GEOLOGY OF CERTAIN LIGNITE FIELDS IN EASTERN MONTANA.

By W. R. Calvert.

INTRODUCTION.

The Fort Union coal region, in eastern Montana, constitutes one of the largest fuel-bearing areas in the world. The presence of lignite throughout this region has been known since the earliest explorations of those main arteries of travel—Missouri and Yellowstone rivers—yet until 1910 the facts concerning such resources were gathered either by hasty reconnaissance or by more detailed study of only small and isolated districts. The low-grade character of the fuel together with the almost unlimited supply were among the reasons for the lack of careful study such as has been accorded to many other Western fields.

In 1907 A. G. Leonard and Carl D. Smith examined an area lying mainly in North Dakota, in the vicinity of Medora, but including also six townships in Montana. The published results[1] of this examination and a report by A. J. Collier[2] relating to lignite in the vicinity of Miles City, constitute the only detailed statements available regarding the fuel resources of eastern Montana. General information concerning the lignite of this region is contained in a report[3] by A. G. Leonard.

The chief reason, however, why broad detailed investigations of Montana lignites were not undertaken till 1910 is that prior to that year the region was not included in coal-land withdrawals, such as since 1906 had embraced large areas in western public-land States. Before the passage of the act of June 22, 1910, it was difficult if not impossible for the agricultural claimant to obtain title to lands so withdrawn, and the limitations imposed by the withdrawals were removed only by a noncoal classification. The act referred to, however, effected a separation of surface and underground rights, so that subsequent to its passage withdrawn or classified coal lands have been

[1] Leonard, A. G., and Smith, C. D., The Sentinel Butte lignite field, North Dakota and Montana: Bull. U. S. Geol. Survey No. 341, 1909, pp. 15–35.

[2] Collier, A. J., and Smith, C. D., The Miles City coal field, Montana: Bull. U. S. Geol. Survey No. 341, 1909, pp. 36–61.

[3] Leonard, A. G., The coal fields of parts of Dawson, Rosebud, and Custer counties, Mont.: Bull. U. S. Geol Survey No. 316, 1907, pp. 194–211.

subject to agricultural entry, with the coal reserved to the United States. Under the provisions of this act the entryman filing upon withdrawn lands or lands classified as coal is not permitted to commute at the expiration of 14 months, but is obliged to reside on the entry continuously for a period of five years before final patent issues, whereas lands classified as noncoal are not subject to such conditions. In any withdrawn area, therefore, there is constant demand from prospective settlers for classification not only because of the commutative privilege mentioned but also because patent without reservation is granted in case the lands involved are classified as noncoal.

For the purpose of classifying lands with respect to coal, therefore, five field parties of the Geological Survey operated in eastern Montana in 1910, and the general results of four of those parties are set forth in this report. One party examined an area extending from the north line of T. 4 N. to the north line of T. 8 N., and from the west side of R. 54 E. to the Montana-North Dakota State line, embracing approximately 1,150 square miles. Until early in August this party was in charge of M. A. Pishel and upon his detail to the Fort Berthold Indian Reservation, C. F. Bowen took charge. The area examined by this party is designated the Baker lignite field and is outlined on the index map (fig. 7).

A party examining lands adjacent on the north was in charge of F. A. Herald. The territory examined by this party included about 1,500 square miles, extending from the north line of T. 8 N. to the north line of T. 12 N., and from Powder River eastward to the State line. To this area, shown on the index map, the name Terry lignite field is applied.

A third party, under the direction of J. H. Hance, mapped the area adjoining on the north that previously mentioned. Approximately 1,200 square miles lying west of the Montana-North Dakota State boundary and extending from the north line of T. 12 N. to the north line of T. 17 N., as indicated on the index map, were examined by this party. This area is designated the Glendive lignite field.

A fourth party, in charge of Eugene Stebinger, operated north of the area covered by Mr. Hance. About 780 square miles were examined in detail by this party and approximately 575 square miles in addition were mapped in a reconnaissance way. The area examined by this party is termed the Sidney lignite field, but only the part mapped in detail is indicated on the index map.

These four parties were under the general supervision of the writer, who spent the entire season in the field assisting them in an administrative way and collecting evidence bearing upon the stratigraphy and structure of the region. The present paper discusses only the facts pertaining to the general geology and in this way serves

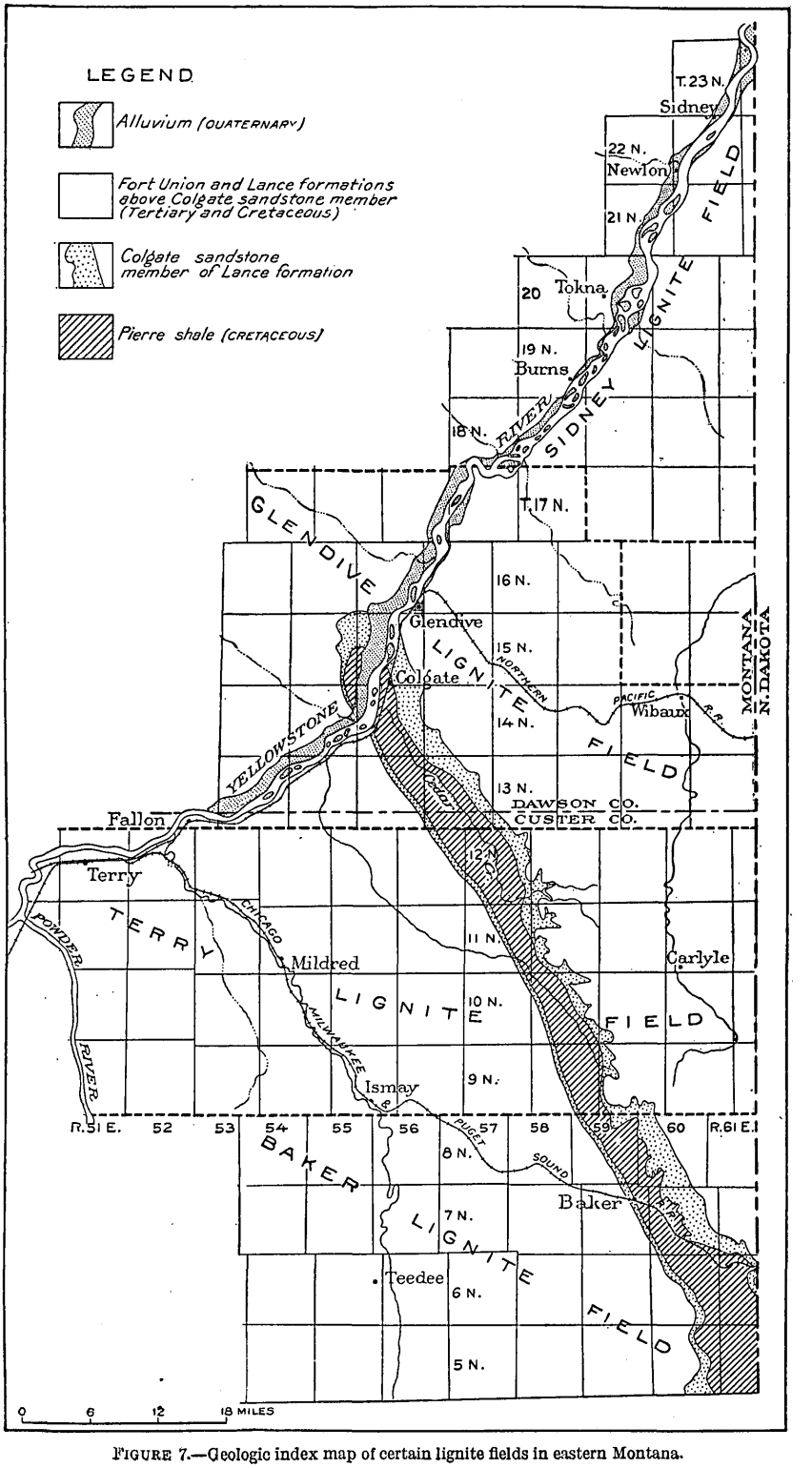


FIGURE 7.—Geologic index map of certain lignite fields in eastern Montana.

as an introduction to the papers which follow and which deal in detail with the economic resources. Many of the data presented herewith were collected by the author during his trips to and from the field parties, but a large part was supplied by the men engaged in economic work and to them belongs much of the credit for the present interpretation of the geology of the region.

SURFACE FEATURES.

RELIEF.

Although the area described is a part of the Great Plains province, and in its broader aspect is a plains country, yet locally it presents considerable diversity in topography. At some previous time the entire area was evidently at nearly one general level and remnants of this old level surface remain as broad interstream divides. Into this upland region the main drainage lines have cut deeply and in certain localities have developed intricate badlands. In the west half of the Baker field (see fig. 7) the topography is controlled to a large degree by clinker produced by burning lignite beds. This clinker is a baked or semifused mass of clay, which because of its induration has protected the softer underlying rocks from erosive agencies. Where erosion has finally succeeded in incising this clinker-protected area mesa-like forms are produced, and as erosion further develops the mesas are dissected into many isolated buttes. In other parts of the region examined clinker, although occurring locally, has not affected the surface features so greatly as has geologic structure, which has caused soft rocks to outcrop in some localities and more resistant rocks in others. Each of the geologic formations in the region weathers distinctively. For example, there is a broad zone of soft Pierre shale exposed from the Montana-North Dakota State line in T. 5 N., R. 61 E., northwestward to the mouth of Cedar Creek, 15 miles southwest of Glendive. In this zone badlands, buttes, and mesas are usually not developed, but instead broad valley flats and low moundlike hills are the characteristic surface forms. In certain localities, however, notably in the upper part of the Cedar Creek drainage basin, this shale area is much dissected by sharply cut stream channels.

On both sides of this zone of slightly diversified topographic forms there is a relatively narrow belt marking the outcrop of a persistent sandstone and here cliffs and sharply cut drainage lines are prevalent, especially in the Glendive and northern part of the Terry field. Farther south the sandstone is much less prominent topographically and its outcrop is usually marked by gently rolling hills. These belts correspond to the outcrop of the Colgate sandstone member of the Lance formation.

Beyond the sandstone outcrop there is a zone in which badlands constitute a common type of topography. The badland areas are in general adjacent to the sandstone belts mentioned in the preceding paragraph, and outside of these the region is marked by relatively smooth surfaces. The zones of badlands with occasional flat areas correspond closely with the outcrop of the Lance formation.

In the greater part of the upland region around the area above described the exposed rocks are in general more consolidated than those mentioned previously, with the possible exception of the Colgate sandstone member, and in consequence they form broad areas with flat or rolling surfaces, which are commonly designated bench lands and are the chief farming localities aside from the larger stream valleys. One such area is found near the eastern border of the region mapped, extending from T. 9 N., Rs. 60 and 61 E., north to Missouri River, and the other lies south of the Yellowstone and east of Powder River. Each of these areas is, however, more or less dissected by the streams so that considerable diversity in topography is found, especially along the lower reaches of the streams flowing into Yellowstone River. These districts are immediately underlain by strata of Tertiary age assigned to the Fort Union formation.

DRAINAGE.

All surface water of the region finds its way eventually to Missouri River, but practically all the streams are first tributary to the Yellowstone, which as shown on the index map traverses the area for about a hundred miles. Powder River, an affluent of the Yellowstone, and the next smaller stream, controls the drainage of the western part of the area. O'Fallon Creek with its tributaries receives the surface waters of many square miles and is next to Powder River in size and importance. Beaver Creek is also a stream of considerable drainage area and it is the only stream of any importance that is a tributary in Montana of Little Missouri River. Many other streams, most of them intermittent, flow through the area examined.

CULTURE.

Until comparatively recent times the region was sparsely settled, its agriculture being developed only in favored localities. The greater part of the area has been devoted to stock raising, for which purpose it is ideally adapted. Of late years, however, there has been rapid influx of dry-land farmers, and practically all lands amenable to tillage have been taken up and farmed, flax, oats, and wheat being the principal products. Two transcontinental lines of railway—the Northern Pacific and the Chicago, Milwaukee & Puget Sound—pass through the region from east to west. A branch line of the Northern Pacific has been constructed from Glendive down

Yellowstone Valley as far as Sidney, and surveys have been extended some distance farther.

Of the several towns of the region, Glendive is considerably the largest, having a population of 2,428 according to the 1910 census. Wibaux, on the Northern Pacific, 30 miles east of Glendive; Sidney, 50 miles below Glendive, on the Yellowstone; Terry, on the Yellowstone, a few miles below the mouth of Powder River, and Baker, on the Chicago, Milwaukee & Puget Sound Railway, are the other centers of population.

GEOLOGY.

STRATIGRAPHY.

GENERAL SECTION.

The stratified rocks of the region belong to the late Cretaceous and early Tertiary, and comprise a total exposed thickness of about 3,000 feet. In much of the area the exposed rock section is considerably less, as the upper part has been removed by erosion and the lower is not exposed to view. The thickness mentioned was measured between the mouth of Cedar Creek and Blue Mountain, 30 miles northeast of Glendive. The table below sets forth the stratigraphic relations of the various geologic formations, together with the thicknesses and general characteristics of each.

Table showing relations and characteristics of formations in eastern Montana.

System.	Formation.	Member.	Thickness (feet).	Characteristics.
Tertiary.	Fort Union formation.		1,190	Mainly yellow to ash-gray sandy clay and friable sandstone. Contains a number of lignite beds.
Cretaceous or Tertiary.	Lance formation.	?	500±	Somber-colored clay and lenticular beds of sandstone. Contains a few local beds of lignite resembling subbituminous coal.
		Colgate sandstone.	175	White and yellowish sandstone.
Cretaceous.	Pierre shale.		300[a]	Drab shale with calcareous concretions and crystals of selenite.

[a] Exposed.

PIERRE SHALE.

A zone of black to drab shale, which because of its lithologic character and fossil content is correlated with the typical Pierre shale of South Dakota, extends in outcrop 3 to 10 miles wide in T. 5 N., R. 61 E., northwestward to Yellowstone River. Exposure of this shale in the area under consideration is due to an anticline from which younger

formations have been removed by erosion. For convenience in reference the anticline will be called the Cedar Creek anticline, as that stream flows along the structural axis for a number of miles. On the map (fig. 7, p. 189) are shown the geologic relation of the anticline to the region examined and the areal distribution of the Pierre shale.

A maximum of not more than 300 feet of Pierre shale is exposed in the Cedar Creek anticline. The strata consist mainly of dark shale with abundant crystals of selenite throughout. These crystals remain scattered over the surface where the shale has weathered, and because of their resemblance to mica the idea has arisen locally that mica might be found in commercial quantity in this shale.

Near the top of the formation calcareous concretions are abundant, and in them many fossil shells occur. Numerous collections were made at this horizon, of which the following species may be considered typical:

NE. ¼ NE. ¼ sec. 13, T. 8 N., R. 59 E.:
- Pecten sp.
- Chlamys nebrascensis M. and H.
- Avicula linguæformis E. and S.
- Inoceramus cripsi var. barabini Morton.
- Crenella sp.
- Modiola meekii (E. and S.).
- Nucula sp.
- Leda evansi M. and H.
- Eriphyla gregaria M. and H.
- Lucina subundata H. and M.
- Procardia subquadrata E. and S.
- Callista ? pellucida M. and H.
- Anisomyon alveolus M. and H.
- Lunatia sp.
- Anchura nebrascensis M. and H.
- Pyrifusus (Neptunella) intertextus M. and H.?
- Nautilus dekayi Morton.
- Baculites ovatus Say.
- Scaphites sp.
- Scaphites nodosus Owen.

SW. ¼ SW. ¼ sec. 22, T. 5 N., R. 61 E.:
- Syncylonema rigida (M. and H.).
- Leda evansi M. and H.
- Trigonarca (Breviarca) exigua M. and H.
- Lunatia sp.
- Baculites compressus Say.

About the center of sec. 22, T. 5 N., R. 61 E.:
- Inoceramus sagensis Owen.
- Modiola meekii (E. and S.).
- Trigonarca (Breviarca) exigua M. and H.
- Lucina occidentalis (Morton).
- Lunatia sp.
- Baculites ovatus Say.
- Scaphites nodosus Owen.

SE. ¼ SE. ¼ sec. 2, T. 5 N., R. 60 E.:
Chlamys nebrascensis M. and H.
Avicula linguæformis E. and S.
Inoceramus sp.
Nucula sp.
Leda evansi M. and H.
Limopsis parvula M. and H.
Eriphyla gregaria M. and H.
Lucina occidentalis (Morton).
Thetis circularis M. and H.
Lunatia sp.
Haminea ? sp.
Anchura sp.
Nautilus dekayi Morton.
Baculites ovatus Say.
Scaphites nodosus Owen.

LANCE FORMATION.

Colgate sandstone member.—Overlying the Pierre shale is a mass of arenaceous strata which attains a maximum thickness of about 175 feet and which because of its prominent development in the vicinity of Colgate station, on the Northern Pacific Railway, is termed the Colgate sandstone member. As indicated on the index map it outcrops in a belt on either side of the Cedar Creek anticline. South of the Yellowstone for a number of miles and on either side of Cedar Creek this sandstone is fairly well exposed, especially on the northeast side of the anticlinal axis. Farther south, however, it is shown only in disconnected outcrops because of the prevalence of grass-covered areas.

In the vicinity of Iron Bluff in the northeastern part of T. 14 N., R. 55 E., Leonard [1] measured a section of the sandstone as follows:

Section of the Colgate sandstone member near Iron Bluff.

	Feet.
Sandstone, white, massive, most prominent stratum in the region	35
Sandstone, brown, fossil leaves in bottom part; forms summit of Iron Bluff	75
Shale and sandstone, fossil leaves in upper 20 feet	75
Pierre shale.	
	185

Although there is in the Iron Bluff section an appearance of transition from the Pierre shale into the overlying arenaceous strata, which suggests that the sandstone occupies the stratigraphic position of the Fox Hills, the evidence of fossil leaves indicates that much if not all of it is of later age. In a collection made by Leonard and Campbell in 1906, in the upper 20 feet of the 75-foot sandstone bed immediately overlying the Pierre shale, F. H. Knowlton identifies the following species:

[1] Leonard, A. G., The coal fields of parts of Dawson, Rosebud, and Custer counties, Mont.: Bull. U. S. Geol. Survey No. 316, 1907, p. 198.

Sequoia nordenskioldi Heer.
Populus cuneata Newb.
Populus amblyrhyncha ? Newb.
Viburnum newberryanum ? Ward.
Viburnum sp. ? (no margin).
Platanus sp., probably P. haydenii Newb.

According to Knowlton these species are of Tertiary age. Elsewhere in the region they are associated with dinosaurian remains in the Lance formation, which are regarded as of Cretaceous types, but whichever view is entertained regarding the position of the Lance formation it is certain that if the Fox Hills sandstone is present in this section it is restricted to the 70-foot interval between the location of the fossil plants and the top of the Pierre shale.

Southward from Iron Bluff the stratigraphy suggests even more strongly that the Fox Hills is not present. In the section near Iron Bluff, as given by Leonard, a white sandstone 35 feet thick is 150 feet stratigraphically above Pierre shale. In the Baker field, however, this white sandstone, which as Leonard states constitutes the most prominent stratum in the region, appears to rest directly on Pierre shale without the intervention of the lower strata so noticeable at Iron Bluff.

The facts so far as known at the present time, therefore, will not allow an exact determination of the age of the lower part of the Colgate sandstone member. If it can be determined that the lower part is Fox Hills, then the sandstone must necessarily be considered as made up of two distinctive parts, the line of separation depending on paleontologic evidence. If, on the other hand, the flora obtained on Iron Bluff about 70 feet above the Pierre shale is found to continue down to the base of the sandy beds, the Colgate sandstone should be considered merely as a member of the Lance formation.

In general there appear to be conformable relations at the top of the Colgate member, but at three places at least there are local unconformities. One of these is in sec. 27, T. 6 N., R. 60 E., where the material overlying the sandstone was evidently laid down on an eroded surface, and in sec. 32 of the same township there is evidence of a similar check in sedimentation at the same general horizon. Southwest of Glendive the top of the Colgate sandstone appears at the base of the bluff along which the Northern Pacific Railway passes, and here for the distance of a mile or more the upper surface of the sandstone is gently irregular, apparently due to erosion prior to the deposition of the dark shale immediately above. Fossil plants have been obtained from the upper part of the sandstone in this locality, which according to Knowlton are Lance species.

Upper or undivided part of the Lance formation.—Overlying the Colgate sandstone member is a mass of somber-colored shale and local

beds of sandstone, all of fresh-water origin and constituting a formation known throughout widely separated districts in Wyoming, Montana, and the Dakotas. To these beds several designations have been ascribed, but the name Lance is now applied by the United States Geological Survey. As the strata are generally characterized by fossil bones of the dinosaur group known as Ceratopsia, they have been called in some publications "Ceratops beds"; in other publications they have been termed "Lance Creek beds" or "Hell Creek beds," from their known exposure on streams of those names in Wyoming and Montana, respectively. In the description of the Sentinel Butte and Miles City fields [1] these strata are designated "somber beds" because of their dark color, which contrasts with the overlying yellow rocks of the accepted Fort Union.

In eastern Montana the Lance formation as mapped is generally about 500 feet thick, and in the upper part are several carbonaceous zones in which lignite may occur. The lignite beds are of only local importance, however, as they are usually of very limited extent along the outcrop. The rocks of the Lance formation are extremely soft and weather rapidly into badland areas, in many places devoid of vegetation. The formation is exposed in a belt on either side of the Cretaceous strata which outcrop along the anticline extending southeast from Yellowstone River to the Montana-North Dakota State line. One rather peculiar feature in connection with the formation is the occurrence in unconsolidated sand of loglike sandstone concretions which usually have an iron-stained surface. Some of these concretions are 3 feet in diameter and 20 to 30 feet long. Their origin is doubtful, but it is possible that percolation of chalybeate waters along restricted channels at the time of deposition of the sandstone may have influenced their formation.

During the work in eastern Montana in 1910 it was found that although "somber beds" is fairly applicable to the Lance formation as a field term, it is in a measure misleading in that the change in color from somber to yellow does not take place everywhere at the same horizon. Excellent opportunity for the study of this phase of the subject was afforded during the mapping in detail of a lignite bed that was arbitrarily considered to be the upper limit of the Lance. In tracing the outcrop of this bed it was ascertained beyond question that although the color change may be fairly sharp at one locality, at another it may be difficult to detect or it may occur at an entirely different horizon. For example, on the south bank of the Yellowstone, in sec. 19, T. 14 N., R. 55 E., a clinker bed, probably representative of a considerable thickness of lignite, is underlain by rocks that are uniformly somber in color and overlain by rocks that are prevailingly yellow. On tracing the clinker southward the

[1] Loc. cit.

somber-colored material was found to transgress upward and within 2 miles the change in color is at a horizon 200 feet higher than it is at the river. Therefore, although the outcrop of the continuous lignite bed serves in a general way as a boundary between somber and yellow colored strata corresponding to the Lance and Fort Union formations, that outcrop will not serve as a distinctive line of contact between the formations. In the southeastern part of the Terry field the change in color is in general several hundred feet stratigraphically above the lowest persistent bed of lignite, and along O'Fallon Creek valley from Ismay nearly to Yellowstone River the strata exposed in the bluffs on either side have every appearance of being a part of the Lance formation, although they represent the same stratigraphic interval that elsewhere is occupied by yellowish arenaceous strata supposed to be indicative of the accepted Fort Union. It is evident, therefore, that in the area mapped the upper limit of the Lance formation can not be based on lithologic grounds, but must instead be dependent upon the occurrence of fossil Ceratopsia bones. In the area treated in this report the highest horizon at which these bones were found is just above the lowest persistent lignite bed, but there is certainly nothing in the character of the overlying strata to suggest that similar bones do not occur therein up through a stratigraphic distance of perhaps 500 feet.

Further illustration of the fallibility of the change in color and lithology as a criterion by which to delimit the Lance formation is presented by the fact that in places the change occurs also below the lowest persistent lignite bed. Although it is true that yellow arenaceous strata are not found so frequently below this lignite horizon as above it, yet this occurrence is far from uncommon.

As a result of these conditions no attempt is made on the index map or on the maps of the various areas treated in this report to differentiate the Lance formation from the overlying strata described in connection with the Fort Union formation. As stated previously, the lowest persistent lignite bed was in the field arbitrarily considered to be the upper limit of the Lance, so that by reference to the maps a general idea can be gained of the areal extent of that formation. In other words, the area bounded on one side by the contact between the Pierre shale and the Colgate sandstone member and on the other side by the outcrop of the lowest persistent lignite bed represents the distribution of the Lance formation as mapped in the field. In this connection, however, it can not be emphasized too strongly that the upper limit adopted is merely suggestive, as the finding of *Triceratops* bones higher in the section will necessitate an upward extension of the formation.

Regarding the age of the Lance formation there has been much controversy, as the vertebrate and invertebrate faunas are said to be indicative of the uppermost nonmarine Cretaceous, or in other words, of the Laramie, whereas the fossil flora appears to be inseparable from that of the undoubted Fort Union of Eocene age. Only by detailed work over large additional areas, together with careful consideration of all the evidence, both stratigraphic and paleontologic, can a final conclusion be reached regarding the correct position of the Lance formation in the geologic time scale.

Many fragmentary fossil bones were observed in the Lance formation, but usually so comminuted as to be undeterminable. One collection from a horizon just above the lowest persistent lignite bed represented the following forms as recognized by C. W. Gilmore:

Sec. 36, T. 13 N., R. 59 E.:
- Turtles:
  - Plastomenus sp. indet.
  - Aspiderates sp. indet.
- Rhynchocephalia:
  - Champsosaurus sp. indet.
- Dinosauria:
  - Caudal vertebra of an undescribed dinosaur.
- Crocodilia:
  - Leidyosuchus sp. indet.
  - Crocodylus?

Fossil leaves are more abundant, and the following forms from collections made in the field were identified by F. H. Knowlton:

Sec. 35 or 36, T. 12 N., R. 58 W.:
- Populus amblyrhyncha Ward.
- Populus cuneata Newb.
- Viburnum elongatum Ward.

Sec. 23, T. 12 N., R. 58 E.:
- Populus amblyrhyncha Ward.
- Platanus haydenii Newb.
- Phyllites n. sp.

NW. ¼ sec. 3, T. 10 N., R. 57 E.:
- Viburnum tilioides (Newb.) Ward.
- Platanus haydenii Newb.

Sec. 14, T. 10 N., R. 58 E.:
- Sapindus affinis Lesq.
- Corylus rostrata Ait.
- Grewiopsis curvinervis? Ward.
- Viburnum sp.

NE. ¼ sec. 17, T. 10 N., R. 59 E.:
- Sabal grandifolia Newb.
- Glyptostrobus ungeri Heer of Lesq.
- Sequoia longifolia Lesq., or n. sp.

FORT UNION FORMATION.

Extending in outcrop over a great area in eastern Montana is a mass of yellowish to ash-gray clay, arenaceous shale, and sandstone

referred to the Fort Union formation. Of fresh-water origin it bears the marks of variable sedimentation from place to place, yet is more or less uniform when considered in its entirety. There is everywhere abrupt lateral alternation in character of material, as a sandstone may merge into a clay or shale in a short distance, so that a detailed section at any one locality can not be matched with another taken only a few rods distant. In general no one type of material extends more than a few feet vertically in the section, but instead there is rapid successive change from one type into another. Probably the most persistent traceable horizons in the entire formation are the lignite beds in the lower portion, some of which are more than 30 inches thick along many miles of outcrop.

The following generalized section shows the number and relations of the various lignite beds present in the Fort Union section of eastern Montana. This section begins at the top of Blue Mountain, the highest point stratigraphically and topographically in the northern part of the area treated in this report, and ends at the lowest lignite bed of the formation at the headworks of the reclamation project on Yellowstone River.

Generalized section of the Fort Union formation in the Sidney lignite field, Montana.

	Ft.	in.
Sandstone and clay, brown to dark gray, the sandstone coarse grained and massive, in beds 10 to 15 feet thick ("upper somber beds" of Sentinel Butte lignite field)	210	
Lignite, bed K	2	4
Sandstone and clay, ash gray to yellow	140	
Lignite, bed J	2	10
Sandstone and clay, gray to yellow in alternating beds	72	
Lignite, bed I	4	5
Sandstone and clay, yellow to ash gray	141	
Lignite, bed H	4	8
Sandstone, clay, and sand, yellow to ash gray	93	
Lignite, bed G	9	1
Sandstone and clay, dark gray, cross-bedded	127	
Lignite, bed F	4	8
Clay, shale, and sandstone, gray to yellow	89	
Lignite, bed E	3	2
Clay and sandstone, gray to yellow, the sandstone in beds up to 5 feet thick	89	
Lignite, bed D	4	
Clay and shale, gray, in many places carbonaceous with impure lignite in thin seams	97	
Lignite, bed C	5	4
Clay and sandstone, gray to yellow	44	
Lignite, bed B	4	6
Clay and sandstone, gray	39	
Lignite, bed A	3	8
	1,189	8

The following section presents in more detail the lithologic character of the lower part of the Fort Union formation and likewise shows the relations of the lignite beds occurring therein:

Section in Blackmore Coulee, about 3 miles east of Intake, Mont., in T. 18 N., R. 57 E.

	Ft.	in.
Clay and sandstone, gray, partly covered (summit of upland)	30	
Lignite, bed G	5	11
Sandstone and clay, very dark gray and cross-bedded (typical "somber beds")	75	
Lignite, bed F	5	1
Clay and sandstone, ash gray to light yellow	32	
Lignite, bed E	2	2
Clay and sandstone, gray, with several very thin beds of lignite	40	
Sandstone, coarse-grained and yellowish, most persistent stratum in the coulee	2	
Clay, yellow	18	
Shale and clay, yellow to gray, with many thin beds of lignite	28	
Lignite, bed D	5	6
Shale and clay, dark gray, locally carbonaceous with impure lignitic streaks	20	
Sandstone, yellow to buff, cross-bedded and concretionary	15	
Lignite, impure	1	
Clay, dark gray, carbonaceous	14	
Sandstone, gray to yellow	8	
Shale, dark gray, carbonaceous	12	
Clay, gray	10	
Lignite, bed C	4	9
Clay, light gray	6	
Lignite, impure	1	
Clay, gray	4	
	339	5

In the detailed section given above and in the preceding more generalized one, the various lignite beds are referred to alphabetically by designating the lowermost as A, the next higher as B, and so on to the highest—bed K. These beds are similarly designated in the detailed description of the Sidney field.

ALLUVIUM.

Bordering all the streams of the region are recent deposits of alluvium, but with the exception of an area in Yellowstone Valley this formation was not mapped. It has little geologic significance, except in an area northeast of Glendive and east of Yellowstone River. Here the streams are cutting through alluvial deposits approaching a maximum of 50 feet in thickness, strongly suggesting a rejuvenation of the drainage in this locality.

STRUCTURE.

As the area discussed lies in the Great Plains region and far removed from mountain uplifts, it would be expected that it would have no marked structural features. On the contrary, however, a strongly pronounced anticline extends from Yellowstone River near the mouth of Cedar Creek southeast for about 70 miles into the Dakotas. The anticline affects the entire rock section exposed and its influence extends to an unknown depth into the Pierre shale and underlying strata. The anticline is asymmetrical, with dips of 10° to 30° on the southwest limb, and with slighter dips—5° or less—on the northeast limb. Southeastward from the Yellowstone the anticline flattens somewhat and the dips, especially to the southwest, lessen noticeably.

Streams have cut into the anticline, exposing a zone of Pierre shale along the axis, with rocks stratigraphically higher outcropping on either side. As a result of the relatively high dips on the southwest limb the Colgate sandstone member and overlying beds of the Lance formation outcrop in narrow belts in that part of the area, whereas on the northeast the outcrops, especially those of the somber-colored beds of the Lance, widen to include a much larger area.

Although northeast of the anticlinal axis the strata dip uniformly at a slight angle as far as the eastern limit of the area mapped, on the southwest limb the strata are inclined locally 25° or more from the horizontal, but this dip flattens rapidly and shortly after passing into the area of the Fort Union rocks it reverses to the northeast. The area between Powder River and the Cedar Creek anticline represents, therefore, a shallow syncline with the axis near the eastern margin.

Throughout the extent of the Cedar Creek anticline there is no observed modification by faults or minor folds. This feature suggests the possibility of the anticline as a natural storage place for oil, although nothing indicative of the presence of petroleum was noted. However, even were oil or gas present in the lower part of the Pierre shale or in underlying strata, the impervious character of the upper part of the shale would preclude escape to the surface, especially as faults or fracture zones were not observed in connection with the anticline. In the absence of drilling, therefore, no statement can be made regarding the possible oil content of the anticline other than that if oil is present in the section below the upper part of the Pierre shale the anticline furnishes a favorable structure for its accumulation and retention.

THE BAKER LIGNITE FIELD, CUSTER COUNTY, MONTANA.

By C. F. Bowen.

INTRODUCTION.

The general geology and topography of the Baker lignite field have been discussed in the preceding paper by W. R. Calvert. The purpose of this paper is to give detailed information regarding the lignite beds.

The horizontal control used in mapping the beds was based on land surveys which, for a few townships, have not yet been accepted by the General Land Office. The land corners are in general well established throughout the field and were easily found wherever looked for.

The accompanying map (Pl. XV, p. 226) was compiled from the field maps made during the progress of the work, and also from land-office plats furnished by the General Land Office.

M. A. Pishel was in charge of the party during the first month of the field work. On August 16 Mr. Pishel was detailed to another field and the writer assumed direction of the work during the remainder of the season. E. M. Parks served as assistant during the entire field season. To these men, and also to W. R. Calvert and E. G. Woodruff for general supervision in the field and office, the writer here expresses his acknowledgments.

STRATIGRAPHY.

The following table shows the relation and thickness of the formations which outcrop in this area:

Geologic formations in the Baker lignite field.

System.	Formation.	Member.	Thickness (feet).
Tertiary.	Fort Union formation.		[a]300±
Cretaceous or Tertiary.	Lance formation.		480
		Colgate sandstone.	90
Cretaceous.	Pierre shale.		[a]200±

[a] Exposed in Baker field.

For descriptions of these formations see pages 192–200.

THE LIGNITE.

GENERAL CHARACTER.

The important lignite beds exposed in the Baker field occur in the upper part of the Lance formation and in the overlying Fort Union. The outcrops of the principal beds are shown on Plate XV.

In this report all the mineral fuel is called lignite, although it is recognized that the lignite from some of the beds is of much better quality than that from others and approaches closely the grade of subbituminous coal.

The distinction between lignite and subbituminous coal is necessarily neither definite nor sharp. The term lignite as used by the United States Geological Survey is restricted to that material which is distinctly brown and woody, whereas the term subbituminous coal is applied to similar material that has lost most if not all of its woody texture and has become black in color. In eastern Montana and adjacent parts of North and South Dakota the coal of the Lance formation generally is more nearly black and less woody than is that of the overlying Fort Union formation, and in some publications it has been called subbituminous coal. In this field the difference between the coals of the two formations is slight and irregular, and therefore as a matter of convenience they are all called lignite.

In the Lance formation beds of lignite 3 feet thick or more occur at two zones, the upper near the top of the formation as its boundary was placed in this field and the other about 100 feet lower in the strata. The lignite of the upper zone is the more important. The lignite of the lower zone was found to be 3 feet or more in thickness only along Sandstone Creek east of Plevna and along O'Fallon Creek in Tps. 5 and 6 N., R. 56 E. Thinner beds of lignite ranging from a few inches to about 30 inches, but generally measuring less than 24 inches, occur both between and below the zones just described. All lignite beds of the Lance formation are exceedingly variable in quality, thickness, and extent. One bed which measures nearly 7 feet of fair lignite at one exposure contains only carbonaceous shale at another exposure about 500 feet away.

The lignite of the Fort Union formation occurs in a zone about 100 feet above the upper lignite zone of the Lance formation. In this zone there are three principal beds distributed through a vertical range of 30 to 60 feet. These beds are more constant in thickness than are those of the Lance formation. This characteristic is particularly true of the northern part of the field, where the beds are thicker and contain a better grade of lignite than in the southern part of the area. Because the Fort Union has been deeply dissected by erosion the lignite of that formation now occurs only in small detached areas.

All the lignite beds have been more or less burned along the outcrop, but in the field as a whole the burning has been more extensive in the beds of Fort Union age than in the older ones. The outcrops of the higher beds are almost everywhere fringed by a broad area of clinker-capped buttes and ridges. This condition may be due in part to a greater tendency to spontaneous combustion in the Fort Union lignite than in the older lignite of the Lance formation, but it is believed by the writer to be dependent to a greater extent on the difference in thickness of cover over the lignite beds of the two formations. This conclusion seems to be borne out by the fact that where the Fort Union formation has been removed by erosion and the lignite beds of the Lance are in a nearly horizontal position and beneath slight cover, they also have been extensively burned along the outcrop. On the other hand, where the Fort Union lignite outcrops along steep slopes and therefore passes under considerable cover in a short horizontal distance, burning along the outcrop has been slight.

DEVELOPMENT.

There are no drifts, shafts, or other development work on the lignite of the Baker field. Lignite has been taken from several surface exposures for local use at ranches. As the country becomes more thickly settled such use will naturally increase, but it is not probable that any extensive mining operations will be undertaken in the near future.

DETAILED DESCRIPTION BY TOWNSHIPS.

In the following detailed description of the lignite of the Baker field, the area is considered by townships, beginning at the northeast corner and going from east to west across the field, each tier of townships being discussed in order from north to south. The sections on Plate XIV are referred to here by numbers only, which correspond with those used on the map (Pl. XV). Measurements of some sections not illustrated on Plate XIV are given in the text.

T. 8 N., R. 61 E.—Three beds of lignite outcrop in the face of the buttes and badland escarpments of this township. All these beds are in the Lance formation. The lowest one is near the base of the buttes and the others follow at distances of about 35 feet A section of the lowest bed measured near the east side of the SW. ¼ sec. 1 shows 2 feet of lignite with 8 inches of bone below it, whereas about one-eighth of a mile away the same bed shows 8 inches of lignite and 18 inches of bone. These two sections are indicative of the variability of this bed throughout the township.

The outcrop of the middle bed is represented on the map (Pl. XV). The following measured sections show its general character:

Sections of middle bed of lignite in T. 8 N., R. 61 E.

Location 1, sec. 2.

	Ft.	in.
Lignite	1	
Parting		1
Lignite, bony	1	2
	2	3

Location 2, sec. 2.

	Ft.	in.
Bone	1	
Shale	1	
Lignite		3
	2	3

Location 3, sec. 14.

	Ft.	in.
Lignite		3
Parting		1
Lignite, bony	1	2
Parting		1
Bone		11
	2	6

Location 4, sec. 11.

	Ft.	in.
Lignite		8
Parting		1
Lignite, dirty	1	3
Shale		3
Lignite		5
	2	8

Location 5, sec. 16.

Shale.	Ft.	in.
Lignite		2
Parting		1
Lignite		6
Parting		1
Lignite		4
Bone		10
	2	

Location 7, sec. 8.

	Ft.	in.
Bone		4
Shale		2
Lignite		11
	1	5

Location 7a, sec. 8.

	Ft.	in.
Lignite, dirty		6
Lignite		9
Bone		4
Lignite		2
	1	9

Location 8, sec. 6.

	Ft.	in.
Lignite	1	3
Lignite, dirty		10
Bone		9
	2	10

Location 9, sec. 7.

	Ft.	in.
Shale, carbonaceous	2	
Lignite		4
Shale, carbonaceous		8
	3	

Location 10, sec. 7.

	Ft.	in.
Lignite		10
Lignite, dirty	1	8
Shale	35	
Lignite		4
Bone	1	6
	39	4

Location 11, sec. 7.

Shale.	Ft.	in.
Lignite		10
Bone	1	
	1	10

The bed is thicker and the lignite is of better quality at location 6, sec. 9 (Pl. XV) than elsewhere in the township. The middle bed can be traced without difficulty around the buttes in the northern part of the township.

T. 8 N., R. 60 E.—A thin bed of lignite outcrops in the road between the Pugh and Damon ranches located in secs. 3 and 10, respectively. Lignite also occurs near the tops of a few isolated buttes to the east and northeast of the Damon ranch. The lignite is thin and of poor quality and was not mapped. About half of the

township is covered by the Pierre shale and Colgate sandstone member of the Lance, which are not lignite bearing.

T. 8 N., R. 59 E.—The boundary between the lignite-bearing and nonlignite-bearing formations passes diagonally through this township from about one-eighth of a mile west of the southeast corner of sec. 35 to a little east of the north quarter corner of sec. 6. No lignite occurs east of this line. To the west of and parallel with it the outcrops of two burned lignite beds are indicated by a series of isolated clinker hills.

The lower of these beds seems to be unimportant. Near the center of sec. 8 its position is indicated by the partially burned condition of the overlying rocks, which were baked and reddened but not fused by the burning of the lignite. Near the center of the NW. ¼ sec. 21 is another area of clinker and just north of it the lignite bed is exposed and shows about 4 feet of carbonaceous material in which a member about 12 inches thick contains lenses or streaks of lignite. In the NW. ¼ sec. 6, just east of and 40 feet stratigraphically below No. 13, the following section was measured on a bed exposed in the bottom of Pennel Creek:

Section of lignite bed in Pennel Creek.

	Inches.
Shale, brown.	
Lignite	5
Clay, bluish	11
Lignite	2
Bone	6
Clay.	
	24

This may be the same bed as that represented by the outcrops just described above or possibly it is still another lens not noticed elsewhere.

The upper bed is marked along the greater part of its outcrop by well-fused clinker beds capping hills at intervals of one-eighth of a mile to a mile or more, between which no exposures occur. In the north bank of Pennel Creek, about 1,000 feet S. 30° E. from the northwest corner of the township (No. 13), the lignite is exposed and measures 7 feet 10 inches in thickness. The greater part of the bed seems to be of poor quality, but the outcrop is so badly weathered that it gives little indication of the character of the fresh unweathered material. At the level of the creek the lignite is of better quality than it is higher in the section. The dip at this place is 15° SW.; the strike is N. 30° W.

Southeast of the above-described locality the position of the same bed of lignite is indicated by clinker at the following localities: Northwest corner of sec. 8; central part of S. ½ sec. 8; northwest of the east quarter corner of sec. 17; southwest corner of sec. 16; NW. ¼

and southeast corner of sec. 21; SW. ¼ sec. 27; and about one-fourth mile west and a little north of the east quarter corner of sec. 34. This last locality is less than a mile distant from the preceding one and is characterized by a marked decrease in the amount of fused clinker and a corresponding increase in the amount of burned material, which probably indicates that the bed is somewhat shaly. Nearly one-half mile farther southeast, near the center of the SW. ¼ sec. 35, at the same horizon as nearly as could be determined, 29 inches of carbonaceous shale is exposed. This shale can be traced southward about three-fourths of a mile into the next township to the south where the outcrop swings west, following the escarpment on the north side of the valley of Sandstone Creek, and reenters this township just east of the south quarter corner of sec. 34. The bed can be followed with little difficulty from here to the west side of the township, as is indicated by the outcrop on Plate XV. At location 12, sec. 32, it contains 12 feet 4 inches of carbonaceous shale overlying 1 foot of good lignite. This seems to be characteristic of the bed in this part of the field. It seems probable from the character of the clinker along the eastern outcrop of the bed that good lignite will be found a short distance back of the burned outcrop from about the south side of sec. 27 northwestward through the township. Because of the steep dips (12° to 17°) the burning of the lignite has probably not extended far back of the outcrop.

