 3 feet thick and an acre or so in extent crops out. If this is actually bed M, it probably represents the northwestern edge of the same lens, which thus originally covered a considerable area.

Bed M is made up for the most part of clear coal and generally carries very few partings, though a considerable amount of pyrite was observed near the bottom of the bed at several localities. At certain points in T. 1 N., R. 37 E., the bed seems to be abruptly replaced by black shale, but owing to the extent to which it is burned and its outcrop obscured by clinker slumped from above the relations and extent of these areas are very difficult to work out. It is believed, however, that this condition, which is treated in more detail in the description of T. 1 N., R. 37 E., is due to the formation of channels in the old swamp. It is impossible to ascertain the course and the width of these channels in advance of actual development work, but it is probable that they are less than 1,000 feet wide and that they do not broadly affect the variation in thickness of the bed; they have therefore been disregarded in drawing the lines of equal thickness on the map (Pl. XIV). The bed is also rather abruptly replaced by shale in sec. 35, T. 2 N., R. 36 E., but as the upper part of the Fort Union is eroded to the north and west there is no way of ascertaining the relations of this area of replacement; it may represent the edge of the old swamp or possibly an island in the swamp. A marked thinning of the bed was also observed in a small

area on East Sarpy Creek, which may be due to the fact that an island existed in the swamp for a time but was finally submerged and covered by the vegetal matter that now forms the upper part of the bed.

Bed N underlies the northern part of T. 1 N., R. 36 E., where its maximum thickness is slightly more than 2 feet. A thin bed occurs at about this horizon in T. 2 N., Rs. 37 and 38 E., and T. 3 N., R. 38 E. Its thickness does not exceed 24 inches at any point and is more than 18 inches only in a few very small areas in the locality named. Bed O is thicker than 18 inches in two comparatively small areas in the east half of T. 1 N., R. 36 E., and the southeast corner of T. 2 N., R. 36 E., where its maximum thickness is 3 feet. In comparison with the thicker Fort Union coals beds N and O are of very slight importance.

Bed P in much of the southeastern part of the field is broken into benches or even separate beds by partings or beds of shale. Owing to the thickness of carbonaceous material at this general horizon and to the fact that it is everywhere partly or wholly burned, many of the measurements made are thought to be incomplete. The greatest measurement made in the southern part of the area is that in sec. 13, T. 1 N., R. 36 E., where the bed is burning at the present time. At this point the bed contains 21 feet of coal in one bench, part of which is somewhat impure, and only small amounts of coal in several lower benches. (See section 441, Pl. XII.) In T. 1 N., R. 38 E., at locality 474, a measurement of a part of the bed indicates a total thickness of almost 35 feet, but an unknown portion of this thickness is probably shale, and the measurement is therefore unreliable. The maximum thickness of bed P is considered to be that in sec. 30, T. 2 N., R. 38 E., where it contains 24½ feet of coal split into two beds by 8½ feet of shale. From a line joining this place and that at which the bed is 21 feet thick the coal appears to become thinner in all directions—gradually to the south and east but very abruptly to the north. To the northwest the bed is eroded, and therefore the original size of the lens can not be determined. The bed becomes thinner than 18 inches a short distance north of Horse Creek, or in the same general locality in which bed M feathers out.

Bed Q attains its maximum thickness of 11 feet in sec. 22, T. 2 N., R. 38 E.; from this place it thins gradually to the south but abruptly to the north. The thickest part of this lens therefore occurs almost directly above those of beds M and P, but bed Q is thinner, and the lens is somewhat smaller areally. Bed Q is eroded or entirely burned out in most of R. 37 E., and the areas now worth mining are therefore confined largely to Tps. 1 and 2 N., R. 38 E.

Bed R underlies a small area in the extreme southeast corner of the field but elsewhere has been removed by erosion. It is about 5 feet thick and underlies about half a square mile within the field, though it probably extends along the divide to the southeast.

QUANTITY OF THE COAL.

The following estimate of the tonnage of coal in this field was made in accordance with the lines of equal thickness, the construction of which has been explained above. It is believed, for reasons already stated, that these lines furnish the best means of summing up all thickness data and therefore form the most reliable basis for a tonnage estimate. The estimate is made on the assumption that the average thickness of all coal in the area lying between two thickness lines is the mean between the two—that is, that the coal in the area bounded by the 36 and 42 inch lines for example, has an average thickness of 39 inches. By measuring the acreage of a tract bounded by two of these lines and multiplying it by the average thickness, the quantity of coal in acre-feet is determined. An acre-foot of coal, or a bed of coal 1 foot thick and 1 acre in extent, weighs about 1,800 tons. The following estimate shows the total quantity of coal in the field, of which at least 60 per cent is recoverable under ordinary mining conditions:

Total estimated quantity, by townships, of Lance and Fort Union coal beds thicker than 18 inches in the Tullock Creek field, in short tons.

Township.	Lance formation Tullock member.	Fort Union formation.		Total.
		Lebo shale member.	Upper division.	
T. 1 S., R. 37 E.			19,000,000	19,000,000
T. 1 S., R. 38 E.			83,400,000	83,400,000
T. 1 N., R. 34 E.	700,000			700,000
T. 1 N., R. 35 E.	3,800,000			3,800,000
T. 1 N., R. 36 E.	3,700,000		142,800,000	146,500,000
T. 1 N., R. 37 E.			585,500,000	585,500,000
T. 1 N., R. 38 E.			451,500,000	451,500,000
T. 2 N., R. 34 E.	7,800,000			7,800,000
T. 2 N., R. 35 E.	33,300,000			33,300,000
T. 2 N., R. 36 E.	3,600,000	100,000	14,400,000	18,100,000
T. 2 N., R. 37 E.			56,400,000	56,400,000
T. 2 N., R. 38 E.			287,100,000	287,100,000
T. 3 N., R. 34 E.	3,600,000			3,600,000
T. 3 N., R. 35 E.	30,100,000			30,100,000
T. 3 N., R. 36 E.	18,000,000	2,500,000		20,500,000
T. 3 N., R. 37 E.	200,000			200,000
T. 3 N., R. 38 E.			13,600,000	13,600,000
T. 4 N., R. 35 E.	55,300,000			55,300,000
T. 4 N., R. 36 E.	43,700,000			43,700,000
T. 4 N., R. 37 E.	9,900,000			9,900,000
T. 4 N., R. 38 E.	6,400,000			6,400,000
T. 5 N., R. 35 E.	30,500,000			30,500,000
T. 5 N., R. 36 E.	12,800,000			12,800,000
	263,400,000	2,600,000	1,653,700,000	1,919,700,000

Of the total quantity, 85 per cent occurs in the upper division of the Fort Union, less than 1 per cent in the Lebo member, and

about 14 per cent in the Tullock member of the Lance. Of the coal in the upper division of the Fort Union only about 3 per cent is in beds less than 6 feet thick. In the Tullock member of the Lance, on the other hand, none of the coal is thicker than 59 inches; 37 per cent of it is in beds between 30 and 59 inches thick; and the remainder, or 60 per cent, is in beds between 18 and 30 inches thick.

RELATIONS OF THE COAL LENSES.

Lines of equal thickness, if drawn to the extreme edges of the coal bed, define the limits of the ancient swamp in which the coal was formed. They also furnish a clue to the topography of the swamp, or, more strictly, to the changing topography of the area during the time that swampy conditions prevailed. Many factors tend to destroy an exact relation between the ancient topography and the thickness lines, but they are nevertheless highly suggestive in attempting to reconstruct the conditions under which the coal was formed. The smallest thickness represented by lines on the maps accompanying this report is for economic reasons 18 inches; these maps, therefore, do not attempt to show the total area in which swampy conditions prevailed, but merely those portions of that area in which swamps existed long enough to permit the formation of 18 inches or more of coal. If 12 and 6 inch lines were also shown, the size of the lenses would be considerably enlarged, and most of those here shown as isolated would merge into one or more large lenses.

With these considerations in mind, the general distribution of the Lance coal lenses as shown on the thickness maps (Pls. XIV to XVI) is very striking. All that portion of bed A over 18 inches thick is contained in a zone 6 to 8 miles wide trending almost north; and if 12 and 6 inch lines were also shown, the lenses would occupy practically all of this zone. Although the belt would then doubtless be somewhat wider, the general linear arrangement of the lens or lenses would not be destroyed. Bed A also underlies Pine Ridge, 15 miles to the west of this belt, and there forms an elongated lens similar to those on Tullock Creek.[21] Similarly, bed C, in the northern part of the field, is essentially continuous in an east-west belt 6 miles wide. This bed also forms two lenses in the southern part of the field which might be included in the same belt if it were curved. All the lenses of bed I, except the smallest two, lie within a straight belt about 15 miles long and 4 miles wide. Throughout this belt the bed itself is continuous, but because in many places it is too thin or impure to be of value the economic lenses shown on the map appear to be isolated. The prolongations of all three of these well-defined

[21] Rogers, G. S., Geology and coal resources of the area southwest of Custer, Mont.: U. S. Geol. Survey Bull. 541, pp. 316–328, 1914. See especially thickness map on p. 325.

belts lie in areas from which the coal has been eroded, so that there is no way of determining their original length.

There is little information extant as to the exact shape and relations of coal lenses in other parts of the world, and the significance of the facts pointed out above can be only a subject of speculation at the present time. The linear distribution of the lenses strongly suggests, however, that the swamps were formed along well-defined drainage lines. As stated under "Geologic history," the Lance strata were probably laid down on a comparatively flat coastal plain, which during at least the coal-forming period was sinking at about the rate at which it was being built up. The sediment was brought from the mountains by rivers which in depositing it must have continuously meandered over the plain, building up their immediate channels and so temporarily leaving lower basins between. It is probable, also, that the rivers developed distributaries, or a system of smaller channels roughly parallel or diverging slightly toward the coast. Within these channels deposition or upbuilding was actively going on, but in the elongated basins between them swampy conditions were probably developed and very little sediment was deposited. Finally the streams would overflow the natural levees that they had been building up and inundate the lower-lying areas, bringing the accumulation of vegetal matter to an end. It is also probable that such periods of deposition alternated with periods of gentle erosion in places, and that broad, flat river valleys were formed in which swampy conditions developed. Other physiographic conditions may be imagined to account for the formation of these coal beds, but their lenticularity and their comparatively small extent indicate that unbroken swampy conditions did not exist throughout a very great area; their elongated shapes suggest a connection with watercourses; and their irregular variation in thickness probably indicates that the shape of the swamps did not remain constant and possibly that they were formed on a somewhat uneven surface.

The areal extent of the upper division of the Fort Union in this field is not great, and each coal bed represented in that division forms only one lens. The areal relations of the lenses of any one bed can therefore not be determined, but the relation of the several beds to one another is interesting. The point at which bed M is thickest is in sec. 13, T. 1 N., R. 37 E.; that at which bed P is thickest is probably 2 miles to the northeast; bed Q is thickest at a point 2 miles still farther northeast. Beds M and P decrease in thickness from these places at about the same rate and on the north pass below 18 inches in the same general locality. To the northwest bed M may have extended farther than bed P, but on the west, it is inferred, they were roughly coincident. Bed Q is much thinner than either

of these beds, and its areal extent is correspondingly smaller, but the rate at which it decreases in thickness is about the same.

In the Fort Union epoch, therefore, swampy conditions recurred three times within the same small area and continued long enough to allow the formation of a total maximum thickness of 58 feet of coal. So far as can be ascertained in this field, this area was roughly circular rather than elongated, and its relation to drainage lines is not apparent, although the well-defined channels in bed M indicate that considerable drainage must have passed through the swamp. During each period of coal formation a basin must have existed, the slopes of which were relatively regular and symmetrical. This may imply only that the main drainage lines remained constant during the deposition of 125 feet or so of strata and that at certain periods they were clogged and became swamps, but the repeated formation of a basin in the same locality suggests that the area was subjected to gentle down-warp. Be that as it may, the swamps formed were very different from those of the Lance formation in longevity and in constancy of shape, and it appears probable that the process of formation was also different. These swamps were perhaps more comparable to the Dismal Swamp of Virginia and North Carolina than to the smaller irregular bogs forming along certain rivers today.

BURNING OF THE COAL BEDS.

The coal beds in the upper division of the Fort Union in the southern part of the field have become ignited at some time since the early part of the Pleistocene and in burning have baked and fused the overlying strata. The outcrop of the coal is thus replaced by a zone of baked and reddened rock which extends back 50 feet or more from the outcrop. In some localities this zone is well defined and is only a few feet thick, but in others 30 or 40 feet of rock is affected. Where several burned beds crop out on a steep slope the clinker of the upper beds may slump down and apparently coalesce with that of the lowest, so that the whole hillside has the appearance of being baked. (See description of T. 1 N., R. 37 E., pp. 153–154.) This is the common condition in the southeastern part of the field, but in the Fort Union area north of Horse Creek the beds are burned only locally. No burning was observed in the Lebo member of the Fort Union. In the Tullock member of the Lance the beds have burned at only a few places, and even there the burning has not affected the overlying strata to any great extent.

The burning of coal beds on the outcrop, which is common in Montana, Wyoming, Colorado, and the Dakotas, has been variously ascribed to spontaneous combustion, to lightning, and to the agency of man. In the opinion of the writers, spontaneous combustion due

to the oxidation of finely divided and therefore inconspicuous pyrite is probably the common cause. It is most likely to occur where topographic conditions cause the bed to crop out on a fairly steep bank, so that a quantity of fine coal dust accumulates over the lower part of the outcrop. The thickness of the cover probably also affects the chances of the bed burning, and the fact that the Fort Union coal is not extensively burned in T. 3 N., R. 38 E., where the beds are thin, suggests that a thick bed is more likely to ignite than a thin one, a conclusion substantiated to some extent by observation in other areas.

Whatever the cause, the combustion, once started, spreads first along the outscrop, where the heat is for the most part lost, so that the outcropping strata are only very slightly affected. It is only as the burning progresses back under cover that enough heat is conserved to bake and fuse the overlying rocks. The underlying strata are also generally somewhat affected, but in many places the coal has not burned entirely to the base of the bed, so that the underlying rocks are more or less protected. The burning thus usually bevels back the outcrop, progressing farthest back at the top of the bed. Finally a point is reached where the combustion is smothered by the lack of oxygen. In general, where there is a cover of more than 10 or 20 feet the coal will not burn more than 50 or 75 feet back from the outcrop, although exceptionally the burning extends farther. If the coal bed lies flat and is within a few feet of the surface, it may burn for areas of many square miles. The vertical extent of the effects depends on the quality and amount of the coal and on the compactness or jointing in the overlying strata. In general, a 3-foot coal bed burning under 50 feet of cover and along a zone 25 feet or more back from the outcrop probably bakes from 10 to 20 feet of strata. The effect is of course much greater where two or more fairly thick coal beds separated by 10 or 20 feet of rock are concerned; under these conditions, if the beds burn synchronously, the heat may affect 100 feet or more of the overlying rock.

Aside from the strictly thermal effects of the burning, the fact that the coal in the course of its combustion is largely dissipated must be taken into account. The space previously occupied by the coal is taken up by the slumping of the overlying beds. When this occurs the beds have been baked hard and are commonly in a state of incipient fusion, so that in slumping down the large angular fragments have a tendency to cohere. This gives rise to a rock of which 30 or 40 per cent is air space, and vertical and perfectly stable cliffs of this hard natural brick contain many crevices large and long enough to allow the insertion of a man's arm. It is chiefly through this rock that oxygen is supplied to the coal burning farther back.

In general, the fusion extends but a short distance above the coal, and beyond this the rocks are only baked, but locally they may be fused for many feet above the bed. The gases formed in the combustion escape through fissures in the overlying strata and, being highly heated, tend thoroughly to fuse the rock along their paths of escape. Small fissures may control these paths and thus start the formation of well-defined chimneys. As the material forming the immediate walls of these fissures or chimneys is rendered molten it tends to sink and clog the passage, so that the gases may be slightly diverted and thus be caused to act on a greater volume of material. The pasty or molten rock coheres on cooling and forms an irregular cylindrical mass of clinker. Chimney-shaped masses of this kind resist erosion to a greater degree than the partly baked strata around them and thus weather to form the curious pinnacles that surmount many clinker bluffs or buttes.

The exact character of the clinker formed depends largely, of course, on the amount of heat to which it has been subjected. The great bulk of the rock affected is merely baked to a light-red color and retains its original texture. Higher degrees of heat destroy the original texture and, especially when acting on shale, produce a smooth, red material resembling jasper but commonly showing flow lines, flow brecciation, and other evidences of its origin. Both of these types are formed by the action of moderate heat under simple oxidizing conditions, and therefore no very extensive chemical changes take place. The heat is generally only sufficient to fuse the edges of the grains; and cooling is generally so rapid that the melted portion hardens as an amorphous glass.

Very different effects are produced, however, in the rock immediately above the burning bed and in the chimneys formed by the escape of the gases. Here the burning gases not only thoroughly fuse the rock but also play an important part as reducing agents. Inasmuch as the combustion of the coal takes place in presence of a scanty supply of oxygen a considerable proportion of carbon monoxide is doubtless formed, and if the rock is ferruginous the reducing action may be very striking. Outside of the chimneys the iron is oxidized and the rocks are merely baked red, but along the paths of the gases the iron is partly or wholly reduced, and gray, green, yellow, and black slag is formed. When the reduction is partial magnetite may be formed, in some places in sufficient quantity to produce a black slag that affects the compass needle. However, when the rock is thoroughly fused under reducing conditions a great deal of the ferrous iron formed is taken up in the formation of new minerals and a light-colored slag results. If this thoroughly fused slag is rapidly cooled, amorphous glass resembling obsidian is formed, but when the rate of cooling is slower a more or less com-

pletely recrystallized rock results. The recrystallized material is generally if not always confined to the chimneys. It is usually gray to dark grayish green in color and except for its vesicularity is very similar in appearance to a fairly basic igneous rock. The grain is generally fine, though in one specimen a crystal one-tenth of an inch in diameter, resembling pyroxene, was observed.

A number of thin sections of baked, fused, and recrystallized rock have been examined by the senior writer.[22] In general, the baked rock examined under the microscope shows little alteration, except for the formation of minute scales of hematite that impart the characteristic reddish color. Higher degrees of heat cause incipient fusion, with the formation of small areas of amorphous glass, and all gradations from this type to rock composed entirely of glass may be observed. When the rate of cooling is sufficiently slow to allow recrystallization a variety of minerals may form, depending chiefly on the chemical composition of the original sediment. Plagioclase in well-formed laths and magnetite are apparently universal. Diopside and other members of the pyroxene group are fairly common, and minerals resembling epidote and melilite in general habit were observed. Cordierite, sillimanite, garnet, and what seemed to be spinel form the bulk of one specimen. In some places the fusion is only partial, and the rock is made up of grains of the original quartz set in a glass containing some magnetite and a few slender needles of pyroxene. Very interesting types of rock are thus locally produced by this pseudo-igneous action, even though the crystallization of the molten mass is comparatively rapid. In shales of the type found in this region the molecular ratio of the alumina generally exceeds that of the lime, potash, and soda; hence in many localities the molten mass acts as an aluminous rather than as a siliceous magma, and its crystallization seems to follow the laws formulated by Morozewicz.[23]

The chemical composition of sedimentary rocks varies considerably, however, and under certain conditions very exceptional products apparently result from their fusion. Thus, on the edge of a chimney of thoroughly fused rock projecting up through slightly baked arkosic sandstone in sec. 25, T. 1 N., R. 36 E., a mass of hematite 1 foot in diameter was found. The origin of this hematite is not clear, for the surrounding rock contains only about 5 per cent of iron. Native (metallic) iron formed by the burning of coal beds and the consequent reduction of clay-ironstone nodules in the overlying strata has been observed on North Saskatchewan River.[24]

[22] Rogers, G. S., Baked shale and slag formed by the burning of coal beds: U. S. Geol. Survey Prof. Paper 108, pp. 1–10, 1918.

[23] Morozewicz, Jósef, Experimentelle Untersuchungen der Minerale im Magma: Min. pet. Mitt., vol. 18, pp. 1–90, 195–240, 1898.

[24] Tyrrell, J. B., Naturally reduced iron: Am. Jour. Sci., 3d ser., vol. 33, p. 73, 1887.

Some indication of the age of the clinker in several places is afforded by its relation to the present topography, although, according to the principles stated above, an exposure of thoroughly fused clinker implies in itself that a certain amount of erosion has taken place since the burning, for such clinker is formed only after the burning has progressed some distance back from the outcrop, where the cover is sufficient to conserve the heat. However, bed M, the lowest of the group of burned coal beds, is near the level of the creek bottoms in much of the area; and as only the youngest coulees have cut back through the burned zone and exposed the coal, it is probable that in most places the bed was burned at a comparatively recent date. The clinkers of beds P and Q lie at about the level of the divide tops and also cap many outlying buttes, some of which, at least, have probably been isolated by erosion since the burning took place. In some places, therefore, these beds were burned at a much earlier time than bed M. However, exposures of all these beds were found in which the coal is mingled with ash and is only partly burned. This condition in many places probably represents the point at which the burning was smothered by lack of oxygen, owing to its distance from what was the outcrop at that time; a considerable amount of erosion must thus have taken place since the burning in order to bring these points to the surface. The presence of worn pebbles of clinker in stream gravel far from their source also indicates that some of the burning took place at a rather early date. On the other hand, the comparative recency of some of the burning is indicated by the fact that it is found on one side of a young coulee and not on the other. The burning is therefore not confined to any one period, nor does a bed once ignited necessarily burn throughout a large area. Bed P, which was burned in Pleistocene time in some places, is still burning in sec. 13, T. 1 N., R. 36 E.

OUTLOOK FOR DEVELOPMENT.

At the time of the writers' examination the coal resources of this field were almost entirely undeveloped. In sec. 14, T. 4 N., R. 36 E., an entry apparently about 30 feet deep, now caved, has been driven on coal bed C, and at a few other places a little coal has been stripped from the outcrop for local use. Thus, in sec. 30, T. 1 N., R. 38 E., there is a small strip pit on the upper 5 feet of bed P that supplies fuel to some of the ranchers in Sarpy Basin, and similarly, on Horse Creek, Unknown Creek, and at some other places the outcrop has been cleaned off and a little coal removed. At the head of Cut-off Creek, in T. 4 N., R. 35 E., a small amount of prospecting has been done, most of it at exceptionally unfavorable places. It is reported that about five years ago considerable land in this locality was taken

up and "mines" (merely entries 4 or 5 feet deep) were sold to business men in Billings and elsewhere. Owing to the abundance of pine timber in the field there is no great local demand for other fuel, and the lack of transportation facilities has so far prevented any commercial development.

The commercial relations of the field have been described under "Geography." The Northern Pacific Railway passes within 3½ miles of coal bed A at the head of Forty-four Coulee (see Pl. XI), but the intervening district is so rough that transportation to the railway would be very expensive. Beds A and C crop out on Unknown Creek about 5 miles from the railway, and development in this locality would doubtless be more successful. Bed C is 5 feet thick at the head of Lightning Creek, and there are many other places in the lower valley of Tullock Creek where coal may profitably be mined, but the long haul to the railway will probably discourage development for some time. However, as the country becomes more thickly settled and more of the land is devoted to agriculture, the local demand for coal will increase. This demand should and doubtless will be supplied by strip pits and small mines within the field, but development on an extensive scale is entirely dependent on better transportation facilities.

In Sarpy Valley the Lance coal beds are generally thinner than on Tullock Creek, and the only localities in which development is likely to take place for some years are on West Corral, West Bear, East Bear, and West Beaver creeks. If the coal mined at these places were destined for railroad shipment, it would have to be hauled from 15 to 25 miles. Except to supply a local demand, therefore, it is probable that no coal will be mined in the lower valley of Sarpy Creek until railroad transportation is provided.

The area of the Fort Union coal land in the southeastern part of the field contains about 85 per cent of the coal in the field. The stocking quality of this coal is probably not so good as that of the Lance coal, but its ash content is very low, and it forms a very desirable fuel for domestic use. Furthermore, 97 per cent of it is in beds more than 6 feet thick, and probably 50 per cent is in beds between 6 and 10 feet thick, which under ordinary conditions is the most favorable thickness in mining. Practically all of this coal, however, is more than 30 miles from the Northern Pacific Railway and more than 20 miles from the Chicago, Burlington & Quincy Railroad, and it can not be commercially developed until railroad connection is provided. This can be done most economically by building a spur line from the Northern Pacific at Sanders up Sarpy and East Sarpy creeks. If other factors besides the coal are con-

sidered in planning a road, Tullock Creek might be thought a more favorable route, or it might follow Sarpy Creek to Horse Creek and thence cross the divide into Armells and Rosebud valleys. Roads on any of these routes would pass close to or directly through the Fort Union coal area and would in addition traverse the areas of Lance coal farther north.

Timber of the size and quality suitable for mine lagging and props is available anywhere in the coal-bearing part of the field, though especially abundant in the Fort Union area. Moderate supplies of water are available on the larger creeks and at the heads of many of the smaller coulees. As already stated, the flow of ground water is controlled chiefly by the geologic structure, or the dip of the rocks, and advantage should be taken of this fact in locating a mine. In general, the mine entry should be so located as to allow drifting up the rise of the bed, in order to take advantage of the natural drainage and to lessen the cost of hauling out the loaded cars. Thus, in the Fort Union area the general dip is to the southeast, and as a rule entries should therefore be located on the west side of Sarpy and East Sarpy creeks. There are many minor variations in structure, however, which are shown on Plate X; and the local topography, structure, thickness of coal, and other features are set forth in more detail in the township descriptions below.

As already stated, the coal in this field is probably equal to that of Sheridan, Wyo., and almost equal to that of the Bull Mountains. In the absence of transportation facilities, this coal can not compete in the open market with that mined along a railroad, and for some time it will serve merely to supply the increasing demand for domestic fuel within the field.

TOWNSHIP DESCRIPTIONS.

GENERAL SCOPE.

In the following descriptions will be given the local details that have served as a basis for the general conclusions as to stratigraphy, structure, thickness, and character of coal, and other features of the field set forth above. Thus, for example, the description of the general character of the coal beds is based on the maps showing lines of equal thickness, which sum up measurements made throughout a considerable area, but in the township descriptions especial stress will be laid on the actual outcrop measurements obtained in each particular township. The structure and stratigraphy are similarly treated. The topography and geology of each township will be sketched in a general way, but particular emphasis will be laid on the location and character of the coal beds, the thickness of their cover, and any special peculiarities noticed concerning them.

Each township description is therefore complete in itself, but the significance and relations of many of the facts given are summed up only in the first part of the report.

On the economic map (Pl. XI), to which constant reference will be made in the following pages, the outcrops of the coal beds are shown by different patterns, which indicate the value of the bed. (See p. 67.) The sections taken on the several coal beds are numbered with regard to drainage lines, starting northward along the west side of the Tullock-Big Horn divide and returning south on the west side of Tullock Creek; thence north on the east side of the creek, and so on. The townships are therefore described in rough conformity with this order, starting in the southwest corner of the field and finishing in the northeast corner. The localities at which sections were measured are marked on the map by numbers, and the sections, correspondingly numbered, are shown in Plates XII and XIII or are given in the text. The thickness maps (Pls. XIV, XV, and XVI) sum up the measurements of the six most valuable beds and indicate the land which in the writers' opinion is underlain by these beds.

T. 1 S., R. 33 E.

Only the east half of sec. 1, T. 1 S., R. 33 E., is included in the Tullock Creek field. A patch of fertile bottom land inclosed by bluffs 100 feet high lies in the northern part of this section; the remainder is a fairly level gravel-covered terrace. The Claggett shale, containing no coal, crops out in this area.

T. 1 N., R. 33 E.

Only that portion of T. 1 N., R. 33 E., lying east of Big Horn River was examined. Along the river there is a strip of fairly level ground which is followed by the main river trail. This level tract, which is about 125 feet above the river, is covered with gravel and represents the first terrace. At two places at the foot of the terrace there are isolated patches of bottom land about half a square mile in extent, but elsewhere the bluffs immediately adjoin the river. East of this level bench the land is higher but is extensively dissected by the drainage of Ninemile and other creeks, and though the total relief is not great the surface is very rough. Cottonwood trees grow on the bottom land and in the lower valleys of the larger creeks, but there is practically no pine timber in the vicinity.

In the southern part of this township the Clagget shale is exposed and, being covered with gravel, gives rise to the peculiar rounded though steep surface forms already described. North of Ninemile Creek the Bearpaw crops out under the same conditions, and the

surface is of similar character. Along Ninemile Creek Judith River sandstone is exposed; its outcrops have been described in detail on pages 13–14. The composition of the formation in this vicinity can not be definitely determined, but it is thought to be made up of two sandstones, the upper of which forms a prominent bluff along the river just south of Ninemile Creek. The lower sandstone is exposed in the bluff back of Brandt's ranch, in sec. 22, and also farther east. Along Ninemile Creek the strata dip 12°–20° N., but the dip flattens in the northern part of the township and probably also in the southern part. No coal is exposed in this township, nor is any thought to underlie it.

T. 2 N., R. 33 E.

Only that portion of T. 2 N., R. 33 E., lying east of Big Horn River, namely, the eastern tier of sections, was examined. Much of the area is an almost level plain at an altitude of about 125 feet above the river, dissected by the deep valleys of Cottonwood and two other creeks. This land is too high above the river to make future irrigation likely, and dry-farming methods will probably have to be employed. There are one or two tracts of fertile bottom land on the river, however, and the one on which the Oldhorn ranch is situated has been under cultivation since about 1885. There are no pine trees in the township, except in secs. 1 and 12, but cottonwoods are abundant on the Oldhorn bottom and in the valleys of the larger creeks.

The contact between the Lance and Bearpaw formations crosses the northeast corner of this township (see Pl. X) and is well exposed in the bluffs inclosing the Oldhorn bottom. The contact seems to be somewhat irregular, and in several places there is a slight discordance in dip in the two formations. The following stratigraphic section measured in this bluff shows the lithologic character of the top of the Bearpaw and the base of the Lance. At the point at which it was measured the Bearpaw dips 1½° N., and the Lance is perfectly flat.

Section measured from north quarter corner to northeast corner of sec. 13, T. 2 N., R. 33 E.

	Feet.
Sandstone, partly concealed by gravel	31
Sandstone, yellow, thin-bedded, hard (base of Lance)	26
Sandstone, yellow, soft (top of Bearpaw)	15
Shale, light green	13
Sandstone, yellow, soft, and shale, yellowish green, sandy	32
Shale, dark green	10
Alluvial flat.	
	127

The general dip of the strata, as exposed in this bluff, is about ½° N. It is not uniform, however, the beds being thrown into a series of flat

local folds, the limbs of which dip at about 2°. It is believed that the strata in secs. 25 and 36 dip at somewhat greater angles, but that the average dip in the township is about 1°. There is no coal in this township, nor any mineral likely to be of immediate economic importance.

T. 3 N., R. 33 E.

Only a small part of sec. 36, T. 3 N., R. 33 E., lies east of Big Horn River and is included in the area examined. It is chiefly bottom land lying at the mouth of Eighteenmile Creek. The rocks that crop out in this area belong to the lower part of the Lance formation and are noncoal-bearing.

T. 1 S., R. 34 E.

Only that portion of T. 1 S., R. 34 E., lying north of the Crow Indian Reservation—that is, the northernmost tier of sections—was examined. Most of this area is underlain by the Claggett shale, but the Judith River underlies part of sec. 1. The strata in sec. 1 dip 5° E. The alkaline character of the soil renders it unfavorable for plant growth, and it supports little but sagebrush and cactus. There is no coal in the township.

T. 1 N., R. 34 E.

The Tullock-Big Horn divide forms the approximate eastern boundary of T. 1 N., R. 34 E., so that all the drainage of the township leads to the west. In the southern part of the township the divide is fairly low, but in the northern part the outcrop of the coal-bearing rocks forms a series of precipitous bluffs that rise nearly 200 feet higher. The divide here is comparatively flat-topped, with steep sides impassable to wagon travel, whereas to the south it is a narrow ridge with gently sloping flanks and is crossed by three roads. In the northeastern part of the township there is an abundance of sandstone, which supports a scattering growth of pine, but the southern and western parts are practically treeless. Water is scarce in this township, and it contains little land suitable for cultivation.

The Lance, Bearpaw, Judith River, and Claggett formations underlie this township, and nearly the full thickness of each is exposed. In secs. 1, 12, and 13 the Tullock member of the Lance formation makes the high escarpment on the divide referred to above. To the west and south the lower part of the Lance crops out in a broad belt (see Pl. X) in which the surface is much less rugged than in Lance areas farther north. The southwestern half of the township is underlain by the three formations of the Montana group—the Bearpaw, Judith River, and Claggett. The full thickness of the Bearpaw shale, about 1,000 feet, is exposed in a belt of varying

width, which is bounded on the south and west by the outcrop of the Judith River formation. Owing partly to the mantle of gravel that covers this area exposures of the Judith River are rare and very inconspicuous, but the distinct hogback formed by this formation, tilted to the north, is shown in Plate I, *A*. The relation of the few scattered sandstone outcrops can not be satisfactorily made out, but it is believed that the Judith River is made up of two sandstone beds separated by shale. The upper sandstone is probably represented by the exposures in secs. 21, 27, and 28, and the lower by those in secs. 19, 20, and 29. Below the Judith River lies the Claggett shale, which resembles the Bearpaw in every way. The eight fossil collections made in this township have been considered in the descriptions of these formations.

In this township the strata dip more steeply than in any other part of the field. Along the outcrop of the Judith River formation the dip is 30° in the west and central parts of the township but considerably less in the eastern part. As indicated by the trend of the outcrop, the strike changes from east in sec. 19 to northeast in sec. 27 and north in sec. 35. On both sides of the outcrop, however, the dip flattens. It averages less than 8° in the lower part of the Lance and less than 2° in the upper or Tullock member. The dip in the Claggett shale can not be satisfactorily measured, owing to the obscurity of the bedding planes, but it is believed to be slight.

In this township the Tullock member of the Lance contains only one coal bed thicker than 18 inches—bed C. In the southern part of sec. 1, at location 3 (see Pl. XIII), this bed contains 25 inches of coal. At location 4, in the northern part, however, it contains only 20 inches, part of which is impure, and north of this place the bed disappears. At 30 feet below this bed is bed A, which marks the base of the Tullock member, but in this township bed A is everywhere less than 18 inches thick. The general character of the Tullock member in this township is shown in section 5, Plate IV.

Section of coal bed C at location 4, in the NW. ¼ sec. 1, in T. 1 N., R. 34 E.

	Ft.	in.
Shale.		
Coal	1	5
Coal, impure		3
Bone		5
Shale, carbonaceous.		
	2	1

T. 2 N., R. 34 E.

The crest of the Tullock-Big Horn divide is approximately coincident with the eastern boundary of T. 2 N., R. 34 E., although in the

northern part of the field it has been crowded somewhat to the east by the size and vigor of Pocket Creek. The crest of the divide is formed by the high escarpment in which the coal-bearing rocks crop out. At the foot of this escarpment the country is extremely rough, and the area known as the Devil's Pocket is practically impassable even to horseback travel. The relief is not great, however, and in most of this district a young type of topography prevails, the country being a grassed plateau extensively dissected by narrow canyons rather than a maturely developed tract of badland. In the basin of Cottonwood Creek, which is separated from the Devil's Pocket by a tongue of coal-bearing rocks that extends westward for almost 2 miles, the country is much smoother. The western part of the township is comparatively level, except immediately along the courses of the larger creeks, and some of this land is adapted to dry farming.

Three formations are exposed in this township—the Lebo shale member of the Fort Union, all of the Lance including the Tullock member, and the Bearpaw shale. Only about 25 feet of the basal part of the Lebo shale is exposed; its approximate outcrop is shown on the map (Pl. X). The full thickness of the Tulloch member of the Lance is exposed in a comparatively narrow belt along the precipitous west flank of the divide, where sections 3 and 4 (Pl. IV) were measured. Below the Tullock member the non coal-bearing portion of the Lance crops out, and the roughness of the Devil's Pocket and adjoining areas is due chiefly to the abundance of cliff-forming sandstones in this part of the formation. (See section in description of T. 3 N., R. 34 E.) The basal part of the Lance is comparatively shaly in this township, however, and to this fact may be ascribed in large part the relative flatness of the western part of the area. The character of the basal part of the Lance is shown in the following section:

Section of lower part of Lance formation measured 2 miles along line northeast from Oldhorn ranch, in sec. 13, T. 2 N., R. 33 E.

	Feet.
Shale, yellow and green, variegated	66
Sandstone, yellow	10
Shale, yellow, with several thin sandstone lenses	34
Sandstone, yellow, massive	16
Shale, yellow, sandy	11
Shale, green	28
Sandstone, yellow, massive	21
Concealed, probably green shale	31
Sandstone, yellow, thin bedded	4
Shale, light green	11
Sandstone, yellow	2
Shale, yellow, sandy	10

	Feet.
Sandstone, yellow	2
Concealed, probably light-green shale	25
Sandstone, massive, with thin-bedded cap 1 foot thick	12
Shale, green	21
Sandstone, massive, with small sandy shale lenses	15
Shale, light green	30
Concealed, probably shale	10
Sandstone, yellow, prominent, bedded	57
Bearpaw shale.	
	416

In the southwest corner of the township the Bearpaw shale is exposed and gives rise to a relatively flat country which is sharply marked off from that of the Lance by the total absence of pine trees.

The general dip of the rocks in this township is to the northeast and ranges from less than 2° in the southwestern part to ½° in the northern part. (See Pl. X.) However, the general inclination is complicated by many minor rolls, which, though of only local extent, serve to increase the difficulty of tracing the coal beds.

Three coal beds are exposed in this township, none of which is more than 30 inches in thickness. The highest one, bed J, is about 30 feet below the top of the Lance formation. It crops out as an outlier on the crest of the divide in the southern part of the township and forms another large outlier in sec. 23. (See map, Pl. XI.) In sec. 23 it contains an average of about 30 inches of coal (see sections 8 and 10, Pl. XIII), but along the eastern edge of the township it is somewhat thinner and part of the coal is impure (sections 9 and 12, below). In sec. 24 its outcrop crosses into T. 2 N., R. 35 E., where it falls below 18 inches within a short distance. This bed is in general under a cover of less than 30 feet. Bed C, which is stratigraphically 235 feet below bed J, was mapped only in secs. 36 and 25 as a continuation of the mapping in the township to the south. In sec. 36 it is probably not more than 18 inches thick, and in sec. 25 it contains only 3 inches of coal. (See section 5, below.) The horizon of bed B was recognized in sec. 13, but the bed carries only 15 inches of coal (section 11, below). Bed A, 265 feet below bed J, was found to be more than 18 inches thick at only one place of measurement—location 7, in sec. 26, where it contains 30 inches of coal split by two 1-inch partings. (See section 7, Pl. XIII.) As shown in section 6 below, the bed in sec. 36 contains only 15 inches of coal. Location 7, in sec. 26, is the only point on the west side of the divide at which bed A is of mining value, although on the east side of Tullock Creek it is thicker than 18 inches throughout a considerable area. The sections of bed J at locations 8 and 10 are given in Plate XIII.

Sections of coal beds in T. 2 N., R. 34 E.

Location 5. SW. ¼ sec. 25 (bed C).

	Ft.	in.
Shale, sandy.		
Coal		3
Shale	5	
Coal		3
Shale.		
	5	6

Location 6. NW. ¼ sec. 36 (bed A).

	Ft.	in.
Shale.		
Bone		½
Shale		1½
Coal		2
Parting, sandy		1
Coal	1	2
Shale.		
	1	7

Location 9. SW. ¼ sec. 24 (bed J).

	Ft.	in.
Shale.		
Shale, carbonaceous		6
Bone		4
Shale		1
Coal, very impure	1	3
Coal	1	2
Shale, carbonaceous	2	8
Shale.		
	6	

Location 11. SW. ¼ sec. 13 (bed B).

	Ft.	in.
Shale.		
Coal	1	3
Shale, carbonaceous	1	5
	2	8

Location 12. SE. ¼ sec. 13 (bed J).

	Ft.	in.
Shale.		
Coal		10
Shale, carbonaceous		4
Coal, impure	1	3
Shale, carbonaceous.		
	2	5

T. 3 N., R. 34 E.

Big Horn River crosses the western part of T. 3 N., R. 34 E., and the area lying west of the river was not examined. The crest of the Tullock-Big Horn divide lies just west of the eastern border of the township, and practically the whole township drains to the west. The crest of this ridge rises steeply some 300 feet above the general level of the land in the central part of the township, which is extensively dissected by many creeks. In the vicinity of Pocket Creek especially it is very rough, though the total relief is not great. Along the river and about 125 feet above it there is a fairly level terrace in places, but this is generally only about half a mile wide. Mission Bottom, in secs. 4 and 9, is a fertile area of flood plain that has been under cultivation for a number of years, but the settlement is practically inaccessible except when the river is frozen over. There are no wagon roads in the township.

The rocks in this township belong to the Lebo shale member of the Fort Union formation, the Tullock member of the Lance, and the lower portion of the Lance. Only about 25 feet of the base of the Lebo shale crops out on the crest of the divide, and its exposure

was only approximately mapped. The full thickness of the Tullock member is exposed on the slopes of the ridge, and below it, in the very rough country mentioned above, the non coal-bearing portion of the Lance crops out. Sections 1 and 2 on Plate IV show the character of most of the Tullock strata, and the following section shows the abundance in this locality of cliff-forming sandstones in the lower part of the Lance.

Section of lower part of Lance formation, measured eastward from Mission Bottom.

	Feet.
Sandstone, yellow, soft, massive, with brown sandstone lenses and irregular swirls of conglomerate	35+
Shale, greenish, with some layers of gray and yellow and with several lenticular sandstones 6 to 10 feet thick	123
Sandstone, white, massive, with lenses of hard brown sandstone	38
Shale, greenish, sandy at base	29
Sandstone, white, massive, homogeneous	51
Shale, dull yellow to greenish	50
Sandstone, shaly, hard	1
Shale, green, soft	15
Creek bed about 30 feet above Big Horn River.	
	342+

The strata in this township are folded into a gentle trough plunging to the west (see Pl. X), but this general structure is complicated by many minor flexures. Thus in the SE. ¼ sec. 24 the beds locally dip 8° SW., but this dip disappears within a short distance. Similarly, in the SW. ¼ sec. 1 there is a local dip of 5° NE. As stated elsewhere, local irregular dips of this kind may indicate the presence of concealed faults near by. In a long neck extending westward from the divide in sec. 11 a gentle north-south anticline is exposed, but this is of only local extent. An apparently normal fault with a vertical displacement of about 30 feet cuts the strata in secs. 13 and 14. Its displacement increases to the east, and in that direction it was traced for more than 2 miles.

Of the numerous carbonaceous beds and lenses that crop out in this township only beds H and I are of economic value. The character of bed J in this township is shown by section 27 below. Bed I is only 11 inches thick in the SE. ¼ sec. 2, but at location 25, in sec. 12 (see Pl. XIII, a mile to the south, it is 20 inches thick. It thins gradually toward the south, and at location 23 it is only 19 inches thick. (See sections below.) At location 22, in sec. 26 (Pl. XIII), it is 19 inches thick, and at location 21 it carries a total of 22 inches of coal. On the east side of the divide the bed is of no value north of sec. 12 (see section 28, below), but south of this locality it is about 20 inches thick, as shown in sections 29 (Pl.

XIII) and 35. Its outcrop on the east side of the divide lies mostly in T. 3 N., R. 35 E. (see map, Pl. XI), where the bed reaches a maximum thickness of 30 inches in sec. 17 (section 42, Pl. XIII). The crest of the divide rises about 125 feet above bed I and affords a thick cover, except in secs. 12 and 13, where the extensive drainage of West Burnt Creek has cut back into the ridge and formed a low saddle in which the coal crops out. In sec. 12 bed H, 21 feet below bed I, reaches 19 inches in thickness (section 26, Pl. XIII), but at no other place is this bed thicker than 18 inches. Bed A is very thin along the west side of the divide in this township, but from measurements made in the township to the east it is believed to be thicker than 18 inches in small areas under the divide in secs. 12 and 13. (See Pl. XIV.) On the east side of the divide it crops out at the head of West Burnt Creek in sec. 13, but as shown in section 34 below, it is here broken by many thin partings.

Sections of coal beds in T. 3 N., R. 34 E.

Location 21. SE. ¼ sec. 24 (bed I).

	Ft.	in.
Shale.		
Coal, impure		6
Coal	1	4
Shale, carbonaceous.		
	1	10

Location 23. NW. ¼ sec. 13 (bed I).

	Ft.	in.
Shale, carbonaceous.		
Bone		3
Coal, impure		3
Coal	1	4
Shale, carbonaceous.		
	1	10

Location 24. NW. ¼ sec. 13 (bed I).

	Ft.	in.
Shale.		
Coal, impure		2½
Shale, carbonaceous		½
Coal		11
Coal, impure		6
Coal		3
Shale, carbonaceous		½
Bone		2
Shale.		
	2	1½

Location 27. SW. ¼ sec. 1 (bed J).

	Ft.	in.
Shale.		
Shale, carbonaceous		6
Bone		4
Shale, carbonaceous	1	7
Coal, impure		3
Bone, with coal streaks		11
Shale, carbonaceous		3
Bone		4
Coal		2
Shale, carbonaceous		1
Coal, impure		3
Coal		9
Shale, carbonaceous	1	
Bone		5
Shale.		
	6	10

Location 28. NE. ¼ sec. 12 (bed I).

	Ft.	in.
Sandstone.		
Shale, carbonaceous		4
Coal, very impure	1	4
Sandstone.		
	1	8

Location 34. NE. ¼ sec. 13 (bed A).

	Ft.	in.
Shale, carbonaceous.		
Coal		1½
Sandstone		½
Coal		1
Shale, carbonaceous		½
Coal		6½
Parting, sandy		1½
Coal		10
Shale, carbonaceous		4
Shale.		
	2	1½

Location 35. SW. ¼ sec. 13 (bed I).

	Ft.	in.
Shale.		
Shale, carbonaceous		1
Coal	1	8
Bone		1
Shale.		
	1	10

T. 4 N., R. 34 E.

Big Horn River traverses T. 4 N., R. 34 E., only the eastern part of which is included in the field. Tullock Creek crosses the northeast corner and empties into the river in sec. 2, so that the divide between this stream and the Big Horn trends north-northwest across the township. The divide here is lower than in the townships to the south and is considerably dissected. In the central part of the township, however, it is broad and flat topped and, rising abruptly from the fairly level bench about 125 feet above the river, constitutes the second well-marked terrace. This level portion is only thinly gravel covered, and much of the land is adapted to dry farming.

The rocks that crop out in this township belong to the Lance formation, and those in the southeast corner to the coal-bearing Tullock member of the Lance. Coal bed I was mapped in T. 3 N., R. 34 E., almost to the southern line of this township, but in that locality it is less than 18 inches thick. It was not found to be workable in this township, and in the SW. ¼ sec. 36 it contains only 13 inches of coal. Bed A was mapped in most of T. 3 N., R. 35 E., but this bed also becomes too thin to be of economic value just south and east of T. 4 N., R. 34 E. No coal bed as thick as 18 inches was observed in this township.

Beneath the Tullock member the non coal-bearing portion of the Lance is exposed. A section measured in T. 3 N., R. 34 E., and given in the description of that township shows the character of these strata. The beds in this township have a slight general dip toward the south. (See Pl. X.)

T. 5 N., R. 34 E.

Big Horn River flows into the Yellowstone in sec. 28, T. 5 N., R. 34 E., and only that portion of the township lying east of the two rivers is included in the area examined. A strip of fertile bottom land about 5 miles long and in places as much as 1½ miles wide in-

cludes most of the eastern part of the township. The town of Big Horn, on the Northern Pacific Railway at the northeast corner of sec. 27, supplies the settlers in this area. Big Horn Bottom is inclosed by precipitous bluffs from 75 to 200 feet high, which increase in height and close in to the river edge in sec. 12, confining the railroad track to a narrow strip of filled-in land. (See Pl. II, *A*.)

The rocks that crop out in this township belong to the lower part of the Lance formation and contain no coal. In this general district the non coal-bearing Lance might be further divided into an upper predominantly shaly portion 300 feet thick and a lower member containing a great amount of sandstone. The line separating these divisions is distinct enough to follow in this vicinity, but in the southern part of the field the two can not be differentiated. In this township the rocks belong almost entirely to the lower, resistant sandy division, the shale division appearing only on the highest buttes. A normal fault with a vertical displacement of 30 feet appears to cut the strata exposed in the bluffs in the NE. ¼ sec. 13. The beds in this township have a very low dip, probably to the south.

T. 6 N., R. 34 E.

That portion of secs. 25 and 36, T. 6 N., R. 34 E., lying east of Yellowstone River is the only part of the township examined. The river is here flanked by bluffs that rise very steeply to a height of 75 to 300 feet and confine the railway to a narrow strip of land which in many places is artificially made. The terrace at the top of these bluffs is level and grassed in small areas but is extensively dissected by narrow canyons as much as 300 feet deep.

The rocks that crop out in this township belong to the lower part of the Lance formation and consist largely of sandstone and sandy shale. A normal fault with a vertical displacement of at least 30 feet is exposed on the railway track in sec. 25, about 2,000 feet northeast of the siding known as Rancher. (See map, Pl. X.) The strata have a very slight dip, probably to the south.

T. 1 S., R. 35 E.

Only that portion of T. 1 S., R. 35 E., lying north of the Crow Indian Reservation—that is, the northernmost tier of sections—was examined. The character of the surface in this township is similar to that in the township to the north. The lower portion of the Lance formation crops out in the northeastern part of the township, but in the western part the Montana group is exposed. The topography in this district is even more gentle than in that to the east, but the soil is less fertile, and trees are entirely lacking. In sec. 6 Judith River sandstone crops out, and to the west the Claggett shale is exposed. There is no coal in the township.

T. 1 N., R. 35 E.

Tullock Creek flows northward across the eastern part of T. 1 N., R. 35 E., in a flat and fertile valley. The divide between Tullock Creek and Big Horn River coincides roughly with the western boundary of the township, so that the greater part of the township is on the eastern flank of this ridge. In contrast to the townships on the north, where the valley of Tullock Creek is bordered by steep ridges, the land here slopes gently and gradually from the crest of the divide to the creek, and therefore the sharp break between rolling upland and flat bottom land seen in the rest of the field is lacking here. The land along Lazyman and West Cabin creeks, though somewhat broken, is not rough in comparison to that in adjacent townships, and much of it is suitable for dry farming. North of Meadow Creek, however, a dissected escarpment rises nearly 200 feet above the level of this plain, and the topography is of the badland type. The old U-M ranch, in sec. 25, which was started about 25 years ago, was for a long time the only settlement in this part of the country, and its location has controlled to a large extent the direction of the roads in this vicinity. Three trails cross the divide in the gently rolling district south of the escarpment, but there is no locality for 20 miles to the north at which a wagon may be taken across.

The Tullock member of the Lance formation, the lower portion of the Lance, and the Bearpaw shale are exposed in this township. The outcrop of the Tullock member is confined to the district north of Meadow Creek, where it forms the precipitous slopes and rough topography mentioned above. The character of the Tullock member in this locality and the abundance of carbonaceous streaks in it are shown in section 5, Plate IV. South of Meadow Creek the lower portion of the Lance is exposed from the valley of Tullock Creek continuously to the crest of the divide and gives rise to the gentle topography characteristic of this part of the township. The Bearpaw shale outcrops only in sec. 31.

The strata in this township dip at various angles to the north and east. (See Pl. X.) In the valley of West Cabin Creek the dip ranges from 5° to 10°, and the strike ranges from north to east. North of this creek the dip is lower, averaging probably about 3°. In the northern tier of sections, where the coal-bearing rocks crop out, the dip is nearly 1° NE. This slight inclination is sufficient, however, to limit the outcrop of these rocks sharply on the south, and as shown on the geologic map the formation boundaries are only partly controlled by the topography.

Three coal beds, all in the basal 50 feet of the Tullock member, attain a thickness of 18 inches or more in this township. The lowest one, bed A, is 16 inches thick at location 102 and only 4 inches thick at location 100 (see sections below), and at location 97 it contains

about 2 feet of coal. From this point east as far as sec. 3 it averages more than 2 feet in thickness, but at location 91 it carries only 18 inches of impure coal. (See sections 91, 92, 94, 96, and 97, Pl. XIII.) Along the north township line the bed is rather variable in quality and thickness, carrying about 2½ feet of coal at location 87 (see Pl. XIII) and less than 12 inches at location 85. At the next measurement made along the outcrop to the west (section 83, below), the bed contains only 8 inches of impure coal. On Plate XIV these measurements are summed up and correlated with those made in the township to the north. Bed A also crops out on the east side of Tullock Creek in sec. 1, where it carries 16 inches of coal (section 129, below).

About 15 feet above bed A is bed B, which is of value only in a small area. The bed is thickest at location 101 (Pl. XIII), where it contains 25 inches of good coal. To the east it decreases in value, carrying at location 99 less than 2 feet of coal and at location 95 29 inches of coal, nearly half of it impure. (See sections below.) At location 93 it contains only 13 inches of impure coal and was traced no farther. Bed B also outcrops on a small outlying butte in sec. 17, where it is 21 inches thick (section 104, below).

About 30 feet above bed A is bed C, which is of value only in secs. 7 and 18. In this locality the bed forms an outlier at the south end of the outcrop of the Tullock member on the main divide, and in this outlier it averages about 23 inches in thickness. (See sections 1 and 103, Pl. XIII, and section 2, below.) Although it maintains a thickness of more than 18 inches for some distance on the west side of the divide in T. 1 N., R. 34 E., on the east side it thins abruptly and is only 13 inches thick at location 98. This member contains carbonaceous beds at a number of other horizons in this locality, but none of them reach 18 inches at any point of measurement.

Sections of coal beds in T. 1 N., R. 35 E.

Location 2. SW. ¼ sec. 7 (bed C).

	Ft.	in.
Shale.		
Coal, dull luster		8
Coal, vitreous	1	5
Shale, carbonaceous.		
	2	1

Location 83. NW. ¼ sec. 6 (bed A).

	Ft.	in.
Shale, carbonaceous.		
Coal, impure		8

Location 93. SW. ¼ sec. 4 (bed B).

	Ft.	in.
Shale.		
Shale, carbonaceous		1
Coal, impure	1	1
Shale, brown		3
Sandstone.		
	1	5

Location 95. SW. ¼ sec. 5 (bed B).

	Ft.	in.
Shale.		
Shale, carbonaceous		2
Coal, impure	1	1
Coal		10
Shale, brown		½
Coal		6
Shale, brown.		
	2	7½

Location 98. NE. ¼ sec. 7 (bed C).

Shale.	Ft.	in.
Bone		3
Coal	1	
Bone		½
Coal		1
Shale, carbonaceous		3
Shale.		
	1	7½

Location 99. NE. ¼ sec. 7 (bed B).

Shale.	Ft.	in.
Coal	1	3
Coal, impure		3
Coal		4
Shale.		
	1	10

Location 100. NE. ¼ sec. 7 (bed A).

Shale, brown.	Ft.	in.
Coal		4
Shale, carbonaceous		4
Shale.		
		8

Location 102. SE. ¼ sec. 7 (bed A).

Shale.	Ft.	in.
Shale, carbonaceous		7
Coal		10
Coal, impure		6
Shale, carbonaceous.		
	1	11

Location 104. SE. ¼ sec. 17 (bed B).

Shale.	Ft.	in.
Coal, impure		3
Coal	1	6
Shale.		
	1	9

Location 129. NE. ¼ sec. 1 (bed A).

Shale.	Ft.	in.
Coal		1½
Parting sandy		½
Coal	1	3
Bone		1
Shale.		
	1	6

T. 2 N., R. 35 E.

Tullock Creek flows northward through the easternmost tier of sections of T. 2 N., R. 35 E., in a flat and fertile valley about a mile wide. The crest of the Tullock-Big Horn divide is approximately coincident with the western boundary of the township, so that the uplands and the eastern slope of this ridge cover the greater part of the township. The ridge is in general broad and flat topped, although in sec. 19 the valleys of Pocket Creek on the west and Cottonwood Creek on the east have been deeply incised, leaving only a very narrow divide. A large creek in the northern part of the township has developed a zone of badlands, and similarly along Cottonwood Creek and the streams to the south the country is very rough. On the divides between these streams, however, and also on the main divide, except in sec. 19, areas of a square mile or more are level and grass covered, and there is considerable land suitable for dry farming. Tullock Valley borders the east township line, and nearly all the bottom land is under cultivation.

The Lebo shale member of the Fort Union formation, the Tullock member of the Lance formation, and the lower portion of the Lance are exposed in this township. The Lebo shale crops out on the flat-topped ridge in the western part of the township, though only a few feet of its basal portion remains. Its outcrop is obscured by

the character of the topography and was only approximately mapped. The Tullock member crops out in the remainder of the township except in the valleys of Tullock Creek and its larger tributaries. It is made up largely of shale but contains a sufficient number of sandstone beds to give rise to a very rough topography along the courses of the larger creeks. (See sections 7 and 8, Pl. IV.) Beneath it lies about 100 feet of the lower portion of the Lance, the outcrop of which, being confined to the creek valleys, is largely covered by alluvium.