T. 8 N., R. 58 E.—Three beds of lignite have been mapped in this township. In addition to the beds mapped, there are as many more distributed throughout the exposed section. The lowest bed outcrops at several places in the bottom of Sandstone Creek. Locations 42 and 43, in secs. 6 and 8, T. 7 N., R. 59 E., are discussed in connection with that township and are the thickest measurements obtained on this bed. In this township the bottom of the bed is usually beneath the creek. At location 20, on a higher level, this bed is only 4 inches thick and is exposed at the water's edge.

The lowest bed indicated on the map is exposed along the south bank of Sandstone Creek wherever the meanders are undermining the lignite-bearing formation.

The following sections of this bed were measured at the places indicated on Plate XV:

Sections of lignite bed in T. 8 N., R. 58 E.

Location 18, sec. 35.

	Ft.	in.
Shale.		
Lignite		3
Shale		4
Lignite		4
Shale	3	8
Lignite		4+
	4	11+

Location 19, sec. 34.

	Ft.	in.
Lignite		3
Shale		4
Lignite		4
Shale.		
		11

Location 20, sec. 34.

	Ft.	in.
Shale.		
Lignite		4
Shale	16	
Lignite		4
	16	8

Location 21, sec. 28.

	Ft.	in.
Sandstone.		
Bone		8
Shale		7
Lignite, dirty	2	2
Shale	18	6
Lignite	1	
Shale.		
	22	11

The character of the bed west of the last-mentioned location is shown by sections 22 to 25 on Plate XIV. By an examination of these sections it will be seen that the lignite has a thickness of more than 3 feet in secs. 28 and 29 but is thinner and poorer in quality to the east. On the north side of the Sandstone Creek valley what is believed to be the same bed shows the following sections:

Sections of lignite bed in T. 8 N., R. 58 E.

Location 16, sec. 26.

	Ft.	in.
Bone		10
Lignite	2	3+
	3	1+

Location 26, sec. 20.

	Ft.	in.
Lignite	2+	
Shale.		

Location 17, sec. 22.

	Ft.	in.
Lignite		7
Shale		3
Lignite	2	3+
	3	1+

A complete section could not be obtained except at location 17 because the bottom of the bed is below water at the other localities.

The middle bed indicated on the map (Pl. XV) is too high to be exposed in the south bank of Sandstone Creek but undoubtedly underlies the grass-covered slope back from the creek. Along the face of the escarpment on the north side of the valley this bed is represented by numerous hills of slightly burned rocks, and the unburned lignite is exposed in several of the coulees which cut the escarpment. The lignite is of medium quality, brown, and woody. At two localities the bed is exposed with the following sections:

Sections of lignite bed in T. 8 N., R. 58 E.

Location 14, sec. 25.

	Ft.	in.
Bone		8
Lignite	2	
	2	8

Location 15, sec. 24.

	Ft.	in.
Bone		10
Lignite, dirty		2
Lignite	1	3
	2	3

It is not known to be more than 2 feet 6 inches thick at any place in the township.

The upper lignite bed is a continuation of the upper bed described in T. 8 N., R. 59 E., and is easily traced in the badland escarpment. Two detailed sections (Nos. 27 and 28) near the east and west sides of the township are given. No. 28, which was measured in a butte a little south of the main outcrop, has a thickness of 10¼ feet, but it is so impure as to be of doubtful value.

T. 8 N., R. 57 E.—In this township lignite exposures are confined to the valley of Sandstone Creek. The lowest bed exposed (No. 29) outcrops in the northwest corner of sec. 35, in the west bank of the creek, about 400 feet east and a little south of the section corner. The bed is 12 feet thick. The bottom of the bed is about 4 feet above the creek bed at the middle of the exposure but in either direction along the outcrop soon passes below the creek level. It is believed from what is seen at the exposure that the bed is brought to the surface by a slight upward flexure at that point and passes beneath the creek bottom in either direction from the outcrop. In the field this bed was correlated with the upper bed mapped in the township to the east. The westward dip observed northwest of Plevna is sufficient to carry the lignite below creek level in this township.

Along the creek to the northwest of location 29 lignite is exposed in cut banks to a point less than a mile from Westmore. Vertically the position of the lignite ranges from near the bed of the creek to 10 feet or more above that level.

The character of the bed in the northern part of the township is shown by the following section:

Section of lignite bed at location 32, sec. 5.

	Ft.	in.
Sandstone.		
Bone		5
Lignite		7
Lignite, dirty		6
Lignite	2	
Shale.		
	3	6

Sections 30 and 31 on Plate XIV indicate the character and thickness of the bed. The locations of other outcrops along this horizon

are shown on Plate XV. Most of these exposures show 1 to 2 feet of fairly good lignite, but in some places the entire bed is of very poor quality.

T. 8 N., R. 56 E.—One bed of lignite is exposed in this township. It occurs near the top of the Lance formation and is exposed at places on both sides of O'Fallon Creek wherever cut banks occur in the lignite-bearing formation. The lignite outcrop is generally about on a level with the alluvial terraces bordering the stream, and for that reason the bed is represented (see Pl. XV) as being cut out by the stream in the alluvial area. In order to better understand the conditions in this township, one outcrop (No. 38) will be considered, which occurs in the NE. ¼ sec. 1, T. 8 N., R. 55 E. At this location 10 lignite beds range through a vertical distance of about 33 feet. Most of these are less than a foot in thickness, but about 10 feet from the base of the section there is a 36-inch bed of lignite with a 1-inch parting 1 foot from the bottom; 10 inches higher an 18-inch bed occurs, making in all 54 inches of lignite with two partings 1 inch and 10 inches thick.

No exposures of lignite are shown between location 38 and the center of sec. 17, T. 8 N., R. 56 E. At the latter locality 12 inches of dirty lignite, separated by 3 feet of clay from a carbonaceous shale above, is exposed on the east bank of O'Fallon Creek. On the opposite side of the creek, about one-half mile farther south in the northeast corner of the SE. ¼ SE. ¼ sec. 18 a bed of carbonaceous shale 18 inches thick with 3 inches of lignite near the top is exposed. The bed dips 5° S. These last two exposures probably represent one of the upper beds of the section at No. 38. One mile still farther south 40 inches of lignite, the upper 18 inches of which is of rather poor quality, is exposed on the east side of the creek in the SE. ¼ sec. 20. Sections 34 to 36 represent a bed exposed on the west side of the stream near the east side of sec. 30. These exposures, from north to south, show 47, 52, and 58 inches, respectively, of fair lignite. Near the south side of the township in the northeast corner of the SE. ¼ SE. ¼ sec. 31 the bed (No. 37) is 59 inches thick, but the quality is poor, except 24 inches at the bottom. Exposures 33 to 37 in this township and 38, just beyond the northwest corner of the township, have a fairly uniform thickness and with one exception (No. 37) a uniform quality also, and seem to warrant the conclusion that the entire township, except the creek bottom, is probably underlain by good lignite.

T. 8 N., R. 55 E.—Only two outcrops of lignite are known to occur in this township. The more important (at location 38) is described under T. 8 N., R. 56 E. The bed is also exposed about one-half mile farther north, near Burt's house, so that it seems quite certain that a part, at least, of this township is underlain by that bed.

The only other outcrop of lignite known is in the southwestern part of the SW. ¼ sec. 8, where 22 inches of lignite overlain by 20 inches of

bone was measured. This lignite is in the Fort Union formation and probably represents an isolated remnant of one of the lower beds of that formation exposed in the township to the west.

T. 8 N., R. 54 E.—Several beds of lignite of poor quality are exposed in this township. The exposures are more numerous and prominent in the northern than in the southern half of the area. The following sections give measurements and approximate locations:

Location and thickness of lignite outcrops measured in T. 8 N., R. 54 E.

Sec. 3 (1,500 feet west of southeast corner).

	Inches.
Bone	18
Lignite	2
Bone	9
Lignite	10
	39

SE. ¼ NE. ¼ sec. 7.

	Inches.
Bone	11
Lignite	7
Interval	3
Lignite	5
	26

Sec. 7 (one-half mile south of preceding measurement).

	Inches.
Carbonaceous shale	12
Lignite	12
Interval	25
Carbonaceous shale	5
	54

SW. ¼ sec. 11.[a]

	Inches.
Bone	12
Lignite	15
Interval	3
Lignite	12
	42

SW. ¼ sec. 17.

	Inches.
Bone	9
Lignite	7
Interval	9
Lignite	4
Interval	3
Carbonaceous shale	6
Lignite	4
	42

In the southwestern part of the township, in the area shown on the map (Pl. XV) by the symbol for burning, the lignite of the Fort Union formation has been burned out, resulting in heavy beds of clinker capping the hills in that area.

Other outcrops were noted in this township as follows: NW. ¼ NW. ¼ sec. 13, carbonaceous shale with streaks of lignite; NW. ¼ sec. 15, carbonaceous shale 42 inches thick, with three streaks of lignite up to 4 inches thick; SW. ¼ NW. ¼ sec. 20 and west quarter corner of sec. 36, not measured, lignite very dirty; and NW. ¼ NW. ¼ sec. 21, poorer quality of lignite than that in any of the preceding outcrops.

T. 7 N., R. 61 E.—Lignite is not exposed at the surface anywhere in this township. The surface rock over most of the area is the Lance formation, the upper part of which is not present.

T. 7 N., R. 60 E.—Almost the entire township is covered by the Pierre shale and Colgate sandstone, which are not lignite bearing.

[a] Best lignite exposed in this township.

The lower part of the undivided Lance formation is present in the northeast corner of the area but so far as known contains no lignite.

T. 7 N., R. 59 E.—The lowest lignite bed exposed in this township is that in the bottom of Sandstone Creek. The following sections were measured in that locality:

Section of lowest lignite bed along Sandstone Creek.

Location 41, sec. 9.

Shale.	Ft.	in.
Lignite		2
Bone	1	8
Lignite	1	7
	3	5

Location 42, sec. 8.

	Ft.	in.
Bone	1	8
Lignite		1
Shale	3	11
Lignite		2
Shale		4
Bone		9
Lignite		2
Bone		3
	7	4

Location 43, sec. 6.

	Ft.	in.
Shale, carbonaceous	1	3
Sandstone		11
Shale, carbonaceous		5
Bone		8
Lignite		3
Parting		1
Lignite		11
Parting		1
Lignite		5
	5	

The lignite at location 41 can not be definitely correlated with that at locations 42 and 43, as there are no intervening exposures and the dip is uncertain, but it is probable that the three exposures represent the same bed. Location 41 is a little lower relative to the creek bed, but the gradient of the stream is sufficient to account for the difference if the strata are horizontal, as they apparently are. The lignite is thinner but of better quality at location 43 than at location 42 and is used locally.

A lignite bed is exposed near the east side of the SW. ¼ sec. 15 (No. 40), about one-fourth of a mile south of the road leading to Baker and on the southern slope of the hill. The section at this place is as follows:

Section of lignite bed at location 40, sec. 15.

	Ft.	in.
Bone	2	2
Lignite		2
Bone	2	5
Lignite		3
Bone		11
Lignite		3
Shale		4
Lignite		2
Shale		8
Lignite		2
Bone		3
Lignite		1
	7	10

The bed undoubtedly underlies the entire hill above the level of the section. Its presence is indicated at places on the north side of the hill by burned rock along the outcrop. The lignite is reported to have been burning in 1909, but no evidences of burning were visible at the time of this examination.

In the SW. ¼ sec. 36, a short distance east of the wagon bridge across Red Butte Creek, the bed represented by section 39 is exposed in the north bank of the creek. It has a total thickness of 49 inches with about 20 inches of lignite in three benches. The same bed is exposed at several other places on each side of the creek in this area and also in T. 6 N., R. 60 E., in connection with which another detailed section (No. 62, Pl. XIV) is given.

Two thin beds, showing a total of 22 inches of good lignite, are exposed on the east side of a gully in the southeast corner of sec. 34. Just west of the center of sec. 32, 8 inches of good lignite is shown. These are doubtless the same beds as are exposed in the coulees in the township to the south where they range from 10 to 15 inches in thickness.

Over a large tract southwest of Baker a lignite bed which has been completely burned out is represented by a heavy well-fused clinker which caps the buttes in that area.

About 1½ miles northwest of Baker there are two clinker hills which are on the strike line of the easternmost burned hills in T. 8 N., R. 59 E. The bed represented by these clinker areas is probably correlated with the lower (easternmost) bed described under T. 8 N., R. 59 E.

The lignite outcrop indicated on the map (Pl. XV) in secs. 3 and 4 is a continuation of the bed traced through the township to the north. It is represented here by carbonaceous shale only.

T. 7 N., R. 58 E.—One important lignite bed outcrops in this township. It occurs near the top of the Lance formation, and its outcrop follows the western brow of the ridge which lies east of the valley of South Fork of Sandstone Creek. Just west of the east quarter corner of sec. 27 (No. 44) the bed is exposed and was opened to a depth of 4 feet without reaching bottom. The lignite had been affected by burning along the outcrop and was also badly weathered, so that it gave no indication of the quality of the unaltered material. From this point the bed has been burned along the outcrop to the south side of the township. The clinker produced by the burning is very thick and shows evidence of almost complete fusion.

A little north of location 44 the clinker ends abruptly, and from there northward the lignite horizon is marked by carbonaceous shale containing thin seams of lignite. A short distance southeast of the west quarter corner of sec. 5 seams of lignite and shale are distributed

through a vertical distance of about 31 feet, as shown by the following section:

Section of lignite bed at location 44a, sec. 5.

	Ft.	In.
Shale.		
Lignite	1	
Shale	11	
Lignite		4
Shale	10	
Bone	1	3
Lignite		2
Bone		6
Lignite		1
Lignite, dirty		4
Lignite		2
Lignite, dirty		6
Shale		7
Bone		5
Shale.		
	26	4

Just north of this location the bed is again burned along the outcrop, but the heat produced was not sufficient to cause fusion in the overlying clay and shale.

If the quality of the lignite and the character of the clinker produced bear the same relation to each other in this township as on this same bed in T. 6 N., R. 60 E., then it is likely that lignite of fair quality exists west of the clinker belt in the southern part of the township, and that north of the clinker belt the lignite is of very poor quality.

Along the lignite horizon the strata strike N. 15° to 20° W., and dip 3° to 5° SW.

T. 7 N., R. 57 E.—The lignite of the Fort Union formation underlies two detached areas in this township, the boundaries of which are indicated on the map (Pl. XV). In the smaller area, in sec. 4, the bed is exposed only at location 50. Elsewhere the lignite has been burned along the outcrop, as a result of which the overlying strata have been completely fused into clinker beds.

The second and larger of the two lignite areas includes all or a part of secs. 8, 9, 13 to 17, and 21 to 26. On the south side of the area three lignite beds are exposed. No. 49 represents the top and middle beds, which are separated by an interval of 15 feet. Nearly a mile to the southeast, in the SE. ¼ sec. 22 (No. 48), the lower bed is partly exposed at a horizon about 20 feet below the middle bed. The top and middle beds are 4 feet and 4 feet 7 inches thick, respectively, and a thickness of 6 feet 2 inches of the lowest bed is exposed, the bottom being concealed and inaccessible because of water. On the north side of the area lignite is exposed at Nos. 45, 46, and 47. These exposures represent either the top or middle bed. The lignite

area is surrounded by a broad fringe of clinker buttes, which represent the former extension of the lignite bed. In some places lignite is exposed in these buttes. Lignite is also exposed among the clinker buttes in sec. 32, but the occurrences are too small to be of economic importance.

T. 7 N., R. 56 E.—The lignite near the top of the Lance formation outcrops at intervals along each side of O'Fallon Creek in the western part of the township. An exposure of 26 inches of lignite occurs on the west side of the creek in the NE. ¼ SW. ¼ sec. 5 (No. 52). The next exposure on the west side of the creek (No. 56) is west and a little south of the east quarter corner of sec. 30, where there is 16 inches of lignite in two benches separated by 14 inches of bone and clay and overlain by alternating beds of clay and shale. On the south side of Hay Creek, in the SW. ¼ NW. ¼ sec. 31, the bed is also exposed at location 57. The section is about the same as at No. 56 except that the carbonaceous shale layers are more numerous.

On the east side of the creek the exposures of the same bed are more numerous and are represented by the following sections:

Sections of lignite bed on east side of O'Fallon Creek.

Location 58, sec. 33.

	Ft.	in.
Lignite		2
Shale	2	1
Lignite		7
Bone		8
Lignite		5
Shale		2
Lignite		6
	4	7

Location 55, sec. 17.

	Feet.
Lignite	2

Location 54, sec. 9.

	Ft.	in.
Lignite		6
Shale		9
Lignite	1	
Shale		5
Lignite		1
	2	9

Location 53, sec. 4.

	Ft.	in.
Bone	2	8
Lignite, bony		10
	3	6

The best section is that measured at location 51 in sec. 4, which is shown on Plate XIV.

From these sections it will be seen that this bed is of poorer quality in this township than in the township to the north.

The Fort Union lignite horizon is represented by clinker capping many of the buttes in the northeast corner of the township, but the lignite has been completely burned in that area. There is an exposure of 23 inches of lignite with a parting of 5 inches on the north side of Pine Creek, in the SW. ¼ sec. 13.

T. 7 N., R. 55 E.—Except for a small outcrop of poor lignite on Hay Creek, in the SW. ¼ SW. ¼ sec. 32, no exposures of lignite are known in this township. The surface formation over the greater part of the area is the Fort Union, the Lance formation occupying

only a narrow strip along the lower course of Hay Creek. There are numerous buttes in the west half of the township which are capped by clinker caused by the burning of the Fort Union lignite, and it is possible that in secs. 8 and 10 a small amount of unburned lignite may exist under the slight cover which overlies the bed, but the burning has been so extensive that the amount of unburned lignite, if any, is small.

If important beds of lignite exist in this township they are in the Lance rather than the Fort Union formation, and must be found by drilling. As favorable conditions have been found to the east, along O'Fallon Creek, and to the west in the Miles City field, in the upper part of the Lance formation, it is possible that lignite may be found in that formation in at least the northern part of this township.

T. 7 N., R. 54 E.—The Fort Union is the surface formation over this township. The greater part of the area, exclusive of stream valleys, is one of clinker hills. Two and probably three beds of lignite have burned, and the resulting clinker is very thick.

In the southwestern part of the township two areas, one extending from the west quarter corner of sec. 30 to the southwest corner of sec. 31, and the other in the southern part of sec. 32, are under sufficient cover so that the burning probably did not extend far back of the outcrop. Each of the above areas is thought to be underlain by good lignite. North of the North Fork of Locate Creek two small areas in secs. 4, 8, and 9 surrounded by heavy clinker are under thin cover. Some lignite may be found under these areas, but because of their small extent, thin cover, and the extensive clinker beds surrounding them, it is probable that most of the lignite has been burned.

About 60 feet stratigraphically below the burned beds described above a bed of very impure lignite is exposed at the base of many of the hills at the outer margin of the clinker area. This lignite was examined at the following localities: Near the north boundary of sec. 25 west of the quarter corner; about a mile farther to the southwest; north of Spring Creek in the NW. ¼ sec. 14; again to the northwest, probably in the NW. ¼ sec. 14 or NE. ¼ sec. 15; in a butte by the farmhouse on Locate Creek in the SW. ¼ sec. 20; and on the east line of sec. 12 about 700 feet south of the northeast corner of the section. In none of these exposures was more than 12 inches of good lignite found. Generally there were several thin streaks of fair lignite intercalated in very dirty impure lignite, at places little better than carbonaceous shale.

In the SE. ¼ sec. 20, east of the farmhouse and in the bed of a creek, there is an outcrop of lignite belonging to a bed below the dirty lignite described in the preceding paragraph. This exposure shows 33 inches of brown woody lignite. The bed was not seen at any other

place, but a neighboring farmer said he had opened it at other places along the creek and found it too dirty to use.

As in the township to the east, and for the reasons given under its discussion, at least a part of this township may be underlain by good lignite belonging to the upper part of the Lance formation, but the presence and quality of such can only be demonstrated by prospecting with drill or other method.

T. 6 N., R. 61 E.—With the exception of a small area in the extreme northeast corner, the nonlignite-bearing Pierre shale and Colgate sandstone constitute the surface formations in this township, and therefore it is believed that lignite does not occur in the area.

T. 6 N., R. 60 E.—The upper boundary of the Colgate sandstone member of the Lance formation extends in a general southeasterly direction from one-fourth mile east of the northwest corner of the township to the north quarter corner of sec. 34, where it turns slightly to the west of south and crosses the south line of the township just west of the southwest corner of sec. 34. East of this boundary the non-lignite-bearing rocks constitute the surface formations; to the west the Lance formation appears at the surface and is locally lignite-bearing.

A lignite bed outcrops in the east bank of Red Butte Creek along the west line of sec. 6 from the quarter corner north (No. 62). The bed has a total thickness of 35 inches, the upper 10 inches of which is bony. This lignite underlies the area between the outcrop and the crest of the low grassy ridge about one-half mile to the east. What is probably the same bed is represented by clinker in the northwest corner of sec. 8 in two small red buttes. A carbonaceous shale containing local lenses of lignite is exposed on the east side of Brackett Butte, in the SE. ¼ sec. 17. Lignite is exposed along the badland escarpment in secs. 20, 29, and 30, where it shows the following sections:

Sections of lignite bed in the southwestern part of T. 6 N., R. 60 E.

Location 59, sec. 30.

	Ft.	in.
Lignite		3
Shale	12	
Lignite		9
Shale	3	
Lignite	1	
Shale		2
Lignite		10
Sandstone and shale	15	
Lignite		8
	33	8

Location 60, sec. 29.

	Ft.	in.
Lignite	3	2

Location 61, sec. 20.

	Ft.	in.
Lignite	1	
Shale	12	
Lignite	1	6
	14	6

East of location 60 the lignite is generally burned along the outcrop; it can be traced about halfway to Brackett Butte and is then obscured by a grassy slope. West of location 59, in the SE. ¼ sec. 30, the badland escarpment gives way to a grassy slope beneath which the lignite is obscured. Several exposures of lignite are shown along the west side of secs. 29 and 30. The following section was measured about 1,000 feet south of the west quarter corner of sec. 29, in the bank of a deep gulch:

Section of lignite bed in sec. 29, T. 6 N., R. 60 E.

	Ft.	in.
Lignite		2
Shale		10
Lignite		6
Parting		¾
Lignite		4
Shale, brown.		
	1	10¾

This is probably the same lignite bed as that represented by sections 59 and 60.

Thinner beds of lignite up to 1 foot in thickness are exposed at several places in the badlands and were especially noted in the NW. ¼ sec. 28 and in secs. 32 and 33. None of these occurrences are important. At only one locality in this township (No. 59) was the lignit found to attain a thickness of 3 feet, and here the upper part is dirty. However, it is used to some extent for fuel by ranchers in the vicinity.

T. 6 N., R. 59 E.—The Lance formation occupies the surface of this township. Several lignite beds are exposed, only one of which is of sufficient thickness to warrant mapping. The lowest lignite beds exposed outcrop in the SE ¼ sec. 26, also near the east quarter corner of sec. 36, and in almost all the coulees crossed in going from east to west across the middle of the township. These beds are thin, ranging from a few inches up to 15 inches in thickness. The outcrops were not plotted.

Near the center of the SW. ¼ sec. 35 lignite is exposed on the north side of a gulch (No. 63). The exposure shows 5 feet 4 inches of lignite, with an inch parting 18 inches from the bottom, overlain by alternating layers of lignite and shale. This outcrop was traced around the point of the ridge and into the next coulee north, about 500 feet away, where the entire bed is represented by carbonaceous shale.

At a still higher horizon occurs a lignite bed which is about 30 feet stratigraphically below the bed represented by sections 64 and 65. The bed has a maximum thickness of about 4 feet with one intervening clay parting, but is very impure from admixture with earthy matter throughout the section.

The lignite which was mapped occurs near the top of the Lance formation, and its outcrop follows the western brow of a prominent ridge through most of its course in this township. The dip of the strata along the lignite outcrop is about 7° SW. At the northwest corner of sec. 19 the bed consists of carbonaceous shale. Southeast of this point about one-fourth mile the bed is more coaly and within one-half mile it has been burned along the outcrop, producing a heavy well-fused clinker which continues southeastward for about 2 miles. Along the west face of this clinker ridge the top of the lignite is in places exposed by slumps or in coulees. Near the center of sec. 29 (No. 65) about 11 feet of lignite is exposed, and a little to the northwest the exposed section is somewhat thicker. At these places the lignite is a brown tough woody variety of fair grade and is used locally by a few ranchers. A little southeast of location 65 the clinker ends, and at the next exposure of the lignite (No. 64) its quality is considerably poorer through the admixture of shaly matter. South of location 64 the ridge declines rather abruptly to a considerably lower altitude and the lignite is not exposed. A lignite bed which is probably the same as that at location 64 is exposed at the head of a coulee north of the east quarter corner sec. 32 (No. 66). Beyond this point the bed can not be traced in this township, as the surface is grass covered. Its presence is indicated farther southeast, however, in T. 5 N., R. 59 E., by a few clinker hills.

T. 6 N., R. 58 E.—Lignite occurs in this township in both the Lance and Fort Union formations. The bed in the lower formation is a continuation of the bed mapped in the township to the east. It enters this area at the southeast corner of sec. 13 and continues northwestward through secs. 13, 12, 11, and 2 to the north side of the township. The bed is represented by carbonaceous shale through sec. 13. In sec. 12, southeast of the west quarter corner, the outcrop is indicated by a heavy clinker which probably represents an original bed of lignite of good quality. Beyond this clinker area the bed is concealed nearly to the north side of sec. 11. From there to the north side of the township the outcrop is again represented by well-fused clinker. The lignite is not exposed at any place in the vicinity of the burned beds, so that its quality in such places can only be inferred from the character and amount of the clinker formed. Between the clinker areas the bed consists of carbonaceous shale or very dirty coal.

On the west side of Coon Creek, the main Fort Union lignite is indicated by clinker beds extending from the northwest corner nearly to the southeast corner of sec. 7. Near the center of sec. 17, at location 68, a bed has the section and character shown on Plate XIV. At location 69 the bed is thinner, containing only 17 inches of good lignite underlain by 6 inches of bone and 4 inches of bony lignite. In the northwest corner of the section, at location 70, the bed

shows the same structure, but the bench of good lignite is 2 inches thicker than at location 69. As elsewhere in the Baker field, this zone contains three beds of lignite. Sections 68 to 70 were measured on the middle bed. There are no other exposures of lignite, but the bed can be traced by the burned outcrop to the southeast corner of sec. 17, where the clinker terminates. The lignite can not be traced any farther to the southeast, but its horizon is probably indicated by the beds of carbonaceous shale exposed in the coulees in secs. 35 and 36.

The outcrop of a higher lignite was traversed in secs. 30 and 31. The bed was prospected and measured in two places with the results indicated by sections 136 and 138. At location 137 the bed consists of good lignite 2 feet 11 inches thick. This bed occurs about 50 feet below a heavy clinker which caps the highest hills in this part of the township.

T. 6 N., R. 57 E.—Most of this township is underlain by good lignite which is of Fort Union age. The beds have, for the most part, been burned along the outcrop, but because of the prevailing badland topography the exposures of the lignite are more numerous than usual. In this area, as in the township to the north (T. 7 N., R. 57 E.), this zone is characterized by three beds of lignite ranging through a vertical distance of 30 to 60 feet. The outcrop of the lower beds only are shown on Plate XV by sections 73 and 76 to 89. These range in thickness from 3 feet 6 inches to 9 feet. At location 74 lignite 8 feet 8 inches thick is exposed. At locations 75 and 90 the bed is less than 30 inches thick. At the former there is 2 feet of good lignite, and at the latter only 15 inches, broken by a sandy parting 5 inches thick. In general the lowest bed is the thickest, but the quality of the lignite is commonly poorer than that of the other beds. A sample was taken from the lower bed at the opening at Coal Bank Spring (No. 77) and an analysis, made at the Bureau of Mines, is given on page 221. At this locality the lignite is brown, tough, woody, and of good quality and is used locally by ranchers. Each of the beds has produced a heavy clinker wherever the lignite has been burned.

The sample for analysis was collected as follows: All weathered material was removed from face of bed, which was then trenched across from top to bottom, and about 5 pounds of lignite per foot of depth obtained. The sample was collected on oilcloth, broken to the required fineness, and quartered down so as to fill the sample can.

Analysis of lignite from Coal Bank Spring, near Westmore, Custer County, Mont.

[Laboratory No. 10910. Air-drying loss, 26.2 per cent. A. C. Fieldner, chemist in charge.]

	As received.	Air dried.	Moisture free.	Moisture and ash free.
Moisture	38.7	16.9	.....	.....
Volatile matter	27.0	36.6	44.1	51.8
Fixed carbon	25.1	34.0	40.9	58.2
Ash	9.2	12.5	15.0	.....
Sulphur	.30	.41	.49	.58
Calories	3,345	4,530	5,455	6,420
British thermal units	6,020	8,160	9,820	11,550

T. 6 N., R. 56 E.—Four lignite beds in the Lance formation and one in the Fort Union were found in this township. The lowest bed is exposed in the east bank of O'Fallon Creek near the north side of sec. 30 (No. 95), about the middle of the section, and also a little south of the line between secs. 30 and 31. At the last two localities only the top of the bed was seen, so that a complete section was possible only at location 95, where it is 32 inches thick and the lignite is of good quality.

About 40 feet higher stratigraphically occurs another bed, which is 44 inches thick, with a 3-inch parting 10 inches from the top, at location 96 and 22 inches thick at location 97. What is believed to be the same bed is exposed farther north near the southwest corner of sec. 17 (No. 93), where there is 5 feet of lignite with a 12-inch parting about the middle of the section.

The next lignite is about 20 feet above the bed just described and is exposed in the west side of the NW. ¼ sec. 29 (No. 94), in the SW. ¼ sec. 29, and in sec. 32, a little east of the west quarter corner. At No. 94 there is a total of 4 feet 4 inches of lignite, with several partings and bony streaks which make it of doubtful value. The exposure in sec. 32 consists entirely of carbonaceous shale.

The highest lignite bed of the Lance formation is about 20 feet above the one just described. The bed is exposed in the NE. ¼ SE. ¼ sec. 7 (No. 92), where it has a total thickness of 28 inches, including 9 inches of bone. From location 92 southward the bed may be traced by local light brick-colored areas along the escarpment to the northeast corner of sec. 20 (No. 91), where 21 inches of lignite is exposed, overlain by more than 4 feet of carbonaceous shale containing lenses of lignite. To the south and southeast the horizon is indicated by a few burned areas or shale outcrops throughout the remainder of its course in this township.

The horizon of the Fort Union lignite is represented in this township by a heavy clinker, which caps the buttes and ridges in the eastern and northeastern parts of the area. At the following localities the clinker passes under slight cover, beneath which some

unburned lignite may exist: Two small areas in the SW. ¼ and SE. ¼ sec. 22; one just east of the south quarter corner of sec. 24 and one in the central part of the same section; one in the northeastern part of sec. 13 and the eastern part (nearly half) of sec. 12; one in the NE. ¼ sec. 11; two small areas in the SE. ¼ and the NW. ¼ sec. 2; and one at the west quarter corner of sec. 2, extending into sec. 3. In all of these places the lignite has been burned along the outcrop, and exposures do not occur. The reader will be able to judge of the probable quality of the lignite by referring to the sections (Nos. 85 to 90) measured at the same stratigraphic horizon along the township line in T. 6 N., R. 57 E.

T. 6 N., R. 55 E.—A number of isolated lignite exposures occur at various altitudes in the valley of Miles City Creek. These outcrops probably represent the same beds as those exposed along the east side of O'Fallon Creek in the township to the east. As the lignite is of inferior quality and the beds are thin, no attempt was made to correlate them and only the upper one was mapped. The following sections of this bed were measured in this township:

Sections of lignite bed in T. 6 N., R. 55 E.

Location 98, sec. 24.

	Feet.
Lignite	2

Location 100, sec. 22.

	Ft.	in.
Lignite		2
Shale	1	1
Lignite	1	9
	3	

Location 99, sec. 23.

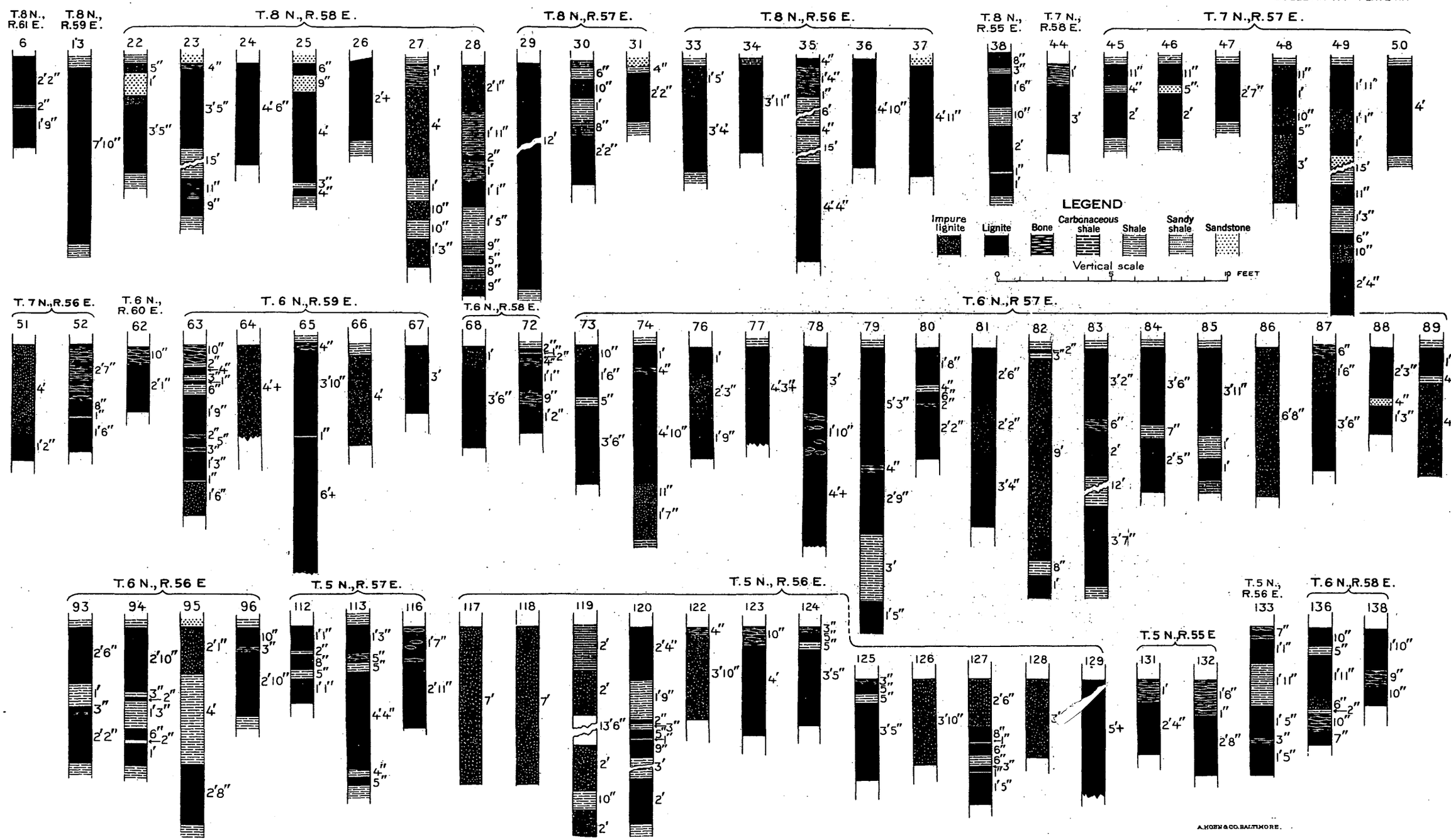
	Ft.	in
Lignite		3
Shale		2
Lignite		5
Shale		8
Lignite	2	
	3	6

The lignite beds of the Fort Union are represented by clinker in the northwestern part of the township. The lignite has been burned out over most of the area; however, some may still remain beneath a small area in the NW. ¼ sec. 8. There may also be a small amount of lignite in the burned area occupying the southern part of secs. 7 and 8.

T. 6 N., R. 54 E.—A small area in secs. 5 and 6 of this township was mapped as containing lignite which belongs to the Fort Union formation, on the basis of the thickness of cover above the lignite horizon. Outward from the margin of this area heavy clinkers exist and it is believed that all the lignite has been burned.

T. 5 N., R. 61 E.—The surface rocks over this township belong to the Pierre shale, which is not known to contain any lignite.

T. 5 N., R. 60 E.—The entire thickness of the Lance formation is present in the western part of the township but is not known to carry lignite. Although the lignite horizon near the top of the formation



SECTIONS OF LIGNITE BEDS IN THE BAKER LIGNITE FIELD, CUSTER COUNTY, MONTANA

is believed to pass through secs. 30 and 31, a careful search there failed to disclose its presence.

T. 5 N., R. 59 E.—Small clinker hills occur in the NW. ¼ sec. 3 and in sec. 14 of this township. These clinker beds are about on the line of strike of the upper lignite of the Lance formation in the township to the north and hence were correlated with that bed. The bed could not be traced southward beyond the clinker outcrop in the SE. ¼ sec. 14; therefore the mapping was discontinued. The clinker in this township has about the same physical characters as in T. 6 N., R. 59 E., where it is associated with good lignite.

Lignite in the Fort Union outcrops west of Wiley's ranch (sec. 6) along the sides of a coulee and was traced from there to the northwest corner of the township. West of Wiley's (location 101) an attempt has been made to use the lignite, but because of its poor quality the prospect has been abandoned. The total thickness of the bed is 3½ to 4 feet, of which about 18 inches might be classed as medium-grade lignite.

T. 5 N., R. 58 E.—Along the north side of secs. 1 and 2 and just north of the section line at the northeast corner of sec. 3, lignite is exposed at locations 71, 72, and 102 to 104. At No. 102 the entire thickness is 30 inches, all very dirty. At No. 103 the total thickness of the bed is 33 inches, of which less than 1 foot is lignite. At No. 104, out of a total of 26 inches, the lignite measures 9 inches. At No. 72 (Pl. XIV) the bed is 3 feet 10 inches thick and has a total of 31 inches of lignite in four layers separated by bone or shale. At location 71 the section is the same as at location 104. All of these exposures are above the lignite at Wiley's and probably represent the middle and top beds of this Fort Union zone.

The outcrop mapped in the southeast corner of the township is exposed in the NW. ¼ sec. 36, where the bed is 20 inches thick, with about 12 inches of rather poor lignite. The position of this bed is uncertain.

Across the divide, on the west side of the township, lignite outcrops were found at locations 105 to 107 in secs. 29 and 32. At location 105 there is 15 inches of bony lignite; at location 107 there is 20 inches of lignite, and at location 106 there is 27 inches, of which 11 inches is bone. On the map (Pl. XV) the bed outcropping at these locations is correlated with that exposed at Coal Bank Spring (No. 77). An exposure in sec. 33 (No. 108) can not be definitely correlated with any other bed in this vicinity, but it may be the same as that represented by section 107. It contains only 18 inches of good lignite in a total thickness of 31 inches.

T. 5 N., R. 57 E.—The lignite which outcrops in this township is in the Fort Union formation. In this area, as in the township on the north, three lignite beds are present. The outcrop of the lowest bed

was mapped, but exposures are few and the identification of beds is somewhat uncertain. Locations 109 to 116 are the places at which sections of the lignite beds were measured. At location 109 is a single bed of lignite 2 feet thick; at location 110, only 15 inches of lignite divided into two benches by a parting of shale 2 inches thick; and at location 111 the bed is 30 inches thick, but the upper part, 18 inches thick, is dirty and of little value. The character of the bed at locations 112, 113, and 116 is shown on Plate XIV. At location 114 the bed has a total thickness of only 2 feet 7 inches, consisting of two benches, the uppermost of which is 1 foot 2 inches thick and the lowermost 1 foot thick, with 5 inches of shale between. A comparison of these sections with those given for the township to the north shows that the beds are thinner and the lignite of poorer quality in this township than in that to the north.

A small outcrop of lignite in the south bank of Lame Jones Creek, near the southwest corner of sec. 5, is believed to be in the Lance formation, and hence that lignite horizon was mapped as extending up Lame Jones Creek into this township.

T. 5 N., R. 56 E.—Lignite is exposed in the banks of O'Fallon Creek at locations 120 to 125 in the northwestern part of this township. The bed is a continuation of the lowest lignite bed in the Lance formation described in the discussion of T. 6 N., R. 56 E. At location 121 about 2 feet of the bed is exposed above low-water level of the creek. At locations 122 to 125 the bed is about 3 feet 10 inches thick and the lignite is of good quality. At location 120, on the east side of the creek, the bed is much broken by partings which detract from its value.

About 80 feet above the bed just described the upper lignite of the Lance formation is represented in the escarpments east of O'Fallon Creek but does not appear on the west side of the creek in the north half of the township. Sections 119 (in the NW. ¼ sec. 9), 117 (near the center of the N. ½ sec. 27), and 118 (just east of the southwest corner of sec. 33) show the character of this bed. Its position is indicated on the north side of Milk Creek and along O'Fallon between Milk and Spring creeks by a few exposures of baked and reddened clay and shale. On the west side of O'Fallon Creek, from the northwest corner of sec. 19 to the southwest corner of the township, the outcrop of the bed is marked by clinker. At location 126 the bed is 3 feet 10 inches thick but very dirty and has numerous streaks of bone. At this locality the overlying strata have not been fused by the burning of the lignite. At location 127 the total thickness of the bed is 5 feet 8 inches, but the lignite, like that at location 126, is very dirty. At location 128 the lignite is of poorer quality than in either of the preceding sections. From about the north side of the NW. ¼ sec. 31 to the south side of the field the clinker produced by the burning of the lignite is thicker and

shows a higher degree of fusion than that which occurs farther north. At the southwest corner of the township a small isolated butte is capped with clinker and just to the south, in the head of a coulee (No. 129), 5 feet of lignite is exposed with the bottom of the bed concealed. The lignite is badly weathered and partly burned so that its quality can not be determined without more extensive uncovering.

T. 5 N., R. 55 E.—The lignite outcrop along the eastern side of this township south of Ash Creek was discussed in the description of T. 5 N., R. 56 E. The same bed outcrops along the south side of Ash Creek from the east side of the NE. ¼ sec. 24 to the west quarter corner of sec. 33. Throughout most of this distance the bed has been burned along the outcrop, which is marked by low hills of red indurated rocks that exhibit little or no evidences of fusion. The bed is exposed on the west side of sec. 24 south of the quarter corner (No. 130), where it has a total thickness of 7 feet with two partings of 14 and 16 inches. The lignite at this point is very dirty and where burned the heat produced was not sufficient to induce fusion in the overlying material. In the northeast corner of sec. 27 (No. 131) the total thickness of the bed is 3 feet 4 inches, of which 12 inches is bone. Another outcrop occurs in the bottom of a draw just west of the east quarter corner of sec. 32 (No. 132), where 4 feet of the bed is exposed, but its total thickness is not known. At this exposure, 18 inches from the top of the bed, is a thin shale parting above which the lignite is worthless, but below the parting the bed as far as exposed is fair-grade lignite and some is used locally. The bed could not be traced westward beyond this point.