The general dip in this township is to the northeast. (See Pl. X.) Altitudes on the coal beds in the two southern tiers of sections indicate a dip in that locality of nearly 2°, which, as shown on the map, carries the lower part of the Lance up the creek nearly to the crest of the divide. In the center of the township, however, the dip is little more than ½° (11 feet to 1,000), and in the northern part of the township the beds dip considerably less than ½°. Practically everywhere in the township the dip is too small to be visible to the eye except in the center of sec. 3, where very local dips as high as 7° were measured. Notwithstanding the generally flat attitude of the strata, a small overthrust fault was observed in this locality. The total displacement of this fault, which is well exposed in the bank of the creek (Pl. VIII), is only 29 inches, but its occurrence in nearly flat strata is unusual and interesting.

Six coal beds crop out in this township—beds A, C, D, F, I, and J. Bed A, the base of the Tullock member, crops out along the east side of Tullock Creek not far from the east township line. In the southern part of the township it averages 23 inches in thickness, but it decreases toward the north and in sec. 1 has a net thickness of only 16 inches. (See sections 130, 131, and 139, Pl. XIII, and 132, 143, 150, below.) On the west side of Tullock Creek the outcrop of the bed enters the township in sec. 31, at the head of the creek that flows along the south township line. (See Pl. XI.) At this place the bed contains only 8 inches of impure coal, but at location 84 it is 19 inches thick. It increases in thickness as far north as location 79, where it contains more than 2½ feet of good coal. At location 76, however, it carries only 27 inches of coal, and at location 74 only 14 inches. (See sections 76, 79, 84, and 86 to 90, Pl. XIII, and sections 74, 78, 80, and 85, below.) North of location 74 bed A is too thin to be of value everywhere west of Tullock Creek in this township. The probable size and shape of this lens are shown in Plate XIV.

About 15 feet above bed A is a carbonaceous band representing bed B, the character of which is shown in section 64, below.

Bed C, which is recognizable at many places in the field, is in this township about 25 feet above bed A. The bed is only 12 inches thick

south of Cottonwood Creek (see section 77, below), but at location 75 in sec. 23, it contains 34 inches of coal. From this place as far north as sec. 2 it averages about 26 inches, though at location 72 it contains 32 inches of coal. (See sections 65, 66, 69, and 75, Pl. XIII, and sections 68, 72, and 73, below.) It decreases in thickness to the west, as shown by sections 63 and 69, and at location 62, in sec. 2, it contains 23 inches of coal, 9 inches of which is impure. It probably falls below 18 inches a short distance north of this place, as section 61, measured just north of the township line, shows but 13 inches of coal. On the east side of Tullock Creek this bed is more than 18 inches thick at location 135 in sec. 25, where it carries 20 inches of coal, but at location 134, a short distance to the southeast, it is only a foot thick. (See sections below.) All these measurements are summed up on Plate XV, which shows by lines of equal thickness the probable shape of the whole lens.

Bed D, which is about 15 feet above bed C, is thicker than 18 inches in a small area on the east side of Tullock Creek in secs. 24 and 25. (See Pl. XI.) At location 133, in sec. 25, the bed is 15 inches thick, but half a mile to the north it contains 20 inches of coal. In sec. 24, where its outcrop passes out of the township, it contains 22 inches (sections 133, 136, and 138, below).

Bed F is about 60 feet above bed C and is of value only in two localities. At location 71, in sec. 16, the bed consists of two benches, each about two feet thick, separated by 5 feet of shale (section 71, Pl. XIII); but 2,300 feet to the east the bed contains only 10 inches of coal (section 70, below). Bed F at location 67, in sec. 11, is about 18 inches thick (see section 67, below), but about half a mile to the southwest it consists of two 1-foot benches separated by about 8 feet of shale. Bed F is probably 18 inches or more thick only in very small areas and was not found elsewhere in the township. The strata between beds F and I were examined at a number of places on the east side of the divide, but no coal thicker than 12 inches was found.

Bed I, which in this township is about 175 feet above bed A, is thicker than 18 inches only in the northwest corner of the township, where it crops out on the west side of the divide. At location 16, in sec. 18, it carries only 15 inches of impure coal, but at location 17, in sec. 7 (Pl. XIII), a mile to the north, it is 25 inches thick. At location 18, near the north township line, it is only 18 inches thick. Careful search on the east side of the divide failed to reveal a bed of appreciable size at this horizon. As shown in Plate XVI, the area in which this bed is over 18 inches in thickness is very irregular in shape. On the east side of Tullock Creek bed I was examined in sec. 25, where it carries less than 18 inches of coal (section 137, below).

Bed J, which in this vicinity is only 70 feet above bed I, is of value only in the southwestern part of the township. This bed forms a large outlier on the crest of the divide, as shown on the map (Pl. XI), where it averages slightly less than 2 feet in thickness (sections 13, 81, and 82, Pl. XIII). It also occurs in several outlying areas on the rolling upland east of the crest, but in this locality the bed is less than 18 inches thick or under so thin cover that it was not mapped. The divide is relatively low at the head of Cottonwood Creek and the outcrop of bed J crosses it; north of this place the bed is everywhere 17 inches or less in thickness (sections 14 and 15, below). Bed J in the large area on the crest of the divide is under 25 to 50 feet of cover.

Sections of coal beds in T. 2 N., R. 35 E.

Location 14. SE. ¼ sec. 18 (bed J).

	Ft.	in.
Shale, sandy.		
Coal, impure		3
Shale, carbonaceous		2
Coal	1	2
Shale, carbonaceous.		
	1	7

Location 15. NE. ¼ sec. 18 (bed J).

	Ft.	in.
Shale, sandy.		
Bone		4
Shale, carbonaceous		2
Coal	1	4½
Shale, carbonaceous.		
	1	10½

Location 16. NE. ¼ sec. 18 (bed I).

	Ft.	in.
Sandstone.		
Coal, impure	1	3
Shale, carbonaceous.		

Location 18. NE. ¼ sec. 6 (bed I).

	Ft.	in.
Sandstone.		
Coal	1	3
Coal, impure		3
Shale, carbonaceous		10
	2	4

Location 62. NE. ¼ sec. 2 (bed C).

	Ft.	in.
Shale, carbonaceous.		
Bone		2
Coal, impure		9
Coal	1	2
Bone		1
Shale.		
	2	2

Location 63. NW. ¼ sec. 3 (bed C).

	Ft.	in.
Shale.		
Coal		2
Shale, carbonaceous	2	
Coal		6
Sandstone	6	
Shale	1	6
Shale, carbonaceous		½
Coal		11
Bone		1
Coal		6
Bone		½
Shale.		
	11	9

Location 64. SW. ¼ sec. 2 (bed B).

	Ft.	in.
Shale.		
Coal, impure		4
Coal		10
Shale	1	1
Shale, carbonaceous		1
Coal		4½
Shale		5
Coal		3½
Sandstone.		
	3	5

Location 67. NW. ¼ sec. 11 (bed F).

	Ft.	in.
Shale.		
Coal		6
Parting, sandy		¼
Coal	1	½
Shale.		
	1	6¾

Location 68. NW. ¼ sec. 14 (bed C).

	Ft.	in.
Shale.		
Shale, carbonaceous		1
Coal	1	11
Shale, carbonaceous		½
Coal, impure		3
Shale.		
	2	3½

Location 70. NE. ¼ sec. 16 (bed F).

	Ft.	in.
Shale.		
Coal		10
Shale.		

Location 72. NE. ¼ sec. 23 (bed C).

	Ft.	in.
Shale.		
Shale, carbonaceous		2
Coal	2	8
Shale, carbonaceous		2
Shale.		
	3	

Location 73. NE. ¼ sec. 23 (bed C).

	Ft.	in.
Sandstone.		
Coal		2
Shale	1	5
Coal	1	10½
Parting, sandy		½
Coal		3½
Shale.		
	3	9½

Location 74. NE. ¼ sec. 23 (bed A).

	Ft.	in.
Sandstone.		
Coal	1	2
Shale, brown.		

Location 77. NE. ¼ sec. 26 (bed C).

	Ft.	in.
Shale.		
Coal	1	
Shale.		

Location 78. NW. ¼ sec. 26 (bed A).

	Ft.	in.
Sandstone.		
Shale		1
Coal		4½
Parting, sandy		1
Coal	2	1
Shale.		
	2	7½

Location 80. NE. ¼ sec. 32 (bed A).

	Ft.	in.
Shale.		
Coal		½
Shale		1
Coal, impure		3½
Parting, sandy		1
Coal, impure	1	11
Shale.		
	2	5

Location 85. SE. ¼ sec. 32 (bed A).

	Ft.	in.
Shale.		
Bone		2
Coal		3½
Shale, carbonaceous		1
Coal		5
Bone		½
Coal		4
Bone		1
Coal		2
Bone		1
Shale, carbonaceous		2
Shale, brown.		
	1	10

Location 132. SE. ¼ sec. 25 (bed A).

	Ft.	in.
Shale.		
Coal		1½
Bone		1
Coal	1	7½
Bone		1½
	1	11½

Location 133. SE. ¼ sec. 25 (bed A).

	Ft.	in.
Shale, carbonaceous.		
Bone		2½
Coal	1	3
Shale, brown.		
	1	5½

Location 134. SE. ¼ sec. 25 (bed C).

	Ft.	in.
Shale, carbonaceous.		
Coal	1	
Shale.		

Location 135. NE. ¼ sec. 25 (bed C).

	Ft.	in.
Shale.		
Coal	1	8
Shale.		

Location 136. NE. ¼ sec. 25 (bed D).

	Ft.	in.
Shale.		
Coal		6
Bone		1
Coal	1	3
Shale.		
	1	10

Location 137. NE. ¼ sec. 25 (bed I).

	Ft.	in.
Shale.		
Coal, impure		1
Coal		8
Bone		2
Coal, impure		6½
	1	5½

Location 138. SE. ¼ sec. 24 (bed D).

	Ft.	in.
Shale.		
Coal		5½
Shale, brown		1
Coal	1	6
Shale, carbonaceous.		
	2	½

Location 143. SE. ¼ sec. 13 (bed A).

	Ft.	in.
Shale.		
Shale, carbonaceous		1
Coal	1	10
Parting, sandy		½
Coal		2
Shale, carbonaceous		1
Shale.		
	2	2½

Location 150. NE. ¼ sec. 1 (bed A).

	Ft.	in.
Shale.		
Shale, carbonaceous		4
Coal		8
Parting, sandy		3
Coal		11
Shale, carbonaceous		10
Shale.		
	3	

T. 3 N., R. 35 E.

Tullock Creek flows northward across the eastern part of T. 3 N., R. 35 E., in a flat valley about a mile wide. Two good roads follow this valley on either side of the creek, and practically all the bottom land is under cultivation. The valley is bordered by steep sides about 100 feet high, which rise to nearly 300 feet a mile or so back. The upland is dissected by many side streams, along which the surface is very rough, especially in the northern part of the township, where West Burnt Creek has cut far back into the main divide. Although much of the upland is level and grass-covered, considerably more than half the land is too broken for farming and is suitable only for grazing.

The Lebo shale member of the Fort Union formation crops out on the highest points of the Tullock-Big Horn divide in the southeast corner of the township. Only about 25 feet of the base of the Lebo is exposed, however, and because of the grass-covered character of the surface its outcrop was only approximately mapped. The Tullock member of the Lance formation is exposed in the greater part of the township. Although this member is made up mostly of shale, it contains enough heavy sandstone beds to make its outcrop in many places very precipitous. The lower portion of the Lance formation crops out in the valley of Tullock Creek and also is exposed up the

valleys of many of the side streams, notably that of West Burnt Creek. (See map, Pl. X.) Although its outcrop is for the most part covered by alluvium, there are two cliff-forming sandstones from 10 to 50 feet thick less than 150 feet below the base of the Tullock member, and the upper of these in particular is prominent almost everywhere in the township.

This township lies in the structural trough already described, which crosses the whole field and within which the strata are irregularly warped. (See Pl. X.) The warping is especially pronounced in this township, where the dips are irregular, though generally low. Thus in sec. 29 there is a local dip to the south of 9° in the NE. ¼ and 14° in the SE. ¼. In the NW. ¼ sec. 26 a local dip of 4½° S. was observed, and in the NE. ¼ sec. 25 there is a local dip of 2½° SE. These dips, though locally pronounced, have little effect on the broad structure, and it is possible that they are compensated by small faults, as stated elsewhere. As shown in Plate X, the only structural variations in this township large enough to be disclosed by means of 50-foot contour lines are two gentle troughs, one extending into the township from the southeast and the other crossing the northern part of the township. That the irregular stresses to which the strata have been subjected have resulted in faults is shown by the fact that two faults were actually observed. In the SE. ¼ sec. 7 a fault with a vertical displacement of 70 feet is clearly exposed, bringing coal bed A directly against the upper of the two thick sandstone beds mentioned above. The fault plane dips 47° N. and in places is slickensided. The beds on both sides of the fault dip 4° S. This fault was traced to the west, and in that direction the displacement decreases until in the NW. ¼ sec. 13, T. 3 N., R. 34 E., where it cuts bed I, it is only 30 feet. In the NE. ¼ sec. 36 the other fault has displaced bed A about 45 feet.

Two coal beds crop out in this township—bed A and bed I, which is about 175 feet above A. Bed A near the south quarter corner of sec. 36 contains only 14 inches of coal (section 151, below), but at location 152, a mile to the north, it is 22 inches thick. From this place northward along the east side of Tullock Creek the bed increases in thickness until at location 159 it contains 4 feet of good coal. North of this point it is thinner, but it is not less than 25 inches in net thickness and averages over 30 inches. The character of the bed on the east side of the creek is shown by sections 151, 172, 173, 179, 200, and 202, below, and sections 152, 158, 159, 170, 171, 201, 203, and 206 on Plate XIII.

On the west side of Tullock Creek bed A is less than 18 inches thick in the southern part of the township (see sections 59 and

60, below), but at location 58, in sec. 26, it contains 27 inches of coal. For a mile north of this place it averages 22 inches, but it is thinner than this at location 55 and carries practically no coal at location 54. (See sections 54, 55, 57, 59, and 60, below, and sections 56 and 58, Pl. XIII.) A mile to the west, however, at location 49, the bed is about 30 inches thick, and at location 45 it is more than 3 feet thick (see map), but at location 44 it drops to 13 inches. (See sections 43 to 45, below, and section 49, Pl. XIII.) Between this place and the upper part of West Burnt Creek the bed is too thin to be of value, but at location 31 it contains 21 inches of coal. Most of the measurements made above this place on West Burnt Creek show nearly 3 feet of coal (sections 31, 32, and 38, Pl. XIII, and sections 33, 39, and 40, below). The coal thins to the west, however, as section 33 shows only 25 inches of coal, and at locality 34, just west of the township line, there is less than 18 inches. North of West Burnt Creek bed A is thinner than 18 inches everywhere on the west side of Tullock Creek valley, as shown by a number of sections, of which section 30, below, is representative. The probable shape and position of the irregular area in which bed A is thicker than 18 inches is shown on Plate XIV.

Bed B, about 15 feet above bed A, was examined in sec. 13, where it carries about a foot of coal (section 178, below). Bed C is more than 18 inches thick in the township to the south, and its outcrop was mapped for a short distance in sec. 35 of this township, but at location 61 it was found to contain only 13 inches of coal (section 61, below). Sections of a number of other thin beds were measured at several places in the township, but as they have no bearing on the coal resources of the area they are not included here.

Bed I crops out on the east side of Tullock Creek only in sec. 1, where it underlies a small neck of high ground. In this locality (see section 205, Pl. XIII) it contains 2 feet of coal. On the west side of Tullock Creek bed I is slightly thicker than 18 inches in an irregular area near the crest of the divide. (See Pl. XI.) On the east side of the divide the bed is less than 18 inches thick in the southern part of the township, but in secs. 29 and 20, at locations 48 and 50 to 53, it contains about 20 inches of coal, part of which is impure. (See sections below and on Pl. XIII.) At locations 46 and 47, still farther north, it is slightly thicker (see sections below), and at location 42 (Pl. XIII) it attains its maximum thickness of 30 inches. The outcrop trends to the west from this point (see map), and measurements made in this locality indicate a somewhat smaller thickness. At the point at which the outcrop passes into T. 3 N., R. 34 E., the bed carries only 19 inches of impure coal (see sections 36 and 41, below, and

section 37, Pl. XIII). In that township the bed averages 20 inches in thickness as far north as sec. 12, but at location 28 it is only 6 inches thick. (See sections 24, 28, 29, 35, in description of T. 3 N., R. 34 E.) On the west side of the divide the outcrop of bed I is mostly in T. 3 N., R. 34 E.; it enters this township only in secs. 30 and 31, where it is 18 inches or less thick. (See sections 19 and 20, below.) These observations are summed up on Plate XVI, which shows the probable shape of this coal lens.

Sections of coal beds in T. 3 N., R. 35 E.

Location 19. SW. ¼ sec. 31 (bed I).

	Ft.	in.
Sandstone.		
Coal, impure		6
Coal	1	
Bone		1
Coal		2
Bone		2
Shale, carbonaceous.		
	1	11

Location 20. SW. ¼ sec. 31 (bed I).

	Ft.	in.
Shale.		
Coal, impure		5
Coal		7
Bone		1½
Coal		1½
Bone		½
Coal		½
Shale.		
	1	4

Location 30. SE. ¼ sec. 5 (bed A).

	Ft.	in.
Shale.		
Coal	1	1
Parting, sandy		1
Bone		½
Coal		2
Bone		1
Clay		1
Coal, impure		1
Clay		½
Coal		2
Clay		2
Coal, impure		½
Clay		4
	2	4½

Location 33. Center of sec. 7 (bed A).

	Ft.	in.
Shale.		
Bone		1
Coal		2
Shale		¼
Coal		3
Parting, sandy		1
Coal	1	9
Shale, brown		4
Coal		½
Shale, carbonaceous		1
Coal		2
Shale.		
	2	11¾

Location 36. NW. ¼ sec. 19 (bed I).

	Ft.	in.
Shale.		
Coal, impure	1	7
Shale and streaks of coal		4
Bone		1
Shale.		
	2	

Location 39. NE. ¼ sec. 18 (bed A).

	Ft.	in.
Shale.		
Coal		9
Parting, sandy		1¼
Coal	2	2
Bone		½
Shale, carbonaceous.		
	3	¾

Location 40. SE. ¼ sec. 7 (bed A).

Shale.	Ft.	in.
Coal		8½
Parting, sandy		1¼
Coal	2	2
Shale, carbonaceous	1	½
Coal		3½
Shale, brown		1
Shale.		
	4	4¾

Location 41. NE. ¼ sec. 19 (bed I).

Shale.	Ft.	in.
Coal, impure		6
Coal	1	1
Bone		1
Coal, with shale streaks		7
Bone		3
Shale.		
	2	6

Location 43. SW. ¼ sec. 15 (bed A).

Shale.	Ft.	in.
Coal		4
Shale		1
Coal		1
Parting, sandy		1
Coal		2
Shale	1	
Shale, sandy	7	
Coal	1	5
Shale.		
	10	2

Location 44. Center of sec. 16 (bed A).

Shale.	Ft.	in.
Coal	1	1½
Shale.		

Location 45. NW. ¼ sec. 21 (bed A).

Aluvium (top of bed eroded).	Ft.	in.
Coal		5+
Shale		1
Coal		5½
Parting sandy		1
Coal	2	4½
	3	5+

Location 46. SE. ¼ sec. 17 (bed I).

Shale.	Ft.	in.
Coal, impure		4
Coal	1	3
Coal, impure		4
Bone		2
Coal, impure		4
Shale.		
	2	5

Location 47. NE. ¼ sec. 20 (bed I).

Shale.	Ft.	in.
Shale, carbonaceous		3
Coal, impure		11
Coal	1	3
Shale and bone		3
Shale.		
	2	8

Location 50. NW. ¼ sec. 29 (bed I).

Shale.	Ft.	in.
Shale, carbonaceous		1
Coal	1	6½
Bone		½
Coal, impure		3
Shale, carbonaceous		2
Shale.		
	2	1

Location 51. NW. ¼ sec. 29 (bed I).

Shale.	Ft.	in.
Coal, impure		4
Coal	1	6
Shale, carbonaceous.		
	1	10

Location 53. SE. ¼ sec. 29 (bed I).

Shale, sandy.	Ft.	in.
Coal, impure		3
Coal		8
Coal, impure		3
Coal		1
Coal, impure		1
Coal		4
Shale, carbonaceous.		
	1	8

Location 54. NW. ¼ sec. 22 (bed A).

Sandstone.	Ft.	in.
Shale, carbonaceous		2
Shale	1	5
Shale, carbonaceous		4
Coal, impure		3
Shale	4	6
Coal, impure		5
Shale		4
Bone		½
Coal		1
Parting sandy		1
Coal		3
Bone		½
Shale.		
	7	11

Location 55. NW. ¼ sec. 23 (bed A).

Shale.	Ft.	in.
Bone		1½
Parting sandy		1
Coal, impure		8
Coal	1	4
Shale.		
	2	2½

Location 57. SW. ¼ sec. 22 (bed A).

Shale.	Ft.	in.
Coal		1½
Parting, sandy		½
Coal		1
Shale		2
Coal		7
Shale		11
Shale, carbonaceous		½
Coal		6
Parting, sandy		1½
Coal		5
Shale, carbonaceous		½
Shale, sandy	1	2
Coal	1	7
Sandstone.		
	5	9½

Location 59. NE. ¼ sec. 27 (bed A).

Shale.	Ft.	in.
Coal	1	4
Bone		1
Shale.		
	1	5

Location 60. SW. ¼ sec. 26 (bed A).

Shale.	Ft.	in.
Bone		½
Shale		½
Coal		1½
Parting, sandy		1
Coal, impure		3
Shale		4
Coal	1	3
Shale, brown.		
	2	1½

Location 61. SE. ¼ sec. 35 (bed C).

Shale.	Ft.	in.
Coal	1	1
Shale, carbonaceous	4	
Shale	3	
Bone		2
Shale	2	
Coal, impure		5
Shale	4	
Coal, impure		7
Bone		2
Coal		7
Shale, carbonaceous	1	
	17	

Location 151. SE. ¼ sec. 36 (bed A).

Sandstone.	Ft.	in.
Coal		1
Parting, sandy		1
Bone		3
Coal		10
Shale, carbonaceous		½
Coal		4
Shale, carbonaceous		½
Shale.		
	1	8

Location 172. SW. ¼ sec. 13 (bed A).

Shale.	Ft.	in.
Coal, impure		7
Shale		3½
Coal		9½
Shale	1	7
Coal		2½
Parting, sandy		1½
Coal	2	1
Shale.		
	5	8

Location 173. NE. ¼ sec. 13 (bed A).

Sandstone.	Ft.	in.
Bone		3
Shale		5
Coal, very impure		7
Shale		6
Coal		4
Parting, sandy		½
Coal	2	5
Shale		2
Coal, impure		7
Shale.		
	5	3½

Location 178. NE. ¼ sec. 13 (bed B).

Shale.	Ft.	in.
Coal, impure		8
Parting, sandy		¼
Coal		5
Shale		½
Coal		1
Shale, carbonaceous		2
Shale.		
	1	4¾

Location 179. NW. ¼ sec. 13 (bed A).

Shale.	Ft.	in.
Coal		6
Shale, brown		3
Coal		11
Shale	2	
Shale, carbonaceous		½
Coal		4
Parting, sandy		1
Coal	2	5
Clay		1
Coal		4½
Shale.		
	7	

Location 200. NE. ¼ sec. 14 (bed A).

Shale.	Ft.	in.
Shale, carbonaceous		7
Coal, impure		8
Shale, carbonaceous		1
Shale, brown		3
Coal, impure		11
Shale	4	
Shale, carbonaceous		1
Coal		2
Parting, sandy		1
Coal	2	4½
Shale, brown.		
	9	2½

Location 202. NE. ¼ sec. 11 (bed A).

Shale.	Ft.	in.
Shale, carbonaceous		1
Coal		3
Parting, sandy		1
Coal	2	3
Bone		½
Shale.		
	2	8½

T. 4 N., R. 35 E.

Tullock Creek flows diagonally across the southwestern part of T. 4 N., R. 35 E., in a broad, flat valley. This valley is bordered on the west by the steep-sided Tullock-Big Horn divide, which in this locality is about 250 feet high. On the east the Sarpy-Tullock divide rises to a height of about 700 feet, but the flank of the ridge is much incised by many small creeks, which have developed a very rough and intricate system of badlands. The tops of both of the main divides are, however, grass covered and rolling and afford good cattle range and some dry-farming country, and in the valley of

Tullock Creek there is some valuable agricultural land. A rude trail follows up Lightning Creek and, crossing the divide into Boxelder, affords communication between Tullock Valley and the town of Hysham.

The rocks that crop out in this township belong to the Lebo shale member of the Fort Union formation, the Tullock member of the Lance formation, and the lower part of the Lance. (See map, Pl. X.) The Lebo is exposed only on the crest of the divide in the northeast corner of the township, where its outcrop is largely covered by Quaternary gravel and could be only approximately mapped. The Tullock member crops out on the western slope of the divide below the Lebo and forms the rough badlands mentioned above. It is also exposed in a small area in the southwest corner of the township on the Tullock-Big Horn divide. The character of the lower part of the Tullock member in this township is shown by sections 9, 10, and 11, Plate IV. The central part of the township, including the valley of Tullock Creek and the lower slopes of the ridges, is underlain by the lower portion of the Lance, which in this township contains a smaller amount of sandstone and gives rise to a less rough topography than in areas to the west. The character of the lower part of the Lance in this township is shown by the following stratigraphic section:

Section of lower part of Lance formation in secs. 5 and 7, T. 4 N., R. 35 E.

	Feet.
Coal A, base of Tullock member of Lance formation.	
Shale, yellow	19
Coal and bone	1
Shale, yellowish	19
Sandstone, brownish, thin bedded	2
Shale, yellow, sandy	8
Shale, greenish gray	29
Sandstone, yellow-gray, prominent and persistent, weathering into odd shapes. (See Pl. VI, *A*.)	9
Shale, yellowish to greenish, with several carbonaceous layers	43
Sand, yellow, becoming sandstone in places	18
Shale, variegated green, with a calcareous lens	12
Shale, variegated green, with lenses of calcareous gray shale, weathering yellow	31
Sandstone, with hard yellow cap	7
Shale	10
Shale, yellow, fairly soft, massive, with conglomeratic swirls	30
Shale, greenish	40
Sandstone, gray	2
Shale, greenish	28
Sandstone, white, soft, with hard brown cap 1 foot thick	11
Shale, greenish	11
Sandstone, yellow, shaly, hard	1
Sandstone, white, soft, massive	11
Shale, greenish	46

	Feet.
Sandstone, white, soft, with hard yellow cap	17
Shale, variegated greenish and yellowish, with several 6-inch carbonaceous streaks	31
Flood plain of Tullock Creek.	
	436

This township lies on the lower slopes of the gentle dome that dominates the structure in the northern part of the field, and there are here few of the sharp local dips that characterize the township to the south. The general dip of the rocks is to the south. (See Pl. X.) In the southern part of the township the dip is about 10 feet in 1,000 feet, but in the central part it is considerably less. In the northern part the dip is about 6 feet in 1,000 feet.

Six coal beds attain a thickness of 18 inches or more in this township—beds A, C, and D within 50 feet of the base of the Tullock member and beds H, I, and J in the upper part.

Bed A, the base of the Tullock member, is thicker than 18 inches in the northern and southern parts of the township, but in the valley of Lightning Creek, in the central part, it is less than a foot thick. Along East Burnt Creek, on the south township line, the bed is nearly 3½ feet thick, but from this place it thins toward the north and east. (See sections 219, 224, and 233, Pl. XIII.) At location 232, near the east township line, it contains only 21 inches of coal, part of which is so impure that the bed is not considered worth mining under present conditions, and at location 236 it is less than 18 inches thick (see sections below), though sections 238 and 241 (Pl. XIII), measured farther southwest, show nearly 3 feet of coal. In Lightning Creek, however, the bed contains only a few inches of coal, as shown by sections 242, 245, 260, 262, and 264, below. At location 265 bed A is about 2 feet thick, and from this place it increases in thickness to the north, until at locations 278 and 280, near the north township line, it is about 3 feet thick (see sections 265, 272, 277, 278, and 280, Pl. XIII, and sections 270 and 279, below). Two distinct lenses of bed A therefore occur in this township, as indicated on Plate XIV.

Bed C is normally about 35 feet above bed A and 10 to 15 feet below bed D, but in this township the intervals are irregular, and bed C is generally lower in the section than elsewhere. (See Pl. IV.) Bed C attains its maximum thickness of 57 inches at the head of Lightning Creek and becomes thinner in all directions from this place, though workable practically everywhere in the northern part of the township. (See Pl. XV.) In the southern part of the township the bed is less than 18 inches thick (section 234, below). At location 240, half a mile to the west, it is 28 inches thick, and from

this place along the outcrop to the north it gradually increases in thickness. (See sections 243, 246, 248, 257, and 259, Pl. XIII, and sections 252 and 258, below.) The bed is more than 4 feet thick in an area of about 3 square miles on Lightning Creek, but north and west of this locality it is thinner. At locations 261, 263, and 267 it is about 3 feet thick, and at locations 273 and 274 it contains about 3½ feet of coal separated into two benches. (See Pl. XIII.) It decreases in thickness to the west, and at location 277 carries only 15 inches of coal. At location 279 a bed 4 feet above bed A is believed to represent bed C; this bed is about 21 inches thick (section 279, Pl. XIII). In the northeast corner of the township the bed is nearly 3 feet thick (see sections 281 and 293, Pl. XIII), and a sample for chemical analysis (see p. 63) was collected at location 293. The quality of the coal of bed C in this township is generally excellent, though as shown by the analysis the ash is high.

Bed D, which is 40 to 50 feet above bed A, is slightly thicker than 18 inches in an area of about 6 square miles in the southeastern part of the township. At location 218, in sec. 36, the bed is only 16 inches thick, but at location 221 it is 19 inches thick. At the next location to the east, No. 223, it is slightly less than 18 inches thick, but from this place it increases in thickness to the east and north and is 23 inches thick at locations 225, 234, and 239. However, on Lightning Creek it is 20 inches thick at location 244, 19 inches at location 247, and less than 18 inches at location 249. (See sections below and on Pl. XIII.)

Bed H is of very minor importance, being more than 15 inches thick at only one place (section 237, below). At this place it contains 20 inches of coal split by partings, but 1,500 feet away on either side the bed is only about a foot thick.

Bed I is about 170 feet above bed A and crops out near the tops of the highest ridges in the township. The bed does not exceed 3 feet in thickness at any place and is thicker than 18 inches only in two narrow necks of high land in the southern part of the township and in a small area in the northeast corner. In the more southerly of the two necks the bed is about 2 feet thick near the east township line, but farther to the west, at location 222, it is 32 inches thick (section 217, below, and sections 222 and 226, Pl. XIII). On the southern divide of Lightning Creek the bed is 21 inches thick at location 231, but at location 235, half a mile to the southwest, it contains only 16 inches of bony coal. At location 251, where the outcrop passes out of the township, the bed contains 25 inches of impure coal (see sections 235 and 251, below, and section 231, Pl. XIII). North of Lightning Creek bed I is less than 18 inches thick for nearly 2 miles, but at locality 268 it is 23 inches thick, and at location 271 it is 21 inches thick. (See section 266, below, and sections 268 and 271,

Pl. XIII.) It becomes thinner to the north, containing 19 inches of partly impure coal at location 282, and a foot of coal at location 294. (See sections below.) The areas of coal beds exceeding 18 inches in thickness in the southern part of the township probably represent the northeastern extremity of a long, narrow lens that once extended from T. 3 N., R. 35 E. (See Pl. XVI.) The quality of the coal of bed I is generally poor, there being a considerable proportion of impure coal and bone.

Bed J, the highest coal bed in the Tullock member, occurs only in the northeastern corner of the township. At location 275 it is 2 feet thick, but about a quarter of a mile on either side of this place it contains only about a foot of impure coal (section 275, Pl. XIII, and sections 269 and 276, below).

This township contains more coal than any other township in the field outside of the Fort Union coal district. One of the richest areas of coal land is in the valley of Lightning Creek, which is comparatively accessible. A mine on bed C at the head of this creek could supply the local demand for coal, and the surplus output might be hauled to Big Horn and there shipped.

Sections of coal beds in T. 4 N., R. 35 E.

Location 217. SW. ¼ sec. 36 (bed I).

	Ft.	in.
Shale.		
Bone		3
Coal		6
Sandstone	3	
Coal	1	11
Shale, carbonaceous.		
	5	8

Location 218. SW. ¼ sec. 36 (bed D).

	Ft.	in.
Shale.		
Coal	1	4
Shale	6	
Coal		7
Shale		10
Coal		6
Shale.		
	9	3

Location 220. NW. ¼ sec. 35 (bed A).

	Ft.	in.
Shale.		
Shale, carbonaceous		½
Coal	7	
Shale		¼
Coal		4
Parting, sandy		1
Coal	1	11½
Bone		¼
Shale.		
	3	½

Location 223. SE. ¼ sec. 26 (bed D).

	Ft.	in.
Shale, carbonaceous.		
Coal, impure		3
Shale, carbonaceous		1½
Coal, impure	1	3
Shale.		
	1	7½

Location 232. NE. ¼ sec. 25 (bed A).

	Ft.	in.
Shale.		
Coal		2½
Parting, sandy		½
Coal		5
Shale		½
Coal		8
Coal, very impure		6
Shale.		
	1	10½

Location 234. NW. ¼ sec. 25 (beds D and C).

	Ft.	in.
Shale.		
Coal		4
Bone		1
Shale, carbonaceous		2
Coal	1	10
Shale and sandstone	29	
Coal		7
Shale		½
Coal		10
Shale.		
	32	10½

Location 235. SW. ¼ sec. 24 (bed I).

	Ft.	in.
Sandstone.		
Coal, with streaks of bone	1	4
Bone		5
Shale.		
	1	9

Location 236. NW. ¼ sec. 25 (bed A).

	Ft.	in.
Shale.		
Coal		4
Shale	1	6
Coal		2
Parting, sandy		¾
Coal	1	4
	3	4¾

Location 237. SE. ¼ sec. 23 (bed H).

	Ft.	in.
Sandstone.		
Shale		3
Shale, carbonaceous		½
Coal		3
Shale, carbonaceous		¼
Coal		2
Clay		2
Coal	1	3
Bone		½
Sandstone.		
	2	2¼

Location 240. NE. ¼ sec. 26 (bed C).

	Ft.	in.
Shale.		
Coal		5
Sand		¼
Coal	1	11
Shale, brown.		
	2	4¼

Location 242. NW. ¼ sec. 26 (bed A).

	Ft.	in.
Sandstone.		
Coal		9
Shale, carbonaceous		4
Coal		1½
Parting, sandy		2½
Coal		1
Sandstone		9
	2	3

Location 245. SW. ¼ sec. 23 (bed A).

	Ft.	in.
Shale.		
Coal		2
Parting, sandy		1
Coal		2
Shale	1	
Coal		5
Shale.		
	1	10

Location 247. NE. ¼ sec. 23 (bed D).

	Ft.	in.
Shale.		
Coal	1	7
Shale.		

Location 249. SW. ¼ sec. 13 (bed D).

	Ft.	in.
Sandstone.		
Coal		3
Shale, sandy		1
Coal		3
Sand		¼
Coal		1
Shale		½
Coal		9
Shale		5
Bone		1
Coal		3
Shale.		
	2	2¾

Location 250. SW. ¼ sec. 13 (bed H).

	Ft.	in.
Shale, sandy.		
Coal		11
Shale.		

Location 251. SW. ¼ sec. 13 (bed I).

	Ft.	in.
Shale, brown.		
Bone		½
Coal, impure	2	1
Shale.		
	2	1½

Location 252. NE. ¼ sec. 13 (bed C).

	Ft.	in.
Shale.		
Coal		6½
Bone		1
Coal	4	1
Shale, brown		3
Shale.		
	4	11

Location 258. SE. ¼ sec. 12 (bed C).

Shale.	Ft.	in.
Coal		5½
Bone		2
Coal	4	2
Shale, brown		5
Shale.		
	5	2½

Location 260. NW. ¼ sec. 14 (bed A).

Shale.	Ft.	in.
Coal		2
Parting, sandy		1
Coal		4
Shale		1½
Coal		6
Shale, carbonaceous.		
	1	2½

Location 262. SW. ¼ sec. 15 (bed A).

Shale.	Ft.	in.
Shale, carbonaceous		6
Coal		1
Clay		2
Coal		3
Bone		½
Coal		2½
Parting sandy		¾
Coal	1	1
Shale, carbonaceous		3
Shale, brown.		
	2	7¾

Location 264. SE. ¼ sec. 16 (bed A).

Shale.	Ft.	in.
Bone		4
Shale		1½
Coal		1½
Parting, sandy		1
Coal		11
Bone		2
Shale.		
	1	10

Location 266. NE. ¼ sec. 11 (bed I).

Shale, sandy.	Ft.	in.
Coal		6½
Sand		¼
Coal		5
Sand		¼
Coal		5
Shale.		
	1	5

Location 269. SW. ¼ sec. 2 (bed J).

Sandstone.	Ft.	in.
Shale, carbonaceous		10
Bone		8
Coal		3
Bone		4
Coal, impure		3
Shale, carbonaceous.		
	2	4

Location 270. SW. ¼ sec. 2 (bed A).

Shale.	Ft.	in.
Coal		9½
Parting, sandy		1
Coal	1	7
Bone		3
Shale, sandy.		
	2	8½

Location 276. SE. ¼ sec. 3 (bed J).

Shale.	Ft.	in.
Coal, impure	1	2
Shale, carbonaceous.		

Location 277. SE. ¼ sec. 4 (bed C).

Shale.	Ft.	in.
Bone		1
Coal	1	3
Shale.		
	1	4

Location 279. NW. ¼ sec. 4 (bed A).

	Ft.	in.
Shale	2	7
Coal		7
Coal, impure		3
Coal		8
Parting, sandy		1
Coal (bottom not exposed)	1	6+
	5	8+

Location 282. SE. ¼ sec. 2 (bed I).

Sandstone.	Ft.	in.
Coal, impure		6
Coal		1
Shale, carbonaceous		7
	2	2

Location 294. NE. ¼ sec. 1 (bed I).

Sandstone.	Ft.	in.
Coal	1	
Shale.		

T. 5 N., R. 35 E.

T. 5 N., R. 35 E., includes part of the north end of the Sarpy-Tullock divide, which in the center of the township stands about 800 feet above Yellowstone River. The north end of the ridge is extensively dissected by Cut Off, Unknown, and Boxelder creeks and Forty-four Coulee, which flow northwest and north directly into the river. These creeks have cut deep gorges in the high plateau, so that it has considerable relief and is very rough. There are in the township a number of rather persistent sandstones that form cliffs and render the scaling of the sides of the stream gorges very difficult, in some places necessitating long detours. It is practically impossible to travel across the drainage lines in this township on horseback. The top of the divide, however, is grass covered and rolling and affords excellent grazing, and in the valley of Unknown Creek, a flowing stream, there is some good agricultural land. A rough wagon trail following up Unknown Creek, crossing the divide, and running down Boxelder Creek connects the towns of Big Horn and Hysham.

The Lebo shale member of the Fort Union formation caps the divide in secs. 35 and 36, but except in this locality the township is underlain by the Lance formation. The lower boundary of the upper or Tullock member of the Lance, though somewhat shortened by the slight southerly dip (see Pl. X), is practically a topographic contour around the north end of the divide and indicates the degree of dissection which the plateau has undergone. The character of the Tullock member is shown by stratigraphic section 12, Plate IV. Below this member the lower portion of the Lance crops out. In this general vicinity it may be further divided into an upper predominantly shaly member 300 feet thick and a basal sandy member about 500 feet thick. The cliff-forming sandstones that make travel in this area so difficult are nearly all contained in the lower member. Although this division does not hold in the southern part of the field, the sections given on pages 22–23 show that these two members may be differentiated in this township. The strata have a general inclination to the south, but the dip in the southern part of the township is less than 1°. (See Pl. X.) The exposures of the Tullock member are shortened on the north by a local dip of 2° to 5°, but north of this locality the dip flattens again and is probably less than 1°.

The outcrop of bed A, whose base forms the bottom of the Tullock member, was mapped continuously around the north end of the ridge in this township. Throughout nearly all this distance it contains from 2 to 4 feet of good coal, and the bed may be readily recognized by the 1-inch brown sandy parting already described. At location

283, near the place at which the outcrop enters this township, the bed is about 30 inches thick. (See Pl. XIII.) At locations 287 and 289, on an outlying butte in sec. 28, the bed contains 29 inches of coal, but at location 288, about 1,000 feet to the north, the bed is apparently represented by 10 feet of carbonaceous shale and bone. A similar condition exists at location 286, 500 feet south of locations 287 and 289, and also at location 284, 1,500 feet farther south, although at the locations nearest to No. 284 (283 and 295) the bed contains over 2½ feet of coal. (See sections below.) Apparently, therefore, at least two channels of considerable width existed in the old swamp, one passing through locations 284 and 286 and the other through location 288, but the course of these channels could not be traced. To the west of this locality, at the head of Unknown Creek, bed A is about 3 feet thick, as shown by sections 295, 297, and 298 (Pl. XIII). Toward the north it is somewhat thinner (see section 300, Pl. XIII), but increases to 3½ feet at location 301. In this locality the bed is cut out for a few hundred feet and replaced by an overlying sandstone. At a point 300 feet to the northeast of location 301 (Pl. XIII) this sandstone is about 8 feet above the bed, but it thickens to the southwest until it immediately overlies the bed and a short distance farther southwest replaces nearly the whole of it. This condition exists along the outcrop for a distance of about 400 feet, but beyond this stretch the sandstone becomes thinner again and the coal reappears. Apparently an ancient stream crossed this area after the coal had been deposited and by locally deepening its channel eroded practically all of the bed and deposited sand unconformably upon it. North and east around the divide from this place the bed is from 2 to 3 feet thick as far as the head of Forty-four Coulee, where it is more than 4 feet thick (sections 302 to 306, Pl. XIII). The bed is somewhat thinner on the northeast end of the ridge, but ranges from 2 to 3 feet in thickness as far as the head of Boxelder Creek (sections 307, 308, and 310, Pl. XIII, and section 309, below). At location 315, at the head of the creek, the bed is only 14 inches thick, but farther north it is nearly as thick on the east side of the valley as on the west side (sections 315, 319, and 320, below). The probable shape of the area in which bed A is over 18 inches thick is shown on Plate XIV. Bed A is under a maximum cover of about 300 feet in this township. Except on a few long necks, notably those at the north end of the ridge, the cover is everywhere more than 50 feet.

Bed C, which is about 30 feet above bed A, is over 18 inches thick only in the southern part of the township. The bed is probably thicker than 18 inches at the place at which its outcrop enters the township, but in sec. 28 it is not workable, as shown by sections 285

and 290, below. At location 291 (Pl. XIII) it is more than 20 inches thick, and at location 296 (Pl. XIII) it is 38 inches thick, its greatest observed thickness in this township. It is 27 inches thick at location 299 (Pl. XIII), but a mile to the northwest it contains only 8 inches of coal, and from this place around the end of the divide as far as the head of Boxelder Creek the bed is less than 18 inches thick. In that vicinity it contains 29 inches of coal at locality 312, but 1,000 feet to the north it is slightly less than 18 inches thick. (See sections 311, 313, and 314, below, and section 312, Pl. XIII.) These measurements are plotted on Plate XV, which shows the variation in thickness of the bed and the probable shape of the area in which it is more than 18 inches thick.

Bed I was examined at a number of places in this township and was found to be more than 18 inches thick only at location 316, in sec. 25, where it contains a total of 24 inches of coal. (See section 316, Pl. XIII.) At location 318, half a mile to the north, it is only 16 inches thick, and elsewhere it is generally thinner. (See sections 292 and 318, below.)

The coal resources of this township are more accessible to the railway and to the towns of Big Horn and Hysham than those of any other township in the field. The railway crosses Unknown Creek half a mile west of the township line, and some of the coal in this area is therefore within 4 miles of it. The richest area of coal land is at the head of Unknown Creek, about 6 miles from the railway, but the grade is fairly steep, and the haul would not be difficult. If the coal were to be hauled to Hysham, the area on Boxelder Creek would be more favorable, but a mine at the head of Cut Off Creek would be more accessible to the town of Big Horn. Beds A or C, or both, are 2½ to 3 feet thick in all these localities.

Sections of coal beds in T. 5 N., R. 35 E.

Location 284. NW. ¼ sec. 33 (bed A).

	Ft.	in.
Shale.		
Shale, carbonaceous	1	6
Shale.		

Location 285. SW. ¼ sec. 28 (bed C).

	Ft.	in.
Sandstone.		
Coal		8
Shale and sandstone	3	4
Coal		4
Shale.		
	4	4

Location 286. SW. ¼ sec. 28 (bed A).

	Ft.	in.
Shale.		
Shale, carbonaceous and bony	10	
Shale.		

Location 287. SW. ¼ sec. 28 (bed A).

	Ft.	in.
Shale, brown.		
Coal		6½
Parting, sandy		1½
Coal	1	11
Bone		½
Shale, brown.		
	2	7½

Location 288. SW. ¼ sec. 28 (bed A).

	Ft.	in.
Shale.		
Shale, carbonaceous	10	6
Shale.		

Location 289. SE. ¼ sec. 28 (bed A).

Shale.	Ft.	in.
Coal		8
Parting, sandy		1
Coal	1	9
Shale, brown.		
	2	6

Location 290. SE. ¼ sec. 28 (bed C).

Shale, brown.	Ft.	in.
Bone		3
Coal, impure		11
Shale, carbonaceous		½
Bone		2
Coal		1
Shale, carbonaceous		1½
Coal		10
Bone		6
Shale, brown.		
	2	11

Location 292. SW. ¼ sec. 34 (bed I).

Shale, brown.	Ft.	in.
Coal	1	½
Bone		1
Coal		1
Bone		1
Coal		1
Shale.		
	1	4½

Location 309. NE. ¼ sec. 23 (bed A).

Shale.	Ft.	in.
Shale, brown		1
Coal		3
Parting, sandy		1
Coal	2	7
Shale, carbonaceous		1
Shale.		
	3	1

Location 311. NW. ¼ sec. 36 (bed C).

Shale.	Ft.	in.
Bone		3
Coal, impure	1	3
Sand		2½
Coal		4
Shale.		
	2	½

Location 313. SE. ¼ sec. 36 (bed C).

Shale, sandy	Ft.	in.
Coal	1	1
Bone		1
Coal		3
Shale.		
	1	5

Location 314. NE. ¼ sec. 36 (bed C).

Shale.	Ft.	in.
Shale, carbonaceous		2
Coal, impure		1
Coal		3
Bone		1
Coal	1	2
Shale, brown.		
	1	9

Location 315. NE. ¼ sec. 36 (bed A).

Shale, sandy.	Ft.	in.
Coal, impure	1	2
Shale, brown		2
Shale and sandstone	13	
Coal		6
Shale, sandy.		
	14	10

Location 318. NE. ¼ sec. 25 (bed I).

Shale.	Ft.	in.
Coal	1	4
Shale.		

Location 319. NE. ¼ sec. 25 (bed A).

Shale.	Ft.	in.
Coal		3
Parting, sandy		½
Coal	1	
Bone		2
Coal, impure		10
Shale, sandy.		
	2	3½

Location 320. SE. ¼ sec. 24 (bed A).

Shale.	Ft.	in.
Bone		4
Parting, sandy		1½
Bone		3
Coal	1	10
Shale, brown.		
	2	6½

T. 6 N., R. 35 E.

Yellowstone River traverses T. 6 N., R. 35 E., and only that portion of the township lying southeast of the river was examined. This part of the township contains the roughest country, except the Devil's Pocket, found in the Tullock Creek field. The abundance and persistence of thick cliff-forming sandstones render even foot travel across the drainage lines difficult and horseback travel impossible. Guys Bluffs, from 100 to 350 feet in height, rise almost sheer from the river edge and confine the Northern Pacific Railway track to a narrow strip of land, which in many places is artificial (Pl. II, *A*). In the northeast corner of the township, however, the river meanders away from the bluffs, leaving a strip of flood plain some 3 miles wide. Myers station is at the west end of this flat and fertile plain, which extends eastward for 15 miles and upon which are the towns of Hysham and Sanders.

The rocks exposed in this township belong to the Bearpaw shale and Lance formation. The bottom land in the northeast corner of the area is practically coincident in extent with the outcrop of the soft Bearpaw shale, though a narrow strip of the Bearpaw is exposed along the river for some distance east of Myers. (See Pl. X.) The contact between the two formations, as exposed along the railway, seems to be irregular, and in several places a slight angular unconformity was noticed. Owing to the fact that the top of the Bearpaw is sandy and resembles the Lance, it is difficult to fix the exact contact; but it seems certain that the heavy-bedded sandstones of the Lance rest upon an indented surface, which is presumably to be considered the top of the Bearpaw, as here mapped. The section measured near Myers (p. 23) shows the abundance of heavy sandstone beds in the lower portion of the Lance, to which the roughness of the southern part of the township is due.

The strata in this township rise to the north on the flank of the large gentle dome that dominates the structure in the northern part of the field. (See Pl. X.) The general dip is to the south and southwest at angles of nearly 2°, although local dips of 5° or more are not uncommon.

T. 1 S., R. 36 E.

Only the northern tier of sections in T. 1 S., R. 36 E., was examined. Tullock Creek flows north across sec. 5 in a flat-bottomed valley about half a mile wide. The part examined is underlain by the lower portion of the Lance formation, the Tullock member of the Lance, and the Lebo shale member of the Fort Union formation, each with its characteristic surface features. (See Pl. X.) Coal bed A, which forms the base of the Tullock member, is less than 18

inches thick in this part of the township, and several higher beds examined are also too thin to be of value.

The strata dip about 2° NE., though local dips as high as 10° in this direction were observed. (See Pl. X.) Although the thickness of the Tullock member was not measured in this vicinity, it was estimated that about 600 feet of it is exposed. In view of the irregular dips observed, this is believed to indicate the presence of a fault, which has caused the repetition of the whole member. This belief is strengthened by a small isolated exposure of dark-gray strata resembling Lebo shale, well down toward the valley of Tullock Creek. The exposures in this township are not particularly good, and unfortunately time was not available for studying the structure to the south, but a fault of considerable magnitude is strongly suggested.

T. 1 N., R. 36 E.

The valley of Tullock Creek forms the approximate western boundary of T. 1 N., R. 36 E., and the crest of the Sarpy-Tullock divide is roughly coincident with the east line of the township. The area therefore includes the western flank of the ridge, which in this vicinity rises about 750 feet above the creeks. Its height is emphasized by the fact that the slope is not regular but is broken into several steps or terraces. The main ridge has a flat top, which is rolling and grass-covered and in some places suitable for dry farming. Except in a few localities, this plateau is bounded by precipitous bluffs about 275 feet high, fringed by outlying buttes, at the foot of which a relatively flat bench occurs. (See Pl. V, *B*.) This gently sloping area is similarly bounded by steep bluffs of the same height, and below them the land slopes more gently to Tullock Creek. The extensive drainage of Plum and East Cabin creeks, which occupy broad valleys, has in places destroyed the continuity of the terraces, but in the northern part of the township in particular they are very striking. In the southern part East Cabin Creek has broken down the lower terrace throughout a considerable area and has formed a broad and relatively gentle basin in which there is considerable land adapted to agriculture. This basin is bounded on the east by the upper terrace, but the main divide in this part of the township is not so high as it is to the north, and the whole district is therefore less rough. Wagon trails follow Plum and East Cabin creeks to the divide (see map, Pl. X) and afford communication between Sarpy and Tullock valleys.

The topography in this township, as described above, is directly controlled by the geology. The flat top of the ridge is underlain by the yellow standstones of the Fort Union formation. (See stratigraphic sections 19 to 21, Pl. IV.) A sandstone about 75 feet thick

occurs at about the base of these beds, and about 50 feet above it is another that ranges from 20 to 60 feet in thickness. (See Pl. IV, *A*.) The resistance to erosion of these sandstones is further increased by the fact that they contain two coal beds varying from 10 to 20 feet in thickness, which are almost everywhere burned on the outcrop. This burning has baked and clinkered the adjacent strata, producing a very resistant formation, which rises with conspicuous abruptness from the flat terrace underlain by the soft Lebo shale member. The Lebo member includes only the basal 140 feet of the Fort Union formation, but its outcrop forms a broad band along the slope of the divide. (See map.)

The more precipitous ground below the Lebo bench is caused by the outcrop of the Tullock member of the Lance formation, the character of which is shown in sections 6 and 7, Plate IV. As the Tullock member forms a steep escarpment, especially in the northern part of the township, its outcrop is limited to a comparatively narrow zone. The lower portion of the Lance formation is exposed in the valleys of Tullock, Plum, and East Cabin creeks. Its outcrop is largely covered by débris and alluvium in the northern part of the township, and the country which it underlies is characterized by rather gentle topography. In the southern part, however, nearly 300 feet of these beds are exposed, and in places they give rise to irregular escarpments.

The general dip in this township is to the northeast at an angle of 2° or less. It is more pronounced in the southern part of the township, where, in conjunction with the drainage of East Cabin Creek, it has caused the formation boundaries to swing back to the east. Thus along the south township line the dip is 3°–5° NE., whereas in the central and northern parts the average inclination is only 1° or 2°, although local dips as high as 7° were measured. In sec. 19 a normal fault with a displacement of about 30 feet cuts the strata, and in sec. 25 a fault of 105 feet is well shown by the displacement of the heavy sandstone near the base of the upper division of the Fort Union formation.

Four coal beds in the upper division of the Fort Union attain a thickness of more than 18 inches in this township. The highest of these, bed P, is generally either burned on the outcrop or exposed on the grass-covered crest of the ridge, where the topography is such as to prevent adequate examination. The thickness of the clinker that this bed has formed indicates that it is generally a thick bed, but at only one place in the township was it possible to make a satisfactory measurement. At location 441, in sec. 13, the bed contains over 21 feet of coal in one bench, 7½ feet of which is impure; and below this are four benches from 6 to 22 inches thick (section 441, Pl. XII). The bed is burning at the present time at this place,

but the measurements given are probably nearly correct. Notwithstanding the thickness of the bed at this place, there are many localities at this horizon on the grass-covered top of the divide at which only a small amount of coal is exposed. This is due in part to the thinning of the bed to the west, but in some places it is probably due to the fact that the bed is split into a number of benches, only one or two of which happen to be exposed. Thus in the center of sec. 13, not far from location 441, an apparently complete measurement showed only 2 feet of coal, but the rest of the bed is doubtless represented by a heavy clinker 30 feet above. At location 123 (Pl. XII) an apparently complete section was obtained which shows only about 6 feet of coal, but this also may represent only one bench. At location 425 the bed is partly burned but contains 7 feet of good coal at the base and 4 feet of partly burned material, possibly representing good coal, above. (See Pl. XII.) No measurements were obtained in the northwestern part of the township, but despite the possibility that the bed at locations 123 and 425 may be thicker than the measured sections indicate, it is believed from measurements made in adjacent townships that the bed is much thinner to the west. (See Pl. XV.) Bed P in the areas mapped on the north divide of Plum Creek is in places under a cover of 50 feet or more, but it is entirely burned out in the smaller areas and partly burned in the larger ones. On the main Sarpy-Tullock divide, where the bed is not burned to any extent, it is commonly under thin cover and is in many places badly weathered. Although in this vicinity the bed contains 20 feet or more of coal its value is thus impaired by its thin cover, and owing to the extent to which it has burned out it probably can be mined only in small areas.

Bed O, which is stratigraphically 35 to 50 feet below bed P, attains its greatest thickness in the southern part of the township. At location 112, in sec. 6, T. 1 S., R. 37 E., only 18 inches of impure coal is exposed, but the section is not complete, and at location 114, in sec. 25, the bed is 3 feet thick (section 114, Pl. XII). At location 116, 1½ miles to the north, it contains only 1 foot of impure coal, and at location 118, in the SE. ¼ sec. 11, only 8 inches. At location 120, however, the bed contains 20 inches of coal, and at location 124 over 2 feet. Along the outcrop to the north and east from this place it averages about 2 feet in thickness. (See sections 124, 421, 424, and 435, Pl. XII.) Bed O is commonly burned and in most places concealed by the slumped clinker of bed P, so that it is difficult to trace and examine satisfactorily.

The interval between beds O and N seems to range from 30 to 65 feet. (See sections on Pl. IV.) It is possible that the sections here referred to bed N belong to two lenticular beds, but it is believed from the character of the sections and of the roof and floor rocks

that they all represent one bed. The extent to which the coals have burned and so caused slumping of the overlying strata makes the correlation of isolated exposures rather uncertain. Bed N contains only 16 inches of coal at location 115, but at location 119, 2 miles north of this place, it is a little more than 2 feet thick. The bed maintains about this thickness throughout the northern part of the township, as shown in sections 119, 121, 125, 423, and 437, Plate XII. No trace of the bed was found in T. 1 N., R. 37 E., however, and it is believed to decrease in thickness to the east and to be less than 18 inches thick within a short distance.