T. 5 N., R. 54 E.—Lignite outcrops at places in the badlands in the southwestern part of this township, but because of its inferior quality the bed was not mapped. On the west side of sec. 19, a little less than one-fourth mile north of the west quarter corner (No. 135) two beds of lignite, separated by a 10-foot interval, are exposed on the north side of a creek. The upper bed has a thickness of 3 feet 3 inches, in which are two streaks of bone 8 inches and 6 inches thick. The lignite is of poor quality. The lower bed is 4 feet 6 inches thick with 2 feet of fair lignite, in which is a thin shale parting. Just east of the west quarter corner of sec. 30 lignite is exposed in the side of a butte. A detailed section was not made, but the quality is inferior to that at location No. 135. Near the south side of the SE. ¼ sec. 31 (No. 134) lignite is exposed on the south side of a butte. The bed has a total thickness of 3 feet 6 inches, the upper 2 feet of which is bony and is separated by a 3-inch clay parting from 15 inches of lignite below. About 500 feet east and 200 feet south of the south quarter corner of sec. 32 there is a carbonaceous bed 5 feet thick in which about 1½ feet of lignite is exposed. Near the southeast corner of sec. 32 (No. 139) a bed nearly 8 feet thick is exposed in the bottom of a coulee. It has a total thickness of about 3 feet of good lignite but is so broken by bone and partings

as to be of little value. A fairly good fusion of the overlying strata has been produced by the burning of the lignite in this vicinity and the continuation of the burned outcrop could be seen to the south for at least a mile.

The lignite outcrops just described are in the Lance formation, which is capped by Fort Union on all the higher ridges. In sec. 35, extending from the southeast corner northwest to a little beyond the center of the section, the Fort Union lignite underlies a very narrow ridge with a badland scarp on the southwest and a grassy slope on the northeast. The lignite is exposed along the scarp and is represented by section 133, which was measured on the township line. The bed is nearly 7 feet thick with a 23-inch parting. There are streaks of the lignite that are very dirty. This same lignite horizon is indicated farther to the northwest and also in the northeastern part of the township by clinker capping several of the higher buttes, but the lignite has been completely burned in those localities.

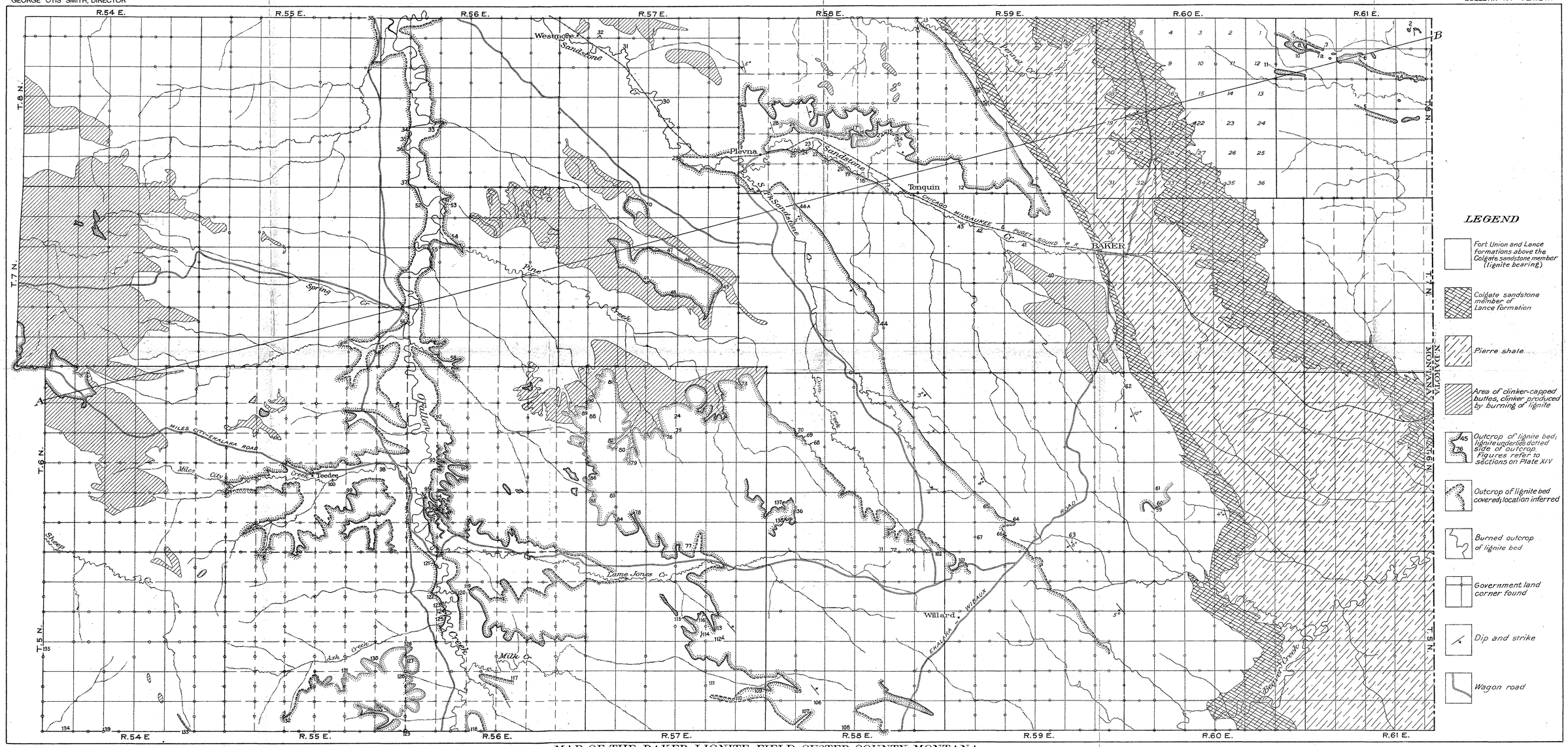
QUANTITY OF LIGNITE.

A lignite bed 1 foot thick and 1 acre in extent contains approximately 1,800 tons of lignite of a specific gravity of 1.3. On this basis the quantity of lignite contained in the Baker lignite field in beds not less than 36 inches thick (the minimum thickness established by the Interior Department as minable in this field) is estimated to be 1,596,054,000 short tons. If all lignite beds which have a thickness of 14 inches or more are taken into consideration a conservative estimate would be 2,394,071,000 tons for the entire field.

The table below gives the estimates by townships for the areas classed as coal land:

Lignite tonnage in beds not less than 36 inches thick.

T.	R.	Lance formation.		Fort Union formation.		Total.
		Acres.	*Short tons.*	*Acres.*	*Short tons.*	*Short tons.*
6	54	.....	.....	885	4,779,000	4,779,000
7	54	310	1,674,000	2,680	19,296,000	20,970,000
8	54	21,780	196,020,000	.....	.....	196,020,000
5	55	270	2,214,000	.....	.....	2,214,000
7	55	3,320	29,880,000	.....	.....	29,880,000
8	55	21,780	196,020,000	.....	.....	196,020,000
5	56	240	1,944,000	.....	.....	1,944,000
6	56	1,760	36,432,000	460	2,967,000	39,399,000
7	56	120	1,062,000	.....	.....	1,062,000
8	56	19,960	152,694,000	.....	.....	152,694,000
5	57	.....	.....	2,560	16,512,000	16,512,000
6	57	.....	.....	18,270	490,549,500	490,549,500
7	57	.....	.....	1,550	20,268,000	20,268,000
8	57	19,550	275,655,000	.....	.....	275,655,000
6	58	870	9,972,000	1,215	12,589,500	22,561,500
7	58	815	8,802,000	.....	.....	8,802,000
8	58	6,020	82,345,500	.....	.....	82,345,500
6	59	785	13,894,500	.....	.....	13,894,500
8	59	2,845	20,484,000	.....	.....	20,484,000
.....	.....	.....	1,029,093,000	.....	566,961,000	1,596,054,000



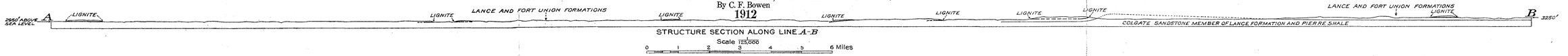
LEGEND

- Fort Union and Lance formations above the Colgate sandstone member (lignite bearing)
- Colgate sandstone member of Lance formation
- Pierre shale
- Area of clinker-capped buttes, clinker produced by burning of lignite
- Outcrop of lignite bed; lignite underlies dotted side of outcrop. Figures refer to sections on Plate XIV
- Outcrop of lignite bed covered; location inferred
- Burned outcrop of lignite bed
- Government land corner found
- Dip and strike
- Wagon road

MAP OF THE BAKER LIGNITE FIELD, CUSTER COUNTY, MONTANA

By C. F. Bowen

1912



STRUCTURE SECTION ALONG LINE A-B

Scale 125,000

0 1 2 3 4 5 6 Miles

THE TERRY LIGNITE FIELD, CUSTER COUNTY, MONTANA.

By FRANK A. HERALD.

INTRODUCTION.

During the summer of 1910 W. R. Calvert supervised the examination of four lignite fields in eastern Montana for the purpose of classifying the land as to its lignite-bearing character. The Terry field, one of the four, was surveyed by the writer and the present report contains the data collected by him during this work. As an introduction to this somewhat detailed report, dealing primarily with the lignite, Mr. Calvert has prepared a general report in which he describes the topographic and geologic features of the entire region, and to his paper (pp. 187-201) the reader is referred for information on these subjects.

The data regarding the lignite are not complete, because the examination was made for the purpose of classifying and valuing the land as to its coal-bearing character and only such data were gathered as had a direct reference to this subject. According to the present regulations of the Department of the Interior, the classification and valuation of lignite-bearing land depends on the presence or absence of a bed of lignite at a depth of less than 500 feet below the surface. In valuing the lignite-bearing land the minimum price allowed by law is placed upon it whether the land contains one bed or more than one bed of economic value. The minimum thickness which in this field is considered of economic value is 30 inches. This limit was determined from analyses in accordance with the department's regulations. As any number of beds would not increase the valuation of the land, examination after sufficient data were collected to prove the existence of one valuable bed was entirely incidental and was made only when it would not cause material delay in the progress of the work. Lignite is exposed at several places in the field other than those shown on the map. However, such exposures are within areas believed to be underlain by other beds of lignite.

The writer was assisted in the field by J. R. Hoats, L. E. Trout, and J. B. Newby. W. R. Calvert exercised general supervision in

the field and has given valuable advice in preparing the data in the office. The writer wishes to acknowledge his personal obligation to each of these men and also to residents of the field who offered assistance during the progress of the work.

POSITION AND EXTENT OF THE TERRY FIELD.

The shape, extent, and geographic position of the Terry field are shown by the index map (fig. 7, p. 189). As shown by that map and by Plate XVIII (p. 270), it includes Tps. 9 to 12, inclusive, and extends from Yellowstone and Powder rivers on the west to the Montana-North Dakota State line on the east, its area being 1,500 square miles. The name of the field is taken from Terry, a town in the western part of the field, near Yellowstone River, reached by both the Northern Pacific and the Chicago, Milwaukee & Puget Sound railways. This town is the most important in the area, hence its name is applied to the field though it is not centrally located.

GEOLOGY.

The geologic formations exposed in the Terry field are presented in the following table:

Relations and characteristics of geologic formations in the Terry field.

System.	Formation.	Member.	Thickness (feet).	Characteristics.
Tertiary.	Fort Union formation.		[a] 400	Soft friable yellow sandstone and gray shale. Contains many beds of lignite.
Cretaceous or Tertiary.	Lance formation.		550	Shale and sandstone, mainly of somber color. Contains many thin beds of lignite and locally some of considerable thickness.
		Colgate sandstone.	150	Mainly sandstone. Soft white sandstone at top underlain by yellow sandstone and shale.
Cretaceous.	Pierre shale.		[a] 300	Drab shale containing crystals of selenite and fossiliferous calcareous concretions.

[a] Exposed.

These formations are described in the preceding paper by Mr. Calvert. Their areal distribution is shown on the map (Pl. XVIII). The lowest two—the Pierre shale and the Colgate sandstone member of the Lance—do not contain lignite; the undivided Lance contains only lenticular beds of lignite, especially in the upper part, whereas the Fort Union has numerous thick beds of lignite throughout. Only the lowest bed of lignite in the Fort Union was mapped in detail, but

incidental investigation revealed other beds wherever any considerable section of the formation is exposed. The location of the outcrops of practically all of the lignite beds in the Lance more than 30 inches thick is shown on the map (Pl. XVIII).

Structurally the field is a part of a great monocline dipping very slightly eastward and locally interrupted by small undulations, one of which has considerable magnitude. This fold, called the Glendive anticline, crosses the field a little east of the center in a general northwest-southeast direction and divides it into two general lignite-bearing areas. The smaller area to the east is called the Beaver Creek district, from the stream which drains it; the area to the west is named the O'Fallon Creek district, from the largest stream contained therein.

THE LIGNITE.

CHEMICAL AND PHYSICAL PROPERTIES.

As there is no underground development in the field and no strip pit which has reached below the zone of weathering, an unaltered sample of lignite could not be obtained for study or analysis. The only sample collected was cut from the lower 41 inches of a bed at its surface exposure, near the northwest corner of the SW. ¼ NW ¼ sec. 24, T. 12 N., R. 50 E., described on page 246.

Only the lower bench was included in the sample, because it seemed less affected by weathering than the rest of the bed. At the time the sample was taken, July 15, 1910, lignite was being stripped from this place for use at the Terry steam laundry. The pit was opened only three or four days previously and operation was discontinued within a week, when a shipment of higher-grade coal was received for use at the laundry. An analysis of the sample as made at the Pittsburgh laboratory of the Bureau of Mines is given below.

Analysis of lignite taken from strip pit in the SW. ¼ NW. ¼ sec. 24, T. 12 N., R. 50 E.

[A. C. Fieldner, chemist in charge. Laboratory No. 10677. Loss of moisture on air drying, 19.9 per cent.]

	Air dried.	As received.	Moisture free.	Moisture and ash free.
Moisture	10.3	28.1	.....	.....
Ash	19.9	15.9	22.1	.....
Sulphur	.34	.27	.38	0.49
Calories	4,375	3,505	4,875	6,265
British thermal units	7,870	6,310	8,780	11,270

Samples obtained by J. H. Hance in the Glendive field to the north were taken under more favorable conditions and are believed to represent the properties of the lignite better than the analysis given above. Therefore the reader is referred to the discussion in Hance's paper on pages 273–276 for information concerning them.

In this report all of the mineral fuel in this field is called lignite, although it is recognized that the lignite from some of the beds is of much better quality than that from others and approaches closely the grade of subbituminous coal. The distinction between lignite and subbituminous coal is necessarily neither definite nor sharp. The term lignite as used by the Geological Survey is generally restricted to that material which is distinctly brown and woody, whereas the term subbituminous coal is applied to similar material that has lost most if not all of its woody texture and has become black in color.

In eastern Montana and adjacent parts of North and South Dakota the lignite of the Lance formation is generally more nearly black and less woody that that of the overlying Fort Union formation and in some publications it has been called subbituminous coal. In this field the difference between the coals of the two formations is slight and irregular, and therefore as a matter of convenience they are all called lignite.

STRATIGRAPHIC OCCURRENCE.

LANCE FORMATION.

The Lance is the lowest lignite-bearing formation in the field. Beds less than 20 inches thick are distributed throughout the formation, but thicker ones are rare. All are lenticular, though some can be traced for several miles. The most persistent bed exposed in this formation is on the west side of the Beaver Creek district, where it was mapped continuously between locations 63[1] and 104. The map shows the outcrop of other lenses, but none so large as the one mentioned above. Though thin beds occur throughout the formation, only the upper part contains beds more than 30 inches thick. The following section of the upper part of the Lance, measured in sec. 19, T. 11 N., R. 59 E., shows the thickness and stratigraphic position of the lignite beds at that place.

Section of the upper part of the Lance formation in sec. 19, T. 11 N., R. 59 E.

	Ft.	in.
Lignite, base of Fort Union formation	4	3
Shale, brown	2	
Sandstone, soft, yellow	9	
Shale, gray	3	
Lignite		10
Shale, brown	4	
Sandstone, soft, yellow	3	
Shale, black, carbonaceous		6
Shale, gray	42	
Lignite		6

[1] Numbers refer to sections in Plates XVI and XVII and to the locations at which they were measured, as shown on Plate XVIII.

	Ft.	in.
Shale, brown	2	
Sandstone, gray, argillaceous	15	
Shale, gray	3	
Lignite		3
Shale, brown	2	
Lignite		3
Shale, brown	8	
Lignite	2	4
Shale, brown	2	
Shale, gray	13	
Band of concretions composed of ferruginous shale		4
Sandstone, gray, argillaceous	5	
Shale, gray, arenaceous	5	
Shale, brown, carbonaceous	1	6
Shale, grayish yellow	3	
Lignite		5
Sandstone, soft, yellow	8	
Band of concretions composed of ferruginous shale		6
Sandstone, soft, gray	16	
Sandstone, yellow	3	
Sandstone, soft, gray	10	
Shale, ranging in color from gray to brown	10	
Lignite		7
Shale, brown		5
Lignite	3	7
Shale, brown	2+	
	186	3

The Lance formation outcrops in a narrow irregular band along the west side of the O'Fallon Creek district, and, after dipping beneath the surface, reappears in a more even band of outcrop on the east side of the basin on the flank of the Glendive anticline. East of this fold it is exposed in a much wider and very irregular band. From this zone of outcrop it extends eastward under the Fort Union to the east line of the field. As the lignite beds of this formation are local, their position and extent in the interior of the basins can be determined only by deep prospecting.

FORT UNION FORMATION.

At the base of the Fort Union formation is a persistent lignite zone, containing one or more beds of lignite, which will be referred to subsequently as lignite at the base of the Fort Union. As indicated on the map (Pl. XVIII), there is in this zone, along the entire western and southern borders of the Beaver Creek district, at least one bed of lignite more than 30 inches thick. A similar condition exists along the east margin of the O'Fallon Creek district, except in T. 10 N., R. 57 E., where the zone that so persistently carries thick beds elsewhere is barren, and in a small area without lignite in this

zone in T. 11 N., Rs. 50 and 51 E., in the western part of the district. Northwest and southeast of these comparatively small areas the zone at the base of the Fort Union contains the normal amount of lignite. This zone, which is very rich in lignite, extends from its line of outcrop on the west side of the Beaver Creek district to the east line of the State and stretches westward from the Glendive anticline to Powder and Yellowstone rivers. It therefore underlies nearly all of the Beaver Creek district and practically all of the O'Fallon Creek district, but as the dip is very moderate the zone probably does not reach a depth greater than 500 feet at any point in the field. The detailed study of this zone consequently furnished a basis for land classification, and the large area which it underlies generally contains lignite of commercial importance. For this reason the upper rocks were not studied in detail, and few outcrops are shown on the map, though many beds were found.

Lignite occurs in the Fort Union formation at various stratigraphic distances above the zone at the base and is exposed at many places in the field. In many localities where it is not exposed, clinker beds indicate that the lignite has burned along the outcrop, but as data for land classification were not needed in areas where the higher beds occur, these beds were not studied, and the area occupied by them is blank on the map. Considerable information regarding them was obtained, however, incidental to the main purpose of the work. Sections of some of these beds are shown graphically on Plates XVI and XVII, and further data are presented in this report, mostly under the descriptions by townships. The general stratigraphic position of the higher beds is presented in the following section, which includes the beds exposed between the top of the divide in the northwest part of sec. 10, T. 12 N., R. 59 E., and a point near the northwest corner of lot 3, sec. 5, of the same township.

Section of Fort Union formation in secs. 4, 5, 9, and 10, T. 12 N., R. 59 E.

	Ft.	In.
Sandstone, hard, yellow	1	6
Sandstone, soft, yellow	15	
Shale, somber-colored	8	
Shale, brown, carbonaceous	10	
Sandstone, soft, yellow	30	
Shale, brown	3	
Sandstone, soft, yellow	25	
Lignite		6
Shale, carbonaceous	2	
Lignite		4
Shale		1
Lignite		5
Shale		2
Lignite	1	5
Shale		10
Lignite	3	7

	Ft.	in.
Shale and soft sandstone, brown and yellow	15	
Lignite	5	4
Shale, somber-colored	35	
Sandstone, soft, yellow	25	
Lignite	4	
Shale and soft sandstone, somber and yellow	30	
Lignite	2	6
Shale, brown	1	2
Lignite	1	8
Shale, somber and brown, arenaceous	15	
Lignite	1	10
Shale and soft sandstone, yellow and somber	25	
Shale, brown, carbonaceous	1	
Lignite	2	9
Shale, black, carbonaceous, bone and lignite	3	
Shale, brown and gray	5	
Sandstone, yellowish-brown, argillaceous	6	
Lignite	1	
Shale		1
Lignite	1	6
Shale		½
Lignite	2	7
Shale, black, carbonaceous, and bone		3+
	286	6½+

On the western border of the field, in the O'Fallon Creek district, exposures are generally not so good as in the eastern part of the field, but from evidence obtained it is believed that there are fewer beds of lignite in the strata above the zone at the base of the Fort Union and that in general the beds are thinner and perhaps contain more impurities. On the north side of Yellowstone River, in T. 12 N., R. 51 E., there are good exposures of the strata from the river to the crest of some ridges which are much higher than the general level of the country to the south. On the slopes of these ridges the following section was measured from the top of one of the highest hills in sec. 5 to a point near the river in sec. 8. It is introduced to show the general character of the strata in this part of the field and the relative position of the lignite beds.

Stratigraphic section from the top of one of the highest hills in sec. 5, T. 12 N., R. 51 E., to Yellowstone River, in sec. 8.

	Ft.	in.
Clinker	20	
Shale, yellow and white, arenaceous	15	
Lignite		6
Shale, white	10	
Shale, brown	1	
Shale, white, arenaceous	10	
Shale, yellow, arenaceous	25	
Lignite	2	4
Shale, brown		7
Lignite	2	4

	Ft.	in.
Shale, brown		6
Shale, gray	4	
Shale, yellow, arenaceous	40	
Lignite		10
Shale, brown	4	6
Sandstone, soft, white	2	
Sandstone, yellow, hard	1	6
Shale, white	2	
Shale, carbonaceous		1
Sandstone, white, argillaceous	1	6
Shale, gray	2	
Shale, brown	1	6
Shale, gray	6	
Lignite		6
Shale and soft sandstone, yellow	55	
Lignite		4
Sandstone, carbonaceous	1	3
Shale, gray	5	
Shale, brown, carbonaceous	1	6
Shale, gray	20	
Sandstone, yellow, hard	1	
Shale, gray	30	
Lignite	1	7
Shale, gray	3	
Lignite		9
Shale, gray	15	
Shale, yellow, arenaceous	20	
Shale, brown	1	
Lignite	2	7
Shale, brown and gray	22	
Lignite	3	
Shale, brown	3	
Lignite and bone	2	
Shale and soft sandstone, yellow	45	
Lignite	2	3
Bone	2	6
Shale, gray	1	
Lignite, dirty		7
Shale		1
Lignite		10
Shale		1
Lignite		3
Shale		½
Lignite, dirty	2	2
Sandstone, soft, white	50	
Level of water in Yellowstone River.		
	446	5½

It is probable that in the greater part of the O'Fallon Creek district there is more lignite in the Fort Union formation than there is where the above section was measured, and that there is more or less of a gradation from the numerous thick beds along the eastern border to

the condition at the western border represented by the above section.

The structure of the field is not discussed in this connection because the larger features have been described previously and the minor features are reserved for presentation with detailed descriptions of the townships.

DETAILED DESCRIPTION BY TOWNSHIPS.

The following detailed descriptions show the lignite resources of the Terry field by townships. The descriptions do not present complete data on this subject because information necessary for land classification was the principal object of the investigation. In addition to this, however, many observations were made on the general occurrence of lignite, and such partial data are also included. The following descriptions are arranged in regular order, beginning at the northeast corner of the field and going from east to west, then taking the next tier of townships to the south in a similar order, and proceeding thus throughout the field.

T. 12 N., R. 60 E., and fractional part of T. 12 N., R. 61 E.—The surface rocks of these townships belong to the upper part of the Fort Union formation, which contains many beds of lignite. The area is underlain by beds lower in the Fort Union, and by the lenticular beds of the Lance formation, which is locally lignite bearing. All of the beds of lignite of the Fort Union are within 500 feet of the surface, hence there is abundant evidence for classifying the area as coal land. Some idea of the number and thickness of the lignite beds underlying these townships can be obtained from the stratigraphic section on pages 232–233, which was measured in the township to the west. The uppermost bed in this section has been correlated with a bed that is exposed in the east bank of Beaver Creek at several places in T. 12 N., R. 60 E. As the strata dip gently to the east, it is probable that the whole of this area, except a narrow strip along Beaver Creek, is underlain by strata similar to those shown in the section given above. If a shaft were sunk to a depth of 200 feet at a place near Beaver Creek, in sec. 19, it would in all probability go through five beds of lignite, each more than 30 inches in thickness. The lignite bed mentioned above was measured at two places on the east bank of Beaver Creek, where it shows the following sections:

Section of lignite bed exposed near the center of sec. 19, T. 12 N., R. 60 E.

	Ft.	in.
Shale, yellow	8+	
Lignite, rather dirty	4	10
Shale, brown, carbonaceous	1	6
Lignite		10
Shale, brown and yellow, to Beaver Creek	30	
Total lignite	5	8

To the north this bed is thicker and of better quality than at the point where the section given above was measured. An exposure in the NE. ¼ sec. 7 gives the following section:

Section of lignite bed in the NE. ¼ sec. 7, T. 12 N., R. 60 E.

	Ft.	in.
Shale, gray.		
Lignite	8	7
Shale, gray	4	
Lignite	1	6
Shale, gray.		
Total lignite	10	1

Other higher beds may outcrop in these townships. The surface of the country is gently rolling and mostly grass covered, consequently opportunities to study the lignite beds are few. The data obtained on the structure indicate that the beds are nearly horizontal, but dip slightly to the east away from the Glendive anticline.

T. 12 N., R. 59 E.—As shown by the map (Pl. XVIII) the lignite bed which is supposed to mark the boundary between the Lance and Fort Union formations outcrops irregularly along the west edge of this township. As the rocks dip slightly to the east the surface of all that part of the township lying east of this line of outcrop is formed by the Fort Union rocks, whereas the surface of that part lying west of that line is formed by the Lance formation.

There are several beds of lignite in the Lance formation at the western edge of this township, but none is more than 30 inches thick. The most important of these was measured in sec. 30 near location 8, where there is exposed the following stratigraphic section, which includes this bed near the bottom:

Stratigraphic section of beds exposed in sec. 30, T. 12 N., R. 59 E.

	Ft.	in
Shale, brown (top of Lance formation)	2	
Shale and soft sandstone, yellow	30	
Shale, brown	4	
Lignite		11
Shale, brown		9
Lignite		2
Shale, brown	2	
Sandstone, yellowish gray, argillaceous	15	
Shale, brown	2	
Lignite		6
Shale, brown	3	
Shale, gray	20	
Shale, brown, carbonaceous	1	2
Lignite	2	5
Shale, brown	1+	
	84	11

The 29-inch bed near the base of the section is locally thicker than the normal in the locality where the section given above was measured and is believed to represent the maximum thickness of any bed in the Lance in this township.

As shown by the map (Pl. XVIII), the persistent bed of lignite at the base of the Fort Union formation is exposed in the western part of this township and underlies the township except parts of secs. 7, 18, 30, and 31. Sections 5, 8, 9, 10, and 11, in Plate XVI, show its character and thickness along the outcrop at points indicated by corresponding numbers on the map (Pl. XVIII). Section 5 does not show the entire thickness, as the top of the bed was not clearly exposed, but it seems probable that the bed is not much thicker than is indicated by the section. At location 4, 35 inches of lignite is exposed, but here also the section is not complete at the top. That little is lacking from the tops of these sections is indicated by a thickness of 36 inches measured near the north line of the township, as shown in section 1. Besides this persistent bed, three or four higher beds are present in a large part of the township.

A stratigraphic section of the Fort Union, presented on pages 232–233, was measured in the northwest corner of the township and is typical of the conditions in the surrounding area which contains rocks of this age.

The persistent bed at the bottom of the Fort Union was sufficient for land classification, but higher beds were examined at various places near the outcrop of the lower bed. At location 2 (Pl. XVIII) the lowest of the higher beds is stratigraphically 25 feet above the base of the formation and is more than 38 inches thick. At location 6, in sec. 18, it is 30 feet above the base of the formation and is 38 inches thick. The outcrop of this bed doubtless continues near the exposures of the basal bed across the township, but it is burned along most of the distance, and its thickness could not be determined. Opportunity to study the higher beds is rare, because they are either extensively burned along the outcrop or concealed beneath the grass-covered prairies. At one of these rare exposures in the southeast corner of sec. 11 the following section was measured:

Section of beds of lignite in southeast corner sec. 11, T. 12 N., R. 59 E.

	Ft.	in.
Sandstone, yellow	4+	
Shale, brown	4	
Lignite	5	4
Shale, brown	5	
Lignite		10
Shale, brown and gray	8	
Lignite	1	2
Shale, brown	1+	
Total lignite	7	4

The strata have a general dip to the northeast ranging from 1° to 2°. There are local folds in secs. 4 and 5, but they are not extensive enough to affect land classification.

T. 12 N., R. 58 E.—The Colgate sandstone member, which does not generally contain lignite, occupies an area of about 2½ square miles in the southwest corner of this township; the rest of the area is occupied by the undivided part of the Lance formation, except a few acres along the eastern side underlain by the Fort Union.

Several thin beds of lignite in the Lance formation outcrop in the township. One of the more important of these is 40 to 80 feet below the top of the formation and ranges in thickness from 1 to 2 feet. A section of the bed measured in the SE.¼ NE.¼ sec. 12 shows 23 inches of good clean lignite. Another in the NE.¼ sec. 24 shows 15 inches of lignite with two half-inch partings. This is probably the most persistent of the many small beds in the upper hundred feet of the formation.

About 150 to 200 feet below the top of the Lance formation is a very persistent zone of lignite. A bed, apparently belonging to this zone and lying 180 feet below the top of the formation, is sufficiently important to be mapped in T. 10 N., R. 59 E., and in T. 9 N., R. 61 E. In the township to the north (T. 13 N., R. 58 E.) J. H. Hance found a bed more than 30 inches thick in this zone, but it passes below that limit just north of the boundary of the township under discussion. On the north side of sec. 2, near the quarter corner, this bed reaches its maximum observed thickness in this township—24 inches of good lignite. Above this, separated by about 18 inches of shale, there is about 24 inches of bone, lignite, and shale. The following section represents its character:

Section of lignite bed exposed in sec. 2, T. 12 N., R. 58 E.

	Ft.	in.
Shale, gray.		
Bone	2	
Shale, brown	1	6
Lignite	2	
Shale, gray.		
	5	6

Southeast of the place where the section given above was measured the lignite is largely replaced by shale, so that within less than a mile there is only 6 inches of clean lignite in the bed. Beyond this place it is somewhat thicker, containing 23 inches of lignite at one place in sec. 11 or sec. 12. South of sec. 12 the surface is mostly rolling and grass covered so that it was impossible to trace the bed farther in that direction. Many exposures that seemed to be of beds of this zone were examined, but no valuable lignite was found.

The persistent lignite bed at the base of the Fort Union formation was mapped in secs. 1, 12, 24, and 25 of this township. Measured

sections along its outcrop at locations 3 and 7 (Pl. XVIII) are represented graphically in Plate XVI under corresponding numbers. This bed outcrops in an area that is gently rolling and grass covered. The lignite in the outreaching points is in general under less than 20 feet of cover.

T. 12 N., R. 57 E.—As shown by the map (Pl. XVIII), the Pierre, Lance, and Fort Union formations and the Colgate sandstone member of the Lance are exposed in this township. By far the greater part of the surface is made up of Pierre shale. The Colgate sandstone outcrops in a comparatively narrow band on the west side of the township and in an irregular-shaped area on the east. As set forth in the paper by Calvert (pp. 187–201) the Pierre shale is not known to contain coal or lignite at any place and the Colgate sandstone member of the Lance carries lignite only locally in this region. The undivided portion of the Lance formation is exposed over a comparatively small area in the southwest and northeast parts of the township, but generally it does not carry beds of lignite that have any considerable thickness, though thin beds are common.

The commercially valuable lignite of the township is limited to a very small triangular area in the southwest part of sec. 31 that is underlain by the persistent lignite bed at the base of the Fort Union formation. Location 148 is the only place in this township at which this bed was measured. A higher bed, measured at location 149 is at least 7 feet thick. The bottom was not exposed and the full thickness could not be obtained.

This township is crossed by the axis of the Glendive anticline, which extends across the field in a northwest-southeast direction. In the southwest corner of the township the beds dip about 17° SW., whereas in the northeast part of the township they dip only about 2° or 3° NE. As suggested by Calvert (p. 201), the structure here is favorable for the accumulation of oil.

T. 12 N., R. 56 E.—As shown by the map (Pl. XVIII), the Pierre, Lance, and Fort Union formations are exposed in this township. The Pierre shale and the Colgate sandstone member of the Lance do not contain lignite, and although the undivided portion of the Lance contains many thin beds of lignite none 30 inches thick was found. The large area of Fort Union rocks west of the mapped outcrop contains much lignite.

The persistent lignite bed at the base of the Fort Union formation extends across the township and probably underlies all that portion west of the mapped outcrop. Sections 136, 138, 141, 142, 143, 145, and 147, measured at various places, are shown in Plate XVII. At locations 139 and 144 the bed is not well exposed, but 36 inches of lignite was measured at the former and 72 inches at the latter locality. In both places the bottom of the bed is concealed, so

that the entire thickness is unknown, but judging from adjacent sections it seems probable that most of the bed is exposed.

Above the bed mapped there are various other beds of lignite, to which little attention was given because information relative to the lowest bed was all that was necessary for the purpose of this work. At locations 137 and 140 sections were measured of a bed 12 feet above the one mapped. One of the most conspicuous of the higher beds is stratigraphically about 200 feet above the base of the formation, and is exposed at location 146 in the northeast corner of sec. 26. This bed, as well as others higher in the formation, is extensively burned along the outcrop, so that there is quite a series of clinker-capped hills along the eastern limit of the Fort Union area.

This township is on the west limb of the Glendive anticline, which crosses the Terry field in a northwest-southeast direction. The greatest dips in the township, 18° to 25° SW., are along the base of the Fort Union formation. On either side the strata flatten abruptly, arching over the anticline to the northeast and passing beneath the broad open syncline to the southwest. Though locally the strata dip strongly, the Fort Union formation over most of the area is practically horizontal. The structure in the northeastern part of the township is favorable for the accumulation of oil.

T. 12 N., R. 55 E.—The surface rocks of the whole of this township are of the Fort Union formation and the underlying strata are the same as those that in the township to the east carry important beds of lignite. Hence lignite in all probability underlies the entire area. Outcrops of thick beds of lignite are reported along Cabin Creek, but they were not visited by the writer. No detailed examination was made of this township, as sufficient data for land classification were collected from the adjacent townships.

T. 12 N., R. 54 E.—The surface rocks of the whole of this township are of the Fort Union formation. The lignite-bearing zone at the base of the formation underlies the entire area which is included in the broad syncline between the Glendive anticline and Powder River. No detailed examination of the township was made because sufficient data for land classification were collected along the margins of the basin to show that the entire township is without doubt underlain by lignite at a less depth than 500 feet.

T. 12 N., R. 53 E.—As shown by the map (Pl. XVIII), all the surface rocks of this township are of the Fort Union formation. The lignite zone at the base of the formation underlies the entire township at a less depth than 500 feet. Lignite higher in the Fort Union formation is exposed at the surface, but it was not studied in detail because data relative to the higher beds were not necessary for land classification. Some information, however, relative to the higher beds was obtained. The badlands in the "breaks" of O'Fallon Creek

furnish excellent exposures which reveal the character of a considerable portion of the Fort Union formation in this part of the field. The beds show much irregularity of deposition. Cross-bedding and sharp differences in the character of materials are common. The beds are made up mainly of soft friable sandstone and shale of somber and yellow colors, with a predominance of yellow in the upper part. Seams of carbonaceous shale with small quantities of lignite are distributed throughout the strata. The character and position of the beds of lignite are shown by the following section, which was measured from the summit of the "breaks" in sec. 29 to a point 25 feet above O'Fallon Creek, in sec. 31:

Section of Fort Union strata exposed in secs. 29 and 31, T. 12 N., R. 53 E.

	Ft.	in.
Sandstone, hard	1	
Sandstone, soft argillaceous	19	
Bone		4
Shale, yellow, argillaceous	12	
Bone		11
Shale, gray	6	8
Sandstone, soft gray	11	7
Shale, yellow		6
Shale, gray	12	
Sandstone, soft white to brown, argillaceous	9	
Shale, carbonaceous		2
Shale, gray	12	
Lignite	2	1
Shale, gray	16	
Sandstone, yellow, hard	2	
Sandstone, soft gray	25	
Lignite		5
Bone		4
Shale, gray	4	9
Bone		6
Shale, gray and yellow	7	
Shale, carbonaceous		9
Shale, gray	10	4
Lignite		2
Shale, gray		8
Lignite		4
Shale, gray	11	
Sandstone, soft, yellow, argillaceous	15	
Shale, gray	30	
Lignite		1
Shale, brown		1
Bone	1	2
Lignite	1	4
Shale, gray	17	
Shale, carbonaceous		9
Shale, gray	1	2
Lignite		3
Shale, gray	10	6

	Ft.	in.
Band of red iron nodules		4
Sandstone, soft, yellow, argillaceous	5	4
Lignite		6
Shale, gray	1	
Sandstone, hard, brown		11
Shale, gray	15	4
Shale, carbonaceous		6
Shale, gray	10	3
Shale, carbonaceous		8
Lignite	1	4
Shale, gray	2	
Sandstone, soft, yellow	22	
Shale, gray	4	
Bone		10
Lignite	2	8
Shale, gray		7
Bone		9
Shale, carbonaceous	3	
Shale, gray	14	
Sandstone, yellow	12	
Sandstone, hard, yellow	3	2
Shale, gray	4	
Shale, carbonaceous		3
Lignite	1	4
Shale, gray.		
	350	7

As shown by the above section, thin beds of lignite occur at many places in the Fort Union formation. The 25-inch bed near the top of the section given above was observed at many places to the southeast, where it is considerably thicker. Within half a mile of the place where this section was measured the bed contains 44 inches of lignite. To the southeast, along the exposure in secs. 28, 27, 33, 34, 35, and 36, its thickness ranges from 36 to 45 inches. Lignite has been taken from this bed at many places for local use.

T. 12 N., R. 52 E.—Both the Lance and Fort Union formations are exposed in this township, but the greater part of the area is occupied by rocks of the latter formation. The Lance occurs only in a small triangular area along Yellowstone River in the western part of the township, where only about 15 feet of the gray shale at the top of the formation is exposed. The Fort Union formation constitutes the surface rocks of nearly all of the township and is clearly exposed in badlands on both sides of O'Fallon Creek and on the south side of the river. The beds are irregular and are made up mainly of soft, friable sandstone and shale of somber and yellow colors, with a preponderance of yellow in the upper part. The persistent bed of lignite at the base of the Fort Union is exposed along the south bank of the river in the western part of the township, having a dip to the northeast greater than the gradient of the stream.

It therefore underlies all of the township except a small area along Yellowstone River, mainly in sec. 7 between the two lines of outcrop. A section measured at location 231 is shown on Plate XVII. The bed at the base of the formation is included in the following section, which was measured in the southwestern part of lot 4, sec. 8:

Section of strata measured in the southwestern part of lot 4, sec. 8, T. 12 N., R. 52 E.

	Ft.	in.
Alluvium and gravel	16	
Lignite, top removed	3	
Shale	4	
Lignite, base of Fort Union	6	6
Covered to the level of water in Yellowstone River	10	
	39	6

The higher strata of the Fort Union seem to contain less lignite in this township than they do in that part of the field which lies farther east. The general character of the strata is represented by the following section, which is exposed in the east-central part of sec. 11:

Section of strata exposed in sec. 11, T. 12 N., R. 52 E.

	Ft.	in.
Gravel terrace.		
Sandstone, soft, yellow	50	
Shale, gray	30	
Shale, yellow, sandy	4	
Lignite		7
Shale, grayish yellow	6	
Shale, gray	7	
Sandstone, soft, yellow	20	
Lignite, dirty, and shale, carbonaceous	3	
Shale, brown, carbonaceous	5	
Lignite	1	
Shale, brown	1	
Sandstone, soft, yellow	35	
Shale, black, carbonaceous		8
Shale, brown		10
Lignite	1	3
Shale, black, carbonaceous	1	
Shale and soft sandstone, light gray	4	
Shale, brown, carbonaceous	1	6
Shale, gray	7	
Bone and shale, carbonaceous	2	
Shale, gray	10	
Lignite		10
Sandstone, soft, yellow	10+	
	201	8+

The following sections of a lignite zone above that at the base of the Fort Union were measured near the mouth of O'Fallon Creek. The bed with the shale parting represents the same horizon in each section:

Sections of lignite beds near mouth of O'Fallon Creek.

Sec. 33, T. 13 N., R. 52 E.

	Ft.	in.
Alluvium	5	
Sandstone, soft, yellow	15	
Shale, brown		10
Lignite	1	10
Shale, carbonaceous	1	5
Lignite	2	1
Shale, carbonaceous	1	
Sandstone, yellow, argillaceous	5	
Lignite	1	10
Shale, brown and yellow, to level of water in Yellowstone River	10	
	44	

On east bank of creek, probably in lot 3, sec. 2, T. 12 N., R. 52 E.

	Ft.	in.
Sandstone, white, argillaceous	7	
Lignite	2	1
Sandstone, yellow	15	
Shale, carbonaceous	4	
Lignite	1	11
Shale, carbonaceous	1	2
Lignite	1	5
Shale, sandy.		
	32	7

At various places in the southeastern part of the township higher beds of lignite are exposed. At only a few places, however, is there as much as 28 inches of clean lignite. The following section, measured in sec. 36, represents a local condition:

Section of lignite bed in sec. 36, T. 12 N., R. 52 E.

	Ft.	in.
Shale, gray		
Lignite	2	3
Shale		4
Lignite	2	3
Total lignite	4	6

Within 100 yards on either side of this locality the lignite is almost entirely replaced by shale. Some lignite beds at higher horizons are more persistent. One, for example, was measured at several places in secs. 35 and 36 and found to contain from 25 to 29 inches of lignite. The occurrence of many beds of lignite in the upper part of the formation is shown by the following section, which was measured in sec. 35:

Stratigraphic section exposed in sec. 35, T. 12 N., R. 52 E.

	Ft.	in.
Shale, gray	58	
Lignite	1	8
Shale and sandstone, yellow	34	
Lignite	2	8
Shale, brown and gray	11	
Shale, black, carbonaceous		8
Shale, gray	17	
Lignite		10
Shale, gray		7
Sandstone, white and gray, soft	6	
Lignite	2	1
Shale, carbonaceous		8
Shale, gray	8	
Sandstone, white	4+	
	147	2+

The bottom of this section is probably slightly higher than the top of the section given on page 243, which was measured in sec. 11.

Some prospecting has been done in this township and a small amount of development undertaken. At location 231, in sec. 7, a considerable quantity of lignite has been taken from a strip pit in the lower bench. In the northeast part of sec. 18 there is an old mine. A railroad switch seems to have been built near the mine, but it has long since been removed and it is evident that this mine has not been operated for several years. This township is easily accessible to the railroads and the beds are favorably situated for mining, but the lignite does not seem to be sufficiently valuable to attract commercial development, though it has been stripped from thin beds at many places for local use.