The lowest coal in the upper part of the Fort Union is bed M, which in this township is 100 to 130 feet below bed P. In the southern part of the township, at location 113 (see Pl. XII), the bed contains about 7 feet of pure coal and 3 feet of impure coal, but owing to slumping the measurement is not accurate. A trace of the bed was also observed below location 114, where it is more than 6 feet and less than 11 feet thick. At location 117, in the NW. ¼ sec. 24, a complete section was obtained which shows about 18 feet of coal. (See section, Pl. XII.) The bed decreases in thickness toward the west, however, and at location 122 (Pl. XII) it is only about 11 feet thick. At the west end of the Plum Creek divide, in secs. 4 and 5, the bed was examined at several places, but owing to its partly burned condition (see sections 127 and 128, below) no satisfactory section could be measured. At location 126, however, about 5 feet of good coal is exposed (Pl. XII), and although this may not represent the full thickness of the bed it is probably approximately correct, as the bed is known to become thinner toward the west. (See Pl. XIV.) Farther east, on the north side of the Plum Creek divide, a complete section shows 11 feet of coal, of which 7½ feet is impure, and at location 436 the bed contains over 13 feet of good coal (sections 422 and 436, Pl. XII). At two points at the head of Spring Creek, on the east side of the main divide, over 8 feet of good coal is exposed, but neither section is complete (sections 439 and 440, Pl. XII). At the head of the creek to the south, the bed is 18½ feet thick at location 444 and over 17 feet thick at location 445 (Pl. XII). Bed M is burned on the outcrop almost everywhere except at the heads of the youngest coulees, and complete sections are very difficult to obtain. The thickness of the clinker formed varies considerably, which may indicate abrupt variations in the thickness of the coal between measured sections, but if this condition exists it is probably due to channeling, which does not affect the broad variation in thickness of the bed. (See Pl. XIV.) The cover over this bed is generally thick, ranging from 50 to almost 200 feet.

The Lebo shale in this district contains no coal bed more than a few inches thick. In the upper portion of the Tullock member of the

Lance there is no workable coal, but at the base of the member bed A attains a thickness of more than 18 inches in the valley of East Cabin Creek. It is only 13 inches thick at location 111, but at location 108 (Pl. XIII) it contains over 2 feet of coal. At location 106 (Pl. XIII) it contains 3 feet of coal separated into two benches by 11 inches of shale, but at the next place of measurement, location 105, it is only 8 inches thick. (See sections below.) About 30 feet above bed A is bed C, which has been found more than 18 inches thick at many localities in the field. The bed was mapped for a short distance along East Cabin Creek but does not reach 18 inches in thickness at any point (sections 107, 109, 110, below).

Sections of coal beds in T. 1 N., R. 36 E.

Location 105. SE. ¼ sec. 32 (bed A).

	Ft.	in.
Shale, brown.		
Coal		2
Parting, sandy		1
Bone		8
Shale, carbonaceous	1	2
Bone		2
Coal		8
Shale, carbonaceous.		
	2	11

Location 107. NW. ¼ sec. 28 (bed C.)

	Ft.	in.
Shale.		
Shale, carbonaceous		2
Coal, impure		9
Shale, brown.		
		11

Location 109. NE. ¼ sec. 29 (bed C).

	Ft.	in.
Shale.		
Bone		2
Coal, impure	1	
Bone		1
Coal		6½
Shale, brown.		
	1	9½

Location 110. NW. ¼ sec. 29 (bed C).

	Ft.	in.
Shale.		
Coal		4½
Shale, brown		1
Coal		1½
Shale, brown		1
Coal		3
Bone		½
Coal		3
Shale.		
	1	2½

Location 111. SE. ¼ sec. 19 (bed A).

	Ft.	in.
Shale, sandy.		
Shale, carbonaceous		11
Bone		1
Coal	1	1
Shale, brown		10
Coal		4
Shale.		
	3	3

Location 115. SW. ¼ sec. 24 (bed N).

	Ft.	in.
Sandstone.		
Coal		2
Shale	2	
Bone and carbonaceous shale	1	2
Coal		1
Shale	2	1
Shale, carbonaceous		4
Coal	1	4
Shale, carbonaceous	1	2
Shale.		
	8	4

Location 116. NW. ¼ sec. 24 (bed O).

	Ft.	in.
Shale, carbonaceous.		
Coal, impure	1	
Shale, carbonaceous.		

Location 118. SE. ¼ sec. 11 (bed O).

	Ft.	in.
Shale and bone.		
Coal		8
Shale and bone.		

Location 120. SE. ¼ sec. 10 (bed O).

	Ft.	in.
Sandstone.		
Coal		7½
Bone		1½
Coal	1	1
Shale, carbonaceous		2
Coal		3
Shale, brown		2
Coal		1
Shale, brown		1
Coal		2
Shale		5
Coal, impure		2
Shale.		
	3	4

Location 127. SE. ¼ sec. 4 (bed M).

	Ft.	in.
Shale, brown.		
Coal, in part burned	2	1
Ash		8
Sandstone.		
	2	9

Location 128. NE. ¼ sec. 4 (bed M).

	Ft.	in.
Shale.		
Coal, partly burned and ash	4	
Shale, brown.		

T. 2 N., R. 36 E.

T. 2 N., R. 36 E., includes the divide between Sarpy and Tullock creeks, the latter of which is within a mile of the western margin of the township. The divide is relatively low in most of this township, and its slopes are gentle and grass covered. Along the western margin of the township, however, there is a rough and precipitous belt, and in the southeast corner a dissected escarpment rises abruptly some 250 feet above the rolling plain to the north. The relations of the topography to the geology in this township have been considered in connection with Figure 2 (p. 6).

The Fort Union and Lance formations crop out in this township, and both divisions of each formation are present. The upper division of the Fort Union, baked and clinkered by the burning of the coal, forms the dissected escarpment in the southern part of the township. About 250 feet of these beds are exposed, and their character is shown in sections 19 and 20, Plate IV. In the central and northern parts of the township less than 100 feet of the basal portion of this part of the formation is still unremoved by erosion. This part consists chiefly of soft, homogeneous yellow sandstone, which in places forms abrupt, bare, wind-eroded blocks. In general, however, this sandstone is worn down to a gently rolling and grass-covered surface, and the boundary between the upper division of the Fort Union and the Lebo shale member can not be accurately shown. In the central part of the township a fault was observed (see Pl. VII, *B*) which probably terminates the outcrop of the upper division on the south. It is believed that there is also a parallel fault some 2 miles to the north and that these faults inclose between them a downthrown block (see Pl. X), but owing to the character of the surface, the structure can not be definitely worked out. The Lebo

shale in the northern part of the township is generally worn down to a gently rolling surface partly covered by sandy soil washed from the overlying beds. These districts are generally well grass covered, but in the southern part of the township, where the Lebo is being actively eroded, badlands predominate. The relations of geology to topography along the divide in this township have been described in connection with Figure 2. The Tullock member of the Lance formation crops out in the western part of the township, where it forms a precipitous slope to Tullock Creek. The boundary between this member of the Lance and the Lebo member of the Fort Union is marked by a sandstone rim rock, the outcrop of which sharply separates the steep slopes and broken land of the Tullock member from the gentler slopes of the Lebo. The Tullock member in this township contains little coal, and its character is shown in sections 6 and 7, Plate IV.

The upper division of the Fort Union in this township contains coal beds P, O, and M, but exposures are poor, and conclusions as to the thickness of the coals are based largely on observations in adjacent townships. The highest bed, P, is under very thin cover and has been largely burned out, so that it is generally represented only by a clinker cap on the highest ridges. However, part of the bed still remains unburned in a small area in sec. 35, where at location 428 about 3 feet of coal is exposed. This may represent only the lower part of the bed (section 428, Pl. XII). Bed O was examined at locations 426 and 430, on the west side of the divide, and was found to be about 15 inches thick, but at location 432, on Pleasant Creek, it is about 2 feet thick. (See sections below.) Observations in T. 1 N., R. 36 E., indicate that the bed maintains about this thickness for some distance to the south.

Bed M is not well exposed in this township, and no representative sections were secured. At location 433, 7 feet of coal and ash is exposed, and at locations 429 and 431 between 5 and 6 feet of coal and ash was observed. (See sections below.) At all these places some of the coal has probably been burned, although measurements made in T. 1 N., R. 36 E., suggest that the full thickness of the bed is only slightly greater than these measurements indicate. At location 427 bed M is well exposed but consists only of 12 feet of black shale. A few hundred feet on either side of this exposure a thin band of clinker appears at about this horizon, and the bed probably contains 5 feet or so of coal within a short distance. This replacement by black shale may represent merely a channel in the old swamp, or as the bed thins toward the northwest it may represent the edge of the swamp and therefore the limit of the coal lens.

The Lebo shale member contains but one coal bed thicker than 18 inches—bed K. In sec. 21, at location 146, this bed contains a total

of 43 inches of coal separated into nine benches by partings of bone and shale. About 800 feet on either side of this place, at locations 145 and 147, the bed carries less than 18 inches of good coal. At location 148 it contains 29 inches of coal, but this is so badly broken by partings that the bed is not considered worth working at present. (See sections below.) This bed contains 5 or 6 feet of carbonaceous material throughout the township, and its outcrop forms a conspicuous dark band. The lens in sec. 21 is believed to be the only one in the township which is more than 18 inches thick, but it is possible that there may be other very local lenses that escaped observation.

The Tullock member of the Lance formations contains three coal beds more than 18 inches thick—beds I, D, and A. At the head of a small creek in sec. 19 bed I is 22 inches thick, but two sections measured farther down the creek show a thickness of less than 15 inches. (See sections 141 and 142, below, and section 137 in description of T. 2 N., R. 35 E.) Bed I was also examined at location 149, in sec. 7, where it is 17 inches thick. Bed D is about 20 inches thick at location 140, a short distance east of the township line in sec. 19, but measurements in T. 2 N., R. 35 E., indicate that the bed is more than 18 inches thick only in a very small area. Bed A is not exposed in this township, but measurements on its outcrop in the township to the west indicate that the bed is thicker than 18 inches in a small area along the western margin of this township. (See Pl. XIV.)

The area of Lance coal which lies in the western part of the township is accessible from the main county road up Tullock Creek. The Fort Union coal area is connected by a fair wagon road with Sarpy Creek, which lies about 3 miles east of the township line. A wagon trail also connects the road following the crest of the divide with the Tullock Creek road, by way of Cottonwood Creek.

Sections of coal beds in T. 2 N., R. 36 E.

Location 140. SW. ¼ sec. 19 (bed D).

	Ft.	in.
Shale.		
Coal		6
Shale, brown		1½
Bone		2
Coal	1	5
Shale, brown		3
Shale.		
	2	5½

Location 141. SE. ¼ sec. 19 (bed I).

	Ft.	in.
Shale.		
Shale, carbonaceous, with coal partings	1	6
Coal		10
Bone		½
Coal		4
Bone		½
Coal		9
Shale, carbonaceous		3
Sandstone.		
	3	9

Location 142. SW. ¼ sec. 19 (bed I).

Shale.	Ft.	in.
Coal		5
Bone		2
Coal, impure		5
Coal		5½
Bone		1
Shale.		
	1	6½

Location 145. SE. ¼ sec. 21 (bed K).

Shale.	Ft.	in.
Shale, carbonaceous, and bone	5	
Coal	1	
Coal, impure		7
Shale, carbonaceous.		
	6	7

Location 146. NE. ¼ sec. 21 (bed K).

Shale.	Ft.	in.
Shale, carbonaceous		4
Coal		7
Bone		7
Coal		2
Bone		7
Coal		3
Bone		5
Coal		2
Bone		1
Coal		10
Bone		4
Coal		5
Coal, impure		3
Coal		7
Shale, carbonaceous		2
Coal		4
Shale, carbonaceous.		
	6	1

Location 147. NE. ¼ sec. 21 (bed K).

Shale.	Ft.	in.
Bone		4
Shale, carbonaceous	1	1
Bone		7
Coal		5
Bone	1	6
Bone, with coal partings	1	2
Shale, carbonaceous.		
	5	1

Location 148. NE. ¼ sec. 21 (bed K).

Shale.	Ft.	in.
Shale, carbonaceous, and bone	3	
Bone	1	8
Coal, impure		8
Bone		2
Coal		5
Bone		1
Coal		8
Shale, carbonaceous	2	
Coal, impure		8
Shale, carbonaceous.		
	9	4

Location 149. SE. ¼ sec. 7 (bed I).

Shale.	Ft.	in.
Coal		2
Bone		1
Coal	1	3½
Shale.		
	1	6½

Location 426. SW. ¼ sec. 35 (bed O).

Shale.	Ft.	in.
Shale, black		4
Coal		3
Sandstone, carbonaceous		1
Coal, impure	1	2
Shale.		
	1	10

Location 427. SW. ¼ sec. 35 (bed M).

Sandstone.	Ft.	in.
Shale, black	12	
Sandstone.		

Location 429. SW. ¼ sec. 26 (bed M).

Shale.	Ft.	in.
Coal, clinker, and ash	5	8
Shale, carbonaceous.		

Location 430. NW. ¼ sec. 26 (bed O).

Shale, sandy.	Ft.	in.
Coal		6
Bone		1
Coal		10
Shale, carbonaceous.		
	1	5

Location 431. SW. ¼ sec. 25 (bed M).

Sandstone, shaly.	Ft.	in.
Coal and ash	5	
Shale, carbonaceous.		

Location 432. NE. ¼ sec. 36 (bed O).

Sandstone.	Ft.	in.
Coal	1	3
Bone		3
Coal		11
	2	5

Location 433. NW. ¼ sec. 36 (bed M).

Shale and sandstone	Ft.	in.
Coal, ash, and clinker	7	2+
Shale, carbonaceous.		

T. 3 N., R. 36 E.

The divide between Sarpy and Tullock creeks, which is over 600 feet high, traverses the middle of T. 3 N., R. 36 E. The crest of the divide is marked by steep, rounded, gravel-covered hills, at the foot of which the slope is more gentle. The highest point on the divide is Whiskey Butte, which rises some 150 feet above the surrounding country. Along the eastern and western margins of the township there is a belt of broken land that forms the steep sides of the main two creek valleys. As is usual in this region, the westerly slopes are bare and abrupt and the drains are steeply graded, whereas the easterly slopes and drains have a noticeably lower gradient.

Both divisions of the Fort Union and both divisions of the Lance formation are exposed in this township. The upper division of the Fort Union is confined to the extreme crest of the ridge, where it underlies an irregular strip of land, approximately shown on Plate X. In Whiskey Butte about 150 feet of these beds is exposed, but elsewhere less than 100 feet is still unremoved by erosion. The beds consist chiefly of soft yellow cross-bedded sandstone, which in places forms bare wind-eroded blocks. (See Pl. VI, *B*.) In general, however, the beds are gravel covered and form the low, rounded hills on the crest of the divide. At about the base of these hills the underlying Lebo shale member crops out, but the contact is generally obscured by gravel. The Lebo in the western part of the township forms gentle grassy slopes and is largely covered by gravel in transit from higher levels to the creeks. In the western part, however, the gravel has been eroded, and the soft shale is cut into miniature bad lands. A good section of the Lebo was measured in sec. 23 and is given on page 37. The Tullock member of the Lance forms a dissected escarpment that sharply limits the relatively smooth upland underlain by the Fort Union formation. In the eastern part of the township this member contains no coal beds as thick as 18 inches, but in the western part several beds of greater thickness are exposed. The lower portion of the Lance crops out only in a few of the larger creek valleys on the western margin of the township.

This township is crossed by a zone of structural depression in which the strata are irregularly warped and to some extent faulted.

(See Pl. X.) The faults are mostly confined to a well-marked belt $2\frac{1}{2}$ to $3\frac{1}{2}$ miles wide, trending eastward across the township just south of Whiskey Butte. Several of the faults on the east side of the divide are block faults, but in most of those on the west there has been displacement on only one side, the strain on the other side of the block having been taken up by a local sharpening of dip. (See Fig. 3, p. 52.) Thus the unusual condition is presented of a fault on a dip slope with the upthrow side in the direction of downward dip and the upthrow forming a recovery from the sharp local dip adjoining the fault plane. One of the largest of these faults was traced for more than 3 miles and has a maximum displacement of about 120 feet. In secs. 27 and 28 the recovery is distributive along a branching fault. Small faults having throws of 10 to 20 feet were noted in secs. 18, 21, and 28, as indicated in Plates X and XI.

The basal 100 feet of the upper division of the Fort Union is barren of coal throughout the field, but on Whiskey Butte a coal bed occurs about 150 feet above the base. This bed, which probably represents bed M, forms the surface of the extreme top of the butte, about 5 acres in extent. As shown in section 416 below, the bed is about 3 feet thick, but owing to its small areal extent and its lack of cover it is of little value.

The only coal bed thicker than 18 inches in the Lebo member is bed L, which is about 20 feet below the top of the member. This bed underlies only a small area on the east side of the ridge at the head of Rainwater and East Passage creeks, having been elsewhere removed by faulting and erosion. At location 408, in sec. 3, bed L contains only 16 inches of impure coal, but at location 409, in sec. 11, it is 28 inches thick. Along the neck that extends to the east from this place, the bed contains 21 or 22 inches of coal. (See sections 409 to 413, Pl. XII.) At location 414 it is of about the same thickness but part of the coal is impure, and at location 415 it carries only 19 inches of impure coal. At locations 418 and 420 the bed is only a little over a foot thick. (See sections below.) At location 419, however, between locations 418 and 420, the bed carries 21 inches of coal, of which 9 inches is impure. (See Pl. XII.) This thickening is very local, and the coal, even at location 419, can hardly be considered worth mining at present, but it is evident that bed L is characterized by abrupt fluctuations in thickness, and there may be other local lenses that have escaped observation, in which the bed is more than 18 inches thick. The bed is cut by three faults. The most northerly one is well marked by the displacement of the strata for a distance of over 2 miles, although no sharp escarpment can be seen. It has a downward throw to the south of 30 to 50 feet. The fault in sec. 14 has a somewhat smaller downthrow to the north, and a downthrown block is thus partly inclosed between these two

faults. The most southerly fault is not well defined but has a downward throw of 30 to 40 feet to the north.

The Tullock member of the lance contains three beds more than 18 inches thick—beds I, H, and A. Bed I exceeds 18 inches in three small areas, of which that in the northwest corner of the township is the largest. The bed is very irregular in character, and measurements made along its sinuous outcrop have little significance unless plotted and contoured as on Plate XVI. At the head of the south fork of East Burnt Creek the bed is about 13 inches thick (sections 204, below, and 207, Pl. XIII). Farther down the creek it is thicker, and at locations 205 (see below) and 208 (see Pl. XIII) it is a little more than 2 feet thick. It maintains about this thickness on the north fork of the creek, as shown by sections 210 and 211 (Pl. XIII), and also for some distance north of the township line. South of East Burnt Creek the bed is less than 18 inches thick as far as sec. 19. At locations 177, 176, 168, 175, and 164 the bed is between 18 and 20 inches thick, but at locations 163 and 162, farther east, it is less than 15 inches thick (See map, Pl. XI, and section below.) At location 161, still farther east, the bed contains 19 inches of coal, partly impure. As this is the most easterly place at which the bed crops out, the extent of its area to the east can not be determined, but it is probably small. The coal beds in this locality are cut by a fault (see map), which in sec. 20 has a displacement of 105 feet, decreasing to the west.

Bed H, which is about 25 feet below bed I and is separated from it by heavy sandstone, is slightly thicker than 18 inches in two small areas southwest of Whiskey Butte. Along the same creek on which bed I is workable in sec. 19 bed H attains a thickness of 23 inches (section 166, Pl. XIII). At location 165 (Pl. XIII), 800 feet to the east, the bed is only 18 inches thick, and at locations 160 (Pl. XIII) and 167, to the south and west, it is about 17 inches thick. In sec. 29, at location 155, bed H is 19 inches thick, but at locations 154 and 156 it is less than 1 foot thick. (See sections below and on Pl. XIII). Bed H was examined at a number of other places and is thought to be less than 18 inches thick elsewhere in the township. Bed B at location 174 contains 19 inches of impure coal, and this is the best section of the bed recorded in the township.

Bed A, the base of the Tullock member, is exposed in this township only in secs. 19 and 30, its outcrop along Tullock Creek lying mostly in the township to the west. At location 153 it is about 20 inches thick, and at locations 157 and 169 it is over 2 feet thick. (See sections on Pl. XIII.) On the basis of these measurements and those made in T. 3 N., R. 35 E., bed A is believed to be more than 18 inches thick in a considerable area in this township, as shown on Plate XIV.

Several rough wagon trails traverse this township, as shown on Plate XI. The area of Lebo coal in the eastern part of the township can be reached from Sarpy Creek by the road that crosses the main divide, but none of the coal beds of the Tullock member are easily accessible. Although there are many separate areas of coal land in this township, none of them are of great extent or value, except that underlain by bed A, which would naturally be worked from the valley of Tullock Creek, in the township to the west.

Sections of coal beds in T. 3 N., R. 36 E.

Location 154. SW. ¼ sec. 28 (bed H).

Sandstone.	Ft.	in.
Coal		4
Parting, sandy		¼
Bone		4
Coal, with partings of shale		4
Coal		1
Shale.		
	1	1¼

Location 155. NE. ¼ sec. 29 (bed H).

Sandstone.	Ft.	in.
Shale, streak		½
Coal		9
Bone		½
Coal		10
Shale, brown.		
	1	8

Location 156. NW. ¼ sec. 29 (bed H).

Shale.	Ft.	in.
Shale, carbonaceous		3
Coal		9
Bone		1
Coal, impure		1
Parting, sandy		½
Coal, impure		3½
Bone		1
Shale.		
	1	7

Location 161. NW. ¼ sec. 21 (bed I).

Sandstone.	Ft.	in.
Coal, impure		5
Coal		8
Coal, impure		1
Coal		5
Shale		1½
Shale, carbonaceous		4
Sandstone.		
	2	½

Location 162. NE. ¼ sec. 20 (bed I).

Shale.	Ft.	in.
Shale, black		1
Coal	1	
Bone		2
Coal		4
Shale.		
	1	7

Location 163. NW. ¼ sec. 20 (bed I).

Shale.	Ft.	in.
Coal		10
Bone		3
Coal		6
Shale, carboniferous.		
	1	7

Location 164. NW. ¼ sec. 20 (bed I).

Sandstone.	Ft.	in.
Coal	1	6
Parting, sandy		¼
Bone		1
Shale.		
	1	7¼

Location 167. NE. ¼ sec. 19 (bed H).

Shale.	Ft.	in.
Shale, carbonaceous		2
Coal	1	1½
Bone		2
Coal		5
Parting, sandy		¼
Coal		1
Shale.		
	1	11¾

Location 168. NE. ¼ sec. 19 (bed I).

Shale.	Ft.	in.
Coal	1	6½
Shale, brown		2
Shale.		
	1	8½

Location 174. SW. ¼ sec. 18 (bed B).

	Ft.	in.
Alluvium.		
Shale, brown		2
Bone		3½
Parting, sandy		1
Coal, impure	1	7
Shale		6
Coal		2
Shale.		
	2	9½

Location 175. NW. ¼ sec. 20 (bed I).

	Ft.	in.
Sandstone.		
Coal	1	3
Bone		2
Coal		6
Parting, sandy		¼
Coal		1½
Bone		1
Sandstone.		
	2	1¾

Location 176. SE. ¼ sec. 18 (bed I).

	Ft.	in.
Shale.		
Coal	1	4½
Bone		2
Coal		3
Parting, sandy		½
Coal, impure		1
Sandstone.		
	1	11

Location 204. NE. ¼ sec. 7 (bed I).

	Ft.	in.
Sandstone.		
Coal	1	1
Bone		5
Shale and bone		6
Shale.		
	2	

Location 209. NW. ¼ sec. 6 (bed H).

	Ft.	in.
Sandstone.		
Coal	1	2
Shale, gray.		

Location 408. NW. ¼ sec. 3 (bed L).

	Ft.	in.
Shale.		
Coal, impure	1	4
Shale.		

Location 414. SE. ¼ sec. 15 (bed L).

	Ft.	in.
Shale.		
Shale, brown and carbonaceous		2
Coal, impure		9
Coal		9
Shale, brown		1
Coal		5
Shale.		
	2	2

Location 415. SE. ¼ sec. 15 (bed L).

	Ft.	in.
Shale.		
Coal, impure	1	7
Shale, brown		1
Shale, carbonaceous, and bone		2
Shale.		
	1	10

Location 416. NE. ¼ sec. 16 (bed M?).

	Ft.	in.
Shale.		
Shale, carbonaceous		6
Coal, impure	1	
Coal	1	11
Shale, carbonaceous	1	
Shale.		
	4	5

Location 418. NW. ¼ sec. 22 (bed L).

	Ft.	in.
Shale.		
Coal		5
Coal, impure		3½
Coal		8
Shale, carbonaceous.		
	1	4½

Location 420. SE. ¼ sec. 27 (bed L).

	Ft.	in.
Shale.		
Coal, impure	1	1
Bone		5
Coal		6
Shale, black.		
	2	

T. 4 N., R. 36 E.

The divide between Tullock and Sarpy creeks trends somewhat west of north across the center of T. 4 N., R. 36 E. The upland in this township is not flat but is broken into rounded gravel-covered hills and in the central part of the township is reduced to a narrow ridge by the headward erosion of the numerous branches of Light-

ning and Bear creeks. In the eastern and western parts of the township the slopes are steep and the surface is badly broken. As is usual in this region, the western slope of the ridge is steep and supports only a scanty growth of trees and grasses, whereas the eastern slope has a lower gradient and includes more land suitable for agriculture. A wagon road connecting Tullock Valley with the town of Hysham crosses the northwest corner of the township, and another rough trail follows down Bear Creek to Sarpy Valley.

The Lance and Fort Union formations crop out in this township, but the Fort Union is nearly everywhere overlain by quaternary gravel. This has been reworked at different times and occurs in several more or less well-defined terraces along the creek valleys. The upper division of the Fort Union caps the crest of the divide, but only a few feet of the basal portion is still unremoved by erosion. These beds are exposed on a small butte in sec. 13 but are elsewhere concealed by gravel. The northernmost outlier of this part of the formation in this field is thought to be in sec. 7, but the mapping of this area is entirely inferential. The Lebo shale member of the Fort Union is also generally concealed by gravel, especially on the eastern slope of the ridge. A number of sections of coal beds or carbonaceous bands in the Lebo were measured, but none of them show more than 18 inches of coal. (See, for example, section 254, below.) Owing to the poor exposures, however, it is possible that there are local coal lenses more than 18 inches in thickness that were not observed. On the west side of the ridge, in sec. 17, the surface has been denuded of gravel and the Lebo is cut into badlands.

Below the Lebo, and sharply separated from it by a prominent sandstone rim rock, is the Tullock member of the Lance. This member forms rough bare slopes, in striking contrast to the gentler topography of the Lebo. The character of the Tullock member in this township and the relative positions of the coal beds are shown by sections 16 and 17, Plate IV. In the valleys of West Bear and West Corral creeks the lower part of the Lance is exposed, but its outcrop is mostly covered by alluvium. The general dip of the strata in this township is less than 1° S. (See Pl. X.) This broad structure is modified by a gentle trough which plunges and dies out toward the south.

The Tullock member in this township contains seven coal beds that are thicker than 18 inches in one place or another—beds A, C, E, F, G, H, and I.

Bed A, the base of the Tullock member, is thicker than 18 inches in only one locality in the eastern part of the township. At location 361, at the head of West Corral Creek, the bed contains about 3½ feet of coal, but at location 364, a mile to the east, it is less than 18 inches thick. (See sections on Pl. XIII.) Location 361 represents the

thickest point of a lens which extends a considerable distance to the north and west but which feathers out very abruptly to the south and east. (See Pl. XIV.) Several other sections of bed A were measured on West Bear and West Beaver creeks, and all of them show the bed to be less than 18 inches thick (sections 369, 374, 385, 386, and 402, below). In the western part of the township bed A is not exposed, but from measurements made along its outcrop in the township to the west, it is inferred that the bed is thicker than 18 inches in small areas in the southwest and northwest corners of this township, as shown in Plate XIV.

Inasmuch as bed A is not well developed in most of the eastern part of this township, bed C, which is 35 feet above bed A, was used as a datum plane. Bed C is well exposed on the east side of the main ridge and may generally be recognized by the thick bed of bluish-black shale with which it is associated. Bed C is more than 18 inches thick only in the drainage basin of West Bear Creek. It is less than 18 inches thick at the head of West Bear Creek, but appears to become thicker toward the east, so that the thickest and most valuable part of the lens has been largely removed by the erosion of the valleys of West Bear and Sarpy creeks. (See Pl. XV.) Bed C was examined on West Corral Creek at a place below location 366, where it contains only 9 inches of coal. At location 368, however, the bed is about 2 feet thick, at locations 367 and 372 nearly 2½ feet, and at location 375 nearly 3 feet thick. Still farther southwest, at location 376, it is 29 inches thick, and at location 379 only 7 inches thick. (See Pl. XIII.) At the head of West Bear Creek the bed is less than 18 inches thick, and at location 388, on the south side of the creek, it contains but 20 inches of partly impure coal. East of this place as far as the township line the bed is 2½ to 3 feet thick, as shown by sections 389 to 393. (See below and Pl. XIII.) In sec. 14, on a small drain tributary to West Bear Creek, a prospect has been opened on bed C. The entry is now caved and could not be examined, but apparently it did not extend more than 30 feet into the hill. At location 399, on West Beaver Creek, the bed is only about a foot thick, though at location 400, a quarter of a mile to the southwest, it contains about 2 feet of coal. A short distance farther up the creek, however, it is less than 18 inches thick. The cover above bed C in this locality is in general from 50 to 200 feet thick. In the western part of the township bed C is not exposed, but measurements made along its outcrop in the township to the west indicate that the bed is more than 2 feet thick in secs. 6, 7, and 18. (See Pl. XV.)