This township lies on the west side of the broad open synclinal basin of the O'Fallon Creek district and the rocks have a general dip of about 1° NE. This gentle dip is interrupted by a few local disturbances which have little effect on the outcrops of the formations. A small anticline was observed in the central part of sec. 14, and a dip of 5° N. at the mouth of O'Fallon Creek, just beyond the northern boundary of the township.

T. 12 N., R. 51 E.—The Lance and Fort Union formations comprise the surface rocks of this township except along Yellowstone River, where alluvium covers a large area in the vicinity of Terry. The Lance is exposed only along the valley of the river and contains no important lignite beds. The surface rocks on either side of the mapped outcrop are of the Fort Union formation. The stratigraphic section presented on pages 232–233 was measured on the north side of the river, where the Fort Union is extensively exposed in badlands.

The Fort Union area of this township is underlain by the lignite zone at the base of the formation. Although this zone is extensively exposed in cut banks on the north side of the river, only two sections were measured in that part of the township. One of these (No. 232) is shown in Plate XVII, and the other is included in the stratigraphic section on page 233. The location of the outcrop in the vicinity of the latter was determined only approximately, because no detailed mapping was done on the north side of the river. South of the river the position of the outcrop of the bed at the base of the Fort Union formation was largely inferred because exposures at that horizon are few. The only opportunity for measuring the bed is at the Kempton mine, in the northwest part of sec. 27. This so-called mine is a strip pit from which lignite has been taken for local use for several years, but at the time the writer was there it was not being worked. A section of the part of the bed exposed at the time this pit was visited is shown as section 233 in Plate XVII; a complete section could not be obtained because of water in the bottom of the pit.

T. 12 N., R. 50 E.—Only the portion of this township southeast of Yellowstone River was examined. The Lance and Fort Union formations are exposed in this area, but only the Fort Union contains beds of lignite more than 30 inches thick.

Where exposed in this township, the lignite bed at the base of the Fort Union formation is of considerable thickness, as shown by sections 236 and 237, in Plate XVII. Near the river, at location 234, it shows 6 feet of lignite, but the exposure is incomplete and its total thickness may be somewhat greater. In secs. 23, 26, and 35, its outcrop is grass covered, so that it could not be examined, but from a study of exposures elsewhere in the field it is believed that the bed is fairly represented by the sections mentioned above. A sample for analysis was taken from the lower 41 inches of this bed at location 237. The analysis of the sample is given on page 229.

A bed 15 feet above the one mapped was measured at location 235. Though the exposures are good through a stratigraphic distance of 150 feet above the bed just described, the thickest bed of lignite in that section is only 12 inches.

T. 11 N., R. 60 E., and fractional part of T. 11 N., R. 61 E.—The surface rocks in these townships belong to the Fort Union formation. The entire area is underlain by the persistent lignite-bearing zone at the base of the Fort Union at a less depth than 500 feet and also by the Lance formation, which is locally lignite bearing. There are probably four or five beds of lignite more than 30 inches thick underlying the entire area. Lignite is exposed at several places along Beaver Creek. One such exposure on the east side of Beaver Creek in the NW. ¼ sec. 30 gave the following section:

Section of lignite bed in the NW. ¼ sec. 30, T. 11 N., R. 60 E.

	Ft.	in.
Shale, gray and yellow	10	
Shale, black, carbonaceous	4	
Lignite	1	4
Shale		1
Lignite		2
Shale		2
Lignite		10
Shale		¼
Lignite		3
Shale		½
Lignite	3	
Shale and sandstone, brown and yellow	12	
Total lignite	5	7

T. 11 N., R. 59 E.—The greater part of this township is underlain by Fort Union rocks, but a small area along the western margin contains the Lance formation. The latter, where it is exposed, has thin beds of lignite distributed throughout, but in general they are very lenticular and less than 30 inches thick. The general character of the Lance is shown by the stratigraphic section on pages 230–231. The thick bed at the base of the section is the same as that mapped in sec. 31 and almost across the township to the south. It is the most persistent bed of lignite in the Lance in the Terry field and exceptionally persistent for that formation in the region. Though persistent it is irregular, as shown by its variation in this township. Section 30 represents this bed as it is developed in sec. 19. South of this location it is so broken by partings as to have little value for commercial development. At location 35 it consists of two benches 12 and 13 inches thick separated by 34 inches of shale. At location 63 it is somewhat better, but even there it has 3 inches of shale with 10 inches of lignite below and 18 inches above. In the northern part of the township the bed is poor, as shown by several sections measured in T. 11 N., R. 58 E. So far as this township is concerned, this bed seems to be valuable only in sec. 19. Sections of beds higher in the Lance were measured at locations 14 and 34. The bed at location 14 has a thickness of 23 inches but is broken by a shale parting 2 inches thick into an upper bench 6 inches thick and a lower bench 15 inches thick. The bed at location 34 consists of 22 inches of clear lignite. Other beds of lignite are exposed in the Lance in this township but are too thin to be valuable.

In contrast to the Lance, the Fort Union contains an abundance of lignite. The outcrop of the persistent bed at the base of the formation extends across the western part of the township, and the bed underlies all of the area to the east. Sections 13, 18, and 20 show

that this bed increases in thickness southward from the north line of the township at least as far as sec. 18. At location 20 it is split by a small parting, which is only local, for it does not show at location 18 on the north nor at location 21 on the south. At the last location the bed contains 34 inches of clean lignite. Its condition in the southern part of the township is shown by sections 25, 26, 27, 28, 33, 36, 37, 38, 39, 40, 41, and 42.

These data were ample for classification, but some attention was given to three or four other beds higher in the Fort Union. One thick bed of carbonaceous shale with bands of lignite is exposed entirely across the township. This bed is 40 to 50 feet above the base of the formation and locally contains beds of lignite of commercial value. At location 12, in sec. 6, it contains 31 inches of lignite and at location 22, in sec. 18, 33 inches of lignite. In secs. 29, 32, and 33, it contains thin seams of lignite, but near location 18, in sec. 7, there is only carbonaceous shale at this horizon. It is the central member in the following section, which is exposed between locations 28 and 29, in sec. 19:

Section exposed in sec. 19, T. 11 N., R. 59 E., from location 29 to location 28.

	Ft.	in.
Sandstone, yellow, argillaceous	20	
Shale, brown		6
Location 29: Lignite	3	3
Location 29: Shale, brown		6
Location 29: Lignite	2	5
Shale, brown	3	
Sandstone, yellow and gray, argillaceous	30	
Shale, brown, carbonaceous	8	
Lignite	1	
Shale, brown		2
Lignite	1	3
Shale, brown, carbonaceous		4
Sandstone, yellow, argillaceous	40	
Shale, brown	5	
Bone	1	
Lignite (location 28)	4	3
Shale, gray.		
	120	8

The uppermost bed of lignite in this section is burned along the greater part of its outcrop across this township. A section of this bed is shown as No. 23 in Plate XVI. The following section, which was measured at location 19, includes this bed at the base and also the next higher bed:

Section of beds exposed in sec. 7, T. 11 N., R. 59 E.

	Ft.	in.
Shale, gray, arenaceous	10	
Lignite	1	4
Shale		3
Lignite	1	1
Shale, brown		2
Shale, gray	29	
Lignite (location 19)	3	2
Shale, brown.		
	45	

In the bank of Beaver Creek, in the SE. ¼ sec. 13, the following section of a bed of lignite, which is probably slightly higher in the section than any mentioned above, was measured:

Section of bed of lignite exposed in SE. ¼ sec. 13, T. 11 N., R. 59 E.

	Ft.	in.
Sandstone, yellow, argillaceous	4	
Shale, gray	3	
Lignite		6
Shale		1
Lignite	1	
Shale		1
Lignite	2	4
Shale		1
Lignite	2	1
Shale	1	
Lignite		8
Shale, brown.		
Total lignite	6	7

Besides the bed mentioned above there are others well up in the Fort Union, but for the most part they are burned along the outcrop, resulting in clinker-capped hills over the greater part of the township. The strata have a general dip to the northeast of 1° to 2° away from the axis of the Glendive anticline.

T. 11 N., R. 58 E.—As shown by the map (Pl. XVIII), the Pierre and Lance formations, including the Colgate sandstone member, are exposed in this township. The comparatively persistent bed in the Lance formation, which was mapped in T. 10 N., R. 59 E., was carefully observed and found to contain more than 30 inches of good lignite only in the southeastern part of sec. 24, though at location 30, near the west side of sec. 19, T. 11 N., R. 59 E., this bed contains 43 inches of good lignite without any parting. To the west the bed is dirty, as shown by the following section, measured at location 31:

Section of lignite bed in sec. 24, T. 11 N., R. 58 E.

	Ft.	in.
Lignite, dirty	2	
Shale		4
Lignite, dirty	1	3
Shale		1
Lignite, dirty		4
	4	

At location 32 the bed shows similar characteristics, having the same thickness of shale near the middle of the bed. The upper bench is 1 inch thicker than at location 31, and the bottom bench is solid lignite 20 inches thick. At locations 15 and 16 the bed has little value, as shown by the following sections:

Sections of lignite bed in sec. 12, T. 11 N., R. 58 E.

Location 15.

	Ft.	in.
Lignite		6
Shale		6
Lignite	1	
Shale	1	2
Lignite		4
Total lignite	1	10

Location 16.

	Ft.	in.
Lignite		6
Shale		6
Lignite	1	6
Total lignite	2	

Its condition at location 17 is somewhat better, as shown by the section in Plate XVI.

The strata of this township have a general dip of 1° to 5° NE., away from the anticlinal axis.

T. 11 N., R. 57 E.—The Pierre, the Lance, including the Colgate sandstone member, and the Fort Union formations are exposed in this township. The Pierre does not contain lignite, and the Lance contains only thin beds; hence, the area occupied by them has practically no lignite resources.

As shown on the map (Pl. XVIII) there is a break in the north part of sec. 6 in the continuity of the line representing the outcrop of the lowest valuable lignite bed in the Fort Union formation. The bed mapped across T. 12 N. was traced into this township as far as location 150, where it has the section shown in Plate XVII. As the amount of available lignite in the bed at this place is less than 30 inches, mapping was discontinued and transferred to the next higher important bed, which lies 30 feet above the bed traced through the township to the north. The new bed was mapped across this township, but, as explained under the description of T. 10 N., R. 57 E., a lower bed was found a short distance to the south that exceeded 30 inches in thickness and the mapping of the upper bed was discontinued.

The bed mapped across this township is represented in the northern part by sections 151 and 152. At location 153 it is 33 inches thick, being nearly the same as it is at location 152. Its condition in the southern part of the township is represented by sections 155, 156, 158, and 159. For most of the distance this zone is concealed in a heavily grass covered rolling upland; therefore exposures are rare and measurements of thickness are difficult to obtain, but the line of outcrop can be fairly definitely located over the grassy upland by the material thrown out by gophers in digging their holes.

The following section, which was measured in a cut bank on Cabin Creek at location 158, near the southeast corner of sec. 28, shows the character of the lignite-bearing zone at the base of the Fort Union formation.

Section exposed in sec. 28, T. 11 N., R. 57 E.

	Ft.	in.
Shale, gray.		
Lignite	1	
Shale, gray	3	
Lignite		6
Shale, brown, carbonaceous	2	
Shale, gray, arenaceous	5	
Lignite		7
Shale, gray, arenaceous	12	
Lignite	1	8
Shale, brown, carbonaceous	12	
Location 158: Lignite	6	2
Location 158: Shale		2
Location 158: Lignite		5
Shale, brown, carbonaceous	4	
Lignite		9
Shale, brown, carbonaceous		10
Lignite		5
Shale, black, carbonaceous	1	6
Shale, gray	4	
	56	

Higher beds of lignite are exposed west of the mapped outcrop. These beds are shown by sections 154 and 157. The second bed above the one mapped is marked by conspicuous clinker beds across the greater part of the township.

This township is crossed by the axis of the Glendive anticline. The line of maximum dip, which extends across the township parallel to the axis of the anticline, corresponds approximately to the outcrop of the base of the Fort Union formation. Along this line the dip is from 15° to 25° SW. On either side the strata flatten abruptly, forming a flat arch over the anticline on the one side and one limb of a broad shallow syncline on the other. In the northeastern part of the township the dip is about 2° or 3° NE., and in the southwest

corner the strata are horizontal. As suggested by Calvert (p. 19), this fold is favorable for the accumulation of oil.

T. 11 N., Rs. 54, 55, and 56 E.—These townships are in the broad, shallow syncline constituting the O'Fallon Creek district and are underlain by the persistent lignite-bearing zone at the base of the Fort Union, which is nowhere deeper than 500 feet below the surface. This information was obtained by examination on the two sides of the district, but no detailed work was done in the townships; hence no lines of coal outcrop are shown on the map. Exposures of lignite were observed at several places and clinker beds on the surface are common; hence there is fairly good evidence that the area contains beds well up in the Fort Union as well as the one at the base of the formation which most probably underlies the entire area.

T. 11 N., R. 53 E.—The surface rocks of this township are limited to the Fort Union formation and are well exposed in the badlands along O'Fallon and Whitney creeks. Seams of carbonaceous shale and thin beds of lignite are distributed throughout the exposed part of the formation. The stratigraphic section on pages 241–242 of this report and the description of the township to the north give a fairly good idea of the strata in this township.

The zone at the base of the Fort Union which persistently carries lignite underlies this township at a less depth than 500 feet. It is highly probable, therefore, that the entire township is underlain by at least one bed of lignite more than 30 inches thick. Thin beds of lignite occur at many horizons throughout the exposed portion of the Fort Union. These were not examined carefully, for they do not affect the classification of the land, but as opportunity offered a few sections were measured.

The following is exposed near the crest of a local anticline, in sec. 10:

Section of strata exposed in sec. 10, T. 11 N., R. 53 E.

	Ft.	in.
Sandstone, yellow	8	
Shale, highly carbonaceous	2	
Shale, gray	10	
Sandstone, yellow, hard	10	
Lignite	2	5
Shale, gray.		
	32	5

The lignite bed noted in the above section is partially exposed where it dips under O'Fallon Creek about 200 yards north from the place where the section was measured. At the point where it disappears it is at least 34 inches thick. This bed dips below water level both north and south of the place where the section was measured.

Another section was measured near the top of the "breaks" in the northeast part of sec. 1.

Section of strata exposed in sec. 1, T. 11 N., R. 53 E.

	Ft.	In.
Sandstone, brown, hard	2	
Sandstone, yellow, argillaceous	20	
Shale, gray	15	
Sandstone, gray, hard	1	
Sandstone, light yellow, soft	25	
Shale, black, carbonaceous		7
Lignite	3	8
Shale, gray	7	
	74	3

The bed of lignite in the above section is the same as that examined in the southeast part of T. 12 N., R. 53 E., and discussed in the description of that township.

In general the strata dip slightly northeast. Some minor flexures are evident along O'Fallon Creek, but they are only local.

T. 11 N., R. 52 E.—The surface rocks of this township belong to the Fort Union formation. The bottom of the formation is not exposed, but the lignitic zone at the base doubtless underlies the entire area and it seems probable that it carries valuable lignite beds. Thin beds of lignite occur at many horizons above this lignitic zone, and some of these exceed 30 inches in thickness. One of these, near the northwest corner of sec. 28, measures 33 inches; another, near the top of the divide in sec. 32, measures 40 inches; and still another, in sec. 18, according to report, 60 inches, but this was not visited and the report was not verified. Detailed work was not done on these beds as the lower zone afforded sufficient evidence for the classification of the land.

T. 11 N., R. 51 E.—The Lance and Fort Union formations are exposed in this township. The former outcrops along the valley of Powder River and the latter in the rolling upland in the central and eastern part of the township. That part of the township lying west of Powder River was not examined.

That part of the Lance formation exposed in the valley of Powder River contains some beds of lignite, but they are generally thin and none was found that exceeds 25 inches in thickness.

The lignitic zone at the base of the Fort Union formation, which almost universally carries important beds of lignite in this field, is poorly represented in a part of this area. In the township to the south the lignite of this zone is well developed, as shown by the numerous sections indicated on the map and given in Plate XVII. The bed extends into T. 11 N., across secs. 34, 33, and 28, but it gradually decreases in thickness and value, as shown by sections

248, 247, and 246. North of the locality last mentioned the amount of lignite in the bed is insignificant and at location 245 it consists of nothing but carbonaceous shale, as shown by the following section:

Section of strata exposed in sec. 20, T. 11 N., R. 51 E.

	Feet.
Gravel to top of bluff	20
Sandstone, yellow	10
Shale, gray	10
Sandstone, yellow	15
Shale, brown, carbonaceous	7
Shale, gray	40
	102

This condition holds along the outcrop in secs. 29, 20, 19, and 18, but in the township to the west it again develops into a bed of considerable importance. Of course, it is impossible to determine the shape of the barren area in this township without drilling, but it seems reasonable to suppose that it is roughly circular and that it extends back under cover about half the length of its outcrop. None of the higher beds in the Fort Union were found in the stratigraphic position they generally occupy, hence it was inferred that they are absent.

The rocks of this township have a gentle dip to the northeast into the broad structural basin of O'Fallon Creek.

T. 11 N., R. 50 E.—Examination was made of only that part of the township which lies northeast of Powder River. In this part the surface rocks comprise two formations—the Lance, which outcrops along the valleys of Powder and Yellowstone rivers, and the Fort Union, in the upland area in the northeast part of the township.

The Lance formation contains several thin beds of lignite, but none of these is thick enough to be of commercial value. An apparently small lens is exposed for a distance of about 100 yards in a cut bank on Powder River in sec. 24. At its maximum it contains 32 inches of lignite with a ¼-inch shale parting. Up the stream 75 feet from this point its total thickness is 29 inches, with a parting 2 inches thick near the middle, and 50 feet farther in the same direction there is only 18 inches of clean lignite in the bed. The variation from the point of maximum development is similar in the opposite direction but is not quite so pronounced.

The outcrop of the persistent lignite zone at the base of the Fort Union formation crosses the northeast corner of the township. (See Pl. XVIII.) As shown by the sections, there is a great change in the character of this bed along its outcrop in the township. At its maximum development near the north line of sec. 2 the following section was measured:

Section of lignite bed exposed in sec. 2, T. 11 N., R. 50 E.

	Ft.	in.
Shale, gray.		
Lignite	5	6
Shale and bone	1	3
Lignite	7	
Shale, gray.		
Total lignite	12	6

At locations 238 and 239, as shown by the sections (Pl. XVII), the bed shows a tendency to split into two parts. The shale and bone parting 15 inches thick in the section at the north line of sec. 2 has thickened to 25 inches at location 239. At location 240 this shale is 6 feet thick, separating an upper bench 30 inches thick (section 240, Pl. XVII) from a lower bench which is poorly exposed. The lower bench contains 4 feet of good lignite (Pl. XVII) at location 241, but at location 242 this has changed to impure lignite of little or no value. At location 243 the lower bench is of poor quality and only 38 inches thick (Pl. XVII) and the shale parting above is 8 feet thick. At location 244 the upper bench measures only 29 inches and the lignite is decidedly impure. At location 245 the whole bed is represented only by carbonaceous shale.

T. 10 N., Rs. 60 and 61 E.—The Fort Union formation includes all rocks exposed in these townships. The surface is gently undulating and generally grass covered, so that exposures of lignite beds are not common, but for purposes of land classification a careful study was unnecessary because a close examination of the area to the west showed that these townships are underlain at a less depth than 500 feet by the zone at the base of the Fort Union which persistently carries lignite, and at a somewhat greater depth by the irregular and uncertain beds of the Lance.

There are also higher beds exposed in the townships. The following section shows two of these beds at an outcrop in a cut bank on the east side of Beaver Creek in the NW. ¼ sec. 5, T. 10 N., R. 60 E.:

Section of beds of lignite exposed in the NW. ¼ sec. 5, T. 10 N., R. 60 E.

	Ft.	in.
Shale, brown and gray	10+	
Bone		3
Lignite		1
Shale		1
Lignite		4
Shale, brown	17	
Shale, carbonaceous	1	3
Lignite	3	2
Shale		½
Lignite		4
Shale		½
Lignite	3	6
Shale		6+
Covered to Beaver Creek	15	
	51	7+

In the NE. ¼ sec. 9 of the same township considerable lignite has been taken from a strip pit in the east bank of Beaver Creek. A full section could not be obtained, but there is at least 43 inches of good clean lignite at that place.

The strata have a slight general dip to the northeast away from the axis of the Glendive anticline.

T. 10 N., R. 59 E.—The Lance and Fort Union formations are exposed in this township. Exceedingly rough and bare badlands furnish excellent exposures of the Lance, which contains an unusually persistent bed of lignite about 180 feet from the top of the formation. Its outcrop was mapped from a point near the center of sec. 34 to the north line of the township and for more than a mile into the adjacent township to the north. Near the north line of the township the character of the bed is shown by section 64, which includes a total thickness of 39 inches of lignite. A short distance to the south, at location 65, the bed contains only 22 inches of lignite underlain by 17 inches of bone. The character of the bed across secs. 6 and 5, south of location 65, is shown by sections 66, 67, 68, 69, 70, 71, 72, 73, 74, and 75. At location 76 the section is practically the same as that at location 75, except that the upper bench of lignite is 36 inches instead of 37 inches, the shale parting 6 inches instead of 2 inches, and the lower bench 9 inches instead of 13 inches. The bed shows as a single bench 36 inches thick at location 77 and 33 inches at location 78 (Pl. XVI). Southeast of the last-mentioned location the bed is below the minimum thickness for some distance, containing 20 inches of lignite at location 79, 14 inches at location 80, 27 inches at location 81, and 26 inches at location 82. At location 83 it is 32 inches thick (Pl. XVI) and it keeps about this thickness for some distance along the outcrop, showing 31½ inches of lignite at location 84, 32 inches at locations 85 and 86, 33 inches at location 87, and 31 inches at locations 88 and 89 (Pl. XVI). For some distance beyond location 89 the bed is thin and of little value, being 21 inches thick at location 90, 22 inches at location 91, 25 inches at location 92, 22 inches at location 93, 20 inches at location 94, and 14 inches at location 95. Beyond this place the bed thickens to 34 inches at location 96 (Pl. XVI), 33 inches at location 97, and at locations 98, 99, and 100 the thicknesses shown in Plate XVI. At locations 101 and 102 it is 30 and 31 inches thick, respectively. Beyond the last-mentioned location the bed thins abruptly to 13 inches at locations 103 and 104. Beyond this place the bed was not mapped, but it is known to be thin and unimportant for at least 10 miles. The outcrop mapped represents an unusual development of lignite in the Lance. Sections 60, 61, and 62 show a lenticular bed about 25 feet below the top of the formation. This bed is locally of sufficient thickness at location 62 to be of economic importance.

Within a short distance on either side of this point the bed is too thin to be of value according to the present standard. In addition to those described above, there are a great many thin beds of lignite in the Lance, but none of these exceeds 30 inches in thickness.

The persistent lignite bed at the base of the Fort Union formation was mapped across this township. Throughout the township to the north this bed maintains on its outcrop a thickness of 3 to 4 feet. At location 42 it is unusually thick, consisting of two benches of 40 and 45 inches of lignite separated by 7 inches of shale. A partial exposure of the bed at location 43 shows 32 inches of lignite. This measurement represents only a part of the upper bench. A section measured at location 44 (Pl. XVI) shows that the two benches are present, but both are somewhat thinner than at location 42. The parting also is thinner and apparently thins out to the south. An outcrop exposing the upper part of the bed shows at least 31 inches of clear lignite at location 45. Sections 46, 47, and 48 (Pl. XVI) show the character of the bed at the respective locations. At location 49, the bed consists of 34 inches of lignite overlain by 2 feet of bone and carbonaceous shale. South of location 49 the bed is well represented by sections 50, 51, 52, 53, 54, 55, 56, 58, and 59.

Higher beds of lignite were observed at various places, but were not mapped. Section 57, on Plate XVI, includes two beds, the lower of which is about 60 feet above the base of the Fort Union formation. A higher bed is represented by the following section exposed in the SW. ¼ sec. 11:

Section of bed of lignite exposed in the SW. ¼ sec. 11, T. 10 N., R. 59 E.

	Ft.	in.
Alluvium		6
Lignite		3
Shale, brown		1
Lignite	1	1
Shale, brown		1
Lignite	2	2
Shale, brown		1
Lignite	1	3
Shale, brown		1
Total lignite	4	9

The strata of this township have a general dip to the northeast ranging from a maximum of 4° near the anticline in the southwest corner to nearly zero in the center of the basin in the northeast corner.

T. 10 N., R. 58 E.—As shown on the map (Pl. XVIII) the surface rocks of this township comprise the Pierre shale and the lignite-bearing Lance and Fort Union formations. There are many thin beds of lignite in the Lance, but none is more than 30 inches thick. Of

these small beds the most persistent is one that occurs about 70 feet below the top of the formation. At location 204 this bed measures 18 inches in thickness; at location 213, 22 inches; at location 218, 22 inches; and at location 220, 24 inches.

The bed of lignite at the base of the Fort Union formation outcrops across the southwest corner of the township. At location 207, its most northern point of outcrop, 4 feet of lignite is exposed, but the bottom of the bed was concealed and its full thickness could not be determined. It seems probable that its thickness is about the same as that shown in section 208, measured a short distance south of location 207. The bed holds a thickness of about 5 feet 7 inches at locations 210 and 211. At location 212 it is somewhat broken, as shown in Plate XVII, but at locations 215 and 217 it is clear lignite, though the full thickness of the bed could not be determined at either place. At location 219 it shows about the same as at location 221 (Pl. XVII). Beyond this place it decreases to 35 inches at location 222 near the south line of the township.

Large clinker beds give evidence that a thick bed of lignite occurs about 50 feet above the base of the Fort Union. Still higher there are at least three thick beds of lignite represented by sections 209, 214, and 216, besides some thin ones of more or less local development. The second bed of the group is about 100 feet above the base of the Fort Union formation. Where measured, near the northeast corner of sec. 5, T. 9 N., R. 58 E., it contains 7 feet 8 inches of lignite.

This township is crossed by the axis of the Glendive anticline. The line of maximum dip (15° to 20° SW.) is in general about a quarter of a mile southwest of the outcrop of the base of the Fort Union formation, but the strata flatten abruptly to the northeast on the anticline and to the southwest into the broad synclinal basin of O'Fallon Creek. In the northeastern part of the township the dip is 2° or 3° toward the northeast or away from the anticlinal axis. As suggested by Mr. Calvert, this anticline is a favorable structure for the accumulation of oil.

T. 10 N., R. 57 E.—As shown by the map (Pl. XVIII), the Pierre shale, the Lance formation, including the Colgate sandstone member, and the Fort Union formation are exposed in this township. The Pierre outcrops in the extreme northeast corner of the township only, and the Colgate in an adjacent band on the southwest. In the Lance there are many thin beds of lignite. One, shown at location 178, is 25 inches thick; another, exposed in sec. 3, is represented by section 168 in Plate XVII. The bed mapped in the central part of sec. 11 is an example of an extreme lenticular type of bed; its maximum thickness is 58 inches at location 181; 20 inches at location 180; 25 inches at location 179; and 12 inches at location 182. The bed represented by sections 163 and 164 is also a small lens which is

less than 30 inches thick beyond the limits indicated on the map. A similar lens in sec. 2 is shown by sections 170 and 173 in Plate XVII. Additional measurements made at locations 171 and 172 showed at the former about the same section as at location 170 and at the latter the same as at location 173. A bed 60 feet below the top of the Lance outcrops across sec. 13 and extends on to the southeast. It is 30 inches thick at location 202, 22 inches at location 203, and only 18 inches at location 204. Northward from location 202 it is less than 30 inches thick.

The upper limit of the Lance formation is very indefinite in this township. As explained in the paper by Mr. Calvert, there is no sharp line of differentiation between the Lance below and the Fort Union above. For convenience the line separating these formations has been assumed to lie at the bottom of the lowest persistent bed of lignite. This line generally coincides with a change in color from somber beds below to yellow beds above. The lowest bed of lignite that persists across this township is far up in the beds of preeminently yellow color. The horizon of the bed traversed from a point near the northeast corner of sec. 14 past the northeast corner of sec. 24 and on to the southeast seems to be the natural horizon at which to draw the line of contact between the two formations. It not only marks the lowest important lignite bed but also the line below which the beds of somber color predominate and above which the beds are practically all of yellow color. However, in the northeastern part of sec. 14 and on to the northwest this does not hold true, for great thicknesses of somber-colored material are present above this horizon. The lignite bed that was traversed in the township to the north, and in this township near the quarter corners on the north side of secs. 3 and 14, seems to be the natural place at which to draw the contact between the Fort Union and Lance formations in the township to the north and also in this township as far as sec. 13. The question as to the proper place at which to draw the contact between the Fort Union and Lance formations will necessarily be left unsettled until careful work is done, and then it will probably be settled on paleontologic rather than lithologic grounds.

The bed at about the base of the Fort Union that was traced into this township from the township on the north shows a thickness at location 162, near the north line of the township, of only 17 inches. From this place it increases toward the south, as shown by sections 166, 167, 169, and 174. At location 175 it is only 28 inches thick and beyond this place it is badly broken, as shown by sections 176, 177, and 183. The bed that was mapped as the base of the formation farther south is represented by sections 197, 199, 200, and 205.

A bed somewhat above the base of the formation was mapped in sec. 13. At location 198 this bed has a thickness of only 21 inches, but at location 206 it has a thickness of 5 feet (Pl. XVII). A bed above the main mapped bed in sec. 3 is 28 inches thick at location 165 and 38 inches at location 161 (Pl. XVI). A prospect at location 160 shows 31 inches of lignite (Pl. XVI), but the bed was not traced in either direction beyond this place. What seems to be a higher bed was traced across secs. 10, 11, and 14, but it is practically worthless. At location 184 it shows only 16 inches of lignite and at locations 185 and 186 it is so broken by shale partings that it may be regarded as valueless.

The highest bed mapped shows at location 187 a thickness of about 4 feet, and at location 188 a thickness of 35 inches, but the bottom of the bed was concealed and its full size could not be determined. Its character south of this place is shown in sections 189, 190, 191, and 192. At location 193 the full thickness is not exposed, but 37 inches of lignite was visible. This, however, is probably far short of the thickness of the bed, for at locations 194 and 195 (Pl. XVI) it is a fair-sized bed.

The northeast part of this township is on the southwest limb of the Glendive anticline, which crosses the field in a northwest-southeast direction. The maximum dip is along the line of outcrop of the lower part of the Fort Union formation. As shown by the dip symbols on the map, the strata flatten abruptly on the southwest side of the line of maximum dip and are horizontal or nearly so throughout the southwest half of the township but gradually decrease northeast of the line, toward the axis of the anticline, which is probably beyond the northeast corner of the township.

T. 10 N., Rs. 52, 53, 54, 55, and 56 E.—All these townships lie within the broad shallow syncline which forms the O'Fallon Creek district. They generally contain outcrops of lignite and are underlain at a less depth than 500 feet by the persistent lignite-bearing zone at the base of the Fort Union and at a somewhat greater depth by the Lance, which is locally lignite-bearing. Beds exposed at the surface were not examined in detail because the purpose of the work did not demand accurate information concerning them. They were studied to some extent, however, and data thus obtained are set forth below.

In T. 10 N., R. 56 E., beds of lignite well up in the Fort Union are exposed in various localities. They were not examined in detail, but it was noted that a 4-foot bed is exposed in sec. 7, and considerable lignite is being mined from a 9-foot bed in sec. 36.

In T. 10 N., R. 55 E., lignite beds were found at various distances above the base of the Fort Union, but no sections were measured.

There are good exposures of the strata in T. 10 N., R. 54 E., in the badlands along O'Fallon Creek. The beds are made up mainly of soft friable sandstone and shale beds of somber and yellow color with a predominance of yellow in the upper part. Beds of carbonaceous shale with small quantities of lignite are of common occurrence.

T. 10 N., R. 51 E.—The Lance and Fort Union formations are exposed in this township. The outcrop of the lignite bed that was arbitrarily regarded as at the base of the latter formation is indicated on the map (Pl. XVIII). In most of the township, the rocks above that bed are preeminently yellow, but in the northeast part, in secs. 1, 2, 11, and 12, there are 80 to 100 feet of somber-colored rocks above the persistent lignite zone. The following section, which is exposed between Powder River and a point near the center of sec. 16, is introduced to show the character of the Lance formation at that place:

Section of Lance formation exposed in sec. 16, T. 10 N., R. 51 E.

Fort Union formation.	Ft.	in.
Shale, brown	3	
Shale, somber, arenaceous	20	
Shale and sandstone, carbonaceous	12	
Shale and sandstone, somber	10	
Sandstone, yellow	12	
Shale, somber, arenaceous	15	
Lignite, shale, and bone	1	3
Shale, somber	3	
Lignite, dirty	1	
Shale, somber	8	
Shale and sandstone, yellow	15	
Shale, carbonaceous	1	
Lignite	1	
Shale, somber, arenaceous, to bed of Powder River	50	
	152	3

A bed of lignite 25 to 40 feet below the top of the Lance formation was mapped for a considerable distance in the township to the south and at a few places in this township. On Tenmile Creek, in sec. 2, it has the thickness and character shown in section 255 (Pl. XVII). At location 256, in sec. 3, it has a similar structure and the main bench of lignite has the same thickness, but the dirty lignite above is only 10 inches thick. In sec. 16 the following section was measured on this bed:

Section of lignite bed exposed in sec. 16, T. 10 N., R. 51 E.

Shale, somber, arenaceous.	Ft.	in.
Lignite, shale, and bone	1	3
Shale, somber	3	
Lignite, dirty	1	
Shale, somber.		
Total lignite	2	3

The bed was also noted in sec. 33, where at location 265 it shows the following section:

Section of lignite bed at location 265, sec. 33, T. 10 N., R. 51 E.

	Ft.	in.
Lignite	1	4
Shale, carbonaceous	1	6
Lignite		8
Total lignite	2	

At location 267, in the same section, it has the section shown in Plate XVII.

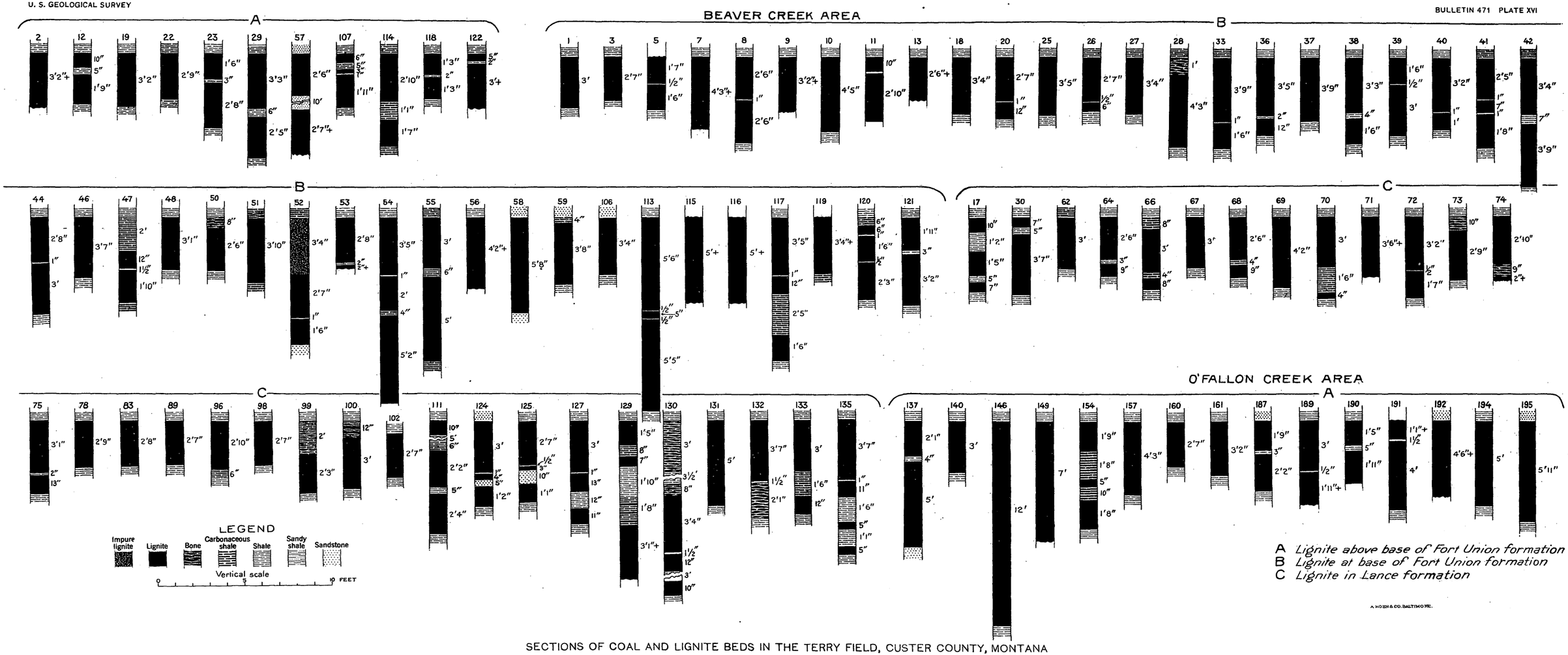
At most of its outcrop in this township this zone consists of two thin beds of lignite separated by about 3 feet of shale, but in the north part of sec. 3, where both beds outcrop, they are so impure that it is doubtful if they can be utilized. At no place except those indicated on the map does this zone contain as much as 30 inches of clean lignite. At the most eastern exposure, on both Tenmile and Coal creeks, the bed shows the thickest section, but at the most western the lignite is replaced largely by shale. It seems probable that the outcrop represents the western edge of a large lens, larger than is common in the Lance formation.

The outcrop of the persistent lignite zone at the base of the Fort Union formation extends across this township, and that zone underlies all of the township to the east of the line of outcrop. In the township to the north the zone contains little lignite of value for a distance of 2 or 3 miles along the outcrop, but near the south line of that township it contains at least 3 feet of good lignite, as explained in the description of T. 11 N., R. 51 E. At location 249, in sec. 2, it has the following thickness and character:

Section of lignite bed at location 249, sec. 2, T. 10 N., R. 51 E.

	Ft.	in.
Lignite	2	8
Shale		5
Lignite	1	
Total lignite	3	8

Sections 250, 251, and 252 show its character where the outcrop crosses the valley of Tenmile Creek. At location 253 its condition is practically the same as at 252, except that the main bench is 42 inches thick instead of 46 inches. Around the point of the outcrop, in secs. 3 and 4, its character is shown by sections 254, 257, and 258. In this district it is much broken by shale partings and at location 258 it is very thin. This condition prevails at location 259, where it has the following section:



SECTIONS OF COAL AND LIGNITE BEDS IN THE TERRY FIELD, CUSTER COUNTY, MONTANA

A. HOEN & CO. BALTIMORE.

Section of lignite bed at location 259, sec. 4, T. 10 N., R. 51 E.

	Ft.	in.
Lignite	1	9
Shale		2
Lignite		8
Shale		½
Lignite		5
Total lignite	2	10

Across secs. 9 and 16 the character of the bed is shown by sections 260 to 263. At location 263 the bed consists of one bench of clear lignite 38 inches thick. Toward the south it is thinner, being only 25 inches thick at location 264. Beyond this location it is not exposed for a distance of 2 miles, but it seems to increase in thickness, as shown by sections 266 and 268.

T. 9 N., R. 61 E.—The Lance and Fort Union formations are exposed in this fractional township. The contact between these formations was drawn arbitrarily at the lowest persistent bed of lignite. In general, throughout the Terry field the beds below this horizon are preeminently of somber color, whereas above this horizon beds of yellow color predominate. In this township, however, there is a prominent band of yellow argillaceous sandstone from 30 to 60 feet in thickness in the Lance formation. On the other hand, about 100 feet of somber shale and sandstone is exposed above the lignite at the base of the Fort Union formation in the north part of sec. 19.

A bed of lignite in the Lance formation is of sufficient thickness along its outcrop in this township to be mapped. The most easterly place where the outcrop of this bed was measured is location 135 and the section of the bed at that place is shown in Plate XVI. At location 134 the section is nearly the same as that at location 135, except that the main bench of lignite is 1 inch and the lower bench 2 inches thicker. The character of the bed at locations 133, 132, 131, 130, and 129 is shown by sections in Plate XVI. The sections at locations 128 and 127 are almost identical and are illustrated by section 127 in Plate XVI. At location 126 the bed seems to have deteriorated into bony material, as shown by the following section:

Section of lignite bed at location 126, sec. 31, T. 9 N., R. 61 E.

	Ft.	in.
Bone	2	7
Shale		1½
Lignite		5
Shale		5
Bone		9
Shale		6
Lignite		10
	5	7½

West of location 126 the bed is of fair thickness as far as the township line, as shown by sections 124 and 125, but west of that line, where mapping was discontinued, the lignite is replaced largely by shale and at no place along its outcrop in the adjoining township to the west does this bed contain as much as 30 inches of clean lignite.

The persistent bed of lignite at the base of the Fort Union formation was accurately mapped about halfway across this fractional township. Sections 120 and 121 show the character and thickness of the bed in sec. 19. At location 123, 25 inches of lignite are exposed, but it seems probable that this is the upper bench only, the lower one being concealed in this locality. In secs. 28 and 29 it is present, though only approximately located on the map (Pl. XVIII), as the classification of the land did not depend on the presence or absence of this bed but on the bed in the Lance formation.

Lignite beds above the base of the Fort Union formation are present in this township, but they were not examined except incidentally. The only measured section of such a bed is represented in section 122.

The strata dip to the northeast at angles varying from about 1° in the northern part to 7° in the southern part of the township.

T. 9 N., R. 60 E.—The contact of the Lance and Fort Union is marked in this township by the outcrop of a persistent bed of lignite, as indicated on the map (Pl. XVIII); the Lance formation lies south of the line and the Fort Union formation north of it.

The bed of lignite in the Lance formation that was mapped in T. 9 N., R. 61 E., degenerates so in quality and thickness that mapping was discontinued near the township line. Its condition in T. 9 N., R. 60 E., is shown by the following section, measured in the central part of sec. 36:

Section of lignite bed exposed in the Lance formation, sec. 36, T. 9 N., R. 60 E.

	Ft.	in.
Shale, gray.		
Lignite, dirty	1	6
Shale, brown		2
Lignite, dirty		8
Shale, gray.		
Total lignite	2	2

There are many thin beds of lignite in the Lance, but no bed is as much as 30 inches thick. The beds are variable in thickness, extent, and character of material, hence no section can be considered typical.

The persistent bed at the base of the Fort Union extends across the township, but its line of outcrop is on gently rolling grass-covered prairies so that exposures are few. Some idea of the character of the bed may be obtained, however, from sections 113, 115, 116, 117, and 119, shown in Plate XVI, which were measured at isolated outcrops. This bed is not well exposed in the west part of the

township, but it is reported to be 10 feet thick in a well in sec. 18. From the information obtained it is reasonably certain that the area within the line indicated on the map as the outcrop of this lignite bed is underlain by at least one bed of lignite and probably most of it by more than one.

Higher beds of lignite outcrop in the township, but they were observed only incidentally, as data relative to them are not necessary for the purpose of this work. Sections 114 and 118 show a bed 15 feet above the base of the Fort Union formation. There are higher lignite beds, but most of them are poorly exposed and measurements of their thicknesses can be obtained with difficulty. Burning has occurred along the outcrop, and where the cover is slight extensive clinker beds have been produced.

The structure in this township is slightly different from that to the northwest. The strike line is deflected from a northwest-southeast trend to an almost east-west direction. In the northwest part of the township the dip is only slightly north of east, whereas near the east boundary it is only slightly east of north. The angle of dip varies from less than 1° in the northern part to about 5° in the southern part.