Bed E is thicker than 18 inches in a small area on West Corral Creek, which includes secs. 2, 3, and 4 and extends also into the township to the north. The bed is thickest at the head of the creek, where

it contains almost 3 feet of coal (section 358, Pl. XIII). It becomes thinner to the east, and at locations 362 and 360 it is respectively about 2½ and 2 feet thick. At location 365 it contains 27 inches of coal, but it is badly broken by partings. (See sections below and in Pl. XIII.) It was examined farther down the creek near the east township line, where it carries but 8 inches of coal, and also on West Bear Creek at location 384, where it is about a foot thick.

Beds F and G, which are 10 feet apart, are slightly thicker than 18 inches in sec. 3. They are not found elsewhere in the township, and bed G was not recognized at any other locality in the field. Bed F at location 359 is about 2½ feet thick, but at location 354, just across the township line, it shows only 17 inches of coal. Bed G is about 2 feet thick at location 357, near the head of West Corral Creek, but at location 356, where the bed passes under the creek bottom, it is badly broken by partings. (See sections below and in Pl. XIII.) The area of each of these beds over 18 inches thick is therefore probably less than a quarter of a square mile.

Bed H, which is 27 feet above bed G, is more than 18 inches in thickness on the divide between West Bear and West Corral creeks. On the upper part of West Corral Creek the bed is less than 18 inches thick, but at locations 363 and 366 it contains about 2 and 2½ feet of coal, respectively. On the small outlier at the east end of the divide in the SE. ¼ sec. 1 the bed is only 15 inches thick, but at location 371, farther southwest, it is about 2½ feet thick. (See map, Pl. XI.) It maintains this thickness as far up West Bear Creek as location 377, but at location 380 it is only 15 inches thick. (See sections 363, 366, and 372, Pl. XIII, and sections 377 and 380, below.) It was also examined a mile farther up the creek, where it is but 8 inches thick. The portion of this bed thicker than 18 inches is therefore confined to secs. 1, 2, 11, and 12, and even in this area a considerable part of the coal is generally impure. Bed H was also examined at several places on the Tullock slope of the ridge. At location 228, in sec. 19, it contains 18 inches of coal, part of which is impure, and elsewhere its thickness is even smaller.

Bed I, the highest coal bed exposed in this township, is characteristically an impure bed, and its thickness fluctuates so irregularly that measurements along the outcrop have little significance unless plotted and contoured. As shown on Plate XVI, the bed is thicker than 18 inches in the western part of the township and also in two small areas on West Bear Creek. On East Burnt Creek, in the southwest corner of the township, the bed is between 20 and 28 inches thick at locations 212, 213, 214, and 216, but at location 215 it contains only 11 inches of coal. (See Pl. XIII.) At the head of the creek to the north it is not more than a foot thick (see sections 227, 229, and 230, below), although from observations in T. 4 N., R. 35 E., the bed is

thought to be thicker than 18 inches in a very narrow strip of land along the township line. At locations 253 and 255, on Lightning Creek, bed I is about 20 inches thick, but on the north side of the creek at location 256 it contains only 7 inches of coal. (See sections below.) In the northeastern part of the township bed I is workable in a small area at the end of the divide between West Corral and West Bear creeks. At location 370 (Pl. XIII), it is about 2½ feet thick, and at location 373, half a mile to the west, it is of smaller thickness, but is badly split by partings. At locations 378 and 381, farther up West Bear Creek, it is less than 18 inches thick. However, at locations 382 and 383, on the south side of the creek, it contains about 30 inches of coal, though badly broken by partings. At location 387, a mile to the east, the bed is less than 2 feet thick, and half a mile farther east it measures only 8 inches. Sections 383 and 387 are given on Plate XIII. Several sections measured farther down this creek show less than a foot of coal. On West Beaver Creek the bed was examined at several places; it is thickest at location 401, where it contains 19 inches of coal separated into seven benches. It is possible that the two small areas in the eastern part of the township are connected with the large lens in the southwest corner, but owing to the variable character of the bed its actual extent beneath the ridge is conjectural.

Sections of coal beds in T. 4 N., R. 36 E.

Location 213. SW. ¼ sec. 32 (bed I).

	Ft.	in.
Sandstone.		
Coal, impure		3
Coal	1	3
Bone		½
Coal, impure		3
Shale.		
	1	9½

Location 215. NW. ¼ sec. 32 (bed I).

	Ft.	in.
Shale.		
Coal		11
Shale, carbonaceous		4
Sandstone	5	
Bone		2
Coal		6
Shale, black		1
Coal		4
Shale, bluish		8
Coal		2
Shale, bluish.		
	8	2

Location 227. Center of sec. 30 (bed I).

	Ft.	in.
Shale.		
Shale, brown		2
Bone	1	3
Shale, brown		1
Shale.		
	1	6

Location 228. SW. ¼ sec. 19 (bed H).

	Ft.	in.
Sandstone.		
Coal, impure		6
Shale	3	
Bone		1
Coal, impure		4
Coal	1	2
Shale, brown.		
	5	1

Location 229. SW. ¼ sec. 19 (bed I).

	Ft.	in.
Shale, carbonaceous.		
Bone		2
Coal		3
Bone		1
Coal		7
Shale, brown.		
	1	1

Location 230. NW. ¼ sec. 19 (bed I).

Shale.	Ft.	in.
Coal and bone, banded		5
Coal, impure		7
Bone		1
Shale, brown.		
	1	1

Location 253. SW. ¼ sec. 18 (bed I).

Shale.	Ft.	in.
Shale, carbonaceous		1
Coal, impure	1	7
Bone		1
Shale, brown.		
	1	9

Location 254. NE. ¼ sec. 18 (bed K).

Shale.	Ft.	in.
Coal		1
Shale and bone		3
Coal		1
Bone		3
Coal	1	2
Shale, sandy		½
Shale.		
	1	10½

Location 255. NW. ¼ sec. 18 (bed I).

Shale.	Ft.	in.
Coal		2
Shale, brown		2
Coal	1	9
Bone		2
Coal		2
Shale.		
	2	5

Location 256. NW. ¼ sec. 18 (bed I).

Sandstone.	Ft.	in.
Coal, impure		7
Bone		2
Shale, brown		4
Shale.		
	1	1

Location 356. NE. ¼ sec. 4 (bed G).

Sandstone.	Ft.	in.
Coal		9
Bone		4
Shale		9
Coal		9
Shale, carbonaceous		11
Coal		11
Shale.		
	4	5

Location 360. NE. ¼ sec. 3 (bed E).

Shale.	Ft.	in.
Bone		4
Coal	1	1
Coal, impure		2
Coal		7
Sandstone		½
Coal		3
Bone		2
Shale, carbonaceous.		
	2	7½

Location 367. SE. ¼ sec. 1 (bed C).

Sandstone.	Ft.	in.
Shale, carbonaceous		6
Coal, impure		5
Shale, black	1	
Coal, impure	1	3
Coal	1	8
Base not exposed.		
	4	10

Location 369. NE. ¼ sec. 12 (bed A).

Shale.	Ft.	in.
Coal, impure		7
Shale, carbonaceous		8
Coal, impure		5
Shale, carbonaceous.		
	1	8

Location 372. NW. ¼ sec. 12 (bed C).

Shale, gray.	Ft.	in.
Bone		4
Coal		4
Shale, black		4
Coal		6
Shale		1
Coal		3
Coal, impure		6
Coal	1	3
Shale, carbonaceous	2	
	5	7

Location 373. SE. ¼ sec. 2 (bed I).

Sandstone.	Ft.	in.
Coal, impure		9
Shale, carbonaceous		2
Coal		7
Parting, sandy		½
Coal		6½
Shale, carbonaceous	1	2
Coal		7
Shale, carbonaceous.		
	3	10

Location 374. NE. ¼ sec. 11 (bed A).

Sandstone.	Ft.	in.
Coal	1	1
Shale	2	2
Coal	1	
Shale	2	
Coal		4
Shale		1
Coal		7
Shale.	7	3

Location 377. SW. ¼ sec. 11 (bed H and underlying strata).

Shale.	Ft.	in.
Bone		5
Coal, impure		6
Coal	1	2
Coal, impure		3
Coal		9
Shale, carbonaceous		6
Shale, gray	3	
Bone		10
Shale, gray	23	
Shale, carbonaceous	2	
Shale, gray	1	
Sandstone, hard	2	
Shale, yellow	6	
Coal		11
Shale	5	
Sandstone, soft, yellow	12	
Coal, impure		1
Sandstone, carbonaceous		½
Coal, impure		6
Sandstone, carbonaceous		½
Coal		9
Shale, carbonaceous.	60	8½

Location 378. SW. ¼ sec. 11 (bed I).

Shale.	Ft.	in.
Coal	1	
Coal, impure		5
Shale, carbonaceous		3
Coal		2
Bone		5
Shale, carbonaceous	1	
Shale.	3	3

Location 379. NW. ¼ sec. 14 (bed C).

Shale, sandy.	Ft.	in.
Coal		2
Sandstone, carbonaceous		½
Bone		4
Sandstone, carbonaceous		¾
Coal		7
Shale.	1	2¼

Location 380. SE. ¼ sec. 10 (bed H).

Shale, sandy.	Ft.	in.
Bone		8
Coal		7
Shale, carbonaceous		8
Coal	1	3
Shale.	3	2

Location 381. NE. ¼ sec. 16 (bed I).

Shale, sandy.	Ft.	in.
Bone		7
Shale, carbonaceous		3
Coal		7½
Shale, carbonaceous	1	1½
Coal		2
Bone		2
Shale		2
Bone		2
Coal		3
Shale, brown		1
Shale.	3	7

Location 382. SE. ¼ sec. 16 (bed I).

Sandstone.	Ft.	in.
Coal	1	5
Shale, black		5
Coal		1
Bone		2
Coal		4
Shale, brown		½
Coal		2
Shale, carbonaceous		2
Coal		6
Shale, brown		½
Shale, black		4
Shale, gray		3
Sandstone.	3	11

Location 384. NE. ¼ sec. 15 (bed E).

Shale.	Ft.	in.
Coal	1	½
Shale, brown		3
Coal		3
Parting, sandy		1
Coal		2
Shale, brown		5
Shale.		
	2	2½

Location 385. NE. ¼ sec. 15 (bed A).

Wash, sandy.	Ft.	in.
Shale, black		1¼
Coal		7½
Coal, impure		4
Coal		7
Shale		½
Bone		¾
Shale.		
	1	9

Location 386. NE. ¼ sec. 15 (bed A).

Shale.	Ft.	in.
Bone		1¼
Parting, sandy		1¼
Coal, impure		2
Shale		11
Coal		4½
Shale, carbonaceous		3
Shale.		
	1	11

Location 388. SW. ¼ sec. 14 (bed C).

Shale, carbonaceous.	Ft.	in.
Shale, black		5
Coal		8
Coal, impure		10
Parting, sandy		¼
Coal, impure		2
Bone		½
Shale, brown.		
	2	1¾

Location 391. SE. ¼ sec. 14 (bed C).

Shale.	Ft.	in.
Coal, impure		6
Coal	2	3
Shale.		
	2	9

Location 392. SW. ¼ sec. 13 (bed C).

Shale.	Ft.	in.
Coal		5
Parting, sandy		¼
Coal		9
Parting, shale		½
Coal		11
Bone		2
Coal		5
Parting, sandy		⅛
Coal		3
Parting, sandy		⅛
Coal		2
Shale.		
	3	2

Location 399. SE. ¼ sec. 24 (bed C).

Shale.	Ft.	in.
Coal		6
Bone		1½
Coal		7
Shale	6	
Coal		5
Coal, impure		5
Shale		1
Coal		4
Shale.		
	8	5½

Location 400. SW. ¼ sec. 24 (bed C).

Shale.	Ft.	in.
Shale, brown		2
Coal	1	1
Bone		4
Coal		1
Bone		1
Coal	1	2
Coal, impure		2
Shale.		
	3	1

Location 401. NW. ¼ sec. 26 (bed I).

	Ft.	in.
Shale.		
Coal		9
Shale, black		1½
Coal		2
Shale, carbonaceous		½
Coal		1
Bone		¼
Coal		1
Bone		¼
Coal		2
Bone		¼
Coal		3
Shale		¾
Coal		1½
Shale, black		2
Shale, sandy.		
	2	1

Location 402. SE. ¼ sec. 24 (bed A).

	Ft.	in.
Shale.		
Coal, impure		2
Parting, sandy		1½
Coal		9
Sandstone.		
	1	½

T. 5 N., R. 36 E.

T. 5 N., R. 36 E. lies at the northern extremity of the ridge between Sarpy and Tullock creeks. Boxelder Creek, which flows northward along the west township line directly into the Yellowstone, bisects the north end of the ridge. The east fork of the ridge therefore lies almost entirely within the township. It is extensively dissected by tributaries of Boxelder Creek on the west and Sarpy Creek on the east. The valleys of these subsidiary creeks are steep sided and have rather abrupt heads, particularly on the southern and western slopes, which are characteristically steeper throughout this region. The ridge tops are relatively flat, though in many localities they are broken into low, rounded, gravel-covered hills. The valley slopes carry a fair growth of small pine trees, but the ridge tops, though grass-covered, are practically bare of trees. In the northern and eastern parts of the township along the lower courses of the creeks there are narrow strips of flood plain suitable for farming, but most of the area is very rough. A fair road follows Boxelder Creek to the crest of the divide and renders the coal in the western part of the township comparatively accessible.

The basal part of the Lebo shale member of the Fort Union formation occupies the crest of the divide in the southwest corner of the township. The Tullock member of the Lance formation occurs in the rough upper slopes of the ridge, and the lower part of the Lance crops out in the lower country to the north and east. The Lebo shale is everywhere concealed by a thick mantle of Quaternary gravel, and in the central part of the township the gravel also rests directly on the Lance formation (Pl. VII, *A*). The gravel is constantly being carried down and reworked by the streams and is

therefore widely distributed elsewhere in the township. The relations of geology to topography in this township have been described in connection with Figure 2 (p. 6).

This township lies on the lower slope of a large, gentle dome that dominates the structure in the northern part of the field, and the strata have a general southerly dip of about 50 feet to the mile. (See Pl. X.) The outcrop of the Tullock member around the north end of the divide is therefore shortened by this dip; the coal crops out near the crest of the divide in sec. 21, whereas on the south township line it is exposed in the beds of the ravines. The character of the Tullock member in this vicinity is shown by sections 13 to 15 on Plate IV. Measurements made at several places in this township indicate that the thickness of the member is 296 feet. It contains four coal beds more than 18 inches thick—beds A, E, H, and I.

Bed A, the base of the Tullock member, was traced from the head of Boxelder Creek around the north end of the ridge to West Corral Creek. (See Pl. XI.) At location 321, close to the point where the outcrop of the bed enters the township, it is 17 inches thick, but at location 322, half a mile to the south, it is about 2 feet thick. Still farther south, at locations 323 and 327, it is less than 18 inches thick, but section 328, measured farther north on the east side of the creek, shows a thickness of 2 feet. The bed is thus more than 18 inches thick in a narrow belt crossing Boxelder Creek in secs. 19 and 20, and around the end of the ridge north of this zone it is less than 18 inches thick (sections 322, 323, 328, Pl. XIII, and 321, 327, and 329, below). In sec. 16, near the north end of the ridge, bed A is cut out by an east-west stream channel about 90 feet deep, now filled with Quaternary gravel. At location 331, on the east side of the ridge, the bed is slightly more than 18 inches thick, and southward from this place it increases in thickness. (See sections 331, 332, 333, 337, 342, 347, and 351, Pl. XIII, and 335, 338, 340, 344, and 352, below.) At locations 342, 344, and 347 the bed is about 30 inches thick. At locations 351 and 352 it contains a little over 3 feet of coal, nearly half of which is impure. The shape of the workable portion of this bed and its extension into the township to the south is shown on Plate XIV.

In the N. ½ sec. 26 there is an isolated group of gravel-covered hills which are about high enough to contain bed A. Owing to the slumping of the gravel on the slopes of these hills, it is impossible definitely to ascertain the presence or absence of the bed. At one point, however, a vertical section of consolidated gravel 40 feet thick is exposed, and if the gravel is everywhere of this thickness, bed A has undoubtedly been replaced by it. If the gravel is thinner on the highest points of the hills, small areas of the bed

may remain, and measurements to the west indicate that if so the bed is 2½ feet or more thick. (See Pl. XIV.) These remarks are applicable also to two isolated hills near the north quarter corner of sec. 27.

Bed E is about 80 feet above bed A and is of value only in the valley of West Corral Creek. The bed was examined at several places in the valley of the stream to the north and was found to be less than a foot thick. (See, for example, section 339, Pl. XIII.) At location 341, however, it is over 2 feet thick, and at locations 343 and 350 a little less than 2 feet. At location 355, where its outcrop passes out of the township, it is nearly 3 feet thick. (See sections on Pl. XIII.) The bed is also fairly thick on the south side of West Corral Creek, as described under T. 4 N., R. 36 E.

Bed H is thicker than 18 inches only in a small area on West Corral Creek. At location 349 the bed contains nearly 5 feet of coal, separated into five benches by partings. At location 345, about 1,000 feet to the east, it is only 16 inches thick, and at location 353, half a mile to the west, the bed is so badly broken by partings that it is not considered profitable to mine under present conditions. (See sections on Pl. XIII.)

Bed I was examined at a number of places in this township and was found to be variable in character as well as in thickness. In many places it is several feet thick but is composed so largely of bone and black shale that it is of no value. At location 324, however, the bed has a net thickness of 20 inches of coal, but several other sections measured in this vicinity show thicknesses of less than 18 inches. (See section 324, Pl. XIII, and sections 317 and 325, below.) On the west fork of Boxelder Creek in sec. 30 the bed is probably thicker than 18 inches in a very small area, as shown by sections 316 and 318 (described under T. 5 N., R. 35 E.). At location 326, in sec. 29, the bed is about 18 inches thick, and at location 330 it contains almost 2 feet of impure coal. At location 334 bed I contains more than 2 feet of good coal, but on the neighboring ridge only a few inches of coal is exposed at this horizon. (See sections, Pl. XIII.) On West Corral Creek, at location 346, bed I is 22 inches thick; but a short distance away, at location 348, the bed consists chiefly of bone and shale. (See sections below.) Bed I was also examined at a number of other localities, where it contained only a few inches of coal.

Bed C was identified and examined at several places in this township but was found to be less than 18 inches thick. Bed F, which is more than 18 inches thick in the northern part of sec. 3, T. 4 N., R. 36 E., was examined at location 354, just north of the township line, and was found to contain but 17 inches of coal. (See sections below.)

Sections of coal beds in T. 5 N., R. 36 E.

Location 317. NW. ¼ sec. 31 (bed I).

	Ft.	in.
Shale.		
Coal		3
Shale, carbonaceous	1	2
Coal		4
Shale, carbonaceous		10
Shale.		
	2	7

Location 321. NW. ¼ sec. 19 (bed A).

	Ft.	in.
Shale.		
Coal, impure		2
Bone		1
Parting, sandy		1
Coal		2
Bone		2
Coal	1	5
Shale.		
	2	1

Location 325. SW. ¼ sec. 29 (bed I).

	Ft.	in.
Shale.		
Coal		8
Bone		5
Coal, impure		6
Coal		5
Bone		1
Coal		5½
Shale.		
	2	6½

Location 327. NW. ¼ sec. 29 (bed A).

	Ft.	in.
Shale.		
Bone		1
Parting, sandy		1
Coal	1	
Shale, brown		6
Coal		9
Shale.		
	2	5

Location 329. NW. ¼ sec. 20 (bed A).

	Ft.	in.
Shale.		
Coal, impure		3
Parting, sandy		3
Shale, brown		6
Shale, gray	5	6
Coal, impure		8
Shale, brown		3
Shale.		
	7	5

Location 335. SW. ¼ sec. 21 (bed A).

	Ft.	in.
Shale.		
Coal, impure		3
Parting, sandy		¾
Coal		10
Bone		½
Coal	1	3
Shale, brown.		
	2	5¼

Location 336. NW. ¼ sec. 28 (bed I).

	Ft.	in.
Sandstone.		
Bone		5
Shale, brown		7
Bone		7
Shale, carbonaceous		1
Shale, brown and gray	1	1
Coal, impure		7
Bone		1
Coal		10
Bone		3
Coal		3
Shale.		
	4	9

Location 338. NE. ¼ sec. 28 (bed A).

	Ft.	in.
Shale, gray.		
Coal, impure		3
Parting, sandy		1
Coal	2	5
Bone		3
Shale.		
	3	

Location 340. SW. ¼ sec. 27 (bed A).

	Ft.	in.
Shale.		
Bone		3
Shale, carbonaceous	1	3
Coal		3
Parting, sandy		1
Coal	2	5
Shale.		
	4	3

Location 344. NE. ¼ sec. 34 (bed A).

	Ft.	in.
Shale.		
Coal, impure		3
Parting, sandy		1
Coal, impure		3
Coal	2	4
Shale.		
	2	11

Location 346. NW. ¼ sec. 34 (bed I).

Shale.	Ft.	in.
Coal		7
Shale, sandy	2	6
Coal	1	10
Shale.		
	4	11

Location 348. NW. ¼ sec. 34 (bed I).

Shale.	Ft.	in.
Shale, carbonaceous		6
Bone		3
Coal		2
Shale, carbonaceous		6
Shale.		
	1	5

Location 352. SW. ¼ sec. 34 (bed A).

Shale.	Ft.	in.
Coal, impure		4
Parting, sandy		1¼
Coal, impure		5
Coal	1	
Shale, carbonaceous		1
Coal		5
Coal		7
Shale, carbonaceous		5
Coal		9
Shale.		
	4	1¼

Location 354. SE. ¼ sec. 33 (bed F).

Shale.	Ft.	in.
Coal		3
Shale, carbonaceous		2
Coal	1	2
Shale, carbonaceous.		
	1	7

T. 6 N., R. 36 E.

The flood plain of Yellowstone River occupies the north half of T. 6 N., R. 36 E., and practically all of this land is under cultivation. The Northern Pacific Railway crosses this township, and the town of Hysham is near the place where the railway crosses Boxelder Creek in sec. 9. The southern limit of the flood plain is marked by rounded gravel-covered hills. This zone is underlain by Bearpaw shale; as shown on Plate X, it is almost 4 miles wide in the eastern part of the township, though less than half a mile wide in the western part. South of this belt the lower or non coal-bearing portion of the Lance formation rises in a series of steep rock terraces and constitutes the surface rock as far south as the township line. The strata in this township dip to the south and southwest, at angles of about 1½°, as shown on Plate X. The areal distribution of the formations is controlled partly by the southwesterly dip and partly by the erosion of the wide valley of Sarpy Creek. A fault having a downthrow of 150 feet to the south was observed in sec. 35.

T. 7 N., R. 36 E.

Only a small part of the southern edge of T. 7 N., R. 36 E., lies south of Yellowstone River and is included in the area examined. This part of the township consists entirely of flood plain and is covered by alluvium.

T. 1 S., R. 37 E.

Only the northern tier of sections in T. 1 S., R. 37 E., or that portion lying outside of the Crow Indian Reservation, was examined. Sarpy Creek flows north through sec. 2, and east of the creek the upper division of the Fort Union, baked and clinkered by the burning of the coal, rises in a steep but dissected escarpment. The western part of the township is underlain by the Lebo shale member of the Fort Union and is a grass-covered plain rising gently to the south. It is broken by a few clinker buttes that rise abruptly several hundred feet above its general level.

Because of the extent to which the coal beds have burned on the outcrop in the small portion of this township examined, it was impossible to obtain complete sections of any of the thicker beds. The horizon of bed M, which lies about 125 feet above the base of the upper division of the Fort Union, is everywhere marked by a heavy band of clinker, and from measurements made in the township to the north this bed is believed to be 6 to 8 feet thick. Bed O was observed only at location 112, on the high butte in secs. 5 and 6. The bottom of the bed at this place is not exposed, but it is probably less than 2 feet thick. It is partly burned and is overlain by brown shale. This bed is believed to be absent farther east. Bed P lies near the top of the dissected plateau formed by the same part of the Fort Union formation, and the heavy clinker produced by its burning fringes the edge of the plateau and caps the higher buttes. The bed is not exposed in this township, but from observations in the township to the north it is believed to be 12 to 14 feet thick. (See Pl. XV.) Bed Q is represented by a small mass of clinker in sec. 1, but elsewhere all trace of the bed has been removed by erosion.

T. 1 N., R. 37 E.

Sarpy Creek flows northward through the middle of T. 1 N., R. 37 E., and is joined by East Sarpy Creek about a mile beyond the north township line. The flat-bottomed and fertile valleys of these streams are bordered by steep slopes, which generally rise almost sheer to a height of 100 to 250 feet and are colored red by the baked rocks and clinker. At the top of these slopes is a grass-covered and rolling upland, which rises gradually toward the east and west township lines. Spring Creek and the other tributaries of Sarpy Creek in the western part of the township occupy steep-sided but fairly flat-bottomed valleys which have only moderately dissected this plateau. The general course of these creeks is east, but near their sources they flow almost north, or parallel to the Sarpy-Tullock divide. (See Pl. XI.) This arrangement of valleys has given rise to a curious deep channel or trough within a mile of the crest of the divide,

on either side of which the land is much higher, a condition which strongly suggests ancient stream piracy. It is probable that Pleasant Creek originally had its source in the southern part of the township and flowed northward along the township line, and that these two younger and more vigorous creeks worked back until they captured nearly half its drainage. A study of the map (Pl. XI) suggests several other but less clearly defined cases of stream capture in this and adjacent townships. On the east side of Sarpy Creek the upland is more extensively dissected, and in the northeast corner of the township, near the mouth of East Sarpy Creek, the country is extremely rough. On the valley slopes of all the larger creeks and in the small coulees that are cutting back into the upland there is an abundant growth of pine trees. In places the growth is very thick, and some of the trees measure as much as 18 to 24 inches at the butt. There is a good road through the valley of Sarpy Creek, and three side trails follow the courses of its tributaries and cross the divides (Pl. X).

The Fort Union formation is exposed throughout this township, the upper division of the formation cropping out everywhere except in the valleys of the larger creeks. There is a persistent sandstone 30 to 100 feet thick near the base of this division, and another thick sandstone about 75 feet above. (See Pl. V, *A*.) The resistance to erosion of the lower part of the upper division is further increased by the fact that the thick coal beds M and P are almost everywhere burned on the outcrop. The burning has baked and clinkered the adjacent strata and given rise to the very resistant material that forms the steep slopes along the stream valleys. The outcrop of the Lebo shale member is confined to the creek valleys and is therefore almost entirely covered by alluvium.

This township lies near the edge of the zone of structural depression which trends southeastward across the field and which, in this area, plunges to the southeast. The structure is not entirely regular, however, and, as shown on Plate X, there are minor variations. The most pronounced is a gentle anticline whose limbs dip ½°–1° and which extend southeastward across Sarpy Creek in the northeast corner of the township. Sharp local dips were observed at several places; at the head of Spring Creek on the west township line a local dip of 4° NE. was observed, and in sec. 23, on the east side of Sarpy Creek, there is a local dip of 8° SE. These dips appear to have no appreciable effect on the general structure, as shown by 50-contour lines on Plate X, and it is possible, as stated above under "Structure," that such local irregular dips are compensated by faults of the type found elsewhere in this structural zone. (See Fig. 3, p. 52.)

Owing to the great extent to which the coal has burned in this township the geology is difficult to decipher. The hills along each

creek and side coulee are covered with a mass of clinker, some of it evidently in place but most of it entirely broken up in such a way as to indicate that it may have been originally at a much higher level and have reached its present position by slumping down concomitantly with the erosion of the hill. The geology is further obscured by the grassy character of much of the surface and by the fairly thick growth of pine trees which covers the slopes of the hills. In a few localities, however, the heavy continuous mantle of clinker resolves itself into two separate bands; and it was by observation in these places that the existence of the two thick coal beds described below was first determined. In this district the upper clinker generally forms the capping of the hills, and it is evident that as erosion progressed this clinker slumped down until in many places in the creek valleys the two clinkers have apparently coalesced. Where there is still an unburned interval between the two beds of clinker, it is generally covered by the débris of the upper bed, and as there are few actual exposures of the beds themselves in this township, it is only by the study of a few critical localities that the thick burned mass may be correctly interpreted. The exposures leave much to be inferred concerning the thickness and regularity of the beds, and the information set forth below represents merely the best judgment of the writers on a more or less obscure subject.