T. 9 N., R. 59 E.—The Pierre shale, the Lance, including the Colgate sandstone member, and the Fort Union formations are exposed in this township. The Pierre shale and the Colgate sandstone member do not contain lignite, but the other two formations contain lignite beds of various thicknesses. The Lance contains many thin beds, one of which, about 15 feet from the top, is locally more than 30 inches thick. Section 111 (Pl. XVI), represents this bed where it is abnormally thick. At location 109 it is much thinner, as shown by the following section:

Section of lignite bed at location 109, sec. 12, T. 9 N., R. 59 E.

	Ft.	in.
Lignite		3
Shale		4
Lignite		3
Shale		6
Lignite		10
Shale		½
Lignite	1	4
Shale		3
Bone		10
	4	7½

Where measured in the north-central part of sec. 1 it is 29 inches thick. These, however, represent its maximum thicknesses along the outcrop. In most places it contains less than 25 inches of clean

lignite. A measurement of a lower bed at location 112, sec. 13, gave only 20 inches of lignite. Of the many beds of lignite in the Lance the only one that approaches economic importance is that about 15 feet from the top of the formation.

The persistent lignite bed at the base of the Fort Union formation was mapped in the northeast part of this township, but few sections of the bed are exposed. An incomplete section of clean lignite 35 inches thick was measured at location 105. At location 106 (Pl. XVI) the section is complete and shows 40 inches of lignite. A similar thickness is shown at location 108, but at location 110 the exposure is poor and only 30 inches of lignite are visible. There are one or more beds of lignite above that at the base of the formation. Section 107 represents a bed 15 feet above the one mapped. Little attention was given the higher beds as information relative to them was not necessary for the purpose of this examination.

The strata have generally a slight dip to the northeast away from the Glendive anticline.

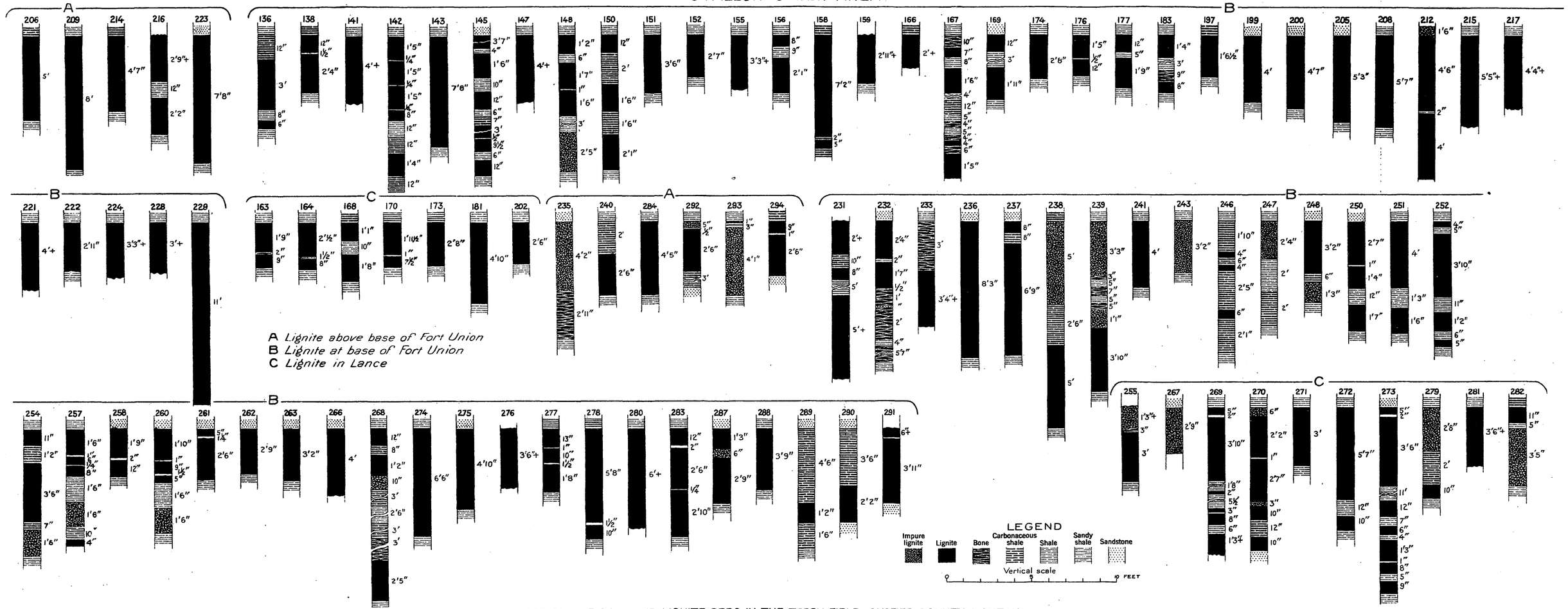
T. 9 N., R. 59 E.—The Pierre, the Lance, including the Colgate sandstone member, and the Fort Union formations are exposed in this township. The Pierre shale and the Colgate sandstone member contain no lignite beds and the Lance none more than 30 inches thick. A bed about 70 feet below the top of the Lance is exposed at many places. At location 225 it is 21 inches thick, at location 226 it is 25 inches thick, at location 227 it is 24 inches thick, and at location 230 it is 23 inches thick.

The persistent lignite bed at the base of the Fort Union formation outcrops for most of the distance across this township on a heavily grass-covered rolling upland; therefore exposures of it are rare. An extensive well-fused bed of clinker indicates that there it has been a thick bed of lignite. A complete section at location 229 in the southwest part of sec. 27 shows 11 feet of good clean lignite. Parts of beds are represented by sections 224 and 228.

Higher beds of lignite have been extensively burned in this township, and as a result many hills are capped by thick clinker beds throughout the area underlain by Fort Union. At location 223 in sec. 5 the second bed above that at the base of the formation is 7 feet 8 inches thick. Little attention was given to the beds above the one mapped, as information relative to them was not necessary for the purpose of the examination.

This township is crossed by the axis of the Glendive anticline. The line of maximum dip is at or near the outcrop of the base of the Fort Union formation, where the dip is from 15° to 22° SW. On either side of this line the strata flatten abruptly. In the northeastern part of the township the dip is about 2° or 3° NE., whereas along the western border the strata are horizontal or nearly so. The

O'FALLON CREEK AREA



SECTIONS OF COAL AND LIGNITE BEDS IN THE TERRY FIELD, CUSTER COUNTY, MONTANA

anticline in this township offers a favorable location for the accumulation of oil.

T. 9 N., Rs. 56 and 57 E.—These two townships are in the syncline occupied by the O'Fallon Creek district and contain Fort Union rocks at the surface. The area is underlain by the Lance, which is locally lignite bearing, and by the zone at the base of the Fort Union which has an abundance of lignite. Lignite beds well up in the Fort Union formation outcrop in these townships. One of these, containing 7 feet of lignite, is exposed in sec. 8, T. 9 N., R. 56 E. Little attention, however, was given to exposures of lignite in these townships because information relative to them was not necessary for purposes of classification.

T. 9 N., R. 55 E.—The surface rocks of this township belong to the Fort Union formation, a part of which is excellently exposed on both sides of O'Fallon Creek. Beds of carbonaceous shale with thin beds of lignite are distributed throughout the formation. The persistent lignite-bearing zone at the base of the Fort Union underlies the entire township at a less depth than 500 feet. Higher beds outcrop at many places, but they were given only incidental attention. One bed was examined at three places along O'Fallon Creek. Sections measured at these places are as follows:

Section of strata exposed near the south quarter corner of sec. 34, T. 9 N., R. 55 E.

	Ft.	in.
Shale, gray.		
Lignite, dirty		4
Shale, brown	2	
Lignite	1	3
Shale, gray	11	
Lignite		4
Shale, gray	2	6
Lignite		8
Shale		3
Lignite	1	6
Shale		10
Lignite, dirty	1	
Lignite	1	
Shale		1
Lignite	1	
Shale, gray	5	
Lignite	1	1
Shale		9
Lignite		4
Shale		2
Lignite		4
Shale, gray	1	6
Lignite		11
Shale, gray	18	
Level of water in O'Fallon Creek.		
	51	10

About half a mile north of the place where the section given above was measured is an exposure in a cut bank, which shows the following:

Section of strata exposed in sec. 34, T. 9 N., R. 55 E.

	Ft.	in.
Sandstone, yellow, soft	15	
Shale, gray		4
Shale, carbonaceous		4
Lignite		5
Shale, gray		10
Lignite, dirty		7
Lignite		9
Shale		3
Lignite	1	2
Bone		4
Lignite		7
Shale		2
Lignite		11
Shale, gray	1	
Lignite		4
Shale, carbonaceous	1	8
Lignite		8
Shale, gray	2	
Lignite		4
Shale, gray	1	3
Lignite		4
Shale, carbonaceous	7	
Level of water in O'Fallon Creek.		
	36	3

The following section was measured in a similar exposure in the north-central part of sec. 33:

Section of strata exposed in sec. 33, T. 9 N., R. 55 E.

Shale, gray.	Ft.	in.
Bone	2	8
Shale, gray	1	
Lignite		4
Shale, brown	1	3
Lignite		4
Shale, brown		6
Lignite		2
Bone	1	6
Shale		4
Bone		5
Lignite	1	3
Shale and sandstone, yellowish gray	20	
Level of water in O'Fallon Creek.		
	29	9

In general, the strata dip slightly to the northeast. There are, however, some minor local folds evident in exposures along O'Fallon Creek.

T. 9 N., Rs. 52, 53, and 54 E.—These three townships lie in the broad, shallow syncline in the O'Fallon Creek district. The surface rocks of all of them belong to the Fort Union. The area is undoubtedly underlain by the persistent lignite-bearing zone at the base of the formation at a depth of less than 500 feet. As these data were sufficient for classification purposes no detailed examination was made of the upper beds in the area except to note one bed at least 34 inches thick in the NW. ¼ sec. 30, T. 9 N., R. 54 E.

T. 9 N., R. 51 E.—Only that part of T. 9 N., R. 51 E., which lies east of Powder River was examined. The rocks exposed in the "breaks" along the river belong to the Lance formation, and those forming the surface of the upland area to the east belong to the Fort Union formation. In this township the Lance contains more lignite than is common in that formation. Besides the many thin irregular beds distributed throughout the formation there is a persistent zone which at many places contains a lignite bed more than 30 inches thick. In the north part of the township this bed is 35 to 40 feet below the top of the formation, but in the south part this distance decreases to 20 feet at the northwest corner of sec. 27. For most of the distance along the outcrop the shale partings are so thick as to render the bed valueless, and as shown by the sections this is true of the bed at some places where it was mapped. Sections of this bed are represented by Nos. 269, 270, 271, 272, 273, 279, 281, 282, and 286. At location 285, midway between locations 282 and 286, the bed is dirty and is 3 feet 4 inches thick. Toward the south the bed decreases in value and at the last place examined, location 295, contains only 16½ inches of clean lignite, underlain by 4 feet of lignite mixed with carbonaceous shale. In the northern part of the township this zone consists of two distinct beds. The section at location 273 includes the entire zone, but at that place it is somewhat thinner than it is in its maximum development. The lower part of the lower bed is not included in section 269. Half a mile west of locations 269 and 273 the lignite in the zone is almost entirely replaced by shale. Section 271 includes only a portion of the upper member. An exposure in a cut bank near the center of sec. 2 probably extends nearly to the bottom of this zone. The section measured at that place is as follows:

Section of lignite bed exposed in sec. 2, T. 9 N., R. 51 E.

	Ft.	in.
Shale, gray	20	
Lignite, dirty		6
Lignite	2	6
Shale		1
Lignite	2	7
Lignite, dirty		3
Lignite		10
Shale, carbonaceous	1	
Lignite	1	

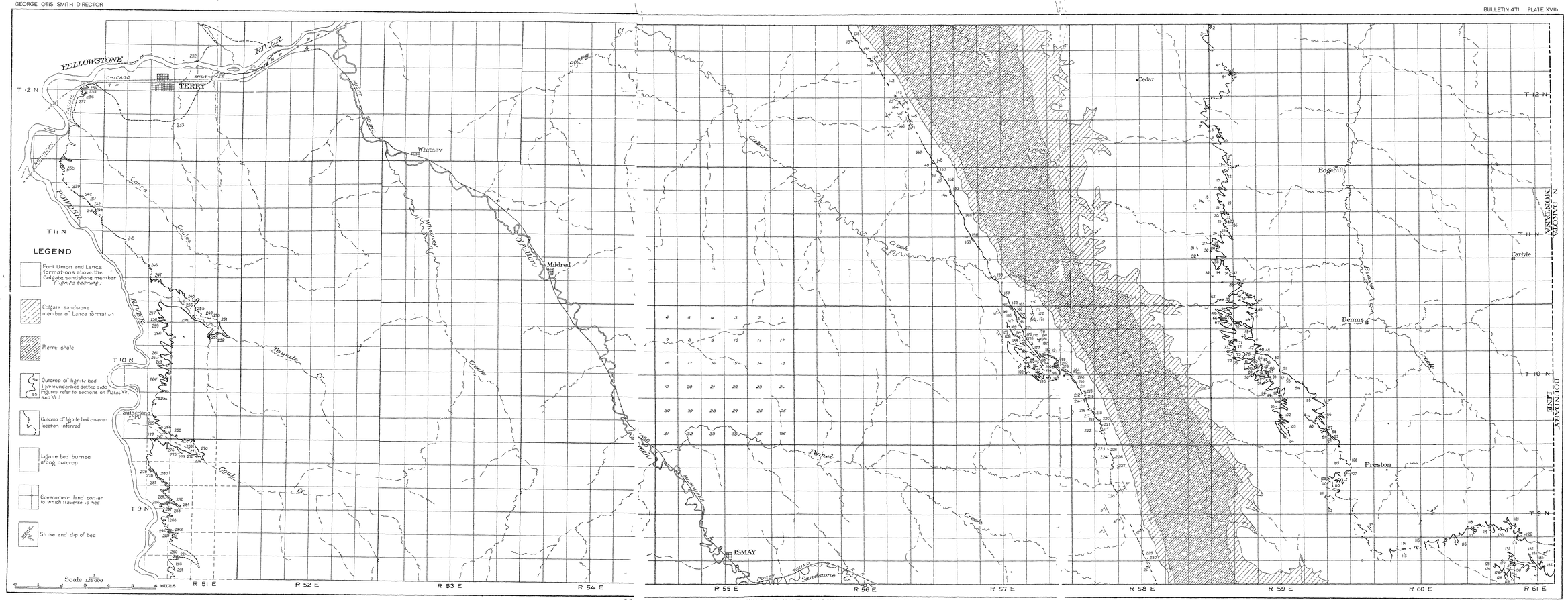
	Ft.	in.
Sandstone, gray	5	
Shale, carbonaceous	1	6
Lignite		5
Shale		¼
Lignite		8
Sandstone, carbonaceous		6
Lignite		4
Sandstone, carbonaceous		2
Lignite	2	4
Shale		3
Lignite		2
Shale		8
Lignite	1	
Shale, highly carbonaceous		10
Level of water in Coal Creek.		
	42	7¼

The general absence of lignite in the Lance is indicated by the log of a well that was being drilled for artesian water in the central part of sec. 28. The drillers reported that three beds of lignite had been penetrated. The first, between 30 and 40 feet down, is 2 feet thick; the second is of about the same thickness; and the third, 57 feet down, is between 3 and 4 feet thick. At the time the well was visited, October 11, 1910, the drill hole was 220 feet deep. The driller says that to that depth the material is practically all of dark-gray color and that there are no lignite beds of considerable thickness other than those mentioned above. The mouth of the well is about 15 feet above the level of Powder River, which is slightly less than a quarter of a mile to the west.

The outcrop of the persistent lignite-bearing zone at the base of the Fort Union formation extends across this township. Mapping was discontinued, however, along Coal Creek because the exact location of the outcrop was not necessary for the purpose of this work. The bed in the Lance about 35 feet below affords a basis for land classification. Sections of the bed at the base of the Fort Union are shown in Plate XVII as Nos. 274, 275, 276, 277, 278, 280, 283, 287, 288, 289, 290, and 291.

There is also some lignite exposed in this township above that at the base of the Fort Union formation. Sections 284, 292, and 293 (Pl. XVII) are on a bed stratigraphically 20 feet higher. A measurement of a bed 23 feet above this one is represented by section 294. Little attention was given the higher beds, as a detailed examination of them was not necessary for the purpose of this work.

The strata have a general dip to the northeast, but there are some local folds in the eastern part of the township.



M OF THE TERRY LIGNITE FIELD, CUSTER COUNTY, MONTANA

By Frank A Herald

1912

THE GLENDIVE LIGNITE FIELD, DAWSON COUNTY, MONTANA.

By J. H. HANCE.

INTRODUCTION.

A preceding paper by W. R. Calvert sets forth the general geologic conditions in the Glendive and contiguous lignite fields and describes the purpose of the survey. The present paper contains a more or less detailed account of the coal resources of the Glendive field.

In the field work upon which this report is based the writer was assisted by Charles H. Taylor and, during part of the season, by Albert D. Brokaw. George B. Harmon also aided considerably in the field operations. To all these men the writer is indebted for the success of the field work. Assistance rendered by Mr. Calvert, both in the field and office, adds materially to the value of this report. The cordial cooperation and hospitality of the residents of the area surveyed were also very helpful and are hereby acknowledged.

LOCATION AND EXTENT.

The Glendive lignite field is located in the eastern part of Montana about midway between the north and south boundaries of the State. It extends from the north line of T. 12 N. to the south line of T. 18 N., and from the east line of R. 52 E. to the Montana-North Dakota line, except about seven townships in the northeast (Pl. XX). Glendive, the county seat of Dawson County, near the center of the field, is a thriving town and the commercial center of the surrounding region. The main line of the Northern Pacific Railway traverses the field in a general east-west direction, but its course following the streams is such that nearly all of the field is less than 15 miles from the railroad. A new branch line from Glendive to Sidney is under construction along Yellowstone Valley and will afford an outlet for this thriving agricultural region by way of Glendive and the main line of the Northern Pacific Railway.

LAND SURVEYS.

All of the area except seven townships has been surveyed by the General Land Office, but some of the surveys of 1909 have not yet been finally examined and approved. These surveys include Tps. 13,

14, and 15 N., Rs. 57 and 58 E. T. 13 N., R. 55 E., is not subdivided. Corner stones were generally found without difficulty and traverses of coal outcrops and geologic formations were tied to them. The Land Office plats were found to agree with features in the field represented on them except in minor details. There was one notable exception, however, in the northern part of the field along the south side of Yellowstone River in T. 17 N., R. 56 E., where an outcrop of a coal bed was found on land which the plat shows to be a part of the river channel.

GEOLOGY.

STRATIGRAPHY.

The following table shows the relation and thickness of the formations which outcrop in this area:

Geologic formations in the Glendive field.

System.	Formation.	Member.	Thickness (feet).
Tertiary.	Fort Union formation.		300
Cretaceous or Tertiary.	Lance formation.		480
		Colgate sandstone.	90
Cretaceous.	Pierre shale.		[a] 200

[a] Exposed.

For a description of these formations see pages 10–18.

STRUCTURE.

The dominating structure of the field is an anticline which is the northwestward extension and termination of the uplift described on page 201. Throughout the area represented by the darker shaded portion of the map (Pl. XX) the beds are considerably affected by the fold, but in the unshaded area they are much less disturbed or still retain their horizontal positions. The maximum dip observed in the field (30°) was measured along Cedar Creek in the southwest part of T. 14 N., R. 55 E. The uplift is unsymmetrical with steep dips to the southwest and more gentle dips to the northeast. The fold dies down to the northwestward in T. 15 N., Rs. 54 and 55 E., and the beds are horizontal near the northern limit of these townships. Along the northeast side of the field the strata are nearly horizontal, the dip in this part rarely exceeding 1° or 1½°. Local warpings were observed in several places in this area, but no other deformation of importance was found.

THE LIGNITE.

OCCURRENCE.

One small bed of lignite was found in the Colgate sandstone member southwest of Glendive, in sec. 15, T. 15 N., R. 55 E. Its maximum thickness is 2 feet and the horizontal extent only a few hundred yards. Lignite was not found at any other place in this formation.

The places where lignite beds are exposed, together with the area containing them, are shown on Plate XX, and their thickness and character are presented on Plate XIX. The map shows that lignite is generally distributed over the field except along the anticline previously described, which is indicated by the shaded portion of the map. The Lance formation contains only thin lenticular beds of lignite, whereas the Fort Union contains several beds, one of which has been found to be continuous for 150 miles and to hold a thickness rarely less than 4 feet.

Overlying the persistent bed noted above and separated from it a distance ranging from 50 to 150 feet is a second bed, which is of better quality and like continuity. Where the lower bed is too thin, or its quality too poor to warrant mapping, the traverse was carried to the second bed, which ordinarily outcrops only a short distance back of the lower bed. Several other beds of good lignite outcrop in this area, but as they are higher in the geologic column and do not affect the classification of land in this field they were neither mapped nor examined. An exact correlation with the lignite beds of the Sentinel Butte field contiguous on the east was not attempted, but the lowest bed there, which Smith[1] designated the Harmon bed, probably corresponds to a bed 250 feet above the base of the Fort Union No. 4 in this field.

PHYSICAL PROPERTIES AND CHEMICAL COMPOSITION.

In general, the lignite in the lower bed is black and probably should be classed as subbituminous, whereas the brown lignite seems to predominate in the second bed. This difference, however, is not true of all exposures in the field under consideration. The fresh lignite is hard, generally tough, and slacks readily. The original grain of the wood is preserved in much of it, and charcoal commonly occurs in thin layers in the beds. In places two sets of cleats are a notable feature. The abundance of silicified wood near the base of the Fort Union suggests that the lignite was largely derived from tree trunks rather than bog deposits. The lignite breaks with a conchoidal fracture and has a brown streak. The odor from the burning lignite is strongly bituminous. Like other lignite, that of the Glendive field slacks quickly when exposed to the air and hence is not suitable for open storage in large quantities. The following table of analyses shows its chemical composition:

[1] Leonard, A. G., and Smith, C. D., The Sentinel Butte lignite field, North Dakota and Montana: Bull. U. S. Geol. Survey No. 341, 1907, pp. 15-35.

Analyses of lignite samples from the Snyder mine, NW. ¼ sec. 27, T. 17 N., R. 55 E., Glendive lignite field.

[A. G. Fieldner and F. M. Stanton, chemists in charge.]

Laboratory No.	Sampler.	Distance in mine.	Thickness of bed sampled.	Air-drying loss.	Form of analysis.	Proximate.				Ultimate.					Heat value.	
						Moisture.	Volatile matter.	Fixed carbon.	Ash.	Sulphur.	Hydrogen.	Carbon.	Nitrogen.	Oxygen.	Calories.	British thermal units.
		Feet.	*Ft. in.*													
11045	J. H. Hance	80	8	23.4	A	32.1	25.6	34.2	8.1	1.36	.....	.....	.....	.....	3,950	7,110
					B	11.4	33.3	44.7	10.6	1.77	.....	.....	.....	.....	5,155	9,280
					C	.....	37.7	50.4	11.9	2.00	.....	.....	.....	.....	5,815	10,470
					D	.....	42.7	57.3	.....	2.27	.....	.....	.....	.....	6,605	11,890
3816	J. A. Holmes	400	6 6	14.2	A	34.9	23.6	33.4	8.07	1.33	6.41	41.66	.56	41.97	3,880	6,980
					B	24.1	27.6	38.9	9.41	1.55	5.63	48.55	.65	34.21	4,520	8,140
					C	.....	36.3	51.3	12.39	2.04	3.89	63.99	.86	16.83	5,960	10,730
					D	.....	41.4	58.6	.....	2.33	4.43	73.04	.98	19.22	6,800	12,240
3820	.....do	200	6 6	9.1	A	33.1	27.5	33.2	6.2	.68	.....	.....	.....	.....	4,320	7,770
					B	26.4	30.2	36.5	6.9	.75	.....	.....	.....	.....	4,750	8,550
					C	.....	41.0	49.6	9.4	1.02	.....	.....	.....	.....	6,450	11,610
					D	.....	45.2	54.8	.....	1.12	.....	.....	.....	.....	7,120	12,810
3817	.....do	100	6 6	12.0	A	31.3	27.2	34.7	6.80	.80	5.99	43.93	.55	41.93	4,075	7,340
					B	21.9	30.9	39.5	7.73	.91	5.30	49.92	.62	35.52	4,630	8,340
					C	.....	39.6	50.5	9.89	1.16	3.67	63.91	.80	20.57	5,930	10,670
					D	.....	43.9	56.1	.....	1.29	4.07	70.92	.89	22.83	6,580	11,850
3819	.....do	25	6 6	11.1	A	33.1	29.4	29.2	8.3	1.03	.....	.....	.....	.....	.....	.....
					B	24.7	33.1	32.8	9.4	1.16	.....	.....	.....	.....	.....	.....
					C	.....	43.9	43.6	12.5	1.54	.....	.....	.....	.....	.....	.....
					D	.....	50.2	49.8	.....	1.76	.....	.....	.....	.....	.....	.....
[a]3815	.....do	0	6 6	13.5	A	33.6	29.1	30.4	6.90	.81	6.10	40.35	.61	45.23	3,720	6,690
					B	23.3	33.6	35.1	7.98	.93	5.32	46.65	.70	38.42	4,300	7,740
					C	.....	43.8	45.8	10.40	1.22	3.56	60.82	.92	23.08	5,605	10,090
					D	.....	48.9	51.1	.....	1.36	3.97	67.87	1.03	25.77	6,255	11,260

[a] Sample badly weathered.

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

The analyses given above are of samples taken from the Snyder mine in the NW. ¼ sec. 27, T. 17 N., R. 55 E. The bed in which this mine is developed is the second in the series counting from the bottom of the lignite-bearing rocks and probably represents a higher grade of lignite than the average of the field. These samples were taken across the working face of the bed, pulverized, quartered down to about 3 pounds, and sent in sealed cans to the chemical laboratory for analysis.

Samples 3816, 3820, 3817, 3819, and 3815 were taken in 1906 to show the effect of weathering, and they were analyzed in the laboratory of the Geological Survey, at that time located at St. Louis. Sample 11045 was analyzed at the Pittsburgh laboratory of the Bureau of Mines.

In the table the analyses are given in four forms, marked A, B, C, and D. Analysis A represents the composition of the sample as it comes from the mine. This form is not well adapted to comparative purposes, for the amount of moisture in the sample as it comes from the mine is largely a matter of accident and consequently analyses of the same lignite expressed in this form may vary widely. Analysis B represents the sample after it has been dried at a temperature a little above the normal until its weight becomes constant. This form of analysis is best adapted for general purposes of comparison. Analysis C represents the theoretical condition of the lignite after all the moisture has been eliminated. Analysis D represents the lignite after all moisture and ash has been removed. Forms C and D are obtained from the others by recalculation. These forms should not be used for comparison, for they represent theoretical conditions that never exist.

The percentages of moisture given in the table are remarkably regular in the analysis of the sample as received, varying not more than 3 per cent, but the air-drying loss ranges from 9.1 to 23.4 per cent. It will be noted that the air-drying loss in all of the samples collected by Holmes averages about 12 per cent, whereas in the sam-

ple collected by the writer it is 23.4 per cent. This difference can be accounted for only by supposing that the samples collected by Holmes were not sealed air-tight at the mine or were allowed to remain a long time before being analyzed. Experimental sampling of lignite has shown that if sealed promptly at the mine and analyzed at once after reaching the laboratory it parts readily with the greater part of its moisture, but if it is exposed to the atmosphere before being analyzed it will part with a much smaller amount. The reason for this change is not understood, but apparently it is due to a change of condition of the moisture which prevents its passing off at the temperature used for such a determination.

The effect of surface weathering is well shown by the analyses of the series of samples cut by J. A. Holmes. As seen from the table, none of these samples show the effect of weathering except Nos. 3819 and 3815, which were cut within 100 feet of the surface. The effect of the weather is indicated in the loss of calorific power, which on the dry coal basis is as follows:

Comparison of heating power of various samples of lignite.

[British thermal units on dry basis.]

Laboratory No. 11045	10,470
3816	10,730
3820	11,610
3817	10,670
3815	10,090

In this report all of the mineral fuel is called lignite, although it is recognized that lignite from some of the beds is of much better quality than that from other beds and closely approaches the grade of subbituminous coal.

The distinction between lignite and subbituminous coal is necessarily neither definite nor sharp. The term lignite as used by the United States Geological Survey is restricted to that material which is distinctly brown and woody, whereas the term subbituminous coal is applied to similar material that has lost most if not all of its woody texture and has become black in color.

In eastern Montana and adjacent parts of North and South Dakota the coal of the Lance formation generally is more nearly black and less woody than is that of the overlying Fort Union formation, and in some publications it has been called subbituminous coal. In the field the difference between the coals of the two formations is slight and irregular and therefore, as a matter of convenience, they are all called lignite

BURNED OUTCROPS.

Many of the lignite beds have been burned along the outcrops and in some places are still undergoing this process.[1] From the character of the slag that is found in some localities the heat generated is believed to have been intense and a large amount of lignite consumed. A conspicuous clinker outcrop extends north across T. 14 N., R. 59 E., and T. 15 N., R. 58 E., and probably corresponds to the "Harmon bed" (p. 273).

DESCRIPTION BY TOWNSHIPS.

In describing the lignite of this field the area will be treated by townships, beginning with the northwest corner and proceeding east across each tier.

T. 17 N., R. 53 E.—This township was not mapped or examined in detail because reconnaissance examination showed that it was undoubtedly underlain by beds of lignite. The beds outcrop a short distance to the south and also to the east and lie under the surface at a less depth than 500 feet. Stratigraphic sections taken on Big Dry and Hell creeks northwest of this area show beds of lignite from 2 to 11 feet thick. In the latter locality the lowest bed at the base of the Fort Union has been traced for 25 miles along its outcrop, showing that it is continuous and that it probably extends under this township.

T. 17 N., R. 54 E.—The only bed of lignite mapped in this township is the second bed from the bottom in the Fort Union formation, which outcrops in sec. 34, where a section containing over 9 feet of good lignite was measured (No. 89,[2] Pl. XX). This bed underlies the township and from the evidence presented in the discussion of T. 17 N., R. 53 E., is believed to be continuous.

T. 17 N., R. 55 E.—The lowest bed of lignite in the Fort Union was traced across this township in almost continuous outcrop, as shown on Plate XX. The bed has been removed by erosion from that part of the field just west of Yellowstone River but underlies the greater part of the township. The thickness ranges from 2 feet 8 inches to 10 feet.

In sec. 1 part of the lignite has probably been removed by river erosion, but several well records indicate that at least a part of the bed still remains. At an old mine in sec. 14 (No. 71, Pl. XX), considerable lignite has been extracted from this bed. Another prospect was opened on it in sec. 22, but no work was being done there in the fall of 1910. A mine (No. 81) had been opened on this bed in sec. 33, but the entry was full of water when examined. An

[1] Near south line of T. 13 N., R. 55 E.; T. 16 N., Rs. 55 and 56 E.; T. 17 N., R. 55 E.; and T. 14 N., R. 58 E.

[2] Numbers in text refer to locations on Pl. XX and most of them also to corresponding sections on Pl. XIX.

old mine car at the mouth suggested that a considerable amount of lignite had been mined in the past. Several other prospect pits had been opened on the bed in this township but had been abandoned previous to the time of examination.

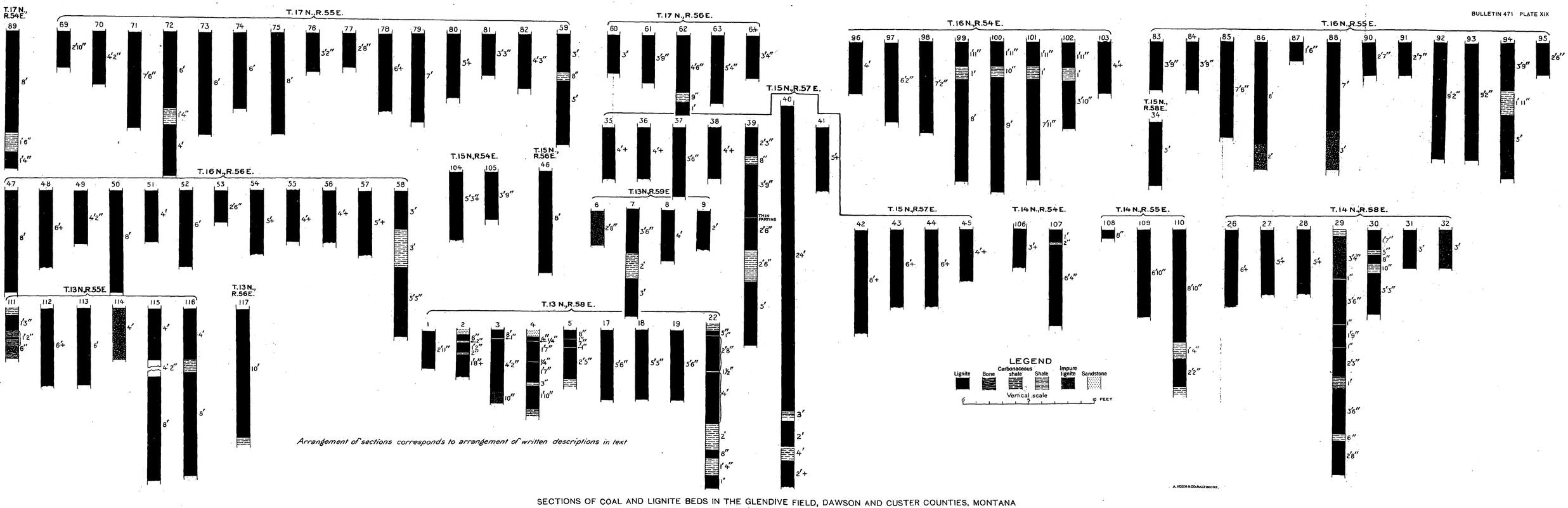
There is a small outcrop on the second bed in sec. 36, where it contains 8 feet of good lignite. In sec. 22, a mine was being opened to the depth of 180 feet on this bed by B. R. Dick. At the end of the entry the lignite is 8 feet thick. On this bed burning was found to extend back into the hill about 100 feet, but beyond this the quality of the lignite seems to be very good. The Snyder mine, in sec. 27, is on this second bed and a good grade of brown lignite is obtained here. A third bed, which was not examined by the writer, outcrops above the Snyder mine in this section and was reported to contain over 6 feet of good lignite.

T. 17 N., R. 56 E.—The lowest bed was traced across this township. In the north tier of sections, along the south bank of Yellowstone River, the lignite is very good and is mined for local use, but in the southwestern part of the township the quality is poor. The character of the bed is shown by sections 60 to 64, inclusive, on Plate XIX. A slight northeastward dip causes the outcrop to pass under the river flood plain in sec. 1, but it probably does not go deep enough to pass under the channel. The second bed, which is here about 40 feet above the lowest lignite, was examined at several places. Good lignite, 3 feet 4 inches thick, was found in this bed in sec. 1, where an opening had been made by the Reclamation Service to obtain fuel for the lower Yellowstone reclamation project. This bed was traced south through secs. 9, 16, 20, 21, 29, 30, and 32. Two measured outcrops in sec. 20 showed 3 feet and 3 feet 9 inches of good lignite. The greater portion of this township is underlain by these two beds and possibly by a third bed about 250 feet higher than bed No. 1.

T. 17 N., R. 57 E.—No detailed examination was made in this township, but a study of the lignite beds outcropping to the west led to the conclusion that undoubtedly the entire area is underlain by lignite. Some exposures of lignite were noted along Boxelder Creek, but these are higher beds, which were not included in the study upon which this report is based; hence no correlation was attempted. However, they probably correspond to the lower lignite beds of the Medora group of the Sentinel Butte field.[1]

T. 16 N., R. 53 E.—No mapping was done in this township. A lignite bed was mapped across the township to the east and the bed undoubtedly continues westward under this area less than 400 feet below the surface. Higher beds of lignite outcrop in this township and in sec. 24 are mined for local use.

[1] Leonard, A. G., and Smith, C. D., The Sentinel Butte lignite field, North Dakota and Montana: Bull. U. S. Geol. Survey No. 341, 1907, pp. 15–35.



Arrangement of sections corresponds to arrangement of written descriptions in text

SECTIONS OF COAL AND LIGNITE BEDS IN THE GLENDIVE FIELD, DAWSON AND CUSTER COUNTIES, MONTANA

A. HOEN & CO., BALTIMORE.

T. 16 N., R. 54 E.—The outcrop of the lignite beds was traced in this township from the south side of sec. 29 northward to the northern part of sec. 17, where the beds pass over the point of the Glendive anticline and the outcrop swings eastward to the south quarter corner of sec. 15. East of this point all surface indications are obscured in a grassy upland and no trace of the lignite could be found in this township. As this same bed is exposed in the township to the east it is believed to be continuous in that direction. Locations 96 to 103 on the lowest lignite bed (in secs. 16, 17, 21, and 29) show from 4 feet to over 9 feet, all good lignite. No exposures were found in sec. 32, where the surface is grassy and nearly level, but as indications of lignite were found 2¼ miles south in sec. 8, T. 15 N., R. 54 E., the outcrop undoubtedly continues southward.

T. 16 N., R. 55 E.—A bed of lignite is well exposed along the north tier of sections on Deer Creek in this township, and was traced southward into sec. 29, where it is completely covered. From contiguous mapping in the township to the west the outcrop is believed to extend across into T. 16 N., R. 54 E., to connect with the lignite bed found there. The thickness of the bed exposed along Deer Creek varies from 1½ feet to over 9 feet. The quality is likewise variable. Detailed sections are presented on Plate XIX. A small prospect was found in sec. 10 and another in sec. 16, but these are probably used by local ranchers for obtaining fuel in winter only. At each of these places approximately 9 feet of lignite—probably the lowest bed—was measured. The burned outcrops of two beds were found exposed in sec. 21, but no fresh lignite was seen.

T. 16 N., R. 56 E.—Good exposures of beds of lignite were found in this township, therefore mapping was done principally on the lowest bed. Measurements on the lowest bed were obtained in secs. 9, 11, 15, 16, 21, 26, 28, 34, and 36. These range from 2 feet 6 inches to 8 feet of good lignite. In sec. 12 three beds of good lignite, each over 3 feet thick, are exposed in outcrop in Cotton Creek, in a vertical interval of about 100 feet above the lowest bed. In secs. 4 and 5 the lowest bed is exposed in outcrop, but the quality of the lignite was considered too poor to warrant mapping. At location 54*a*, in sec. 15, the bed is split into two benches 15 feet apart. The upper bench is 4 feet thick and the lower bench 2 feet thick. Detailed study was confined to the second bed, which contains over 5 feet of very good lignite.

T. 16 N., R. 57 E.—Except for a portion of sec. 31, this township is underlain by the bed of lignite mapped to the west, and consequently time was not taken for a detailed examination. As the strata dip northeastward at a very low angle (about 1°), and as reconnaissance examination showed that several higher beds of

good lignite outcrop in the township, the entire area is undoubtedly underlain by at least one lignite bed less than 400 feet from the surface. Detailed study was not undertaken.

T. 16 N., Rs. 58 and 59 E.—No detailed mapping was done in these townships, because a preliminary examination showed that they are underlain by the lignite beds outcropping to the west. Lignite beds outcrop along Boxelder Creek, but are undoubtedly some distance stratigraphically above the lowest bed of lignite. They are about 300 to 400 feet above the base of the Fort Union formation. The burned outcrop of a lignite bed is exposed along the west range line of T. 16 N., R. 59 E., and doubtless corresponds to the "B" bed of the Medora[1] group examined by Leonard and Smith.

T. 15 N., R. 53 E.—No mapping was done in this township, because it is known to be underlain by lignite beds outcropping to the east. The dip is slight, and as this same bed of lignite outcrops again to the west in T. 17 N., R. 53 E., the continuity of the lignite under the township is fairly certain.

T. 15 N., R. 54 E.—Imperfect exposures prevented tracing the lignite across this township, especially in the western half, which is a grassy upland. Indications of a bed of lignite were found in secs. 4, 8, and 9, although its thickness and character could not be determined. It is reported that 2 feet of good lignite were exposed by a steam traction plow in sec. 8. An old prospect pit in sec. 21, on Sand Creek, has been opened on the second (?) bed, which contains at that point over 5 feet of good lignite. The burned outcrop of a bed, about 40 feet stratigraphically below this opening, is probably that of the lowest bed in the Fort Union formation. In sec. 34, on the north side of Whoopup Creek, nearly 4 feet of good lignite was found in outcrop.

T. 15 N., R. 55 E.—Lignite beds exceeding 2 feet in thickness were nowhere found in outcrop in this township, and as the underlying formations are known to contain no lignite the area is considered noncoal land.

T. 15 N., R. 56 E.—The outcrop of the lignite beds extends across sec. 1 of this township, where 8 feet of good lignite was found exposed in outcrop on the second bed (No. 46). The lower bed is burned, and no fresh lignite was seen. The underlying formations, which comprise the surface rocks over most of the township, do not contain lignite.

T. 15 N., R. 57 E.—Except in the southeast corner of this township, the outcrop of the lignite beds was traced without difficulty, and numerous sections were measured. Measurements taken in secs.

[1] Leonard, A. G., and Smith, C. D., The Sentinel Butte lignite field, North Dakota and Montana: Bull. U. S. Geol. Survey No. 341, 1907, pp. 15-35.

5, 8, 9, 10, 15, 17, 21, 22, and 27 show from 4 feet to more than 24 feet of good lignite. Details of the bed are presented by sections 35 to 45, inclusive, on Plate XIX. No fresh exposures were found in secs. 26, 35, or 36, where the natural outcrops are grass covered, but it is believed that the lignite is continuous across this area because 5 feet of good lignite was found just east of the southeast township corner. The second bed outcrops near the east quarter corner of secs. 9 and 11, where over 4 feet of good lignite was found. Lower beds of lignite outcrop in secs. 20, 28, and 29, but the quality is poor.

T. 15 N., R. 58 E.—With the exception of a small area in the southwest corner, this township is underlain by lignite. In sec. 31 about 5 feet of fairly good lignite was found exposed in an outcrop of the lowest (?) bed. The correlation of the bed is uncertain because the area is grass covered and higher beds of lignite outcrop in this vicinity. The whole area other than the southwest corner is undoubtedly underlain by at least one bed and the greater part of it by more than one bed of lignite.

T. 14 N., R. 53 E.—The lignite resources of this township were not examined in detail because reconnaissance work carried on here and detailed investigation in contiguous areas indicate that the beds of lignite outcropping to the east extend under this township. Lignite is exposed along Yellowstone River, notably near Fallon, in T. 13 N., R. 52 E., southwest of the area shown on Plate XX, where a bed of lignite more than 4 feet thick is exposed in the river bank. This bed undoubtedly extends northward under this township.

T. 14 N., R. 54 E.—Detailed examination extended over only part of this township, because the outcrops of the beds of lignite were generally concealed. In sec. 2 (No. 106), a bed of fairly good lignite 3 feet thick was found exposed. This is believed to be the lowest bed. Higher beds outcrop in secs, 3, 10, and 16. A strip pit in sec. 10 (No. 107) showed 7 feet of good lignite. With the exception of the northeast corner this area is believed to be underlain by several beds of good lignite.

T. 14 N. R. 55 E.—The outcrops of lignite beds extend across the southwest corner of this township. In secs. 19, 20, 29, and 32 the beds were found to range in thickness from 8 inches to 11 feet (Nos. 108, 109, and 110). The quality varies from carbonaceous shale to good lignite. Erosion has removed the lignite beds from the greater portion of the township, exposing underlying formations which do not contain lignite.

T. 14 N., Rs. 56 and 57 E.—Erosion of the rocks raised in the Glendive anticline (p. 272) has removed the lignite beds from the greater part of these townships and brought lower rocks to the surface.

T. 14 N., R. 58 E.—The outcrops of the several beds of lignite cross this township. Exposures believed to be on the lowest bed were noted in secs. 16, 17, 20, 21, 28, and 35 (Nos. 26 to 32). The beds range in thickness from 3 to 18 feet. The quality of the lignite is likewise variable. Northwest from sec. 16 good exposures were not found in this township, but the line of outcrop was traced across secs. 9 and 5 and connected with the outcrop in sec. 31, T. 15 N., R. 58 E.

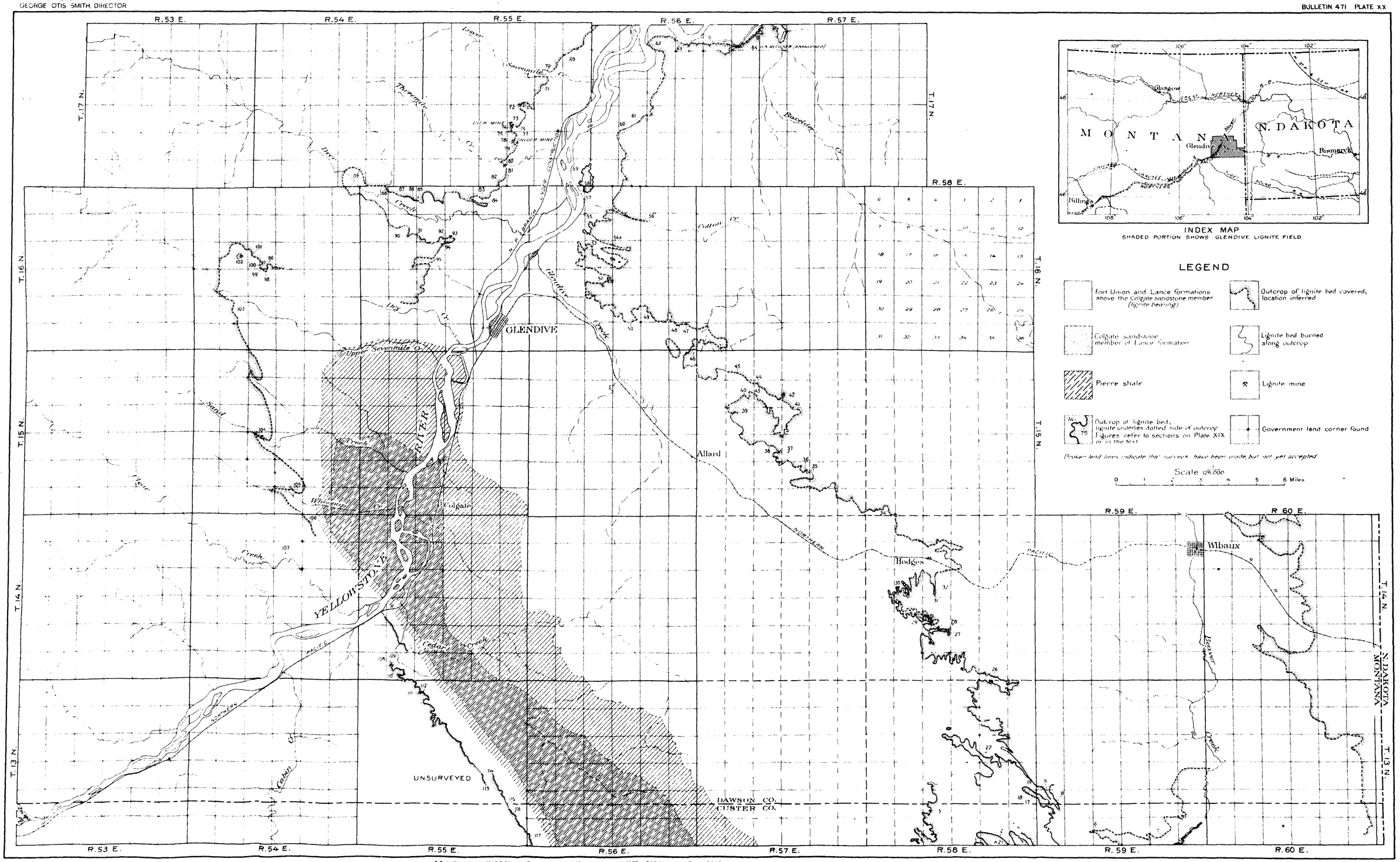
T. 14 N., Rs. 59, 60, and fractional R. 61 E.—No detailed examination was undertaken in the above-named townships, because reconnaissance examination showed that they are underlain by the lignite beds outcropping to the west. Data from wells drilled in this area, and immediately adjoining it on the north, prove the presence of a lignite bed less than 200 feet from the surface. From one to three beds averaging over 3 feet in thickness have been reported by well drillers.

T. 13 N., Rs. 53 and 54 E.—Several exposures of lignite where prospect pits have been dug were examined in these townships. A bed of lignite over 4 feet thick is exposed in the river bank near Fallon, in T. 13 N., R. 52 E., and undoubtedly underlies the greater portion of these two townships. As the lignite beds outcrop in the township to the east (T. 13 N., R. 55 E.) it was not considered necessary to traverse the higher beds here exposed.

T. 13 N., R. 55 E.—Lignite beds are well exposed across this township (Nos. 111 to 116). The lowest bed is variable in quality and was mapped for only a part of the distance on that account. An upper bed, which was traced principally by means of clinker along its outcrop, is of better grade and averages about 6 feet thick. In the northeastern part of the township lower formations are brought to the surface in the anticline.

T. 13 N., Rs. 56 and 57 E.—Lignite beds occupy only a few acres in the southwest corner of T. 13 N., R. 56, having been removed by erosion from the remainder of this area. In sec. 31 of T. 13 N., R. 56 E. (No. 117), the lowest bed was found to contain 10 feet of poor lignite. Lower formations cover nearly the entire area.

T. 13 N., R. 58 E.—The outcrops of three beds of lignite were traversed in this township. The lowest one was traced across secs. 21, 28, 32, and 33. The character of the bed is shown by section 5, Plate XIX. The best lignite was found near the south side of sec. 28, where this bed contains nearly 4 feet of good lignite. North of this the quality is not so good and near the middle of sec. 21 the bed consists of 3 feet of bone and charcoal. Mapping was stopped just before reaching the south township line as there is but 2 feet of lignite left in the bed. The lowest bed in the Fort Union formation, which is about 200 feet above the bed just described, is exposed across the



INDEX MAP
SHADED PORTION SHOWS GLENDIVE LIGNITE FIELD

LEGEND

- Fort Union and Lance formations above the Colgate sandstone member (lignite bearing)
- Colgate sandstone member of Lance formation
- Pierre shale
- 74 / 75 Outcrop of lignite bed; lignite underlies dotted side of outcrop. Figures refer to sections on Plate XIX or in the text
- Outcrop of lignite bed covered; location inferred
- Lignite bed burned along outcrop
- Lignite mine
- Government land corner found

Broken land lines indicate that surveys have been made, but not yet accepted.

MAP OF THE GLENDIVE LIGNITE FIELD, DAWSON AND CUSTER COUNTIES, MONTANA

By J. H. Hance

1912

area, but the quality of the lignite is extremely variable. In sec. 14 it includes about 8 feet of fairly good lignite, whereas measurements in secs. 34, 35, and 36 show a poorer grade and more partings. Its outcrop probably extends across sec. 26, but no exposures were found there. North of the east quarter corner of sec. 10 the second bed was mapped. In secs. 24 and 25 this bed contains 5½ feet of very good lignite. Sections of lignite beds exposed in this township are shown by Nos. 1 to 5 and 17, 18, 19, and 22.

T. 13 N., Rs. 59, 60, and fractional R. 61 E.—Well data furnished the chief evidence of the lignite resources of these townships. The entire area is underlain by lignite less than 200 feet below the surface. The outcrop of the second bed was traced across secs. 30 and 31, T. 13 N., R. 59 E. An upper bed is also exposed in outcrop near the center of sec. 31 and in sec. 36 on Beaver Creek. Correlation was not attempted, however, as exposures are too few.

DEVELOPMENT.

Considerable lignite is mined from strip pits and small entries for local use. There is one mine operating in this field, the Snyder mine, in sec. 27, T. 17 N., R. 55 E. This mine has produced lignite periodically for 7 years. During the summer months the output is one or two wagon loads a day, the maximum daily output in the winter being 50 tons. The average output is 25 tons a day six days a week for four months of the year. The present entry is in 150 feet. An old entry near by was driven in about 1,000 feet to excellent lignite but is now badly caved and is no longer worked. The lignite sells at the mine for $1.25 a ton and is delivered in Glendive for $3.50 a ton. A Sullivan undercutting machine is used.

B. R. Dick is opening a mine on the same bed in sec. 22 of this township. When visited the entry was in about 200 feet.

Several prospects have been opened on the lowest bed, but the lignite from them does not seem to find a ready sale, though analyses of samples from both beds showed marked similarity in quality.

As all parts of the field are easily reached from the railroad, no transportation problems need be solved when active development is begun. Although the lignite will not stand distant transportation because it slacks quickly and contains so large a percentage of water, local consumption will probably equal the production for some time to come. With the rapid progress of the gas producer and internal combustion motor, and its application to farming methods, the lignite of this field is assured a growing market.

THE SIDNEY LIGNITE FIELD, DAWSON COUNTY, MONTANA.

By EUGENE STEBINGER.

INTRODUCTION.

The geologic features of general interest in a large area in eastern Montana are presented in a paper by W. R. Calvert (pp. 5–19). The Sidney lignite field forms the northern part of this area, and the strictly economic features of this area are presented in this paper. During the greater part of the season of 1910 the writer was assisted in the field by C. T. Kirk in the mapping of the lignite outcrops and in the general geologic work. J. D. Saville and P. M. Barnes acted as instrument men, doing all of the plane-table work needed in traversing the intricate lines of outcrop of the lignite beds. About three and one-half months, from July 1 to October 15, 1910, were spent in the field.

In the field work the traverses along the outcrops of the lignite beds were tied to the corners of the Land Office surveys, so that, to a certain degree, the accuracy of the work and the speed with which it could be carried on were dependent upon these surveys. All of the townships in the field, in R. 60 E., and Tps. 17 and 18 N., Rs. 58 and 59 E., had been only recently surveyed and the land corners were found to be well marked and easily found. The remaining townships were surveyed more than 25 years before this work was undertaken and most of the corners could not be located. In Tps. 21, 22, and 23 N., R. 59 E., the surveys of the section and township lines on opposite sides of Yellowstone River were found to be as much as 500 feet off line with each other. These inaccuracies are shown on the map.

GEOLOGY.

STRATIGRAPHY.

The table on page 103 shows the relation and thickness of the formations which outcrop in this and adjacent areas. Detailed descriptions of these formations are given on pages 192–200.

Geologic formations in the Sidney field.

System.	Formation.	Member.	Thickness (feet).
Tertiary.	Fort Union formation.		1,190
Cretaceous or Tertiary.	Lance formation.		480
		Colgate sandstone member.	90
Cretaceous.	Pierre shale.		[a] 200

[a] Exposed.

About 1,250 feet of clay, shale, and friable sandstone belonging to the Lance and Fort Union formations are exposed in the Sidney lignite field. The Lance formation, made up of somber-colored clay and soft sandstone, is relatively unimportant in this field, being exposed in only a very small area along Yellowstone River, in T. 18 N., R. 56 E. There is no definite contact between the Lance and the overlying Fort Union formation, and therefore it was necessary to locate this boundary at the base of the lowest coal bed present—bed A.

The maximum thickness of the Fort Union formation in the field is 1,190 feet. The rocks making up the formation are chiefly ash-gray to yellow clay, shale, and soft sandstone, and include many lignite beds. In the Sidney field the ash-gray coloration in these rocks is more common than shades of yellow, so that the term "yellow beds," which is descriptive of the formation over so much of the Fort Union coal region, is here not very appropriate. Sections of the Fort Union from the Sidney field are given on pages 199–200 of the paper by W. R. Calvert.

STRUCTURE.

The structure of the Sidney lignite field is very simple. The rocks lie so nearly flat that a casual examination of the field would lead one to believe that the dip was not appreciable, but if levels are run on any of the more persistent lignite beds it is seen that there is in general a slight dip to the northeast in all parts of the field. The structure map (fig. 8), compiled from the data of such levels, shows a dip to the northeast, across the field, of 675 feet in 50 miles. The irregular spacing of the structure contours, however, shows that this slope is not uniform, but varies from 5 to 50 feet per mile. If a model of the surface shown on the structure map were made with the horizontal scale equal to the vertical scale, the slope of the surface and the slight irregularities due to the waves in the structure would be barely perceptible.

The greatest average dip occurs in the tiers of Tps. 19 and 20 N., near the center of the field; to the northeast the dips decrease

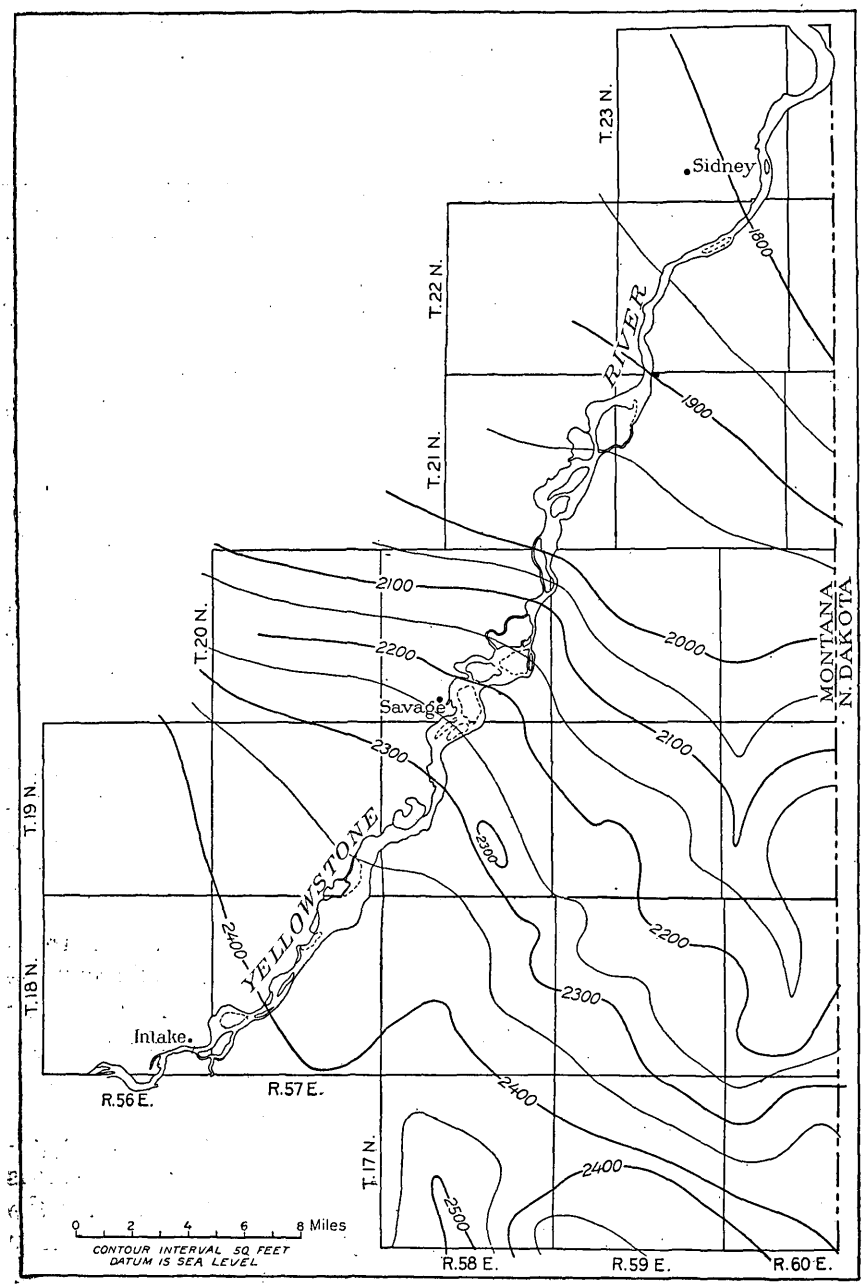


FIGURE 8.—Structure map of Sidney lignite field, Montana.

to 12 feet to the mile and less. In Tps. 18, 19, and 20 N., R. 60 E., there is a long, shallow "trough" in the structure extending in a gen-

eral north-south direction, and elsewhere in the field there are many small swells and depressions, some of which are so slight that they can not be shown by a structure contour interval of 50 feet.

An anticline, described in Calvert's paper, whose axis extends along the valley of Cedar Creek, about 20 miles to the southwest of the edge of this field, is the controlling structural feature in the region. The Sidney lignite field is located on the northeast limb of this broad structural unit. In the extreme northern part of the field, however, the rocks dip more nearly due east in conformity with the easterly dips in the region to the north along Missouri River.

THE LIGNITE.

OCCURRENCE.

There are eleven lignite beds in the Sidney field that were considered sufficiently important to be individually designated and mapped. These are all in the lower member of the Fort Union formation, and as shown on the generalized sections accompanying the maps (Pls. XXIII and XXIV) are fairly equally distributed throughout the 980 feet of rocks making up that member. The beds have been designated alphabetically from the lowest upward, A being the lowest bed in the series. The important lignite data for the field have been summarized in the following table:

Position and thickness of principal beds of lignite.

Designation of bed.	Thickness of beds.				Average distance between beds.
	Average.	Maximum.	Minimum.	Number of measurements on each bed.	
	Ft. in.	*Ft. in.*	*Ft. in.*		*Feet.*
K	2 4	4 8	4 8	4	.....
J	2 10	5	10	27	140
I	4 5	7 1	1	52	72
H	4 8	10 6	2	59	141
G	9 1	21	3 10	61	93
F	4 8	10 4	1	45	127
E	3 2	8 6	6	18	89
D	4	6 3	2 5	12	89
C	5 4	6 4	3 11	8	97
B	4 6	9 3	3	17	44
A	3 8	4 6	2 10	4	39

The proportion of lignite present to the total thickness of the formation in which the beds occur is phenomenal when compared with the standards of the great Carboniferous coal fields in the eastern part of the United States. The proportion of coal to the thickness of the inclosing formation in the Eastern "Coal Measures" is about 1 to 40, whereas the 980 feet of strata making up the Fort Union formation in the Sidney field inclose 49 feet of lignite, the ratio being 1 to 20, or

practically double that in the "Coal Measures." The many minor beds and seams present are not considered in the above estimate but are so numerous that they would considerably increase the amounts. Even larger amounts of lignite and coal are common in other parts of the Fort Union region.

In the earlier descriptions of the lignites in this general region particular emphasis was given to statements that all of the beds were very lenticular and could not be traced more than a few miles on the outcrop. It is true that the beds are variable in thickness along a few miles of outcrop, maxima and minima being as much as double or half of the average thickness for any one bed. Nevertheless, the persistence of the larger beds is easily proved by the practical continuity of exposures of the lignite and outcrops of clinker and slag, produced by burning of the fuel in the field.

IMPORTANT BEDS.

Two of the beds in the field, G and H, are by far the most important because of their size and persistence, and are therefore a great aid in correlating the lignite beds of the surrounding fields. These two beds, separated by a distance averaging 93 feet, lie near the middle of the lower member of the Fort Union, bed G being about 500 feet above the base.

A study of the outcrop of bed G across five townships, from the south line of the field in T. 17 N., R. 58 E., to the point where it finally reaches the level of Yellowstone River in T. 21 N., R. 59 E., shows either exposures of lignite or of slag due to burning of the bed on practically every mile of the distance, so that it seems safe to conclude that the bed is persistent over the entire field. Large areas of clinker on the horizon of the bed far beyond its present limits are evidence that it was at one time continuous over a much greater extent but has been burned out.

Furthermore, correlation with the fields lying to the south of the area described, indicates that bed C is continuous over a remarkably large area in Montana and North Dakota. In the report on the Sentinel Butte lignite field,[1] a large bed, outcropping a few miles north of Wibaux, Mont., on Beaver Creek, is described and correlated with the Harmon bed exposed 35 miles to the southeast on Little Missouri River. In the course of the work on the Sidney field the results of a reconnaissance trip from the south edge of the mapped area to the vicinity of Wibaux seemed to make the correlation of bed G and the Harmon bed described at Wibaux fairly certain. With the continuity of this bed over the area of the Sidney field practically proved, the

[1] Leonard, A. G., and Smith, C. D., The Sentinel Butte lignite field, North Dakota and Montana: Bull. U. S. Geol. Survey No. 341, 1909, p. 25.

combined results of the surveys in this region show it to have a length of over 120 miles along its outcrop.

Bed H, though by no means so persistent as bed G, is continuous for long distances. Fifty-nine measurements of its thickness give an average of 4 feet 8 inches of lignite. Its proximity to bed G and the fact that it is as much as 10 feet thick in many places often caused it to be confused with lignite bed G, unless considerable care were used in determining the horizons.

EXPLANATION OF MAPS.

The maps presented (Pls. XXIII and XXIV) are a compilation on reduced scales of the original field sheets and show clearly the individual lignite beds. The solid outcrop lines indicate actual exposures of the lignite. The edges of the beds where shown by clinker and slag are indicated by dotted lines, and their approximate position on grassy or concealed areas by dashed lines. By using the maps directly in the field a retracement of any of the beds can be made, by careful attention to the lignite outcrops and slag exposures, together with reference to the structure of the locality as shown on the structure map (fig. 8).

The approximate depth to bed G in any part of the field can be determined by taking the difference in elevation between the surface of the ground, shown on the topographic map of the Glendive quadrangle published by the Geological Survey, and the elevation of the lignite bed at the given locality, as shown in figure 8. For example, the elevation of bed G in the center of sec. 36, T. 18 N., R. 59 E., as shown on the structure map (fig. 8), is 2,240 feet; the corresponding elevation at the surface, as shown on the topographic map, is 2,525 feet, giving a difference of 285 feet, which is the approximate depth to the bed. Furthermore, by reference to the distances between the various beds given in the table on page 287, the depth to any bed can be calculated by noting the distance between it and bed G.

QUALITY OF THE LIGNITE.

PHYSICAL PROPERTIES.

The lignite of the Sidney field is classed as true lignite, although in some respects it resembles subbituminous coal. A fresh face of the lignite is blackish brown in color, is tough rather than brittle, and shows much of the original grain of the wood from which it was in part formed. On weathering, the tough woody appearance of the fresh lignite is lost, the grain of the wood disappears, and the color changes from blackish brown to black. In this state it is brittle, and if crushed the small fragments have a shiny black luster. Freshly

mined lignite soon breaks into fine slack and is not suitable for shipment.

The greater part of the lignite was evidently formed from tree trunks and large fragments of wood, and not from the accumulation of fine vegetable matter. Entire logs can often be traced out from the grain of the wood on a fresh face of the lignite. The logs usually lie horizontally and are from a few inches to several feet in thickness.

The various beds in the field differ in quality to a great degree. In general, the lignite below bed G is less brown and woody than that above and is more nearly true subbituminous coal. Beds over 5 feet in thickness are cleaner and of uniformly better grade than smaller ones, although beds having a thickness of 10 to 15 feet of perfectly clean lignite without a parting at one point may become dirty a few thousand feet away, showing unstable conditions in the bogs or marshes in which the vegetable matter accumulated. A clay parting a few inches thick may increase in a short distance and destroy a bed that is otherwise clean.

CHEMICAL ANALYSIS.

There are no mines in the field from which there is a continuous or considerable production of fuel. During the field work lignite was not being mined in any place from under cover but was being removed from open strip pits in small quantities only, so that it was practically impossible to get fresh samples of the unweathered lignite. It has been found that unless samples of coal and lignite for analysis are taken from fresh, unweathered faces under cover the results obtained can not be relied upon. The sample whose analysis is given below was taken 25 feet in on the right wall of a partly caved entry that had not been worked for several years, situated in the SW. ¼ SW. ¼ sec. 31, T. 18 N., R. 57 E. A channel about a foot deep was cut to expose a fresh face of the lignite, and then a sample was taken which was crushed, quartered, and sealed in a galvanized-iron can for shipment to the laboratory. This entry is on bed B, which is 5 feet thick at this point, and all of the thickness of the bed was included in the sample.

Analysis of lignite from entry in the SW. ¼ SW. ¼ sec. 31, T. 18 N., R. 57 E.

[A. C. Fieldner, chemist in charge, Bureau of Mines laboratory. (Laboratory No. 10914.) Loss of moisture on air-drying, 14.3 per cent.]

	As received.	Air-dried.	Moisture free.	Moisture and ash free.
Moisture	31.5	17.3	.....	.....
Volatile matter	28.6	34.6	41.8	46.0
Fixed carbon	33.6	40.5	49.0	54.0
Ash	6.3	7.6	9.2	.....
Sulphur	.65	.79	.95	1.05
Calories	3,820	4,165	5,580	6,150
British thermal units	6,880	8,310	10,050	11,070

For further discussion of the composition of the lignite and the effects of weathering the reader is referred to the preceding paper by J. H. Hance.

BURNING OF THE LIGNITE ON THE OUTCROP.

The occurrence of masses of reddish rock, commonly called slag or scoria in this region, capping many small buttes and lying on the slopes surrounding the uplands and along the sides of the valleys, is a very noticeable feature in the Sidney lignite field. All this clinker or slag is formed by the burning of lignite, which bakes and fuses the overlying clays or sandstones. Much of the rock is perfectly fused over large areas, so that it is to some extent similar to typical lavas and is therefore often erroneously attributed to former volcanic action. It is very probable that the fire is usually caused by spontaneous combustion, for such firing of piles of slack of subbituminous coal and lignite is a common occurrence.

The presence of clinker or slag greatly aids in the location of the various coal beds, and in many places it would not otherwise be possible to trace them. In general, it is true that the cleaner the fuel the more likely it is to burn, and therefore the fact that a bed has burned considerably is evidence that it contained a good grade of lignite.

The base of the clinker where it has not slumped always seems to mark the base of the lignite bed. There is an excellent example of this on the south side of Bull Camp Coulee in sec. 21, T. 19 N., R. 59 E., where a recent change in the course of the stream has cut across a width of several hundred feet of clinker to the unburned coal lying behind it, showing the base of the clinker to be on a level with the base of the bed. The recognition of this fact will aid in the correct location of an entry on a bed near or on a burn, whereas if it is disregarded the entry may be driven completely below or above the lignite, thus leading the workers to believe there is no lignite present.

ESTIMATED TONNAGE.

The season's work in the field has given a large amount of data on the thickness and extent of the various beds of lignite, so that it seems possible to make a fairly accurate estimate of the tonnage present. The beds, however, are with few exceptions known only along the line of outcrop, nothing being known of their persistence back of this line, and any estimate of the tonnage present will be more or less uncertain because of this. In the estimates made, it is assumed that if a lignite persists for a given distance along the line of outcrop it persists at least one-half of this distance back from the line.

The average specific gravity of lignite is 1.3; therefore a cubic foot of the material weighs 81.25 pounds. A square mile of lignite 1 foot thick contains 27,878,400 cubic feet and with the specific gravity given above weighs 1,132,560 short tons, so that the total lignite in any one bed can be computed by multiplying this tonnage by the area in square miles underlain by the bed, times its average thickness in feet. With the above procedure, bed G shows a total of 5,245,905,000 tons and bed H 2,065,336,000 tons.

Beds I, J, and K underlie only the small upland areas in the field, and though their total thickness is considerable the aggregate tonnage amounts to only 328,895,000 tons. The beds in the formation below bed G underlie the greater part of the field, and although due allowance is made for the lack of persistence of some of them, their total tonnage is very great, amounting to about 15,689,694,000 tons. The estimated gross tonnage for the entire field is 23,329,830,000 short tons.

The above estimate is thought to be conservative, because only lignites actually seen and measured were considered, and it is very probable that there are many other beds present which were not noticed, because over half of the area is grass covered and poorly exposed. In considering the above figures it must be remembered that but little over half of this gross tonnage is recoverable under present conditions, so that on this basis the amount that can be mined is about 12,500,000,000 short tons.

DETAILED DESCRIPTIONS BY TOWNSHIPS.

The lignite beds are described below by townships, beginning in the southwest corner of the field and considering each township in order from west to east. A brief account is given of the exposures, character, and thickness of the lignites, together with the surface indications upon which the mapping of the outcrops of the various beds is based.

T. 17 N., R. 58 E.—The lowest lignite exposed in this township is bed E and the highest is bed H. As shown by the columnar section

accompanying the map (Pl. XXIII) the rocks exposed comprise the middle third of the lower part of the Fort Union and contain the thickest and most persistent lignite beds in that formation.

Bed E is exposed in the northwest quarter of the township, where outcrops are very plain in all of the sharply cut coulees on the west side of Castle Creek. There are prominent beds of slag produced by the burning of the lignite in this bed, on the east side of Castle Creek in sec. 7, and on the north side of Cottonwood Creek in sec. 5. The character and thickness of the bed are shown by sections 401, 402, and 404,[1] on Plate XXII. The average thickness of the bed is 3 feet 3 inches where mapped, but elsewhere in the township it is thin and in places is probably absent.

Bed F ranges in thickness from 4 feet 9 inches to 9 feet 10 inches, in many places thinning materially in a very short distance. There are good exposures of the bed along the upper branches of Castle and Sheep creeks, but along Cottonwood Creek the greater part of the outcrop is very poorly exposed and is marked only by one area of slag in sec. 11. Sections 384, 388, 391, 392, 403, 405, 407, 408, and 410 show the character of this bed in widely separated locations in this township. Its average thickness in the nine sections given in Plate XXII and in three others measured in close proximity is 7 feet 5 inches.

Bed G is very easily traced, although exposures are few, because the bed has burned very much along the outcrop. Along the east side of Castle Creek and on the upland area between Castle and Sheep creeks the mapping is based almost entirely on the clinker fringe on the edge of the bed. Along both sides of Cottonwood Creek the location of the outcrop is made fairly certain, both by exposures of lignite at the heads of the smaller tributary coulees and by areas of slag. Sections 376, 377, 378, 380, 385, 386, 387, 389, 393, 394, 395, 397, and 406 (Pl. XXII) were measured at the localities bearing corresponding numbers on Plate XXIII. At location 390, 3 feet of lignite are exposed without reaching the bottom of the bed, but it is probable that this bed, as well as single beds shown in adjacent locations, represents only one bench and that other benches are concealed below. The average of these fourteen sections gives 6 feet 10 inches of lignite, with a maximum of 10 feet 7 inches and a minimum of 3 feet 10 inches.

The only large area of bed H in this township is on the upland between Castle and Cottonwood creeks, where the outcrops are very poor on account of burning. The lignite of bed H has been thoroughly burned over several square miles. The limits of this area are uncertain; therefore the mapping of the bed back of the slag-covered area

[1] Numbers refer to locations on Pls. XXIII and XXIV, and most of them also to sections with corresponding numbers on Pls. XXI and XXII.

is very indefinite. The one section taken (No. 398) measured 6 feet 2 inches.

A lignite-bearing zone of minor importance, in a dark clay lying between beds F and G, carries a series of lenticular masses of lignite, represented by sections 400, 383, and 409 (Pl. XXII), which are locally as much as 15 feet thick. Croppings of these minor beds are in secs. 4, 23, and 31 of the township. Also, beds of similar character occur between beds G and H, at location 379, sec. 26; locations 381 and 382, sec. 22; location 396, sec. 15; and location 399, sec. 16.

T. 17 N., R. 59 E.—The rocks exposed in this township include all of the Fort Union formation, from a horizon some distance below bed G to the highest strata exposed in the entire field, about 200 feet above bed K exposed on Blue Mountain in sec. 2.

Bed G is present in the lower portions of the valleys of each of the branches of Cottonwood Creek, but the determination of its outcrop is very indefinite because there are only a few lignite exposures or slag outcrops on the gentle grassy slopes along the creeks. There are neither exposures nor slag at the horizon of this bed in secs. 30 and 31, but a good exposure a few hundred feet off the west line of these sections in the adjoining township shows 5 feet 8 inches of lignite. On the east fork of Cottonwood Creek the mapping depends on two distinct areas of slag in sec. 18 and the two exposures of lignite (Nos. 361 and 362). The prospect on the north edge of sec. 17 is a small open cut made by the neighboring ranchers to obtain lignite for domestic use. The average thickness of the bed is 5 feet 6 inches.

Ten sections of bed H, ranging from 1 foot 10 inches to 8 feet in thickness, were measured in this township. The thicker part of the bed, which is confined to the northwestern part of the township, is represented in Plate XXII by sections 349, 355, 356, 357, 358, 360, and 364. The measured thicknesses in the other part of the township are as follows: Location 350, 22 inches; location 368, 30 inches exposed, but base not seen; location 369, 36 inches; and location 370, 25 inches. The great range in the thickness seems to be typical of this bed and it is probable that in places it is represented by carbonaceous clay. Along Cottonwood Creek, in the southern part of the township, the location of the outcrop was determined by a few exposures of lignite and many rims of clinker. On the east fork of Cottonwood Creek the outcrop can be traced with considerable certainty by small areas of slag in secs. 6, 8, and 17 and many exposures of lignite along the sharply cut side coulees. The distance to the underlying bed G varies between 98 and 105 feet.

Bed I is well exposed in the northern part of the township in the vicinity of Blue Mountain but is very poorly exposed in the southern part. The bed could not have been mapped except for the presence of a mass of clinker at the proper elevation near the east line of sec.

23 and the prominence of the bed in the townships to the south. Beginning with the clinker rim near the northeast corner of sec. 15, the outcrop around Blue Mountain is very plainly marked by a series of clinker and lignite exposures (Nos. 339, 340, 347, and 352) not more than a mile apart. The bed is very uniform in thickness, the average of five measured sections being 5 feet 5 inches. In the southern part of the township the thickness of the bed is 8 inches at location 372, 6 inches at location 373, 20 inches at location 371, 38 inches at location 366, 17 inches at location 374, and 14 inches at location 375. The distance between this bed and the underlying bed H ranges between 115 and 129 feet.

The determination of the outcrop of bed J is entirely dependent on exposures of lignite along the minor drainage lines on Blue Mountain. The north and northeast slopes of the mountain afford very few exposures, but elsewhere good exposures offer many opportunities to measure the bed. Bed J lies from 70 to 75 feet above bed I, and the seven measurements of its thickness (Nos. 338, 353, 341, 345, 346, 348, and 351, Pl. XXII) range from 2 feet 6 inches to 4 feet 7 inches.

In this part of the field the only outcrop of bed K, at the bottom of the upper and darker member of the Fort Union, encircles Blue Mountain but is very much hidden under the talus from the steep slopes. A section in the NW. ¼ sec. 2 (location 343), at an elevation of 2,850 feet, measures 4 feet 8 inches.

Beds of lesser importance than those listed above were measured at a number of places in the township. These are generally less than 30 inches thick, but in a few places they are thick enough to be considered a part of the fuel resources of the township. Outcrops at locations 363, sec. 18; 365, sec. 16; and 367, sec. 31, show considerable lignite between beds G and H. The thickness at location 363 is shown in Plate XXII; at location 365 there is 4 feet 1 inch of clear lignite; and at location 367 the thickness and character are shown by the following section:

Section of lignite beds at location 367, sec. 31, T. 17 N., R. 59. E.

	Ft.	in.
Shale.		
Lignite	2	6
Shale	23	
Lignite	3	10
Shale	2	1
Lignite	3	
	34	5

At location 354 a small bed lying between beds H and I shows 17 inches of lignite, and a similar bed in Blue Mountain between beds J and K shows the same thickness at location 342 and 28 inches at location 344.

T. 17 N., R. 60 E.—The lignite beds exposed in this township range from bed H to bed J through a stratigraphic distance of 325 feet and include three important lignite beds besides several minor ones.

Bed H outcrops in the north half of the township on both forks of C–S Creek. On South Fork the location of the outcrops is determined by a clinker area in the W. ½ and a fairly good exposure of lignite (No. 327) in the E. ½ sec. 5. Farther upstream in secs. 7 and 18, near the Hall ranch, there are several good outcrops (Nos. 328 and 329) and a small slag area. On the east fork of the creek the only traces of the bed on the gentle grassy slope are several outcrops (No. 323) in the NW. ¼ and one (No. 324) in the SW. ¼ sec. 3. Five measurements of this bed show thicknesses ranging from 2 feet 6 inches to 4 feet 6 inches, with an average of 3 feet 10 inches.

Bed I is from 110 to 125 feet above the underlying bed H. The mapping of bed I was based on a good exposure (No. 330) on an outlier of the main area of the bed in sec. 17, another (No. 336) in the NW. ¼ sec. 28, and two outcrops (Nos. 331 and 332) in sharply cut coulees in sec. 22. There is also a prominent clinker rim on the horizon of the bed in sec. 16. The average thickness of the bed on the four outcrops measured is 5 feet 7 inches.

The distance between beds I and J ranges from 85 to 110 feet, and the average thickness of the three measures on the outcrops of the latter is 2 feet 11 inches. Bed J is poorly exposed except in secs. 19, 22, 27, and 28 (Nos. 335 and 337), and there are no slag areas to aid in tracing the outcrop. At location 333 the bed contains 2 feet of lignite. For the greater part of the distance across the township the position of the bed was determined by the elevations of the above-mentioned exposures. The gentle slopes on all of the upper reaches of C–S Creek afford very poor traces of beds I and J in this township.

There are two minor beds which are locally of considerable importance. One (No. 325) 3 feet 6 inches in thickness is marked in secs. 4 and 9 by a distinct series of burns along several miles of its outcrop. The second bed measures 4 feet 11 inches in sec. 27 (No. 334), but in sec. 28 it is concealed for about half a mile along the outcrop. A small bed only 18 inches thick shows at location 326, in sec. 4.

T. 18 N., R. 56 E.—Only beds A and B were traced in this township. They lie in the lowest 50 feet of the Fort Union formation. Bed A is arbitrarily taken as the base of the formation because there is no definite line of separation between this and the underlying Lance formation.

Bed A is easily traced by good exposures in sec. 31 (Nos. 192 and 193, Pl. XXI). In the railroad cut along the river bank, in the E ½ sec. 32, the exposures (No. 196) are exceptionally good and show a local monocline with a dip of 3° NE., causing the bed to disappear in the alluvium at the level of the railroad grade. To the east bed A is

not again exposed except at a place very near the headgates of the lower Yellowstone reclamation project, in the NW. ¼ sec. 36, where it outcrops for several hundred feet just above the level of the river. An entry was driven on this outcrop (No. 206), but very little lignite was taken out because of the difficulty of mining so near water level. The average thickness of the four sections measured on bed A is 3 feet 9 inches.

The outcrop of bed B, which lies between 37 and 44 feet above bed A, is very distinct. On both sides of Morgan Creek, in secs. 31 and 32, and on Thirteenmile Creek, in sec. 27, there are clinker rims produced by burning and outcrops of the bed at many places in the sharply cut side coulees (Nos. 190, 191, 194, and 195). In sec. 33, just above the stage road, the bed is clearly marked by a series of blossoms and prospect openings (Nos. 197, 199, and 200). On Thirteenmile Creek it is exposed at two places (Nos. 201 and 204) and near the bank of the river (No. 205) in sec. 35. The best exposure, however, is the outcrop about one-half mile in length, in the railroad cut along the bank of Yellowstone River (Nos. 207 and 208), in sec. 25. The bed is well exposed and horizontal except for several small local undulations. Near the center of sec. 25 there are eight small entries on this bed from which lignite was taken for use on the steam shovels during the construction of the canal on the reclamation project. There are 16 small open cuts and entries on bed B in this township, making it the most thoroughly prospected lignite bed in the entire field. In the S. ½ sec. 31 the bed is considerably thicker, the prospect in the SW. ¼ of the section showing 9 feet 3 inches of lignite, whereas the average of all the measurements in the township is only 4 feet 4 inches.

In sec. 33 two small beds above bed B have been prospected at location 198, and beds which mapping proved to be the same were observed on Thirteenmile Creek, where the upper bed (No. 203) has a thickness of 14 inches and the lower bed (No. 202) a thickness of 23 inches. Another bed outcrops at location 209, but it is only 18 inches thick and the lignite is of poor quality.

T. 18 N., R. 57 E.—Six beds of lignite, ranging from B to G, inclusive, were mapped in this township, besides one minor bed which lies very near the summit of the upland, between Cottonwood and Dry creeks in sec. 13. The rocks exposed include the lower part of the Fort Union formation. Reference to the plate shows that all of the lignite beds mapped lie east of Yellowstone River. This is due to the difference in topography on the two sides of the river. The portion west of the river is made up of gentle grassy slopes that conceal traces of all beds except very large ones, whereas the eastern part is very rough and much dissected, and affords excellent exposures.

Bed B, stratigraphically the lowest one exposed in the township, outcrops in secs. 30 and 31, and is very easily traced. South of

Boxelder Creek, in the W. ½ SW. ¼ sec. 31, there is a group of five small entries (No. 210) within a distance of 300 feet along the outcrop, from which lignite was mined during the construction of the lower Yellowstone irrigation project. Along the river front, in the E. ½ secs. 30 and 31, the bed outcrops (Nos. 212, 215, 216, 217, and 218) continuously for over a mile, and is mined in a small entry in the NE. ¼ sec. 31. In the SE. ¼ sec. 30, at the place where section 218 (Pl. XXI) was measured, the bed is at the level of the river alluvium and it is not exposed farther downstream. On the east side of the river the average dip in this locality would bring the bed to river level in the N. ½ sec. 29. The bed was measured at six places in the 2 miles of outcrop, and the thickness was found to range from 4 feet 4 inches to 5 feet 6 inches, with an average of 4 feet 11 inches.

Bed C, which lies at an average distance of 44 feet above bed B, outcrops in the southwest part of the township on the east side of Yellowstone River. The bed slopes to the level of the river in the SE. ¼ sec. 16, and is fairly well exposed from this place to the southwest corner of the township. The outcrop is practically continuous from river level in sec. 16 to Blackmore Coulee (Nos. 228, 227, 223, and 220). From this coulee to Boxelder Creek, a distance of 1½ miles, the bed is concealed, but along Boxelder Creek (No. 219) and the rest of the way to the edge of the township (Nos. 211 and 213) the exposures are good. At location 219 there is 63 inches of lignite, 18 inches of clay, and 13 inches of lignite. On the north side of Boxelder Creek, in the SW. ¼ sec. 31, there is a rim of clinker at the horizon of this bed. Seven sections give thicknesses ranging from 3 feet 11 inches to 6 feet 4 inches, with an average of 5 feet 5 inches.

Bed D outcrops in sec. 31, where it has the thickness shown in section 214, but its best exposures are at location 245 in Blackmore Coulee in sec. 33, where it has the structure shown in Plate XXI, and at location 246, where it shows the following section:

Section of bed D at location 246, sec. 33, T. 18 N., R. 57 E.