Bed M, the lowest coal in the upper division of the Fort Union, crops out in the sides of the stream valleys as described above. On the west side of Sarpy Creek the heavy basal sandstone of this division forms the base of these slopes, and the clinker of bed M commonly crops out at about their middle. Above it another thick sandstone is exposed, and the cliffs are capped by the clinker of bed P. The horizon of bed M is thus plainly marked, but actual sections can be measured at only a few places. A section of part of the bed, showing only about 2½ feet of coal, was made at location 438, in sec. 7, and incomplete sections at locations 439 and 440, on the west township line, show about 9 feet. At location 442, in the southwest corner of sec. 16, the bed contains 17 feet of good coal and 2 feet of partly burned coal. At location 443 it is nearly 15 feet thick, and at locations 444 and 445, on the west township line, about 18 feet thick. At location 446 the bed is nearly 17 feet thick, but in the southern part of the township, at location 449, it is only 10 feet. All these sections are shown graphically on Plate XII.

On the east side of Sarpy Creek bed M seems to vary considerably within short distances. The most striking example of this variation is seen in sec. 11. At location 467 a section of part of the bed shows more than 7 feet of coal, with a concealed space of 5 feet below and 10 inches of burned material at the base, indicating a probable total of more than 12 feet of coal. At location 469, 2,000 feet away, the

bed consists of 9 feet of black carbonaceous shale and 20 inches of ash. (See sections below.) The ash in this section 468 may represent a foot or so of coal, but the remainder of the section indicates that most of the coal has been replaced by shale. Similar conditions were observed in secs. 21 and 23 and are suggested in some other localities by the disappearance of the thick band of clinker that normally marks the horizon of the bed. This abrupt replacement of coal by black shale is probably due to the existence of old channels in the coal swamp, which introduced a considerable amount of black mud; it is therefore thought to be only a local development.

At location 450, in sec. 34, bed M consists of 3 feet of ash and about 5 feet of carbonaceous shale, but at location 461, 2 miles to the north, a section of part of the bed shows 14 feet of impure coal. At locations 462 and 463, however, only 3 feet of ash or partly burned coal with several feet of black shale was found. The thickness of black shale at these places suggests channeling, but the presence of 3 feet of ash indicates that the coal is only partly replaced, if at all. At location 465 the bed contains nearly 17 feet of good coal and 6 feet of impure coal; this is the greatest thickness actually recorded in the field. The abrupt variation between sections 467 and 468 has been considered above. At location 470, on East Sarpy Creek, the bed contains over 19 feet of good coal and 1 foot of burned material. (See sections 465 and 470, Pl. XII, and 450, 461, 462, 463, below.) At location 480, on the north township line, a section of a part of the bed shows 15 feet of coal. (See Pl. XII.) The writers' interpretation of these measurements is given on Plate XIV, which shows the broad variation in thickness of the bed but disregards the abrupt variation due to channeling.

The clinker of bed P generally caps the bluffs that inclose the valleys in this township. Being directly exposed to erosion, the clinker is commonly broken up and badly slumped, and the exact horizon of the bed is therefore difficult to determine. Moreover, bed P is very thick, generally consisting of several benches, and where unburned it commonly crops out on gentle grassy slopes. Although one or more of the benches may be exposed, complete sections of the bed are very rare. In general, the bed is entirely burned out for a considerable distance back from the top of the bluffs, and in the western part of the township especially the location of the unburned coal can be only approximately mapped. In the center of the upland between Spring Creek and the creek to the south there is a considerable area free from clinker which is probably underlain by this bed (see map, Pl. XI), although no trace of the coal is visible on the surface. A similar condition exists on the north divide of Spring Creek, where the inferred location of the unburned coal is also roughly mapped. On the upland in the southwest corner of

the township, however, the bed underlies a considerable area, as shown on Plate XI. At location 448 5½ feet of coal and 1 foot of burned material is exposed, but this may represent only one bench. At location 447, however, the bed is over 14 feet thick. (See Pl. XII.) In all these localities the coal is under a cover of less than 50 feet. Along the west township line runs the irregular trough described above, in which bed P is eroded or almost entirely burned out and which therefore leaves areas to the east as outliers. The only section of the entire bed procured in this district was made at location 441, in the SE. ¼ sec. 13, T. 1 N., R. 36 E. Here the bed contains about 21 feet of coal, 7½ feet of which is impure; and below this are four thin benches from 6 to 22 inches thick.

On the east side of Sarpy Creek bed P is less extensively burned and, owing to the general southeasterly dip in this township, is under thicker cover. The line shown on the map (Pl. XI) represents the outcrop of the clinker formed by the bed, but as the cover behind the outcrop is generally thick it is probable that the burning has not extended more than a few hundred feet back from the outcrop. Bed P at location 451, in sec. 34, contains about 14 feet of coal, some of which is partly burned. (See section 451, Pl. XII.) A section of part of the bed obtained at location 452 shows more than 6 feet of coal and another at location 453 more than 10 feet. At location 460 more than 10 feet of coal at the base of the bed was measured, and at locality 466, in sec. 14, the base of the partly burned bed is exposed, consisting of more than 2½ feet of coal and 9 inches of ash. At location 469, in sec. 12, more than 9 feet of coal at the top of the bed was measured, but the bottom was not uncovered. (See sections 452, 543, 460, 466, and 469, below.) The only section that is even apparently complete taken in this township on the east side of Sarpy Creek is therefore section 451, showing about 14 feet of coal.

In the construction of the map showing lines of equal thickness of bed P (Pl. XV), the only measurements used in this township are those at locations 447 and 451; the other sections are taken to indicate merely that the bed is thicker than the actual measurements show.

Bed Q underlies only a small area along the east township line, being elsewhere removed by erosion. The bed is extensively burned, and the district lying between its outcrop as shown on Plate XI and the outcrop of bed P is covered with small mounds of clinker formed by its burning. At locations 454 and 464 the bed is about 3½ feet thick, but farther east, at location 472, it is only 3 feet thick. (See sections below.) At location 454 in sec. 36, the bed is only 10 feet above bed P, whereas 2 miles farther north it is about 30 feet above.

As already stated, bed P is generally made up of several benches or small beds, and it is possible that the bed called Q at location 454 is in reality only an upper bench of bed P. If the coal exposed at this point is correctly correlated with that mapped as bed Q farther north, then bed Q may be considered an offshoot of bed P, but south of location 454 all trace of bed Q disappears and no further data on its relations could be gathered.

The coal in beds M, P, and Q is for the most part of excellent quality, and the beds are generally free from partings. The abundance of small and medium-sized pine trees in this township would be favorable to mining, and in secs. 24 and 25, especially, the trees are very thick. Sarpy and East Sarpy creeks are perennial streams and furnish a moderate supply of water. This township is about 35 miles from the Northern Pacific Railway, and the length of this haul precludes profitable mining at the present time; but the abundance of coal in this township and the area to the southeast may before long warrant the construction of a railroad in the valley of Sarpy Creek.

Sections of coal beds in T. 1 N., R. 37 E.

Location 438. SE. ¼ sec. 7 (bed M).

	Ft.	in.
Shale, carbonaceous	1	1
Coal, impure		9
Coal		10
Coal, impure		7
Bone		6
Coal	1	6+
Base not exposed.		
	5	3+

Location 448. NW. ¼ sec. 31 (bed P).

Shale.	Ft.	in.
Burned material	1	
Coal	3	5
Shale, brown		1
Coal	1	11
Shale, gray.		
	6	5

Location 450. SW. ¼ sec. 34 (bed M).

Shale.	Ft.	in.
Shale, carbonaceous	3	
Ash	3	
Shale	2	
Shale, carbonaceous	2	
	10	

Location 452. SE. ¼ sec. 36 (bed P).

Alluvium (top of bed eroded).	Ft.	in.
Coal, impure		10+
Shale		8
Shale, carbonaceous		10
Shale, sandy		3
Coal, very impure	1	6
Not exposed	3	9
Coal	3	7
Bone		2½
Coal (base not exposed)	1	10+
	13	5½

Location 453. SE. ¼ sec. 36 (bed P).

Shale.	Ft.	in.
Coal		10
Shale	5	
Coal, impure		5
Coal	2	6
Shale		2
Coal	4	8
Bone		2
Coal (base not exposed)	2	7+
	16	4+

Location 454. NE. ¼ sec. 36 (bed Q).

	Ft.	in.
Sandstone.		
Shale, carbonaceous	1	1
Coal, impure	1	
Coal	2	10
Shale.		
	4	11

Location 460. SW. ¼ sec. 26 (bed P).

	Ft.	in.
Alluvium.		
Coal	10+	
Shale	1	
Coal		10
Shale, brown.		
	11	10+

Location 461. NE. ¼ sec. 27 (bed M).

	Ft.	in.
Shale.		
Coal, impure	13	7
Bone		2
Coal		6+
	14	3+

Location 462. NE. ¼ sec. 22 (bed M).

	Ft.	in.
Shale.		
Ash	3	
Shale, carbonaceous.		

Location 463. SW. ¼ sec. 23 (bed M).

	Ft.	in.
Shale.		
Coal, burned	3	
Shale.		

Location 464. NE. ¼ sec. 23 (bed Q).

	Ft.	in.
Shale.		
Coal		1
Shale, brown		2
Coal		6
Shale, carbonaceous		1
Shale.		
	3	10

Location 466. NE. ¼ sec. 14 (bed P).

	Ft.	in.
Clinker.		
Bone		10+
Coal		8
Bone		7
Shale		4
Bone		6
Shale	2	7
Coal		5
Shale, carbonaceous		2
Coal	2	5
Coal and ash		9
Shale, carbonaceous		3
Coal		5
Shale.		
	9	11+

Location 467. SW. ¼ sec. 11 (bed M).

	Ft.	in.
Shale, sandy.		
Shale, carbonaceous		6
Shale	1	5
Bone		6
Coal	1	10
Bone		5
Coal		3
Shale		7
Bone		11
Coal		3
Coal, impure	2	1
Coal	5	2+
Concealed	5	
Bone or coal, burned		10
	19	9

Location 468. NE. ¼ sec. 10 (bed M).

	Ft.	in.
Shale, black, impure	8	2
Shale, brown		8
Ash	1	
Shale		5
Ash		8
Shale.		
	10	11

Location 469. NW. ¼ sec. 12 (bed P).

	Ft.	in.
Shale, sandy.		
Shale, cabonaceous		11
Bone		4
Coal	2	10
Coal, impure		7
Coal		4
Coal, impure	1	5
Coal	4	+
	10	5+

Location 472. SE. ¼ sec. 24 (bed Q).

	Ft.	in.
Shale.		
Shale, carbonaceous		1
Coal, impure		3
Coal		4
Coal	2	6
Bone		4
Shale.		
	3	6

T. 2 N., R. 37 E.

Sarpy Creek flows northward across T. 2 N., R. 37 E., and is joined by East Sarpy Creek in the southern part of the township. The western part of the township is a relatively gentle plain, broken here and there by small areas of badlands. East of Sarpy Creek the same topography prevails for about 2 miles, but along the eastern margin of the township there is an abrupt serrated escarpment more than 250 feet high, fringed by outlying buttes. In the valleys of Sarpy and Horse creeks there is considerable land suitable for agriculture, but in the western part of the township the soil is not fertile. The steep slopes in the eastern part of the area are clothed by a comparatively heavy growth of pine trees, but elsewhere trees are practically lacking except for a few cottonwoods in the creek valleys. There is a good road along Sarpy Creek, and secondary roads following Pleasant and Horse creeks afford communications with Tullock Valley on the west and Armells Valley on the east.

The steep slopes in the eastern part of the township are formed by the outcrop of the upper divisions of the Fort Union, which is extensively baked by the burning of the coal. The topography in this area is mature, and the country is very rough. The character of this division of the formation is shown by stratigraphic section 22, Plate IV, which was measured in sec. 24. The Lebo shale member of the Fort Union crops out in the greater part of the township and forms the gently sloping plain and the badlands mentioned above. No coal beds more than a foot thick were observed in the Lebo in this township, but owing to the character of the surface a small coal lens of the type found elsewhere in these strata might well escape observation. The Tullock member of the Lance formation crops out in the valley of Sarpy Creek in the northern part of the township, where it is mostly covered by alluvium. This township lies in the structural trough which crosses the whole field and within which the strata are thrown into an irregular series of minor folds. A small anticline extends southeastward across the southwest corner of the township, and the general dip in this area is therefore to the northeast. (See Pl. X.) Two small faults were observed on this anticline in secs. 31 and 32.

The horizon of bed M is at about the middle of the high slopes in the eastern part of the township, but the bed is almost everywhere burned on the outcrop, and only a few sections were procured. At location 484 the bed contains 15 feet of coal in one bench and 2 feet in the other. At location 485, on East Sarpy Creek, a section of the lower part of the bed showing 7½ feet of coal was obtained. At locations 487 and 489, on the south side of Horse Creek, the bed is 14 feet thick, but at location 487 3 feet of this coal is impure. (See

sections 484, 487, and 489, Pl. XII.) At location 498, on the north side of the creek, nearly 8 feet of coal is exposed; the entire thickness of the bed does not appear at this place, but measurements made to the north and east indicate that the bed is probably only slightly thicker than 8 feet. Bed M also caps a small butte in the southwest corner of the township, where at location 434 it contains about 6 feet of coal. (See sections 498 and 434, below.) Half the coal is partly burned, however, and the section is not considered representative. The probable variation in thickness of bed M is shown on Plate XIV.

Bed N was identified in this township but is of very minor importance. It is 23 inches thick at location 496, on the north side of Horse Creek, but at location 497 it contains 15 inches of coal and at location 499 only 5 inches (section 496, Pl. XII, and sections 497 and 499, below). A lenticular bed that is doubtfully correlated with bed N was observed in sec. 36. At location 481 (Pl. XII) it is 3 feet thick, but a short distance on either side of this place the bed disappears.

Bed P lies near the top of the slopes in this township and is nearly everywhere burned. In the southeast corner of the township it is probably over 20 feet thick and consists of two benches or beds, as shown by section 483, made in sec. 30, T. 2 N., R. 38 E. At location 486 the bed contains 14 feet of coal, and a bed 13 feet below, which probably represents the lower division at location 483, is 2 feet thick. From this place the bed thins very rapidly to the north, and at location 488, on Horse Creek, it is only about 7 feet thick, although because of slumping this measurement may be a foot or so short. (See sections 483, 486, 488, Pl. XII.) The heavy clinker formed by the burning of this bed in the district south of Horse Creek has no counterpart in the area north of the creek, and no bed at this horizon could be found. Bed P is therefore believed to be less than 18 inches thick in this township north of Horse Creek. (See Pl. XV.)

Bed Q underlies a few small areas in the southeast corner of the township, where it is under thin cover. The bed is not exposed to measurement in this district, but sections made in T. 2 N., R. 38 E., indicate that it averages about 6 feet in thickness. (See Pl. XVI.)

Sections of coal beds in T. 2 N., R. 37 E.

Location 434. NW. ¼ sec. 32 (bed M).

	Ft.	in.
Shale, sandy.		
Coal	1	1
Coal, impure		4
Coal	1	8
Coal, partly burned	3+	
	6	1+

Location 485. NE. ¼ sec. 35 (bed M).

	Ft.	in.
Alluvium (top of bed eroded).		
Coal	7	6+
Shale.		

Location 497. NE. ¼ sec. 11 (bed N).

	Ft.	in.
Sandstone.		
Coal	1	3
Shale, carbonaceous.		

Location 498. NW. ¼ sec. 11 (bed M).

	Ft.	in.
Shale.		
Coal	7	10+

Location 499. SE. ¼ sec. 1 (bed N).

	Ft.	in.
Shale, carbonaceous.		
Coal		5
Bone		3
Sandstone.		
		8

T. 3 N., R. 37 E.

Sarpy Creek flows northward through the middle of T. 3 N., R. 37 E. In the southern part of the township the creek occupies a shallow box canyon, but in the northern part the valley is wider and its slopes considerably higher. The upland at the top of the steep valley slopes is a dissected plain, broken into tracts of badlands here and there in the southern part of the township. The bottom land in the valley of Sarpy Creek is all under cultivation, and there is some land suitable for agriculture in the lower valleys of East and West Passage creeks. A good road follows Sarpy Valley, and a side trail leading to Whiskey Butte ascends the steep spur between West Passage and Rainwater creeks.

The basal sandstone of the upper division of the Fort Union formation underlies a small area in the southeast corner of this township, but the Lebo shale member of the Fort Union is exposed in more than half of the township. Quaternary gravel overlies the Lebo in the northern and central parts of the township but is absent in the southern part. The gravel modifies and decreases the action of erosive agents on this soft shale, and when thus protected the Lebo commonly forms a gently sloping, sparsely grass-covered surface. In the southern part of the township, however, it is directly exposed to erosion and tends to form badlands. The Tullock member of the Lance formation is exposed in the valley of Sarpy Creek and forms the steep, rocky walls of the valley. In the southern part of the township the prominent rim rock at the top of this member is only about 50 feet above the creek and forms a shallow box canyon that constricts the flood plain to a width of less than 1,000 feet. The lower part of the Lance crops out on Sarpy Creek in the northern part of the township, but it is mostly concealed by alluvium.

This township lies near the foot of the gentle dome that controls the structure in the northern part of the field, and the general dip is therefore to the south. (See Pl. X.) The township borders on the structural trough that separates this dome from that in the southwest

corner of the field, however, and the strata are rather irregularly warped. The eastern extremity of the belt of faults that crosses the Sarpy-Tullock divide near Whiskey Butte is marked in this township by a block fault on the ridge between West Passage and Rainwater creeks. The maximum displacement is 100 feet. Several very small faults were observed elsewhere on the west side of Sarpy Creek, but on the east side there are no faults, and the conspicuous rim rock at the top of the Lance formation crops out without a break the whole length of the township.

No workable coal was observed in the Lebo shale member of the Fort Union in this township, and practically none in the Tullock member of the Lance. The Lebo shale is partly concealed by gravel, but the Tullock member is everywhere well exposed and was carefully examined. The only locality in which coal beds more than a foot thick were observed is in secs. 2 and 3. Bed C at locations 520 and 522 is 15 and 12 inches thick, respectively (see sections below), but sections made on East Beaver Creek, just north of the township line, show a thickness of 22 inches. The bed is therefore probably thicker than 18 inches in a small area within this township, as shown on Plate XV. Bed D is also 22 inches thick at location 523, just north of the township line, and is doubtless thicker than 18 inches in a small area to the south. However, at location 519, half a mile south of the line, it is only 16 inches thick. Below location 523 there is a bed of coal 8 inches thick with a 1-inch sandy parting, at the approximate horizon of bed A. This is one of the few places east of Sarpy Creek at which bed A was identified.

Sections of coal beds in T. 3 N., R. 37 E.

Location 519. SW. ¼ sec. 3 (bed D).

	Ft.	in.
Shale.		
Coal		9
Parting, sandy		¼
Coal		7
Shale, brown.		
	1	4¼

Location 520. NW. ¼ sec. 3 (bed C).

	Ft.	in.
Shale.		
Coal		6
Shale		½
Coal		9½
Shale, black		1
Shale		1
Shale, carbonaceous		2
Shale, brown.		
	2	8

Location 522. NE. ¼ sec. 2 (bed C).

	Ft.	in.
Shale.		
Bone		3
Coal	1	
Shale.		
	1	3

T. 4 N., R. 37 E.

Sarpy Creek flows northward through the center of T. 4 N., R. 37 E., and receives the drainage of four large tributaries—East and West Beaver creeks in the southern part and East and West Bear creeks in the northern part. Except for the narrow strips of flood plain along these creeks, and for small areas of flat upland in the southeast and southwest corners of the township, the land is everywhere broken and the topography very rough. The southern and western slopes are decidedly more steep and bare than those facing the north and east; this difference is perceptible throughout the field but is especially conspicuous in this township. A county road follows Sarpy Valley, and secondary roads lead eastward across the divide by way of East Beaver and East Bear creeks.

The Lebo shale member of the Fort Union formation, the Tullock member of the Lance formation, and the lower part of the Lance crop out in this township. (See Pl. X.) The Lebo caps the ridges in the southwest and southeast corners of the township, where it forms a relatively flat upland, though only a few feet of its basal portion remains. The Lebo shale is overlain by 25 feet or more of Quaternary gravel, and similar gravel, presumably carried down from this level, covers most of the lower ridges as well. This gravel is constantly being reworked and carried still farther down, and most of the smaller streams are choked with it. Below the Lebo the Tullock member of the Lance crops out in characteristic steep slopes, and farther down toward the main valley the lower part of the Lance is exposed.

The character and complete thickness of the Tullock member are shown by stratigraphic section 18, Plate IV. Coal bed A, the base of the member, is less than 18 inches thick everywhere in this township and was positively identified at only one place, location 398, on West Beaver Creek. (See section below.) The lower part of the Lance consists of greenish-gray shale and thick-bedded sandstone and forms the rough surface of the northern part of the township. The valley of East Bear Creek is much narrower at the mouth of the creek than farther up; this constriction is due to the outcrop of one of the heavy sandstone beds of the Lance formation.

This township lies on the south flank of the gentle dome that dominates the structure in the northern part of the field, and the general dip is therefore to the south at about 1°. (See Pl. X.) This dip is slightly modified by a gentle anticline in the southeastern part of the township, but the structure on the whole is unusually regular. No faults were observed in this township.

The Tullock member in this locality contains two coal beds, C and D, whose thickness exceeds 18 inches. The land underlain by

these beds is confined by the gentle southerly dip chiefly to the area south of East and West Bear creeks, although bed C underlies a few acres on the end of a ridge projecting eastward into sec. 6. Bed C in that locality is believed from measurements made in T. 4 N., R. 36 E., to range in thickness from less than 18 inches on the north side of the ridge to 30 inches on the south side. (See Pl. XV.) On the south side of West Bear Creek bed C at location 394 contains over 3 feet of coal, split into several benches. At location 395, a short distance to the southeast, the bed is only a foot thick, but at location 396, farther east, it is 2 feet thick. (See sections below.) At location 397, at the end of the ridge, it is only 18 inches thick, and several sections made in the lower valley of West Beaver Creek show the bed to be even thinner, although farther up the creek, in the township to the west, it is slightly more than 18 inches thick. On

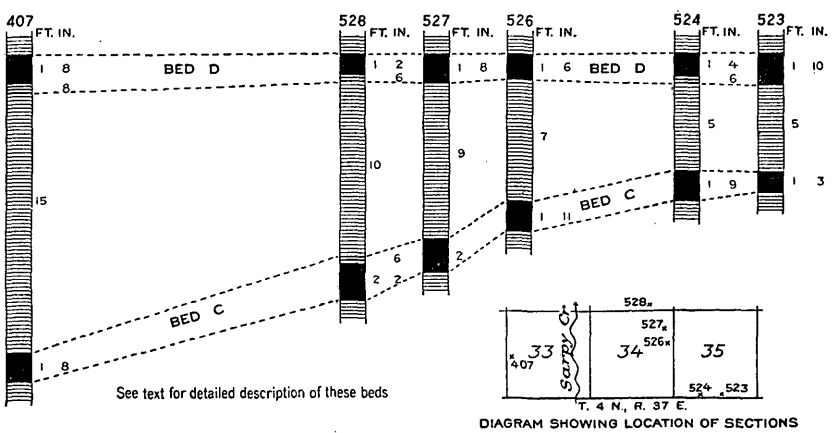


FIGURE 5.—Diagram showing convergence of coal beds C and D in T. 4 N., R. 37 E.

the south side of the creek bed C is less than 18 inches thick as far as location 403, where it contains 28 inches of coal separated into nine benches. At location 404 it is of similar character, but at location 405 it contains 22 inches of coal almost free from partings. (See sections below.) At location 406, however, it is about 16 inches thick, and south of this place it is everywhere less than 18 inches thick.

On the east side of Sarpy Creek bed C is more than 18 inches thick almost everywhere from the south township line to the valley of East Bear Creek. In the valley of East Beaver Creek, at locations 521 and 524, the bed is about 20 inches thick, though for a short distance north of these places it is thinner, as shown by section 525. (See sections below.) At location 528 bed C is 26 inches thick, and at location 529 it contains about 40 inches of coal separated into two benches by a foot of shale. From this place it increases in thickness toward

the north as far as location 533, where it contains 46 inches of coal in one bench. On East Bear Creek, however, the bed is considerably thinner, averaging 2½ feet. (See sections 528, 529, 531, 532, below, and 530, 533 to 535, Pl. XIII.) The variation in thickness of this bed is shown on Plate XV.

Bed D is normally about 10 feet above bed C, but, as shown in Figure 5, the interval in this township ranges from 4 to 15 feet in about 2 miles. On the west side of Sarpy Creek bed D is 20 inches thick at location 407, but elsewhere it is thinner. Opposite this place, on the east side of Sarpy Creek, or in the valley of East Beaver Creek, the bed is more than 18 inches thick in two small areas. At location 523, on the south township line, it is 22 inches thick, but at location 524 it contains only 16 inches of coal. At locations 526 and 527 it is about 19 inches thick, but at location 528 only 14 inches. (See sections below and on Pl. XIII.)

Sections of coal beds in T. 4 N., R. 37 E.

Location 394. NW. ¼ sec. 19 (bed C).

	Ft.	in.
Shale.		
Shale, brown		3
Coal, impure		5
Coal		8
Coal, impure		3
Bone		1
Coal		10
Shale, brown		3½
Coal		11
Shale, brown	1	8
Coal		2
Parting, sandy		½
Coal		10
Shale.		
	6	5

Location 395. SW. ¼ sec. 18 (bed C).

	Ft.	in.
Shale.		
Coal		5
Bone		1½
Coal		3
Shale		½
Coal, bony		5
Shale, brownish	1	3
Shale, black		6
Shale.		
	3	

Location 396. SE. ¼ sec. 18 (bed C).

	Ft.	in.
Shale.		
Coal		3
Shale, brown		½
Coal		2
Shale, brown		1
Coal		2
Shale, brown		1
Coal, impure		1½
Shale, black		½
Coal	1	6
Shale, carbonaceous	2	8
Bone		1
Coal		3½
Shale		1
Coal		8
Shale.		
	6	3

Location 397. NW. ¼ sec. 20 (bed C).

	Ft.	in.
Shale, carbonaceous.		
Coal	1	6
Shale, carbonaceous.		

Location 398. SW. ¼ sec. 19 (bed A).

Shale.	Ft.	in.
Bone		1½
Shale, black, sandy		1
Bone		1½
Parting, sandy		1½
Coal		10
Bone		1½
Shale.		
	1	5

Location 403. NW. ¼ sec 29 (bed C).

Shale.	Ft.	in.
Coal, impure		3
Bone		1
Coal		½
Bone		½
Coal		1
Bone		¼
Coal		1½
Bone		½
Coal		3½
Shale		¾
Bone		¾
Coal, impure		3
Bone		½
Coal		3½
Bone		1½
Coal		9
Bone		½
Coal		3
Shale.		
	2	10¼

Location 404. NW. ¼ sec. 32 (bed C).

Shale.	Ft.	in.
Shale, brown		6
Bone		7½
Coal		2
Bone		1
Coal		7½
Bone		½
Coal		3¼
Bone		¼
Coal		3½
Bone		½
Coal		3¼
Shale, black		1½
Coal		1½
Shale		⅛
Coal		2½
Shale.		
	3	4⅞

Location 405. NW. ¼ sec. 32 (bed C).

Shale.	Ft.	in.
Bone	1	1
Coal		1½
Bone		2¼
Coal	1	
Shale		¼
Coal		10
Bone		2
Shale, carbonaceous.		
	3	5

Location 406. SE. ¼ sec. 32 (bed C).

Shale, carbonaceous.	Ft.	in.
Bone		4
Coal		8
Bone		1
Coal		6
Shale		1
Bone		2
Shale.		
	1	10

Location 407. NW. ¼ sec. 33 (bed D).

Shale.	Ft.	in.
Coal	1	8
Shale, carbonaceous.		

Location 521. SW. ¼ sec. 34 (bed C).

Shale.	Ft.	in.
Coal	1	9½
Shale, carbonaceous.		

Location 524. SW. ¼ sec. 35 (beds D and C).

Shale.	Ft.	in.
Coal		6
Parting, sandy		1
Coal		10
Shale, carbonaceous		6
Shale	4	
Shale, carbonaceous	1	
Coal	1	9
Shale.		
	8	8

Location 525. NE. ¼ sec. 34 (bed C).