	Ft.	in.
Shale.		
Lignite		4
Shale		8
Lignite, impure	1	8
Shale		4
Lignite	1	8
Shale		4
Lignite		9
Total lignite	4	5

In the small coulees on the east bank of Yellowstone River north of Blackmore Coulee the outcrop of the bed can be located very definitely because there are many exposures (Nos. 221, 222, 224, 225,

226, 229, 230, and 231) of the lignite or of clinker. Owing to the lack of exposures it was found impossible to map this bed north of Cottonwood Creek. The general course of the valley of Cottonwood Creek through secs. 24 and 14 is about on the strike of the beds, so that the horizon of the bed reaches the level of the creek in the NW. ¼ sec. 14. Two miles farther up the valley, in sec. 19, T. 18 N., R. 58 E., a slight anticlinal flexure, transverse to the general course of the creek, produces a small elliptical outcrop of bed D, very close to water level. The average thickness of the eleven sections on this bed is 3 feet 10 inches.

In general throughout this township bed E is very irregular in thickness. In the NW. ¼ sec. 36 (No. 252, Pl. XXII) it measures 8 feet 6 inches; in the SW. ¼ (No. 254) it measures 3 feet 10 inches; and in the SE. ¼ of the same section (No. 255) it is only 2 feet 1 inch thick. In sec. 33 the bed has the thickness shown in No. 247 (Pl. XXI); in sec. 34 the thickness is 30 inches (No. 248); but north of location 248 it could not be identified along the outcrop for a distance of 2 or 3 miles. At location 233, in the sharply cut coulee in sec. 22, the bed is only 2 feet 7 inches thick. Eastward from this locality the bed is thin or wanting across secs. 14, 15, and 23, for at locations 236 and 237 no lignite at this horizon thicker than 8 inches could be found. From these localities it seems to thicken eastward to 3 feet 4 inches at location 239, in the SE. ¼ sec. 24, and to 8 feet or more in sec. 36, as mentioned above.

The outcrop of bed F in this township is generally very distinct. It is marked by rims of slag in secs. 34, 22, 23, 24, 35, and 36, and by outcrops (Nos. 249, 243, 234, 235, 240, 241, 242, Pl. XXI, and 253, Pl. XXII) in the upper parts of all the minor drainage courses. The lignite lies at the base of a pronounced bed of dark clay between 20 and 30 feet thick. Seven measurements on this bed show thicknesses ranging from 2 feet 10 inches to 5 feet 2 inches, with an average of 4 feet 2 inches.

Bed G is the highest lignite bed exposed in the township, and underlies only a small area in secs. 35 and 36. Two measurements on the outcrop (Nos. 250, Pl. XXI, and 251, Pl. XXII) gave thicknesses of 5 feet 11 inches and 5 feet 8 inches.

A few beds other than those noted above were measured in this township, but generally they are thin and worthless. One of these beds, lying a short distance below bed F at location 244 in sec. 27, measures 1 foot 10 inches; another on Cottonwood Creek, in sec. 24 (No. 238), measures only 17 inches; and one in sec. 13 (No. 232), 2 feet 9 inches. The latter overlies bed F at a less distance than bed G and therefore is regarded as lying between the two.

T. 18 N., R. 58 E.—The lignite exposed in this township includes all from bed D to bed H in the lower half of the Fort Union formation.

Except for a few square miles along Cottonwood Creek in the southwest and a small area in the northeast part of the township, the surface is covered with gentle grassy slopes and plains, which make the tracing of individual beds very difficult.

The only outcrop of bed D is at location 263, in the W. ½ sec. 19, in the bed of Cottonwood Creek, where a slight anticlinal fold transverse to the general course of the valley, similar to that a mile farther down the creek in the adjoining township, produces a small oval-shaped outcrop very close to the creek. The bed measures 2 feet 6 inches.

Bed E is exposed along the east side of Cottonwood Creek in secs. 19, 30, and 31 (Nos. 256, 259, 261, and 268), but no trace of it was found along Dry Creek. The bed ranges in thickness from 3 feet 4 inches to 4 feet 6 inches, and averages 3 feet 10 inches. The location of the outcrops of this bed was determined in most places from exposures of the lignite and where these were lacking from the slag that had resulted from the burning of the bed.

Bed F is exposed in the west half of the township, where it is variable in thickness and probably is in some places represented only by carbonaceous clay. The greatest thickness measured is 7 feet 7 inches in the E. ½ sec. 31 (No. 257), and the least 1 foot 8 inches, near the northwest corner of sec. 8. Northward from location 257 the bed thins somewhat, but the exact amount is not known, as at the next place where a section was measured, location 260, 4 feet 2 inches of lignite are exposed, but the bottom of the bed was not reached. At location 262 the bed is 4 feet thick and at location 264 is 4 feet 11 inches thick. Beyond this place it thins abruptly to only 27 inches of lignite broken into two benches by 8 inches of shale at location 266. In the valley of Dry Creek it is thin directly north of location 266, showing only 2 feet 6 inches of lignite at location 269, and 20 inches broken into two benches by 10 inches of shale at location 270 on the north side of the valley. It is too thin to have been mapped continuously in sec. 6, but near the north line of the township it has the character shown in sections 271 and 272. Up the valley of Dry Creek it thickens abruptly, as shown by sections 273, 276, and 278 (Pl. XXII). The average of thirteen measurements of this bed is 3 feet 11 inches.

On the east bank of Cottonwood Creek, in the southwest part of the township, the much-dissected topography affords many good exposures of lignite (Nos. 260, 262, and 264) and clinker beds; therefore the location of the outcrop of the bed in that locality is very definite; but in the northern part of the township along Dry Creek, except in secs. 10, 18, and 21, minor tributaries have cut into the gentle grassy slopes, affording very poor traces of the lignite. On Cottonwood Creek the bed lies at an average distance of 30 feet above the underlying bed E.

From the place in sec. 35 where the outcrop of bed G crosses the south line of the township to the point where its outcrop crosses the north line this bed is an excellent example of lignite that can be traced with a fair degree of certainty over gentle grassy slopes with no exposures, provided there are a few clinker rims to serve as guides. Over all of the area south of Dry Creek the mapping is almost entirely dependent on such burns, except at the heads of minor tributaries in secs. 24 (No. 284), 25, 26, and 27, where there are fairly good outcrops. North of the creek, in secs. 11, 12, 13, and 14 (No. 286), the conditions are similar to those to the south, but over the rest of the outcrop the exposures of lignite and clinker are practically continuous. South of Dry Creek the thickness of the bed ranges from 5 feet 11 inches (No. 279) to 7 feet 6 inches (No. 284), whereas north of that stream it ranges from 7 feet 6 inches (No. 286) to 11 feet 10 inches (No. 275), and to 12 feet 1 inch (No. 287) in the extreme northeast corner of the township. The bed lies from 100 to 140 feet above bed F.

Bed H lies under thin cover, near the summit of the upland in the southeastern part of the township, and stratigraphically is at an average distance of 100 feet above bed G. There are good exposures of lignite (Nos. 282 and 283) and a few clinker margins on the north-facing slopes, at the head of the small draws leading into Dry Creek, but the south slopes afford no exposures. In sec. 25 the bed measures 3 feet 11 inches and in sec. 26 it measures 4 feet 8 inches.

Lignite was found at a number of places in this township off the outcrops of the regular beds listed above bed D and at location No. 265 on Cottonwood Creek in sec. 19 shows the thickness given in Plate XXII. A smaller bed a little higher in the formation, but still below bed E, shows higher up in the Cottonwood Valley. This, however, contains only 26 inches of lignite at the place (No. 258) where it was measured in sec. 31. The other sections measured were all on a bed or beds lying between beds F and G. These sections, Nos. 267, 274, 277, 280, 281, and 285, are shown in Plate XXII, and their locations are indicated by the same numbers in Plate XXIII.

T. 18 N., R. 59 E.—The lowest stratigraphic points in the township are in secs. 3 and 19, on Parsons and Dry creeks, where the formation is exposed to a line a few feet below bed G. On the west line of sec. 35, on a north spur of Blue Mountain, the formation is exposed to a few feet above bed J, so that the rocks exposed at the surface in the township include almost all of the upper half of the lower part of the Fort Union formation.

Bed G outcrops in the township in three widely separated areas, (1) on the west line in secs. 18 and 19, (2) in the northwest corner of sec. 6, and (3) on the north edge in secs. 3 and 4. Five sections of the bed measured in these areas give thicknesses ranging from 6 feet to 10 feet 9 inches, the average being 8 feet 6 inches. In sec. 3 the

bed is well exposed, showing a thickness of 6 feet 2 inches at location 292 (Pl. XXII) on the east side of the creek and 6 feet at location 291 on the west side of the creek. In sec. 6, the bed outcrops plainly in all of the sharply cut draws, and is also marked by many areas of slag. In this locality the bed consists of clear lignite from 9 feet 5 inches to 10 feet 9 inches in thickness, as shown graphically by sections 288, 289, and 290. On the forks of Dry Creek, in secs. 18 and 19, the very gentle grassy slopes completely hide all traces of the bed; therefore the outcrop as represented on the map is only an approximation of its true position and is drawn to correspond with the elevations of the bed in the adjoining townships on the west. It is probable, however, that it maintains its thickness in this vicinity, for sections 284 and 286, described under T. 18 N., R. 58 E., show nearly the same amount of lignite that the bed carries in this township.

The thickness of bed H ranges in this township from 2 feet to 6 feet 8 inches, the average being 4 feet 4 inches. The location of the outcrop is generally concealed, but with the aid of several slag exposures it may be determined with a fair degree of accuracy. Passing along the outcrop from west to east, the first trace of the bed is a series of slag exposures near the center of sec. 5, at an elevation of 2,300 feet above sea level. Slag also occurs in secs. 9, 16, and 17. Good outcrops of lignite are found in sec. 9 (No. 293) and in secs. 21 and 22 (Nos. 294 and 295). The next exposure north of sec. 22 is at location 296 in sec. 11 and location 298 in sec. 2. From sec. 11 to the point where the bed crosses the township line along sec. 13 there are several areas of slag and outcrops in every section. In the SE. $\frac{1}{4}$ sec. 24 the position of the outcrop is determined by a single exposure (No. 299). In sec. 25 the position is determined by clinkers and exposures in the adjoining township to the east.

The mapping in this township of bed I is wholly dependent, with the exception of location 353 in sec. 32, on a rim of clinkers. The outcrop is entirely on grass-covered upland slopes, which show no exposures of the bed itself, but the ever-present slag is unmistakable evidence of the presence of the bed. On the upper branches of Dry Creek, in secs. 32, 33, and 34, the clinker beds are not so prominent as they are farther to the east, but they are plain enough to make known the position of the bed. The average distance between beds H and I is 100 feet. The thickness of bed I in the adjoining township to the south averages 5 feet 5 inches and in the township to the east 5 feet 1 inch.

Bed J is both stratigraphically and in altitude the highest bed exposed in the township. It is about 118 feet above bed I and underlies only a small area in secs. 32 to 36. In this township there is only one outcrop (No. 302), which measures 3 feet 8 inches in thickness. The average thickness of the bed on the south spurs of Blue Mountain, in T. 17 N., R. 59 E., is 3 feet 11 inches.

A thin bed between 50 and 60 feet above bed G is exposed in the north part of the township. A section on this bed (No. 297) was measured in the NW. ¼ sec. 3. The only other traces of lignite at this horizon are clinker beds on the left bank of Parsons Creek in secs. 4, 5, and 8. Between the outcrops of beds H and I four sections were measured on what are probably lenticular beds in this interval. These sections are No. 300 in sec. 26 and No. 303 in sec. 36. At location 301 in sec. 26 there are 2 feet 1 inch of lignite and at location 359 in sec. 31 1 foot 10 inches.

T. 18 N., R. 60 E.—As lignite bed G outcrops at the mouth of C-S Creek, just beyond the north line of the township, the rocks exposed range from near the top of that bed to and including bed J. Reference to the section accompanying the map (Pl. XXIII) shows that almost all of the upper part of the Fort Union formation as exposed in this field, with its many lignite beds, is included in the township.

Bed H comes to the surface along C-S Creek and each of its forks throughout the township. For most of the distance the location of the outcrop as shown on the map is fairly definite, but in certain areas it is not well exposed and its position was inferred from surface indications. Thus, throughout secs. 7, 17, and 18, on the west side of the creek, the bed is exposed at only one place (No. 306), and its position generally throughout these sections is marked by almost continuous exposures of slag. Farther south, in every coulee tributary to C-S Creek with the exception of the one in secs. 29 and 30, clinkers mark the position of the bed, but the grass-covered slopes offer no opportunities for its examination or measurement. The elevation of the clinker rim in the SE. ¼ sec. 29 was used to determine the position of the bed along the east side of the creek in that vicinity, and the clinker near the west quarter corner of sec. 29 served a similar purpose along the west bank of South Fork. On the east side of C-S Creek exposures are in general much better and several sections of the bed were measured. These are shown in Plate XXII by Nos. 307, 309, 312, 316, 318, 320, and 322. South of sec. 6 every mile of the outcrop is marked either by clinker beds or exposures of lignite, making it possible to map the outcrop accurately. In the SE. ¼ sec. 8, near location 312, a slight monoclinal flexure of the beds increases the dip to 2°. Seven measurements of the bed in the township give a minimum of 4 feet 1 inch, a maximum of 8 feet 1 inch, and an average thickness of 5 feet 5 inches.

Bed I outcrops high on the sides of the principal valleys and lies from 92 to 115 feet above bed H. West of C-S Creek the bed underlies only a few small scattered areas and is generally well exposed. A thickness of 5 feet 1 inch was measured at location 305 in one of these isolated areas in sec. 17. In secs. 30 and 31 the outcrop is marked by slag on the south edge of sec. 31 and by a lignite ex-

posure in the N. ½ sec. 30 (No. 304.) East of C-S Creek the position of the outcrop was fairly definitely determined, for the bed underlies a large upland area and is rimmed almost continuously with clinker, besides being well exposed in a number of places. At location 314 the bed is not fully shown, only 30 inches of lignite being exposed, but at location 313 the bed measures 5 feet 1 inch thick. Sections 319 and 321 show its thickness in the southern part of the township. Five measurements give an average thickness of lignite of 5 feet 1 inch.

Bed J is between 64 and 70 feet above bed I and underlies the upland east of C-S Creek in secs. 3, 10, and 15. The bed is not very persistent and ranges from 2 to 5 feet in thickness. Its thickness at location 310, in sec. 3, is given in Plate XXII. At location 311, in sec. 10, it contains only 2 feet of impure lignite. Its thickness at location 315, in sec. 15, is 5 feet. In the SE. ¼ sec. 22 it is exposed as shown in section 317 in Plate XXII. The largest area that it underlies is in secs. 10 and 15, but the position of the bed is only faintly marked by a few slag exposures lying on the west-facing slopes. The other smaller areas have either lignite exposures or clinker to determine the position of the outcrop.

A small bed of lignite a short distance above bed H is exposed in sec. 6, and its thickness is shown in section 308, Plate XXII.

T. 19 N., R. 56 E.—The only part of this township in which beds of lignite were examined in detail is the northeast corner east of Burns Creek, where about 250 feet of rocks in the lower half of the Fort Union formation are exposed.

Only one important bed is present, and it is well exposed in sec. 1, being marked by lignite outcrops and clinker. In the NE. ¼ sec. 1 (No. 189) the bed is 21 feet thick, all clean lignite, at an elevation of 2,360 feet above sea level. There is considerable uncertainty as to the correlation of this bed with any of those lying in the eastern part of the field. Throughout T. 19 N., R. 57 E., and T. 20 N., Rs. 57 and 58 E., the only indications of lignite are two very small outcrops of slag in a gentle grassy upland that affords only meager exposures along the watercourses, so that it is impossible to trace the lignite beds even if they are present. However, the bed in secs. 1 and 12 of T. 19 N., R. 56 E., has been tentatively correlated with bed G on the following grounds: (1) The interval between this doubtful bed and the lowest bed of the formation (bed A), outcropping on Yellowstone River in sec. 36, T. 18 N., R. 56 E., is practically the same as the interval between bed A and the clearly defined bed G in sec. 36, T. 18 N., R. 57 E.; (2) bed G as traced east of Yellowstone River is very persistent almost the entire length of the field, a distance of over 70 miles on the outcrop, and furthermore has been traced by reconnaissance as far east as the Big Bend of Little Missouri River, between

Medora and Yale in North Dakota; (3) in T. 18 N., Rs. 57 and 58 E., T. 19 N., R. 58 E., and T. 20 N., R. 58 E., just below bed G there is a striking dark-gray clay and sand clearly defined in the generally lighter materials of the formation, which serve as good markers in tracing the beds of lignite above and below. Beds of similar dark-gray clay and sand are exposed below the lignite bed on the west side of Burns Creek a short distance north of the edge of T. 19 N., R. 56 E.

The thickness of a minor bed of lignite is shown in sections 187 and 188, which were measured in secs. 13 and 12, respectively.

T. 19 N., R. 57 E.—The only exposures in this township are on the sides of the valley of Burns Creek. All the north half of the township is covered with gentle grassy slopes which show no indications of lignite. About 350 feet of the Fort Union formation, containing lignite beds from D to G, inclusive, are present in the area, but only bed G is thought to be persistent. A careful search of the exposures on Burns Creek showed five outcrops of lignite measuring from 1 foot to 3 feet thick. The thickest of these (No. 183) is in the SE. ¼ sec. 27, but about one-half mile to the east at the same elevation is an exposure (No. 182) 2 feet 11 inches thick. Both of these exposures are on mere lentils of lignite not more than half a mile in extent along the course of the creek. The other outcrops are of little value. That at location 184 is 12 inches thick; that at location 185 consists of two beds not exceeding 2 feet in thickness separated by 15 feet of shale, and that at location 186 is composed of two benches 12 and 15 inches thick separated by 12 inches of shale. It is evident from the description given above that beds D, E, and F are not persistent in this township.

Lignite on the G horizon, mapped in secs. 1 and 12 of the adjoining township to the west, probably underlies parts of secs. 5, 6, and 7, but there are no exposures in this township by which to make an accurate determination of its outcrop.

T. 19 N., R. 58 E.—The lignite beds exposed in this township range from bed E to bed H, inclusive. West of Yellowstone River the only trace of lignite is an exposure of clinker in the NE. ¼ sec. 6, which is near the horizon of bed E, but definite correlation is not possible in this case. In the much dissected topography east of the river all of the lignite beds are well exposed.

Bed E is exposed in two localities, one on the steep slopes of Devils Canyon in secs. 28 and 29 (No. 177) and the other along the steep-cut bank facing Yellowstone River in secs. 9 and 16 (Nos. 173 and 174). The bed varies from good lignite to carbonaceous shale. In the SW. ¼ sec. 16 there is a small drift on the bed where lignite is mined for local use. About a mile north of this place the northeast dip of the rocks carries the bed to the level of the river, where it is well exposed.

In this township bed F shows in four localities which will be considered in the order of their position from south to north. The first is in secs. 32 and 33, where there is about 4 miles of outcrop of lignite thick enough to be mapped. Near the center of sec. 33 the bed is over 5 feet thick (No. 180, Pl. XXI), but in sec. 32 it shows a thickness of only 20 inches (No. 181) and the lignite is very impure. This agrees with the deterioration of the bed noted in T. 18 N., R. 58 E. In the eastern part of sec. 33 the bed is generally well exposed along the steep-sided coulees but is also marked locally by an outcrop of clinker in the SE. ¼ of the section. In secs. 23, 24, and 25 there is a thin bed that apparently corresponds with bed F. The outcrops are all on the south side of Smith Creek and near water level, in cut banks, and in the steep-sided tributary draws. At location 157, sec. 24, the lignite is 26 inches thick; at location 158, in the same section, 18 inches thick; at location 159, in sec. 23, 20 inches thick; and at location 160, in the same section, 12 inches thick. A similar thin lenticular bed of lignite is well exposed in secs. 15 and 16 just below a prominent bed of dark clay. At location 172 it is 19 inches thick and at locations 175 and 176 the thickness is 20 inches. The bed is also traceable in secs. 2, 11, and 12. The outcrops are very distinct in sec. 12 (location 164), along the branches of Elm Coulee, where a bed of lignite 3 feet 7 inches thick is exposed. About 300 feet below the forks of the coulee, in the NW. ¼ sec. 12, the lignite is dirty and there are many thin partings of clay. To the north, along the east side of sec. 2, the bed is concealed, but one-half mile off the edge of the township it measures 5 feet 6 inches, so that it probably has a considerable thickness throughout this section.

Bed G is present in the eastern half of the township, both north and south of Smith Creek. This is the best exposed and most easily traceable lignite bed in the township. South of Smith Creek the bed underlies the intricately dissected upland surrounding Devils Canyon, the most typical badland area in the region. The outcrop of the bed is very distinctly marked for practically its entire length either by exposures of lignite or clinker, except in sec. 22, where about a mile of the outcrop is covered. The thickness in the vicinity of Devils Canyon is shown by sections 178, 156, 171, and 154. North of Smith Creek the bed lies for the most part in secs. 1, 12, and 13, and is fairly well marked by slag and exposures of lignite except on a gentle grass-covered slope between Smith Creek and the South Fork of Elm Coulee, in sec. 13. The thickness of the bed in this part of the township is 7 feet 11 inches at location 161 and as shown by sections 162, 166, and 168 at other locations.

Bed H lies from 37 to 85 feet above bed G and underlies only a very few small areas in the township. In the much-dissected tract south of Smith Creek, in secs. 26 and 35, the bed averages about 6 feet in

thickness but is not shown on the map because it is present in only a few very small isolated areas. Sections shown in Plate XXI, measured at locations 155 (sec. 26) and 179 (sec. 34), show its character and thickness in the southern part of the township. Locations 163, in sec. 13, and 167, in sec. 1, represent the bed in the northern part. In secs. 1 and 12 the bed is well marked by slag, but it is so much burned in the former section that it is very difficult to locate the edge of the unburned lignite. The average thickness of the bed throughout the township is 5 feet 1 inch.

A small bed between beds E and F shows in sec. 16 a thickness of 20 inches. Another one between beds F and G in sec. 12 (location 165), shows 6 inches of lignite. The most important of the intermediate beds lies above bed H in sec. 1, where two measurements (Nos. 169 and 170) show thicknesses of 3 feet and 5 feet 3 inches.

T. 19 N., R. 59 E.—Beds G, H, and I are exposed in this township, and the rocks exposed range stratigraphically from just above bed F to about 190 feet above bed I. Bed J is present in the northeast part of the township, but the lignite is too thin and nonpersistent to warrant mapping.

Bed G outcrops along both sides of Smith Creek, almost entirely across the township, and along both branches of Elm Coulee in secs. 7, 8, and 18. South of Smith Creek, in secs. 31 and 32, the location of the bed is plainly shown by a continuous line of outcrops and burns, and locally the bed dips northeast about 100 feet to the mile. Sections 151 and 153 show the character and thickness of the bed in sec. 31. A section was also measured at location 150, which gave a thickness of 11 feet of clear lignite. Across secs. 33 and 34 the bed is entirely covered, although 300 feet south of the township line it is well exposed on both sides of Parsons Creek. In sec. 35 the bed is visible in the cut banks of the creek (No. 119) and in sec. 36 it is marked both by exposures and by masses of slag as far as the center of the section, where it disappears beneath the stream wash. On the north side of Smith Creek the bed is covered in secs. 35 and 36, but is well marked beyond the south line of sec. 27. Sections 120 and 148 were measured in the areas between Smith Creek and Bull Camp Creek. Another section measured at location 121 gave 5 feet 8 inches of clean lignite. Between Bull Camp Creek and Elm Coulee the thickness of the bed is shown by sections 149, 147, 146, 144, 142, and 134 in this township and sections 161 and 162 in T. 19 N., R. 58 E. North of Elm Coulee but one section (No. 135) was made in this township. In sec. 19 and along Elm Coulee the bed is easily traced by the many burns and exposures. In the township fourteen measured sections give a maximum of 15 feet 2 inches, a minimum of 5 feet 2 inches, with an average thickness of 9 feet of lignite.

Bed H lies from 82 to 100 feet above bed G and for the most part is easily traceable. South of Smith Creek the outcrop can be easily located in sec. 31, being marked by several clinker beds and good exposures (No. 152) of the lignite on the upper courses of the minor drainage lines. In secs. 32 and 33 the bed is covered as far as the place where the outcrop turns to the south and passes out of the township, but south of Smith Creek, in sec. 36, it is marked by masses of red slag for about 1,500 feet along the outcrop. North of the creek, in the S. ½ sec. 25, the bed is concealed beneath the prevailing gentle grass-covered slopes, but in the north half of the section the bed is well exposed. The condition of the bed in the area between Smith Creek and Bull Camp Creek is shown in Plate XXI by sections 113, 118, 122, and 125. An additional measurement at location 115 shows 4 feet 3 inches of solid lignite. Between Bull Camp Creek and Elm Coulee the character and thickness of the bed are shown by sections 145, 143, 141, 139, 137, 133, and 129. At location 140 the bed is thin, measuring 27 inches; at location 136 it measures only 20 inches; and at location 130 it is split by a 12-inch parting of shale into an upper bench 18 inches thick and a lower bench 13 inches thick. North of Elm Coulee the bed is thicker, as shown by section 128, which was measured in sec. 5, and by section 167, in T. 19 N., R. 58 E. Thirteen measurements of this bed give an average thickness of 4 feet 9 inches of lignite with extremes of 3 feet 11 inches and 6 feet 8 inches.

Bed I underlies at least a portion of the upland in the northwest quarter of the township. In secs. 13, 14, 23, and 24, the bed is almost continuously fringed with margins of red clinker and has the thickness shown in sections 116 and 117. West of Bull Camp Coulee the bed evidently thins considerably and on the upper slopes of Elm Coulee the outcrop is so completely concealed that it was found impracticable to map it. The only other exposure is on a small tributary of Shadwell Creek in secs. 1 and 2, where the bed is well exposed, as shown by sections 126 and 127. The distance between bed I and the underlying bed H is about 180 feet. Five measurements on the bed give a maximum thickness of 5 feet and a minimum of 2 feet 8 inches, with an average of 3 feet 11 inches.

A small bed of lignite lying between beds G and H was noted in sec. 17, and also in sec. 25. At the former location (No. 138) it is 24 inches thick, and at the latter (No. 114) 22 inches thick. Another bed of considerable importance was found above bed H. Its thickness at locations 123, 124, and 131 are given in Plate XXI. What seems to be the same bed was measured at location 132 in sec. 8. At this place the bed has a total thickness of 37 inches, but the lignite is separated by a 6-inch shale parting into two benches, the uppermost of which is 18 inches and the lowermost 13 inches thick.

T. 19 N., R. 60 E.—The lignite beds exposed in this township range from what is probably bed H up to bed K. There are several hundred feet of the Fort Union formation overlying the latter bed on the upper slopes of the upland in secs. 10, 15, and 16. This is the largest area of what has been called the "upper somber" beds in the field.

A bed of lignite averaging 3 feet 11 inches in thickness outcrops along both sides of Rose Creek near the north line of sec. 29 (No. 110). This bed is believed to be bed H, although there are no outcrops or clinkers on either side of Smith Creek by which to connect this exposure with bed H either in the adjoining townships on the west or the south, in both of which the position of the bed has been accurately determined. It is generally supposed by the inhabitants of this region that lignite can be obtained a few feet below the surface in any locality, but this idea was clearly disproved by the digging of a well near the center of sec. 30 to a depth of 38 feet without striking any bed of lignite. When the stratigraphy is understood it is not surprising that lignite was not encountered, for the top of the well lies below the position of bed H and the well is not deep enough to penetrate the beds lower in the formation.

Bed I is the only prominent lignite exposed in this township and is easily traceable both north and south of Smith Creek and also on the north edge of the township in secs. 4, 5, and 6. South of Smith Creek the bed underlies three small areas (locations 111, 112) in which it is clearly marked by marginal beds of clinker. North of Smith Creek the outcrop is easily traceable across the township. The entire line of the outcrop lying east of Rose Creek and north of Smith Creek is almost continuously marked by red slag, but no exposures of the lignite were found. In secs. 17 and 18, however, there are many good outcrops (Nos. 105, 108, and 109) of the bed except along the upper end of Rose Creek, where, for a few thousand feet, it is covered and concealed. Through secs. 18 and 19 to the edge of the township the bed is also well defined by clinker. On the north edge of the township, in sec. 6, the bed is clearly exposed (No. 103) along the sharply cut drainage ways in the local badlands. To the east, in secs. 4 and 5, there are several clinker margins on the gentle grassy slopes, but no outcrops of the bed. In all six sections, ranging from 3 feet 3 inches to 5 feet 10 inches in thickness, were measured on bed I in this township.

Lignite that probably corresponds to bed J was mapped in secs. 8 and 17 (Nos. 106 and 107). Here there is about 3 miles of fairly well-defined outcrop lying about 40 feet above bed I. This distance is considerably less than the average of the measurements between these beds elsewhere in the field, so that the correlation is doubtful. Bed J measures from 2 feet 6 inches to 3 feet 10 inches in thickness.

Bed K is not prominently exposed in this township and its thickness probably averages less than 3 feet. There are two small areas of clinker beds, one in sec. 16 and the other in sec. 15, but elsewhere there are none, making it impossible to trace the outcrop with any degree of certainty farther than it was mapped. A bed 12 inches thick is exposed at location 104 in sec. 8, and is supposed to be the same as bed K, but exact correlation is impossible. On Blue Mountain, in sec. 2, T. 17 N., R. 59 E., this bed measures 4 feet 8 inches.

T. 20 N., R. 57 E.—The east half of this township was the only part examined in detail for lignite. The only trace of any bed in this part of the area is a small clinker bed on the south side of Dunlap Creek in sec. 14, at an elevation of 2,296 feet above sea level. This is probably bed G, and is so correlated because of the extreme persistence of the bed in other parts of the field where the exposures are good, and because the altitude of this burnt slag lying between the excellent exposure in sec. 1, T. 19 N., R. 56 E., and the bed at the mine in sec. 31, T. 21 N., R. 58 E., places the lignite on the horizon of bed G. The surface of most of the township slopes gently to the east, is grass covered, and there are no outcrops of any sort even in the stream banks.

A rapid traverse was made along the valley of Burns Creek, a little west of the west range line of the township, but the locations were not accurate enough to warrant mapping. Bed G is well exposed and much burned in this locality and the line of outcrop probably reaches this township in secs. 18 and 19. The bed measures 12 feet 4 inches in thickness near the southwest corner of sec. 19.

T. 20 N., R. 58 E.—Excellent exposures on the east side of Yellowstone River in this township show that lignite beds ranging from bed F to bed H are present. West of the river all of the area above the alluvium consists of a gentle eastward-facing grassy slope showing almost no traces of lignite.

Bed F is exposed only along the east side of Yellowstone River. The most southerly exposure on the line of outcrop is in the NW. ¼ sec. 36 (No. 71), and from this place the outcrop extends almost continuously to the south line of sec. 24. At location 70 the bed is 4 feet 9 inches thick and at location 69 it is 5 feet 6 inches thick (Pl. XXI). Across sec. 24 the bed is covered by talus, but is well shown in the steep cut bank on the north line of that section (No. 65) and also on the east side of Harpster Washout (No. 63). The northeast dip finally lowers the bed to the level of the river alluvium in the NE. ¼ sec. 13. Five measurements of this bed give from 3 feet 4 inches to 5 feet 6 inches of lignite, the average being 4 feet 7 inches.

A lignite bed of minor importance outcrops in secs. 13 (Nos. 62 and 64) and 24, where it lies about 50 feet above bed F. The exposures

are practically continuous for the entire length of the outcrop, and give a thickness ranging from 3 feet 6 inches to 5 feet.

The only trace of bed G west of Yellowstone River is a clinker margin due to burning of the lignite, lying on the north township line about 500 feet east of the northeast corner of sec. 3. This burn is clearly on the bed which is well exposed on Sears Creek one-half mile to the north. East of the river the entire length of the outcrop is very definitely marked either by red slag or by actual exposures (Nos. 66, 68, and 72) of the lignite. The thickness varies from 4 feet 2 inches to 10 feet 10 inches.

West of Yellowstone River the clinker rim in the NW. ¼ sec. 4, at an elevation of 2,121 feet above sea level, is probably bed H. This is the only indication of the presence of the bed west of the river. East of the river the bed is so thoroughly burned that it is very doubtful if any of the lignite remains in the township, except possibly in the south half of sec. 36.

A bed of lignite about 3 feet thick, apparently bed G, is reported to have been penetrated by a well in the SW. ¼ sec. 8 at a depth of 120 feet, or 2,020 feet above sea level. The well was drilled to a depth of 170 feet, but no other bed of lignite was encountered. Two wells were drilled in the W. ½ sec. 6 without finding any bed of lignite. One well is about 2,108 feet above sea level and the other 2,190 feet, but neither was deep enough to reach bed G or bed H.

Bed H is known at only one place east of the river. This is at location 67, where it has a thickness of 2 feet.

T. 20 N., R. 59 E.—The lignite beds exposed in this township range from a locally important minor bed lying 50 feet below bed G to bed I, inclusive. Bed J is present in the upland in the southeast portion of the township but is thin and poorly exposed.

The minor bed mentioned above—the lowest one exposed in this township—shows in outcrop in secs. 6 and 7 along the bluffs of Yellowstone River. This bed is somewhat variable in thickness, ranging from 2 feet 11 inches at location 86 to 6 feet 8 inches in a distance of about 3,000 feet. The best exposures are on a cut bank of the Yellowstone, in the SW. ¼ sec. 6 (No. 87) and in the NE. ¼ sec. 7, very close to the bed of Shadwell Creek (No. 88). From the creek south to the edge of the township the bed is first marked by a margin of clinker in the NW. ¼ sec. 7, and for the remainder of the distance by well-exposed croppings (locations 86, 81, 79, and 75).

Bed G outcrops from south to north entirely across the two west tiers of sections in the township. On Shadwell Creek, in secs. 7 and 8, it lies 49 feet above the lignite bed described in the last paragraph, whereas to the south on Harpster Washout, in sec. 1, the distance to the bed has increased to 70 feet. In sec. 31 the bed is so extensively

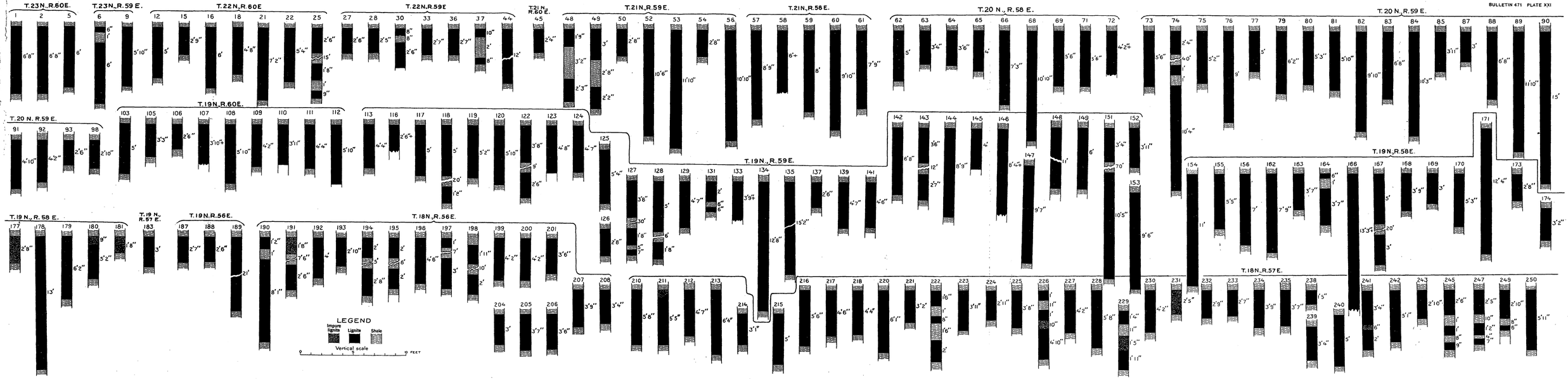
burned that measurements of its thickness could not be obtained, but in the SW. ¼ sec. 30 it has the thickness and character shown in section 74. North of location 74 the outcrop swings to the west into T. 20 N., R. 58 E. but appears again in sec. 19, where it was measured in two places. At location 76 it has the thickness shown in Plate XXI, and at location 78 it shows clear lignite 8 feet 7 inches thick. North of sec. 19 it is represented by sections 82, 83, 84, 89, and 90. North of Shadwell Creek, through sec. 6, the bed is concealed under the upper terrace gravel of Yellowstone River, therefore the location of the outcrop as shown on the map is only approximate. Eight measurements of the bed give thicknesses ranging from 6 feet 8 inches to 15 feet, the average being 10 feet 2 inches.

Bed H is poorly exposed in a part of this township. In sec. 8, on Shadwell Creek, its distance above bed G is 120 feet, whereas a mile and a half to the southwest the distance is 105 feet, and one-half mile south of this last place, in sec. 19, the stratigraphic distance between the beds is 93 feet, showing that the distance between them lessens very abruptly to the south. In sec. 31 the bed is so much burned that the edge of the remaining lignite is very indefinite, only one exposure (No. 73) having been noted, but to the north the bed is easily traceable by clinker and exposures of the lignite along all of the upper parts of Harpster Washout. Similar conditions prevail in sec. 19, but at location 77 a good section showing 5 feet of lignite was obtained. In secs. 5, 7, 8, and 17 the bed is continuously marked either by clinker or by actual exposures of the lignite. The bed as it is developed in this region is represented by sections 80, 85, 91, 92, and 93. The average thickness of the bed in that part of the township mapped is 4 feet 5 inches, the maximum being 5 feet 6 inches and the minimum 2 feet 6 inches.

Bed I is present both north and south of Shadwell Creek, but it carries lignite over 2½ feet thick only in the area south of the creek. The evidence seems to show that this bed thins very abruptly to the west from sec. 36. In sec. 6, T. 19 N., R. 60 E., the bed measures 5 feet; in sec. 36, T. 20 N., R. 59 E., it measures 2 feet 10 inches at location 98 and 12 inches at location 97; and in sec. 26, there are two benches 13 inches thick separated by 3 feet of shale at location 96, and two benches 6 and 12 inches thick separated by 8 inches of shale at location 95.

In the SE. ¼ sec. 28 (No. 94) there are two beds of lignite separated by an interval of about 60 feet. The upper bed is 2 feet and the lower 2 feet 4 inches thick. Neither of these seems to correspond with bed I, nor does the lignite found in the bottom of a well in sec. 34.

T. 20 N., R. 60 E.—The part of the Fort Union formation carrying beds I, J, and K is present in this township. Some traces of beds I and K were found, but there are no indications of bed J. The sur-



SECTIONS OF LIGNITE BEDS IN THE SIDNEY LIGNITE FIELD, DAWSON COUNTY, MONTANA

face of the entire township, with the exception of parts of secs. 31 and 32, consists of gentle grass-covered slopes, and there are almost no outcrops of any sort.

The only definite trace of bed I is a small bed of red clinker on the west side of a small coulee near the southeast corner of sec. 31. Elsewhere the position of the outcrop can be located only approximately by sketching a slightly sloping outcrop line, adjusted to the altitude of the clinker bed in sec. 31 and to the altitude of the bed in the adjoining townships on the west and south. In secs. 33 and 34, south of Shadwell Creek, and in all of the area north of the creek there is no evidence upon which to locate the outcrop of the bed. The bed probably is thin, for if it were of any great size it would almost certainly be burned at some points on the outcrop.

The outcrop of bed K, at the base of the upper somber-colored member of the Fort Union formation, encircles O'Brien Butte and a number of minor summits of the upland between Shadwell and O'Brien creeks. The bed is poorly exposed on the grass-covered slopes, but shows 12 inches of lignite at location 99, sec. 6; 24 inches at location 100 of the same section; and 18 inches at location 102, sec. 9. Southeast from O'Brien Butte the bed contains enough lignite to have burned, forming several well-defined margins of slag in the SE. ¼ sec. 15. Across the State line in North Dakota there is a very large clinker margin on this bed which extends over many miles of outcrop.

A small bed lower than the one mentioned above outcrops north of O'Brien Butte, containing at location 101, sec. 4, two benches of lignite 14 and 15 inches thick, separated by 12 inches of shale.

T. 21 N., R. 58 E.—The surface of that part of the township west of Yellowstone River is grass covered and slopes gently to the east, affording few if any outcrops. On the east side of the river, however, beds G and H and a minor bed are traceable.

On the river bank, near the west line of sec. 35, there are a number of outcrops of this minor bed lying about 50 feet below bed G. This exposure was not accessible and at no other place in the township could a measurement of the thickness be obtained. In the township to the south it is as much as 7 feet 6 inches thick, but it varies greatly in short distances. That it is of considerable thickness is indicated by a distinct margin of clinker on the south side of Alkali Creek in the S. ½ sec. 25. Farther downstream the general northeast dip carries the bed below the alluvium of Yellowstone River.

The only exposure of bed G on the east side of Yellowstone River is on Alkali Creek (location 56, sec. 31, T. 21 N., R. 59 E.), where it measures 10 feet 10 inches. Downstream from this locality, in the W. ½ sec. 36, there are prominent clinker margins on both sides of

the creek. The only other trace of the bed is an area of clinker on the north side of a coulee on the east line of sec. 25.

On the west side of the Yellowstone, bed G is exposed on the south side of Crain Creek, in sec. 15 (No. 57), where it measures 8 feet 9 inches and is opened at two prospects about 50 feet apart, one on the west side of the Glendive-Mondak stage road, and the other farther upstream. Between Crain and Sears creeks the bed is covered under terrace gravel for a distance of about 4 miles, but it shows on both sides of the latter creek in the N. ½ sec. 31 (location 61), where there are several openings from which the lignite is sold for domestic use. The bed measures 7 feet 9 inches. In the SE. ¼ sec. 31 there is a very thick rim of clinker on this bed. The grounds for assuming that the croppings on Sears and Crain creeks are on the same bed are (1) their position at about the same distance beneath bed H, which is prominent and traceable over the entire distance between the two localities; (2) the considerable thickness of the bed where exposed; and (3) the fact that the difference in altitude between the croppings at each place shows a northeast dip of the bed in conformity with the general structure of the region.

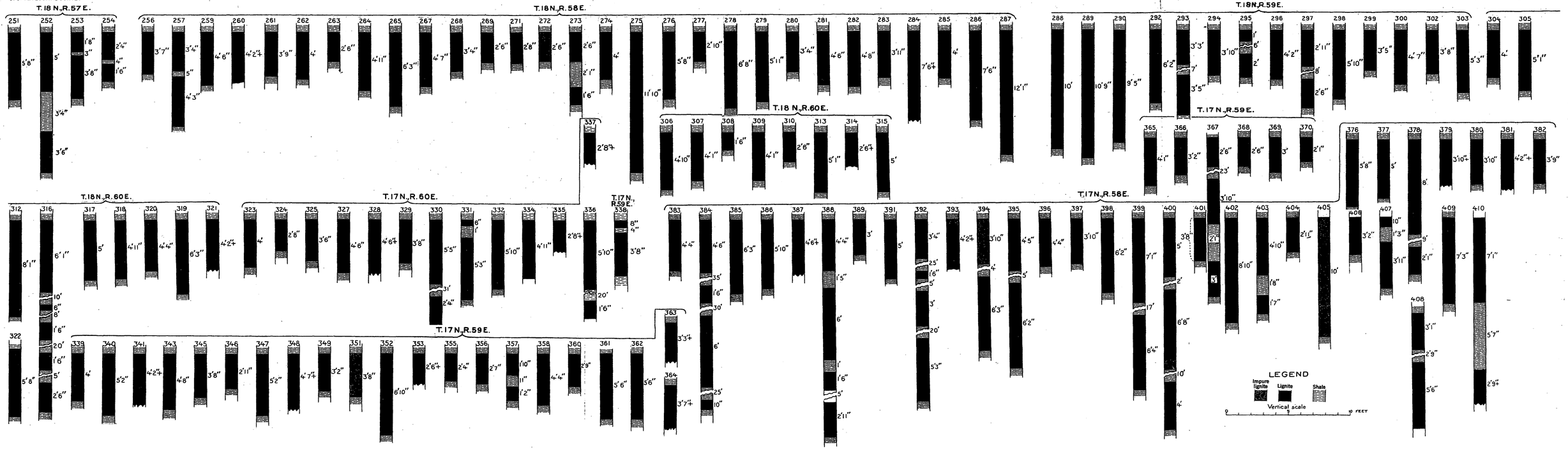
In digging the irrigation canal in the SW. ¼ sec. 32, a bed of lignite was encountered which supplied fuel for the steam shovel during the progress of the work. This is believed to be bed G, although it can not be definitely correlated with any of the beds of the surrounding region.