Shale.	Ft.	in.
Coal		3
Bone		2
Coal		4
Shale, black		¼
Coal		4
Shale		¼
Coal		8
Shale, brown.		
	1	9½

Location 528. SE. ¼ sec. 27 (beds D and C).

Sandstone.	Ft.	in.
Bone		2
Coal	1	2
Shale and sandstone	10	
Shale, carbonaceous		6
Coal	2	2
Shale, carbonaceous.		
	14	

Location 529. SE. ¼ sec. 27 (bed C).

Shale.	Ft.	in.
Coal		6½
Parting, sandy		½
Coal		10
Shale, carbonaceous	1	
Coal	2	
Shale, carbonaceous.		
	4	5

Location 531. NE. ¼ sec. 27 (bed C).

Shale.	Ft.	in.
Coal		5
Bone		1
Coal		8½
Shale, black	1	10
Shale, carbonaceous.		
	3	1½

Location 532. NW. ¼ sec. 26 (bed C).

Shale.	Ft.	in.
Coal, impure		1
Coal	3	4
Shale.		
	3	5

T. 5 N., R. 37 E.

T. 5 N., R. 37 E., lies in the lower part of Sarpy Creek valley. Although the relief is probably not as great as in the territory farther south, the country is very much broken, and outside the flood plain of Sarpy Creek there is practically no flat land. The road from Hysham and Sanders to Sarpy follows the valley of the creek. The fertile flood plain of Sarpy Creek is here from 1,200 to 1,800 feet wide. In this township the coal-bearing strata have been removed by erosion, and the greater part of the surface is composed of the lower part of the Lance formation. Along Sarpy Creek, however, and also in the northeast corner of the township, the upper part of the Bearpaw shale is exposed. The strata dip to the south at an angle of less than 2°. (See Pl. X.)

T. 6 N., R. 37 E.

Yellowstone River flows across the extreme northern part of T. 6 N., R. 37 E., and Sarpy Creek, occupying a broad, flat-bottomed valley, flows north along the west line of the township. At the mouth of this creek the river flood plain is about 2 miles wide, but toward the east its width decreases to less than 1 mile. The Northern Pacific Railway follows the river flood plain, and Sanders station is on it about 2 miles east of Sarpy Creek. At the southern edge of the flood plain the land rises rather gently to the south in a broken gravel-covered slope which extends to the south boundary of the township.

The lowest formation exposed in this township is the Judith River, which crops out in secs. 1 and 2. Only 39 feet in the upper part of

the formation is exposed, the lower part being covered by alluvium. The exposed portion consists entirely of sandstone and forms a low cliff along the railway track. This exposure, which marks the highest structural place in the northern part of the field, is terminated at the west end by a dip of 3° SW. and at the east end by a dip of 1½° SE. It therefore marks a very gentle anticline plunging to the south, or in view of its broader relations it may be considered a small segment on the edge of a large dome.

The Bearpaw shale, overlying the Judith River, is exposed everywhere south of this place as far as the township line, except in secs. 33 and 34, where the basal portion of the Lance formation caps a high ridge.

T. 1 S., R. 38 E.

Only the northwest corner of T. 1 S., R. 38 E., or that portion included in the ceded lands of the Crow Indian Reservation, was examined. This area, which contains about 4 square miles, lies on the western slope of the ridge that separates Sarpy and East Sarpy creeks. The western part of this area, or that nearest Sarpy Creek, is maturely dissected and very rough, and the eastern part rises steeply toward the crest of the divide; the central part, however, is relatively low and is a rolling grass-covered plain. The entire area is underlain by the upper division of the Fort Union formation, which is extensively clinkered by the burning of the coal in the western part of the area but is mostly unaltered in the eastern part. The area lies in the structural trough that plunges southeast across this part of the field, and the combination of this structure with the topography has resulted in the exposure of some 200 feet of strata higher than those found elsewhere in the field.

Bed M underlies practically the whole of this area, but crops out only in the northwest corner. Measurements made in the township to the north indicate that the bed is about 10 feet thick in this locality. (See Pl. XIV.) Bed P is exposed in the western part of the area and is everywhere burned on the outcrop. The bed forms a heavy clinker in the western part of the township, but there is no trace of the bed farther east, where the surface is grass-covered and gently sloping. Sections 451 and 453, made just north of the township line, indicate a thickness of 14 to 16 feet in this district. Bed Q at location 454, half a mile north of the township line, is 10 feet above bed P and is slightly more than 3 feet thick, but in this township its position and thickness can not be ascertained. It is possible, as suggested elsewhere, that beds P and Q coalesce in this locality and that bed P is therefore 2 or 3 feet thicker than is indicated above; it is also possible, inasmuch as bed Q becomes thinner toward the southeast, that it feathers out in this locality. A third possi-

bility, suggested by the abrupt change in topography in the central part of this area and by the disapearance of the clinkers of both beds P and Q, is that a fault tending northeast has lowered a considerable block of strata. The general structural relations of this part of the field suggest the possibility of a fault, but owing to the character of the surface no direct evidence was gathered. Pending the examination of the area to the south, which will doubtless throw light on this problem, the writers prefer to assume that the bed feathers out, as indicated on Plate XVI.

Bed R, the highest coal bed in the field, underlies about half a square mile of the high land in the eastern part of this area. At locations 456 and 458 the bed is about 4½ feet thick (see sections below); at locations 455 and 457 it slightly exceeds 5 feet in thickness (see sections on Pl. XII). These sections suggest that the bed increases in thickness toward the southeast. If there has been no faulting in this area, bed R is about 300 feet above bed Q, but an exact measurement is not possible.

Sections of coal beds in T. 1 S., R. 38 E.

Location 456. SE. ¼ sec. 4 (bed R).

	Ft.	In.
Shale, brown.		
Bone		2
Coal	3	10
Bone		1½
Coal	1	
Shale, carbonaceous		2
Shale, sandy		1½
Bone		1½
Shale.		
	5	6½

Location 458. NW. ¼ sec. 3 (bed R).

	Ft.	In.
Shale.		
Shale, carbonaceous		2
Coal	3	4
Bone		2
Coal	1	3
Shale, sandy.		
	4	11

T. 1 N., R. 38 E.

Only that portion of T. 1 N., R. 38 E., lying west of the old boundary of the Crow Indian Reservation—that is, the two western tiers of sections—was examined. East Sarpy Creek flows northwestward across the middle of this area in a flat valley about half a mile wide. The tributaries of this stream have extensively dissected the upland in the northern part of the township and have given rise to an extremely rough surface. As described under T. 1 N., R. 37 E. (p. 150), the stream valleys in this district are bordered by steep slopes, colored red by clinkers and rising to a height of 150 feet or more, which renders travel across the drainage lines very difficult. In the southern part of the township rolling and grass-covered upland predominates, and there is much land suitable for dry farming. Pine trees are numerous throughout the township, flourishing especially on the steep rocky slopes.

The upper division of the Fort Union formation crops out throughout the township. Its lower portion, which is well exposed in the valley of East Sarpy Creek, contains two thick sandstone beds 25 to 75 feet thick. The two thick coal beds, M and P, which are also contained in this portion of the formation, have burned on the outcrop and have extensively baked and clinkered the overlying strata. The strata above bed P are mostly concealed by grass-covered slopes but appear to contain only a small amount of sandstone and none in thick beds. About 550 feet of this part of the formation is exposed in that portion of the township examined.

This township lies in the structural trough which trends southeastward across the field and which in this vicinity plunges to the southeast. (See Pl. X.) Altitudes determined on the coal beds in this township indicate that the southeasterly dip is very slight, but it is impossible to determine the exact structure in an area in which the only datum planes, the coal beds, are affected by slumping on the outcrop. The strata locally dip at relatively great angles; thus in sec. 32 a dip of 2° E. was observed, and in sec. 19 a dip of 9° NE. As stated under "Structure," it is possible that these irregularities indicate the presence of faults.

Bed M is the lowest coal in the upper division of the Fort Union, its horizon in this locality being about 120 feet above the base and about 90 feet below bed P. Bed M crops out only in the valley of East Sarpy Creek and its tributaries, and in the eastern part of the township its outcrop is so low as to be largely concealed by alluvium. Only two sections of this bed were measured in the township. At location 477 an incomplete section shows 12 feet of coal. At location 471, about a mile away, the bed contains only 5½ feet of good coal with 8 inches of ash. (See sections below.) As shown in the description of T. 1 N., R. 37 E., this bed is subject to abrupt local variations in thickness, and it seems probable that the 8 inches of ash does not represent sufficient coal to bring its thickness at this place up to that in neighboring localities. (See Pl. XIV.) This place may therefore represent an island in the old swamp, which was later submerged and covered by vegetal matter representing the upper part of the bed.

Bed P is extensively burned on East Sarpy Creek, and in the southern part of the township its outcrop is almost everywhere concealed under the grassy surface. Only three sections of this bed were obtained in the township, and all are incomplete. Below location 473, in sec. 19, 5 feet of coal was measured, but the bottom was not exposed. In sec. 29 at location 475, where a very faint smut on the surface is the sole indication of the presence of this thick bed, a pit was opened which exposed 10 feet of coal in the upper part of the bed. At location 474, however, the bed has been partly

stripped and is being mined for local use. (See sections below.) More than 11 feet of coal in the upper part of the bed is exposed, and almost 2 feet at the base, with an intervening space of 21 feet concealed. It is reported that this concealed interval has been explored by drilling and was found to be all good coal, but it is known that farther north this bed is separated by one or more thick shale partings, and it is therefore believed that an indeterminate part of this concealed interval consists of shale. In drawing the lines of equal thickness shown on Plate XV, this measurement has been disregarded, but the general trend of the lines, as determined by measurements elsewhere, indicates that the bed is about 18 feet thick in this locality. Sample 17711 for chemical analysis was collected at location 474, and represented 7 feet in the upper part of the bed, as indicated in the section below. The bed along East Sarpy Creek is almost everywhere burned and is under a cover of more than 50 feet, but in the southeast corner of the area its outcrop is entirely hidden under the grass-covered surface.

Bed Q, which is from 10 to 40 feet above bed P, is not well exposed in this township. Along East Sarpy Creek the bed is generally burned and may be traced by its clinker, but in secs. 29 and 32 its outcrop is almost entirely inferred. Only three sections of the bed were obtained in this township, but in conjunction with measurements made in adjacent areas, they show that the bed becomes thicker to the north. (See Pl. XVI.) At location 476, in sec. 32, the bed is 34 inches thick, and at location 473, in sec. 19, it is 46 inches thick. (See sections below.) At location 478, north of East Sarpy Creek, the bed is 52 inches thick. (See Pl. XII.)

The highest bed, R, is under very thin cover, cropping out only on two high knobs in the southeastern part of the township. It is exposed on a small butte in sec. 30 at location 459, where it contains over 3½ feet of coal, and on the high land in the southeastern corner of sec. 32, where it is 4½ feet thick. (See section 459 below, and sections given under T. 1 S., R. 38 E.) Bed R is probably about 300 feet above bed Q, and the interval between them seems to be barren of coal in this locality. A small bed about 50 feet above bed Q was measured at three places but was found to contain less than 18 inches of coal.

The aggregate thickness of coal in beds M, P, and Q probably ranges from about 27 feet in the southeast corner of this area to about 44 feet in the northwest corner. The coal is for the most part clear and of excellent quality, and the beds are uncommonly free from partings. The abundance of pine trees in the township, especially along East Sarpy Creek, would be favorable to mining, and a moderate supply of water is obtainable from the creek. The coal would, however, have to be hauled more than 35 miles to the

Northern Pacific Railway, a distance which precludes profitable mining at the present time; but the abundance of coal in this and adjacent townships may at some future time warrant the construction of a spur road up Sarpy Creek, and then this district should become a valuable coal field.

Sections of coal beds in T. 1 N., R. 38 E.

Location 459. SW. ¼ sec. 30 (bed R).

	Ft.	in.
Shale.		
Coal, impure		4
Coal	2	10
Bone		2
Coal		10
Shale, carbonaceous.		
	4	2

Location 471. NE. ¼ sec. 18 (bed M).

	Ft.	in.
Shale, carbonaceous.		
Ash		8
Coal, impure	1	4
Coal	4	4
Clay and shale.		
	6	4

Location 473. SW. ¼ sec. 19 (bed Q).

	Ft.	in.
Sandstone.		
Coal	3	4
Coal, impure		6
Shale.		
	3	10

Location 474. NW. ¼ sec. 30 (bed P).

	Ft.	in.
Sandstone.		
Shale.		
Coal	1	4
Shale		7
Shale, brown		6
Shale, carbonaceous		4
Bone		1
Coal	1	2
Bone		2
Coal (sample 17711, p. 63)	7	
Coal, weathered	3	4
Not exposed; reported to be in part coal	21	
Coal		6
Shale		2
Coal	1	2
Shale.		
	37	4

Location 475. SW. ¼ sec. 29 (bed P).

	Ft.	in.
Shale.		
Coal		10
Shale, brown	3	1
Coal	3	1
Shale		2
Coal	6	11+
	14	1+

Location 476. NW. ¼ sec. 32 (bed Q).

	Ft.	in.
Shale.		
Coal, impure		4
Coal	2	6
Bone		3
Shale.		
	3	1

Location 477. SE. ¼ sec. 8 (bed M).

	Ft.	in.
Sandstone.		
Bone		1
Coal, impure		2
Coal		10
Bone		2
Coal	10	11+
	12	2+

T. 2 N., R. 38 E.

Only the western part of T. 2 N., R. 38 E., or that portion included in the ceded lands of the Crow Indian Reservation, was examined.

The divide between Sarpy and Armells creeks traverses the middle of this township, and the portion here described extends eastward almost to the crest of the divide. All the drainage therefore goes westward into Sarpy Creek, the principal tributary of which, Horse Creek, flows westward across the center of the township. Most of this township is maturely dissected and is very rough, though in the southeast corner there is a small tract of fairly level upland. The slopes of many of the hills are heavily timbered. An old Government trail that connected Fort Custer with the military post at Miles City follows Horse Creek across the divide to the east but is now little used. A trail from the settlement of Sarpy at the head of East Sarpy Creek crosses the southern part of this township and connects with the Horse Creek trail.

This township is underlain by the upper division of the Fort Union formation. In the southern part of the township the thick coal beds are almost everywhere burned, as in the townships to the south, but north of Horse Creek the beds contain a much smaller thickness of coal and the effects of the burning are much less conspicuous. The slumping and burned condition of the strata south of Horse Creek leaves much to be desired in the way of data for correlation and thickness, and the field evidence upon which the conclusions given below are based is not entirely conclusive. The character of this part of the Fort Union in this district is shown by section 22, Plate IV. A gentle east-west syncline crosses the township, the axis being located in the valley of Horse Creek. (See Pl. X.)

Beds M, N, O, P, and Q are exposed in this township. Bed M, the lowest coal in this part of the formation, shows only a slight variation in thickness in most of this township, although in the extreme northwestern part it becomes somewhat thinner. (See Pl. XIV.) At location 494, at the head of Horse Creek, the bed is 15½ feet thick and at location 493, on the south side of the creek, about 12 feet of coal was measured but the section was not complete. At location 500, on East Passage Creek, in the northwestern part of the township, bed M is 14 feet thick, but farther east, at locations 503 and 509, it is over 15 feet thick. (See sections on Pl. XII.)

Bed N is more than 18 inches thick only in a small area at the head of East Passage Creek. At locations 502 and 504 it is 19 inches thick, but at locations 505 and 507 it is only about 15 inches thick. (See sections below.) At location 506 a bed 20 inches thick and 55 feet above bed N is exposed. This is thought to represent bed O, but in this vicinity less than 3 acres of land is underlain by the bed, and farther east no trace of it could be found.

Bed P attains its maximum observed thickness in the southern part of this township but thins very abruptly to the north. At loca-

tion 482, on a tributary of East Sarpy Creek, the lower 8 feet of this bed is exposed, and farther up the coulee, at location 483, a total thickness of 24½ feet of coal separated into two beds by 8½ feet of shale was observed. At location 491, however, about 1½ miles to the northeast, the total thickness of the coal is only 12 feet, and that of the shale only 5½ feet. (See sections, Pl. XII.) South of this place the bed is almost everywhere burned and forms a very thick clinker, but between this place and the valley of Horse Creek the clinker becomes thinner and finally disappears. At locations 492 (see Pl. XII) and 495 (see below), on Horse Creek, the bed is only about 2 feet thick. North of the creek it is slightly thicker, and at location 501 it contains 3 feet of coal, but at location 508, in the extreme northeast corner of the township, it is only 2 feet thick. (See Pl. XII.)

Bed Q also attains its maximum thickness in the southern part of this township and is believed to be much thinner in the northern part. At location 479, in the drainage basin of East Sarpy Creek, 11½ feet of coal is exposed, but the section is not complete. At location 490, farther north, the bed contains 8½ feet of good coal with over 2 feet of partly burned coal beneath. (See sections 479 and 490, Pl. XII.) The thickness of the burned coal could not be accurately measured, and although the bed is probably about 11 feet thick at this place, it may be a foot or so thicker. The outcrop of the bed passes out of the field in this locality and reenters it only in T. 3 N., R. 38 E., 5 miles to the north, where the bed is about 2 feet thick.

Sections of coal beds in T. 2 N., R. 38 E.

Location 482. SW. ¼ sec. 30 (bed P).

	Ft.	in.
Alluvium (top of bed eroded).		
Coal	8	1
Shale		5
Bone.		
	8	6

Location 495. NW. ¼ sec. 8 (bed P).

	Ft.	in.
Shale, white.		
Coal, burned, and ash	2	
Shale.		

Location 502. SW. ¼ sec. 5 (bed N).

	Ft.	in.
Sandstone.		
Bone		3
Coal, impure	1	7
Shale, carbonaceous.		
	1	10

Location 504. SW. ¼ sec. 5 (bed N).

	Ft.	in.
Shale.		
Coal, impure	1	7
Shale, carbonaceous.		

Location 505. NW. ¼ sec. 6 (bed N).

	Ft.	in.
Shale, carbonaceous.		
Coal	1	3
Bone		10
Shale, carbonaceous.		
	2	1

Location 506. NE. ¼ sec. 6 (bed O).

	Ft.	in.
Shale, carbonaceous.		
Coal	1	8
Shale, carbonaceous.		

Location 507. NW. ¼ sec. 5 (bed N).

	Ft.	in.
Shale.		
Coal		10
Shale, carbonaceous		2
Coal		7
Shale, carbonaceous		4
Coal, impure		3
Shale, carbonaceous.		
	2	2

T. 3 N., R. 38 E.

Only the western part of T. 3 N., R. 38 E., is included in the Tullock Creek field. The divide between Sarpy and Armells creeks trends north across the center of this township, and the area examined therefore lies on the western slopes of this ridge. Both forks of East Beaver Creek rise in the northern part of this township, but the southern part is drained chiefly by East Passage Creek. In the southern part of the area the land is high and is maturely dissected into badlands, but on East Beaver Creek the relief is considerably less. Wagon trails follow both forks of East Beaver Creek, and another rough road connects them with the valley of Horse Creek in the township to the south.

The rocks that crop out in this township belong to both divisions of the Fort Union formation and to the Tullock member of the Lance formation. The upper division of the Fort Union is best exposed in the southern part of the township, where it forms the very rough topography mentioned above. In this area it contains only a few thin coal beds, which have not burned, as in the district to the south; under these conditions this part of the formation is lithologically almost indistinguishable from the Tullock member of the Lance, as shown in Plate III. Farther north it caps the ridges between East Passage Creek and the north and south forks of East Beaver Creek, but in this vicinity the beds are overlain by gravel and form rounded tree-covered hills; only about 125 feet of the upper division of the formation, or that portion comprising the basal sandy zone, remains in this area. The Lebo shale member forms a gently sloping plain at the foot of the steep hills underlain by the upper division of the formation, or that portion comprising the basal sandy township indicate that the Lebo is about 150 feet thick, or a few feet thicker than in the area west of Sarpy Creek. In the northern part of the township both forks of East Beaver Creek have cut narrow gorges through the resistant rim rock at the top of the Lance formation and have exposed about 100 feet of the upper part of the Tullock member. A coal bed thought to be bed J is exposed on these creeks, but here, as in most other parts of the field, the bed is too thin and impure to be workable. The strata in most of this township lie almost flat, though in the northern part they dip about ½° SE. (Pl. X).

The upper division of the Fort Union in this township contains all the coal beds recognized farther south, but all the beds are less than 5 feet thick. As stated elsewhere, the places at which beds M, P, and Q are thickest are in a small area near the mouth of East Sarpy Creek, and all these beds decrease in thickness toward the north at approximately the same rate. It is probable, therefore, that the basins in which these beds were deposited were roughly coincident in

extent and that none of them extended very far north of the present limits of this division of the formation in this field; hence it is thought that relatively little coal has been lost by erosion to the north.

Bed M, the lowest coal in the upper division of the Fort Union, is 15 feet thick at location 509, just south of the south township line. Between this place and location 514, a mile to the north, the bed bifurcates, and at location 514 it consists of two beds each about 4 feet thick, separated by 10 feet of shale. (See Pl. XII.) At location 515, farther to the northwest, the shale bed is 20 feet thick and the lower coal only 3 feet; the upper coal bed is burned and could not be measured but is probably less than 2 feet thick. (See section below.) Near this place the outcrop of the bed passes out of the field, and no other measurements were obtained.

Bed N is thicker than 18 inches in a small isolated area in sec. 32. At location 510 it is a little more than 2 feet thick, at location 513 slightly less than 2 feet, and at location 517, 18 inches. (See sections below and on Pl. XII.) Bed O was examined at several places, at all of which it is less than 15 inches thick. (See, for example, section 512, below.)

Bed P underlies only a small area on the high ridges at the head of East Passage Creek. At location 511 it is 25 inches thick, but at location 516, farther east, it contains only 14 inches of coal. (See sections below.) Bed Q underlies a few acres of the highest land in the township in sec. 32. At location 518 it is only 22 inches thick, although on Horse Creek, 5 miles to the south, it is about 11 feet thick (sections 490 and 518, Pl. XII).

Sections of coal beds in T. 3 N., R. 38 E.

Location 511. NW. ¼ sec. 32 (bed P.)

	Ft.	in.
Shale.		
Shale, carbonaceous		4
Coal	2	1
Shale, carbonaceous.		
	2	5

Location 512. NW. ¼ sec. 32 (bed O).

	Ft.	in.
Shale.		
Coal	1	2
Shale, carbonaceous.		

Location 513. NW. ¼ sec. 32 (bed N).

	Ft.	in.
Shale.		
Coal	1	5
Shale, carbonaceous		4
Coal		6
Shale.		
	2	3

Location 515. SE. ¼ sec. 30 (bed M).

	Ft.	in.
Shale, baked red	2	
Shale and sandstone	20	
Coal, impure		4
Coal	2	9
Shale, brown.		
	25	1

Location 516. NE. ¼ sec. 32 (bed P).

	Ft.	in.
Shale.		
Coal	1	2
Shale.		

T. 4 N., R. 38 E.

Only the western part of T. 4 N., R. 38 E., was examined. This part lies well up on the eastern divide of Sarpy Creek and is an area of considerable relief. It is drained chiefly by East Bear and East Beaver creeks, tributaries of Sarpy Creek, but the extreme northeast corner of the area examined lies in the drainage basin of a stream flowing north directly into Yellowstone River. South of East Bear Creek there are considerable tracts of fairly level land, but the area north of the creek is maturely dissected and exceedingly rough. A fair road follows the broad valley of East Bear Creek and renders the southern part of the township relatively accessible.

Both divisions of the Fort Union and both divisions of the Lance formation are exposed in the narrow strip of this township examined. The upper division of the Fort Union is confined to a group of gravel-covered hills on the divide between East Bear and East Bear Creek there are considerable tracts of fairly level land, but ber of the Fort Union forms a comparatively level plain, dissected by narrow gorges in which the upper or Tullock member of the Lance is exposed. North of East Bear Creek the Lebo plain, owing to the southerly dip of the strata and the extensive dissection of the creeks, has been almost obliterated, though still occupying a small area along the eastern margin of the field. The Tullock member of the Lance forms the steep escarpment that limits the gentle slopes of the Lebo member. In most of the northern part of the township the whole thickness of the Tullock members, 300 feet, is exposed in a zone less than half a mile wide. The lower part of the Lance formation crops out north of East Bear Creek and forms an irregularly broken and very rough surface.

This township lies on the southern slope of the gentle dome that dominates the structure in the northern part of the field, and the rocks dip to the south at an average angle of about 1°. (See Pl. X.) In the northern part of the township the dip is somewhat more pronounced, reaching about 1½°. In sec. 30 a fault having a downthrow of about 35 feet to the north appears to have terminated the outcrop of the Lebo shale.

Bed C is the only valuable coal bed in this township. On East Beaver Creek this bed is thickest at location 538, where it contains 32 inches of coal. At location 536, to the south, it is about 2 feet thick, and at location 540, to the north, it has a net thickness of 16 inches. (See sections on Pl. XIII.) This area of coal is connected with that in the township to the east and forms part of a large lens that probably once extended across Sarpy Creek. (Pl. XV.) At locations 541 and 542 (see below) the bed is less than 18 inches thick, but at location 543 (Pl. XIII) it is about 2 feet thick. From this

place along the outcrop to the northeast the bed ranges in net thickness from 20 to 27 inches, as shown by sections 546 and 547, Plate XIII, and 544, 545, 548, 549, 550, and 551, below. The area of coal of greater thickness than 18 inches, as indicated by these sections, is possibly connected with that on East Bear Creek, though in the absence of direct evidence it is shown on Plate XV as a separate lens.

A coal bed about 35 feet below bed C and believed to be bed A was examined at a number of places in this township but is generally very thin. (See, for example, section 539, below.) A bed about 100 feet above bed C and thought to be bed H was also examined at several places. At location 548 it is slightly more than 18 inches thick, but at location 549 it contains only 15 inches of coal. A bed that is probably to be correlated with this one was examined at location 537, where it contains 18½ inches of impure coal in three benches. (See sections below.) Other thin beds were examined at a number of places, but the sections show less than a foot of coal and are not included here.

Sections of coal beds in T. 4 N., R. 38 E.

Location 537. NW. ¼ sec. 17 (bed H?).

	Ft.	in.
Shale, brown.		
Coal, impure	1	1
Shale, sandy		1
Coal		2
Bone		2
Coal, impure		3½
Shale, brown		3
Sandstone.		
	2	½

Location 539. SE. ¼ sec. 18 (bed A?).

	Ft.	in.
Shale.		
Coal		2
Parting, sandy		1
Coal		6
Shale, carbonaceous.		
		9

Location 541. NW. ¼ sec. 18 (bed C).

	Ft.	in.
Shale, carbonaceous.		
Bone		5
Coal	1	2
Shale, carbonaceous.		
	1	7

Location 542. SW. ¼ sec. 7 (bed C).

	Ft.	in.
Shale, carbonaceous.		
Coal		4½
Bone		2½
Coal	1	3½
Shale.		
	1	10½

Location 544. NW. ¼ sec. 7 (bed C).

	Ft.	in.
Shale, carbonaceous.		
Bone		2
Coal	1	8
Shale.		
	1	10

Location 545. SE. ¼ sec. 6 (bed C).

	Ft.	in.
Shale, carbonaceous.		
Bone		1
Coal, impure		4
Coal		3
Bone		2
Coal	1	9½
Shale.		
	2	7½

Location 548. SE. ¼ sec. 5 (bed H).

	Ft.	in.
Shale.		
Coal		3
Bone		1
Coal		6½
Parting, sandy		1
Coal		11
Shale, carbonaceous.		
	1	10½

Location 549. SE. ¼ sec. 5 (bed H).

	Ft.	in.
Shale.		
Coal		11
Parting, sandy		1
Coal		5
Shale, carbonaceous.		
	1	5

T. 5 N., R. 38 E.

A strip 1 mile wide on the western margin of T. 5 N., R. 38 E., is included in the Tullock Creek field. This strip lies near the north end of the divide between Sarpy and Armells creeks, and part of the drainage goes westward into Sarpy Creek and part northward directly into Yellowstone River. Most of the strip is underlain by the lower part of the Lance formation, which gives rise to a very rough surface, but in the northern part the Bearpaw shale is exposed. (See Pl. X.) Both of these formations are overlain by the Quaternary gravel. The strata dip about 1¼° S.

T. 6 N., R. 38 E.

The only portion of T. 6 N., R. 38 E., examined is an area 1 mile wide along its western edge. The surface in this area slopes to the north and is drained by streams flowing directly into Yellowstone River. Most of the district is underlain by Bearpaw shale, which forms a monotonous group of gravel-covered hills. At the edge of the river flood plain in the northern part of the township there is a small exposure of Judith River sandstone, which dips about 1½° SE.

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