On the east side of Yellowstone River the only trace of bed H is a small area of clinker in the S. ½ sec. 36, where the bed underlies only a few hundred acres.

West of the river the bed outcrops on a grass-covered slope but is traceable by means of slag. On Crain Creek, in secs. 15 and 16, there are clinker beds on both sides of the creek, and a prospect (No. 58) where the bed is at the level of the creek. A short distance north of Crain Creek the bed slopes to the level of the terrace gravel and is not further exposed. From Crain Creek to the southwest corner of the township clinker beds and outcrops (Nos. 59 and 60) make the determination of the outcrop fairly definite. The average thickness is 8 feet 11 inches.

T. 21 N., R. 59 E.—The beds of lignite exposed in this township range from bed G probably to bed K.

The outcrop of bed G lies in the westernmost tier of sections in the township and is marked by clinkers and one prominent exposure. The general northeast dip brings this bed to the water level of Yellowstone River near the north line of sec. 18, where the beds have been folded locally into a monocline dipping 5° NE. To the south, in secs. 19 and 30, there are clinker rims on the outcrop of the bed, but elsewhere there is nothing to indicate its presence. The bed at location



SECTIONS OF LIGNITE BEDS IN THE SIDNEY LIGNITE FIELD, DAWSON COUNTY, MONTANA

53, in sec. 18, measures 11 feet 10 inches and at location 56, in sec. 31, 10 feet 10 inches in thickness.

The outcrop of bed H is marked by one or more clinker beds or exposures of the lignite itself in every section from the south line of the township to the north line of sec. 18, so in that area the position of the bed is definitely known. The thickness, however, is variable. In sec. 30 (Nos. 54 and 55) it measures from 2 feet to 2 feet 8 inches, whereas in sec. 18 a very prominent exposure (No. 52) measures 10 feet 6 inches. North of sec. 18 the bed is covered by terrace gravel.

In secs. 22 and 27, at an altitude of 2,180 feet, a lignite bed with the section given in Plate XXI is exposed at location 49. The bottom of this bed is 193 feet higher than the bottom of bed H as exposed in sec. 18. In T. 20 N., R. 59 E., adjoining on the south, the distance between bed H and bed I is 182 feet, making it seem very probable that this lignite is in bed I.

In sec. 27 a higher bed is exposed at location 48 (Pl. XXIV), which is supposed to represent bed J.

In the SW. ¼ sec. 35 there are two very small areas underlain by what is supposed to be bed K, measuring 1 foot 8 inches thick at location 47.

A small bed measuring 2 feet 8 inches in thickness is exposed at location 50 in sec. 20, and another 10 inches thick at location 51 in sec. 17.

On the slopes of the upland in secs. 1, 2, 11, and 12, northeast of O'Brien Creek, there are sufficient exposures to make it certain that none of the lignite beds from I to K, inclusive, are prominent in this locality.

T. 21 N., R. 60 E.—The only lignite outcrop mapped in this township is an exposure in sec. 6. The bed, measuring 2 feet 4 inches, is well exposed on both sides of the coulee at location 45, and its outcrop was mapped by means of slag for a considerable distance. Lying at an elevation of 2,140 feet above sea level, it can almost certainly be correlated with bed J lying at about 2,100 feet in sec. 20 of the adjoining township on the north.

In sec. 18 two beds 8 and 10 inches thick, separated by 20 feet of shale, are exposed at location 46.

The slopes of the upland in secs. 7, 18, and 19 afford a sufficient number of exposures to make it certain that there is no other lignite bed of any importance outcropping in the township.

T. 22 N., R. 59 E.—West of Yellowstone River in this township there are no exposures of lignite. Much of the surface is composed of alluvium, but where the rocks of the Fort Union formation are present they are poorly exposed on gentle grass-covered slopes.

East of the river there are two fairly well defined beds of lignite, the lower of which is believed to be bed I, exposed in the southern part of the field, and the upper to be bed J.

A well driven at location 44, in the SE. ¼ sec. 28, passed through 12 feet of lignite at a depth of 130 feet. This is probably bed H, which measures 10 feet 6 inches in an excellent exposure about 4 miles to the southwest. The distance between the lignite in this well and the lowest lignite bed exposed in the township is 130 feet. In the southern part of the field the distance between beds H and I ranges from 115 to 180 feet, so that it seems reasonable to correlate the lower of the two beds mapped with bed I.

Southwest of Benny Pierre Creek, bed I is not more than 2 feet 7 inches thick, as shown by the following measurements:

Thicknesses of bed I southwest of Benny Pierre Creek (Pl. XXI).

Location No.	Quarter section.	Thickness (inches).
28	NW. ¼ sec. 24	29
29	NE. ¼ sec. 24	26
32	SE. ¼ sec. 10	23
33	NE. ¼ sec. 15	31
34	SE. ¼ sec. 15	30
36	SE. ¼ sec. 15	31
40	NW. ¼ sec. 22	23
42	SW. ¼ sec. 22	14
43	NE. ¼ sec. 27	22

In secs. 15 and 22 and along the steep slope just east of the road in sec. 10, the outcrop is practically continuously exposed. Nine sections of the bed given in the above table show thicknesses ranging from 1 foot 2 inches to 2 feet 7 inches. Northeast of Benny Pierre Creek the bed outcrops in the NE. ¼ sec. 1. A few feet north of the north line of this section (location 10) the bed measures 5 feet 9 inches.

In sec. 22 bed J lies from 72 to 94 feet above bed I, and in sec. 24 the distance is 90 feet. The same interval in the southern part of the field is from 64 to 78 feet. The thickness of bed J in the area southwest of Benny Pierre Creek is as follows:

Thickness of bed J southwest of Benny Pierre Creek.

Location No.	Quarter section.	Thickness (inches).
27	SE. ¼ sec. 24	30
30	NE. ¼ sec. 24	[a]38
31	NW. ¼ sec. 24	24
35	SE. ¼ sec. 15	30
37	SW. ¼ sec. 23	[a]18
38	NW. ¼ sec. 22	25
41	SW. ¼ sec. 22	21

[a] In two benches.

Outside of secs. 22, 23, and 24 the only trace of the bed is a small clinker rim near the center of sec. 13.

In sec. 22 a small bed lying between beds I and J at location 39 shows 28 inches of lignite broken by a 6-inch shale parting into an upper bench of 20 inches and a lower bench of 8 inches of good lignite.

T. 22 N., R. 60 E.—Beds I and J are exposed in this fractional township. The thickness and character of bed I are shown in the following table:

Thicknesses of bed I in T. 22 N., R. 60 E.

Location No.	Quarter section.	Thickness (inches).
12	NW. ¼ sec. 6	60
16	SW. ¼ sec. 6	72
18	NW. ¼ sec. 7	56
21	SW. ¼ sec. 7	86
22	SE. ¼ sec. 7	64
23	SW. ¼ sec. 29	26
24	SW. ¼ sec. 32	20

The bed is easily traced by numerous outcrops and clinker rims. Through sec. 7 the bed is practically horizontal at an elevation of 1,960 feet above sea level. In sec. 6 it slopes from an altitude of 1,963 feet near the south line to 1,943 feet near the north line, in less than a mile.

Bed J is well exposed south of Benny Pierre Creek, where it is marked by a small clinker rim. The bed is less than 2 feet 6 inches thick and the average is much below this figure, so that it was not mapped entirely across the township. North of Benny Pierre Creek the bed is well exposed in numerous outcrops at the base of a prominent 20-foot bed of dark clay. The thickness of the bed is shown in the following table:

Thicknesses of bed J in T. 22 N., R. 60 E.

Location No.	Quarter section.	Thickness (inches).
13	NE. ¼ sec. 6	26
15	SW. ¼ sec. 6	33
17	SW. ¼ sec. 6	20
19	NE. ¼ sec. 7	23
20	SE. ¼ sec. 7	23
25	SW. ¼ sec. 30	[a] 30

[a] 29 inches of lignite below this bed.

Two small outcrops of a bed or beds above bed J were noted in this township. At location 14 in sec. 6 there is one bed 10 inches thick separated from another bed 12 inches thick by 20 feet of shale. At location 26 in sec. 30 there are 2 feet of good lignite.

T. 23 N., R. 59 E.—The only part of this township examined for lignite was the small area lying east of Yellowstone River. Bed I outcrops in secs. 25 and 36 and is very easily traced through both sections by an almost continuous line of exposures of lignite and clinker rims. The thickness of this bed is shown in the following table:

Thicknesses of bed I in T. 23 N., R. 59 E.

Location No.	Quarter section.	Thickness (inches).
6	SE. ¼ sec. 25	[a] 72
7	NE. ¼ sec. 36	68
8	NE. ¼ sec. 36	72
9	SE. ¼ sec. 36	70
10	SW. ¼ sec. 36	69

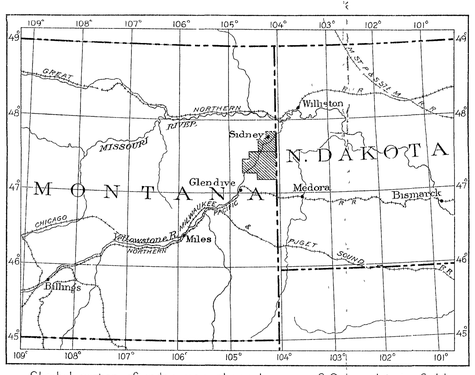
[a] Also on uppper bench 6 inches thick.

In the SE. ¼ sec. 25 (No. 6) there is a short entry in which the bed is mined for local use.

Bed J seems to be small in this township and poorly exposed. Only one measurement, at location 11, sec. 36, was made, at which the bed is 2 feet 3 inches thick.

T. 23 N., R. 60 E.—Bed I is the only one of any importance exposed in this township. It is easily traced through secs. 30, 19, and 20, by an almost continuous margin of slag on the outcrop. The sections of the bed at locations 1, 2, and 5 are shown in Plate XXI. The measurement at location 4 is 6 feet, or exactly the same as that made at location 5.

A small bed lying above bed I shows 20 inches of lignite at location 3 in the NW. ¼ sec. 30.



Shaded portion of index map shows location of Sidney lignite field

R 57 E | R 58 E | R 59 E | R 60 E

T 20 N | T 19 N | T 18 N | T 17 N

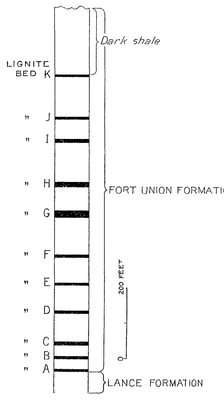
N. DAKOTA — MONTANA

Tokna | Savage | Gordon | Parson | Holms | Bull Butte | O'Brien Butte | Miller | Howe | Burns | Intake | Cummins | Pope | Drury | Carson | Page | Blue Mtn | Mueller | Spring | Parson

Dunlap Cr. | Garden Coulee | Beef Slough | Burns Cr. | Marguerite Cr. | Alkali Cr. | Hargrave Washout | Shadwell Creek | Elm Coulee | Bullcamp Coulee | South Creek | Devils Canyon | Smith Cr. | Dry Creek | Pope Cr. | Pogreba Creek | Castle Rock Coulee | East Fork Cottonwood Cr. | South Fk. Lake Fk. Cr.

U.S.R.S. CANAL CONSTRUCTION UNDER | U.S.R.S. CANAL | YELLOWSTONE RIVER | NORTHERN PACIFIC RAILROAD

Generalized section of rocks in Sidney lignite field, Montana



LEGEND

- Lignite bed continuously exposed. Numbers along beds refer to measured sections on Plates XXI and XXII or in text
- Outcrop of lignite bed covered, location uncertain
- Clinker or slag due to burning of lignite bed
- Lignite prospect (entry)
- Lignite prospect (open cut)
- Area in which lignite is probably burned out
- Alluvium
- Wagon road
- Government land corner found

Scale 1/62,500

0 1 2 3 4 5 6 Miles

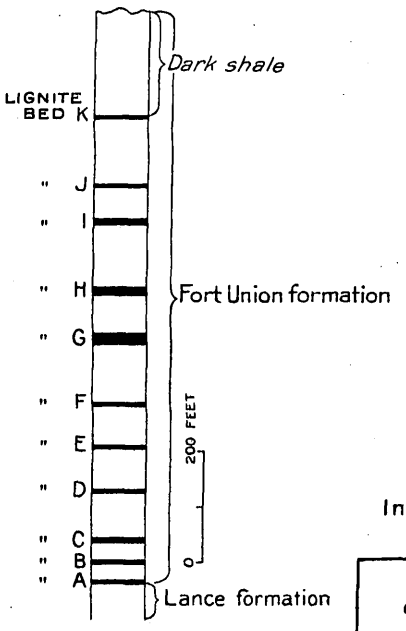
R. 58 E. | R 59 E | R 60 E.

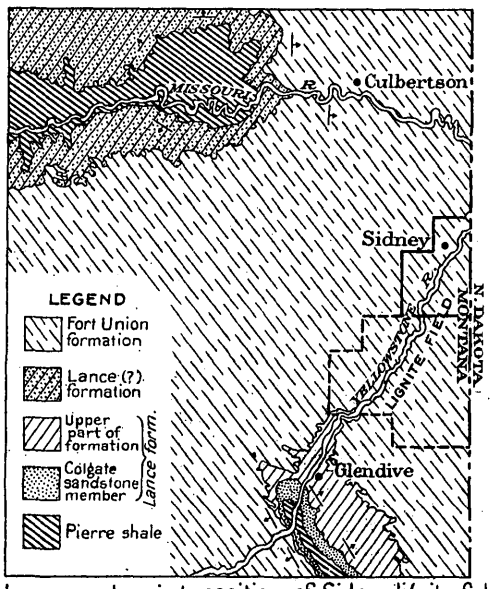
MAP OF THE SOUTHERN PART OF SIDNEY LIGNITE FIELD, DAWSON COUNTY, MONTANA

By Eugene Stebinger

1912

GENERALIZED SECTION OF ROCKS IN SIDNEY LIGNITE FIELD MONTANA





Index map showing position of Sidney lignite field

R. 58 E. R. 59 E. R. 60 E.

T. 22 N. T. 23 N. T. 21 N.

N. DAKOTA MONTANA

Ridgelawn
SIDNEY
U. S. R. S. CANAL
R. R. UNDER CONSTRUCTION
Missouri River
Fox Cr
Newlon
Gossett
YELLOWSTONE
Crane Cr
Crane
Berry
O'Brien Creek
BM 2000
BM 2009
Pierre

LEGEND

- Lignite bed continuously exposed; lignite underlies dotted side of exposure
- Outcrop of lignite bed covered; location uncertain
- Lignite bed burned along outcrop
- Alluvium
- Lignite mine
- Government land corner found
- Wagon road

Numbers along exposures refer to measured sections of beds on Plate XXI or in text

For southern part of coal field see Plate XXIII

A. HOEN & CO. BALTIMORE.

MAP OF THE NORTHERN PART OF THE SIDNEY LIGNITE FIELD, DAWSON COUNTY, MONTANA

By Eugene Stebinger

Scale 1/125,000

0 1 2 3 4 5 6 Miles

1912

THE CULBERTSON LIGNITE FIELD, VALLEY COUNTY, MONTANA.

By A. L. BEEKLY.

INTRODUCTION.

The Culbertson lignite field occupies the extreme northeast corner of Montana and includes approximately 1,500 square miles. It extends from the Canadian boundary line southward to Missouri River and from the North Dakota line westward to Big Muddy Creek, which

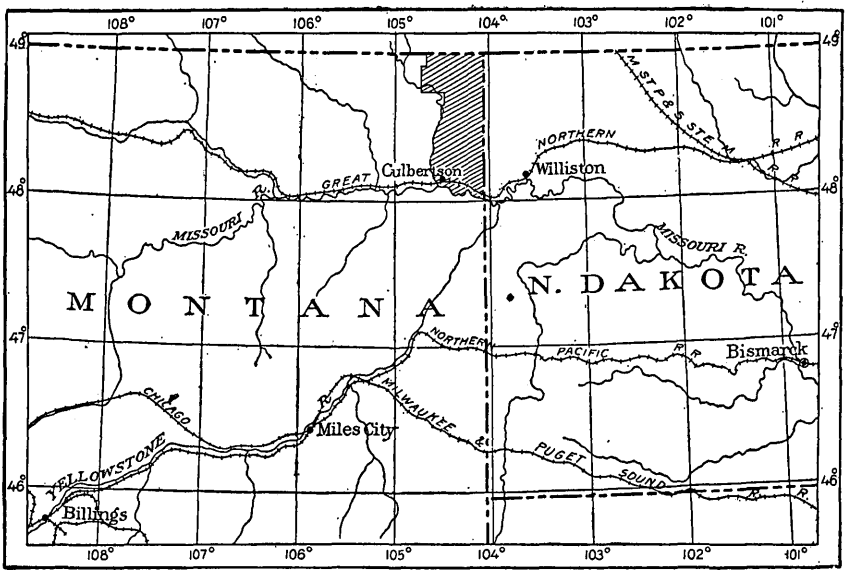


FIGURE 9.—Index map showing location of Culbertson lignite field, Valley County, Mont.

forms the east boundary of the Fort Peck Indian Reservation. (See fig. 9.)

This paper, intended primarily as an economic report, is the result of an investigation conducted by the writer during the field season of 1910 for the purpose of procuring data for the classification of the public land and the valuation of areas containing workable lignite.

The field is the northward extension of the large area known as the eastern Montana lignite field, of which the vicinity of Glendive is

probably the best-known part and the approximate north and south center.

The main line of the Great Northern Railway follows the Missouri Valley across the southern end of the Culbertson field except between Lakeside and Culbertson, where it leaves the river valley and follows a broad valley probably representing an abandoned channel of the Missouri. A recently completed branch line of the Great Northern Railway leaves the main line at Bainville and follows the valley of Shotgun Creek to its source, then passes over a low divide into Big Muddy Creek valley, which it follows northward to Plentywood. Three-fourths of the field lies within 15 miles of these railroads, and even its most remote corner, at the intersection of the eastern Montana and international boundary lines, is within 27 miles of the railroad.

Missouri River is navigable at certain seasons of the year, but since the advent of the railroad it has been practically unused as a means of transportation.

All outcropping lignite was examined in detail and mapped by stadia traverse, and approximate levels were carried throughout the area to aid in the correlation of beds. Generally speaking, the area is one of few rock exposures, and only the badland bluffs bordering the Missouri Valley afford opportunity to examine the geologic section. (See Pl. XXVI.)

The writer is indebted to Messrs. Sidney L. Galpin, Alonzo F. Farrow, Roy L. Nelson, and Louis V. Arbogast for valuable field assistance in collecting the data contained in this report. Acknowledgments are also due to Mr. W. R. Calvert, under whose general supervision the work was accomplished, for many helpful suggestions relating to both field and office work.

TOPOGRAPHY.

RELIEF.

In a general way the Culbertson field may be divided into three topographic units, as follows: An area of prominent hills and broad valleys along the Missouri, an immense flat in the central and southwest central portion, and an area of closely huddled hillocks, ridges, and troughs in the northern part and along the eastern border of the field. The southern end of the field is the much-dissected remnant of a plateau which was probably connected with the extensive upland on the south before its separation by Missouri River.

The former channel of the Missouri between Culbertson and Lakeside station on the Great Northern Railway is marked by the broad flat-bottomed valley which the railroad follows between these towns. Between this abandoned valley and the present channel of the river is an isolated portion of the former plateau aggregating perhaps 50 square miles in extent. This outlier has been reduced by erosion to

the form of a large ridge, the highest part of which lies near and parallel to the river. The south slope of the ridge breaks steeply toward the river, but from the summit northward there is a long, gradual, and comparatively smooth slope toward the railroad in the valley bottom.

The most prominent topographic feature of the field is the present valley of the Missouri, bordered either by alluvial flats from which rise steep much-dissected badland slopes or by precipitous bluffs at points where the river is cutting its north bank. In this area between Culbertson and Lakeside the hills rise from 250 to 350 feet above the river, and near the head of Rip Rap Coulee, a few miles southeast of Lakeside, the elevations above river level of the highest hilltops range from 400 to 500 feet, constituting the maximum relief of the entire field.

The topography of the much broken front facing the river has been influenced considerably by the burning of the two principal lignite beds of the field along their outcrops. These outcrops are burned only in places, and they occur at gradually increasing elevations above the river from the vicinity of Lakeside, where these beds dip below the surface, to an area northwest of Culbertson, where they disappear beneath glacial cover. The beds of baked shale and sandstone resulting from the burning of the lignite form two distinct reddish-colored slaglike horizons, one of which is stratigraphically about 75 feet above the other. These slags are much more resistant than the adjacent unaltered beds and form the cap rock of numerous small flat-topped steep-sided spurs. The result is a series of irregular-shaped mesa-like spurs separated by sharp valleys, alternating in localities where erosion is farther advanced with conical buttes separated by broader valleys. Some of these spurs and buttes are capped by the slag of the upper horizon and some by that of the lower, and together they give the topography a distinctive character which is emphasized by the striking buff to brick-red colors of the burned rocks. The color of these baked rocks varies with the degree of heat developed by the burning lignite from buff through different shades of brown, pink, and red to purple where actual fusion has taken place.

Red beds of slag and baked rocks are also prominent in the more or less rugged hills rising from the north side of the abandoned river valley. A series of flat-topped spurs and cones capped by slag occur a short distance north and northeast of Culbertson, and also northeast of Bainville along Redbank Creek, so named from the slag beds conspicuous along its banks. It is evident that while the Missouri occupied its former channel the topographic forms adjacent to its banks were quite as rugged and very similar in character to those along its present channel. Since the stream has been diverted to the new channel the sharp canyon-like valleys have partially filled,

the slopes are less steep, and the topographic forms have been rounded off.

This area of broad valleys and characteristically sculptured topography is separated from the wide flat area on the north by a prominent ridge crossing the field a few miles north of and roughly parallel to the abandoned valley of the Missouri. The central and western portion of this somewhat dissected ridge is very well defined and prominent from its termination at the east side of Big Muddy Creek valley on the west to the gap cut by Shotgun Creek on the east. From the valleys of Shotgun Creek and its tributaries eastward the ridge is dissected into a chain of hills rising from 350 to 450 feet above the lowest valley bottoms.

The summits of all the more prominent hills and ridges are more or less thickly strewn with glacial bowlders of various sizes and, except for the badlands and the more precipitous slopes, the entire area is covered with grass which grows scantily on the hills and fairly abundantly in the valleys.

In sharp contrast with the rugged topography described in the preceding paragraphs is the large plains area adjoining it on the north. Beginning at the top of the ridge which crosses the field north of Culbertson the surface slopes gently northward for a few miles, beyond which it flattens to a nearly horizontal plain. In general this flat condition prevails throughout all the area extending from the east side of Big Muddy Creek valley eastward to a few miles from the State boundary and extending northward a few miles beyond Medicine Lake and northeastward to the vicinity of Dagmar. (See Pl. XXVII.) Although this area may be broadly described as an immense flat, portions of its surface are gently rolling and somewhat broken by low rounded hills. At other localities long, smooth grass-covered slopes occur in succession, rising and falling so gently as to appear quite flat when viewed collectively. The valley of Big Muddy Creek along the west side of this portion of the field is very broad and flat and is bordered on the east by gradual slopes from the higher land on that side. These slopes steepen in places into fairly distinct benches and farther north between Reserve and Antelope the valley is somewhat narrower and the benches on either side are much more pronounced. The flat alluvial bottom of the valley is practically the only remaining part of the field over which glacial bowlders are not in evidence. In most of the flat portion of the field the scattered glacial bowlders are partly covered with soil or are concealed by the more or less abundant growth of grass covering most of the surface. Wherever the land is under cultivation, however, the presence of the bowlders is revealed, and the rock piles bordering all cultivated fields leave no doubt as to the glacial origin of the surficial rock. The drainage ways of this part of the field are

very imperfectly developed and consist mainly of a few broad, shallow, gently rounded valleys, which seem not to have been made by the small or intermittent streams now occupying them. These broad valleys, together with a few small somewhat sharply cut valleys in which stream erosion has been more active in recent time, constitute the maximum relief in this part of the field, where differences in altitude are usually less than 50 and rarely exceed 100 feet.

A broad, shallow depression, strongly suggestive of a wide preglacial river valley, extends from Medicine Lake northeastward to the border of the flat plains area and continues no less prominently across the hilly region on the northeast. Its course, which is marked by a chain of shallow intermittent lakes, the largest of which are shown on Plate XXVII, passes east of Dagmar, thence northward to the vicinity of Coalridge, where it again takes a northeasterly direction, crossing the State boundary line a few miles northeast of Hammers ranch. This long valley-like depression may have been either the preglacial channel of the Missouri or that of a large river tributary to the Missouri. It seems probable that in preglacial time this channel may have drained an immense area on the north, which the subsequent glaciers covered with a thick mantle of drift, in which no system of drainage has since developed. The occurrence of so small and sluggish a stream as Big Muddy Creek in a broad valley bordered in places by well-marked terraces also indicates that the glaciation of this region brought about marked changes in its drainage ways, as well as in other topographic features. Two typical sand dune areas of considerable size, one near Medicine Lake on the southeast and the other a short distance east and southeast of Helmers ranch, are made up of sand probably derived from the dry beds of streams or perhaps of lakes which formerly occupied the broad, valley-like depressions on the north.

The flat central part of the field gradually merges on the north and east into a region of more or less prominent hills and ridges separated by cuplike and troughlike depressions. Toward the north these hills and ridges are smaller and more closely huddled together and continue so beyond the northern limit of the field. Practically all the forms characteristic of morainal topography are represented in the surface of this area, which though comparatively rough contains few hills or ridges rising more than 200 to 300 feet above the lowest depressions. The entire surface is grass covered. Glacial bowlders ranging in size from a few inches to several feet in diameter are more or less thickly scattered over the well-rounded tops of the hills and ridges. No precipitous bluffs or steep valley walls, affording exposures of the rocks underlying the glacial material, occur in this part of the field.

DRAINAGE.

The amount of precipitation in the Culbertson field, though somewhat variable, is usually comparatively light. A large percentage of the total precipitation falls in the form of snow, which covers the surface to considerable depth in winter and melts gradually in the spring. The sandy grass-covered soil, which covers practically all of the surface, and the prevailing flat or very gently sloping topography are so favorable to the absorption of water that in this field the amount of surplus or run-off water is reduced to a minimum. The drainage system is consequently very imperfectly developed over most of the field and there still remain undrained areas in which lakes and marshes having no outlets hold all the surplus surface water.

Big Muddy Creek, which forms the west boundary of the field, and Little Muddy Creek, which empties into the Missouri near Lakeside, are the principal channels through which the flood waters of the Culbertson field are carried to Missouri River. These two streams with Red Bank Creek, which is a fork of the Little Muddy, and a small stream emptying into Big Muddy Creek in the west side of T. 28 N., R. 55 E., are the only perennial streams in the field. Big Muddy Creek is normally from 20 to 30 feet wide, but on account of its low gradient the volume of the flow is proportionately small. The water is somewhat alkaline, and because of its sluggishness it contains a great deal of organic matter and grows stale, rendering it scarcely fit for stock to drink, especially in summer. Little Muddy Creek is a somewhat smaller stream, though it flows faster and its water is less impure than that of the Big Muddy. From each of these streams channels of various sizes and lengths branch out in sufficient number to drain the major portion of the field. With the exception of Red Bank Creek and a branch of the Big Muddy, designated above as perennial streams, all these branch streams are intermittent. In summer the channels are dry except a few water holes fed by springs or seepage water, and it is only during rainy periods or during the snow-melting period in spring that water flows through them. Springs or seeps occur in many places along the dry or intermittent streams, and in some localities their flow is sufficient to maintain a chain of pools along the stream bed. These springs and seeps are most numerous along the outcrops of lignite beds, which carry most of the water of the Fort Union strata. Rain and snow water descends very readily through the mantle rock of glacial material and through the sand beds of the Fort Union formation until it reaches a lignite bed through which it flows to the surface in the nearest valleys or depressions in which the bed outcrops. The occurrence of springs along such outcrops is so common

that any spring flowing from a grass-covered valley slope or from alluvial wash in the valley bottoms is a good indication of a covered bed of lignite. In the absence of such beds fewer springs occur, and it is probable that their positions along the valleys are marked by the horizon of the water table or saturated zone, which forms immediately above the uppermost impervious clay beds of the Fort Union formation.

The flat area in the central part of the field and the area of glacial topography on the north and northeast contain a great many lakes of various sizes. Portions of these areas are not reached by the drainage system of the field, and here the surface water settles in the lowest depressions, forming broad, shallow ponds and lakes. The water of these lakes almost invariably carries alkaline salts in solution, frequently in sufficient quantities to give it a strong bitter taste. In midsummer the shallowest lakes become dry and a white powdery residue is left covering their bottoms, in some places to a depth of several inches.

Medicine Lake is a large shallow body of water lying just east of Big Muddy Creek in the broad preglacial river channel described on page 323. It is approximately 8 miles in length and its maximum width is about 4 miles. Its long axis lies in an east-west direction. The lake is fed by numerous springs and seeps along its banks and by Lake Creek, an intermittent stream which drains a considerable area on the east. The lake has an outlet at the west end in the form of an overflow channel connecting it with Big Muddy Creek. The water in Medicine Lake is strongly alkaline and grows very stagnant during the long intervals between periods when the volume of flood water from Lake Creek is sufficient to cause a current through the lake.

GEOLOGY.

STRATIGRAPHY.

The lignite-bearing rocks exposed in the Culbertson field constitute a part of the Fort Union formation, which is of early Eocene age. In order to show the relation of these rocks to older formations which underlie the field, the following summary of formations exposed in the Culbertson field and the Fort Peck Indian Reservation adjoining it on the west is compiled from data collected by the writer in 1910 and by C. D. Smith in 1908.[1]

[1] Smith, C. D., Bull. U. S. Geol. Survey No. 381, 1910, pp. 40–59.

Geologic formations in the Culbertson lignite field and the Fort Peck Indian Reservation.

System.	Series.	Formation.	Member.	Thickness (feet).	Description.
Quaternary.	Recent.				Alluvium.
	Pleistocene.			5–150+	Glacial drift; silt, sand, pebbles and bowlders.
Tertiary.	Eocene.	Fort Union formation.		1,400	Light-yellow sandstone interbedded with buff-colored sandy shale, gray and dark banded clay, and lignite beds.
Cretaceous or Tertiary.		Lance formation.		200–300	Somber and buff-colored sandstone and shale interstratified with gray clay and lignite beds.
			Colgate sandstone member.	50–150	Beds of indurated sandstone and somber and yellow clay and shale.
Cretaceous.	Upper Cretaceous.	Pierre shale.		1,000+	Soft shale, mainly dark gray, in places olive and brown.

Glacial drift.—The Culbertson field lies within the immense area of Pleistocene glaciation and is for the most part covered with glacial drift. This material, deposited by the ice which invaded the area in Pleistocene time, was probably continuous over the entire region at the close of the glacial epoch. Along Missouri and Big Muddy valleys, where postglacial erosion has been more extensive and rapid than elsewhere in the field, the glacial material has been removed, leaving the lignite-bearing rocks exposed over an area which constitutes about one-sixth of the entire field. The sheet of drift covering the remainder of the field varies greatly in thickness. In the southern part, where it was observed capping the rocks along many of the cut banks, its thickness ranges from a thin film to 25 feet. In the northeastern part no opportunity is offered for measurement of the drift, but its general appearance and the topographic forms here present seem to indicate that the maximum thickness is between 100 and 200 feet. The glacial material consists of silty bowlder clay containing, in addition to sand and gravel, a great many angular fragments and bowlders of limestone and various igneous rocks. The bowlders, which are usually somewhat worn, range in size from coarse pebbles to rocks weighing a ton or more. They are thickly scattered over a large part of the surface and were used as criteria for mapping the boundary of glacial material on Plates XXVI and XXVII. Over the flat area and the more gentle slopes, however, the bowlders have settled down in the sandy clay and are so obscured by vegetation that the limit of drift is indefinite and the boundary as mapped is necessarily an approximation.

Fort Union formation.—The lignite-bearing strata exposed in the Culbertson field belong to the Fort Union formation, which is of early Eocene age. The outcrop of these rocks may be followed continuously along Missouri River to the type locality of the formation about 2 miles east of the Montana–North Dakota boundary line, where the beds were first described and named by Hayden in 1861.[1] The formation was given the name of an army post, known then as Fort Union but later called Fort Buford, the site of which is marked by the present location of the town of Buford, N. Dak. The lowest rocks exposed in the field lie approximately 550 feet stratigraphically above the contact between beds known to be Fort Union and the Lance formation described by Smith[2] as somber-colored sandstone and clay beds.

The Fort Union formation is composed of thick beds of light-yellowish sandstone alternating with buff-colored sandy shale, gray, drab, and dark banded clays, and beds of lignite. Sandstone and sandy shale predominate and give a characteristic yellow tone to the formation except throughout a narrow somber-colored zone near the top in which the gray and dark banded clays prevail. The sandstones are locally more or less indurated and are in many places so resistant as to form ledges in the more precipitous exposures and the cap rocks of many of the hills and ridges. Sandy concretions of various forms and sizes are common in these beds. Some of them are several feet in diameter and are oval in shape, whereas others resemble petrified logs and are commonly as much as 20 feet in length and almost perfectly cylindrical. The beds are well exposed at various localities along the Missouri, especially in the north river bluff a few miles southeast of Culbertson and in the vicinity of Rip Rap Coulee a few miles east of Lakeside. In the former locality the geologic section includes approximately the lower 300 feet of strata, at the top of which occurs the most important lignite bed in the field, designated bed F. The general easterly dip of the rocks brings this bed down to the level of the alluvium in the river valley near the mouth of Rip Rap Coulee, and here all of the upper rocks of the section are present and exposed. About 2 miles east of Lakeside a group of strata is exposed in a steep bluff rising abruptly a short distance north of the railroad. The following detailed section of the beds exposed in this bluff was measured by W. H. Weed[3] in 1895, and is here quoted for the value of its descriptive details:

[1] Hayden, F. V., Proc. Acad. Nat. Sci. Philadelphia, vol. 13, 1861, p. 433.
[2] Bull. U. S. Geol. Survey No. 381, 1910, p. 43.
[3] Weed, W. H., The Fort Union formation: Am. Geologist, vol. 18, 1896, p. 209.

Section of bluff north of railroad, 2 miles east of Lakeside.

	Feet.
Sandy buff-colored beds alternating with gray beds, 3 to 5 feet in thickness. The general appearance of the upper part of the bluff is that of a smooth clay slope, as the silty wash from above partly obscures the outcrops of the strata	5
Clays, gray and ash-colored, carrying fresh-water shells, the outcrop showing a cracked and muddy surface	7
Lignite (?) seam	1
Limestone, yellowish in color and breaking into small angular bits, the largest three-fourths inch in diameter. The horizon is inconstant, the limestone really forming a lens	3
Clays, arenaceous, buff in color and forming the summit of a prominent bench that circles the bluff	4
Shale, gray, carrying shell remains	1½
Lignite seam, impure and weathering to fine carbonaceous clay	2
Shale, gray	4
Lignite seam, overlain by flaky laminated shale, carrying shell remains	5
Shales, argillaceous, ashy gray, weathering into a silty wash	15
Light-colored bed, whose outcrop is covered with an alkaline efflorescence and with the brittle shreddy fragments of limestone from the weathering of a concretion of this material, whose surface is of a rich terra-cotta color. The base of this zone forms a platform terrace that is 6 feet wide	6
Sandy beds, soft, reddish buff in color, resembling a silt in appearance and weathering with a pitted surface	15
Sands, loosely cemented, with concretions. These concretions have all shapes and sizes up to 6 feet in diameter. The bed forms a marked sandy layer but is not hard enough to weather as a ledge	25
	93½

Aside from the shell beds described in the section given above, from which the writer made a small collection in 1910, the Fort Union rocks of the Culbertson field are comparatively barren of organic remains. A fragment of a fairly well preserved fern was found near the horizon of lignite bed F in the river bluffs in sec. 12, T. 27 N., R. 56 E., and about 200 feet lower a small reptilian vertebra was found near the foot of the bluff in sec. 6, T. 28 N., R. 55 E. (Pl. XXVI). The few fossils collected were examined by T. W. Stanton and F. H. Knowlton and were said by both to be common Fort Union types. Fossil logs and stumps occur very persistently along the horizon of lignite bed G, which lies stratigraphically about 200 feet below the top of the section. As will be seen by the general section on page 331, the Fort Union formation contains an abundance of lignite beds. The persistency of these beds in thickness and in horizontal distribution indicates their formation during a period of very constant or very slowly changing conditions of deposition.

Lance formation.—The somber-colored beds described by C. D. Smith[1] as immediately underlying the Fort Union rocks of the Fort Peck lignite field are in all probability the equivalent of a series of late Cretaceous or early Tertiary beds which underlie the Fort Union formation in the vicinity of Lance Creek, Wyo., and which have, since the publication of Smith's report, been given the name of Lance formation. Although the formation does not outcrop in the Culbertson field, it is probably present throughout the area at depths ranging from 500 to 1,200 feet, depending on inequalities of the surface. In the Fort Peck field the formation is made up of about 300 feet of somber-colored shale, gray clay, and buff-colored poorly cemented sandstone interstratified with lenticular beds of lignite. The transition from the upper beds of the Lance to the Fort Union is so gradual that up to the present time no contact line has been determined with certainty. The lowest persistent lignite bed of the Fort Union, which marks a somewhat abrupt change in the color of the beds from yellow to somber, has been arbitrarily considered the approximate contact in this field. The lignite beds of the Lance formation are known to be lenticular and shaly in practically all localities in which they have been examined. Because of their depth from the surface and their inferiority to the Fort Union lignite beds they are of negligible importance in the Culbertson field.

Colgate sandstone member.—Buff-colored sandstone, interstratified with somber and yellow clay, occurs immediately below the beds described as the Lance formation in the preceding paragraph. These sandy beds, which vary in thickness from 50 to 150 feet, are predominantly sandstone and are in some localities sufficiently indurated to have influenced the topography of the area by forming more or less prominent ridges. The stratigraphic position of these beds immediately above the Pierre shale, together with their sandy character, has been considered a strong indication of their equivalence with the Fox Hills sandstone which normally overlies the Pierre shale. It now seems probable on the ground of similar lithologic character and stratigraphic position that this is the equivalent of the Colgate sandstone and is of Lance age. The type locality of the Colgate sandstone is at Colgate station on the Northern Pacific Railway, 11 miles southwest of Glendive, Mont. On the basis of fossil leaves found in the Colgate sandstone at the type locality it is mainly if not entirely of later age than the Fox Hills, as fossils identical with those occurring also in the Lance formation range downward within 60 feet of the Pierre shale. The Colgate sandstone is fully discussed by W. R.

[1] Smith, C. D., The Fort Peck Indian Reservation lignite field, Montana: Bull. U. S. Geol. Survey No. 381, 1910, pp. 40-59.

Calvert in this bulletin in connection with his report on the geology of certain lignite fields in eastern Montana, which constitute a geologic unit of which Culbertson and Fort Peck fields may be considered a part. The sandstone member does not outcrop in the Culbertson field, but was described by Smith[1] in connection with the Fort Peck field.

Pierre shale.—The outcrop of the Pierre shale nearest to the Culbertson field occurs along Missouri River about 15 miles west of Culbertson. This shale underlies the Colgate sandstone member of the Lance and is of late Cretaceous age. In the Fort Peck field[1] approximately the upper 1,000 feet of the Pierre shale is exposed. The formation is largely made up of soft dark-gray and brownish shales containing thin brownish-colored sandstone at intervals and is normally 3,000 to 5,000 feet thick.

STRUCTURE.

The Fort Union strata in and near the Culbertson field have apparently undergone but little deformation. No faults were observed in the area and the original position of the beds, which was probably approximately horizontal, has been changed only to one of slight eastward dip by a force so far-reaching as to affect the strata for a considerable distance on either side of the field. Comparative altitudes, determined along the outcrop of strata followed continuously across the field, show a general easterly dip of about 20 feet to the mile. Local variations in direction and degree of dip are common and show that the strata are gently undulating. In several localities the beds were observed to dip 2° or more in opposite directions from a central point. Such conditions, however, in most places give way within a few hundred feet to the general easterly dip. West of the Culbertson field the average dip of the strata is about 100 feet per mile, and some distance to the east in North Dakota it flattens to practically horizontal.

THE LIGNITE.

OCCURRENCE.

Lignite beds occur abundantly and are fairly well distributed throughout the strata exposed in the Culbertson field. (See Pls. XXVI and XXVII.) The adjoining area on the west also contains beds of lignite which dip to the east and may fairly be assumed to underlie the Culbertson field. These latter beds, described by C. D. Smith in his discussion of the Fort Peck field,[1] will to some extent

[1] Op. cit.

be taken into account in this report. The following general section, showing the number and thicknesses of the Fort Union lignite beds and the stratigraphic distances between them, is compiled from a section of the lower part of the formation measured between Brockton and the mouth of Big Muddy Creek by Smith and from sections of the strata exposed in the Culbertson field measured by the writer:

General section showing distribution of lignite beds in the Fort Union formation.

	Ft.	in.
Culbertson field, 2 miles east of Lakeside.		
Clay and shale	125	
Lignite bed H	4	
Clay and shale	70	
Lignite bed G	4	
Clay and sandy shale	150	
Lignite	1	10
Sandstone and clay	30	
Lignite	1	2
Sandstone and shale	55	
Culbertson field, sec. 3, T. 27 N., R. 56 E.		
Lignite bed F	7	
Sandstone and shale	45	
Lignite bed E	6	4
Sandstone with some shale	121	
Lignite	1	
Sandstone and shale	24	
Lignite bed DD	4	4
Sandstone and shale	70	
Lignite bed CC	2	5
Sandstone and clay	130	
Lignite	5	7
Fort Peck field, west of Big Muddy Creek (C. D. Smith, 1908).		
Clay	6	
Lignite bed D	9	
Sandstone and clay	95	
Lignite bed C	2	
Sandstone and clay	115	
Lignite bed B	3	
Sandstone and clay	275	
Lignite	5	
Clay	15	
Lignite bed A	7	7
Somber-colored beds.		
	1,390	3

Of the fifteen lignite beds shown in the section above, six have thicknesses of 3 feet or more at all points along their outcrops at which the lignite is accessible for measurement. The outcrops of

these beds are continuous for distances ranging from 5 to 30 or 40 miles and their persistency is a matter of little doubt. Three of the nine remaining beds are more than 3 feet thick at a number of localities on the outcrop of each bed, though exposures are not sufficiently extensive to give assurance of their persistency throughout a large area. The remaining six beds are lenticular in character and though in most places they contain less than 3 feet of lignite their thicknesses are known to range from a few inches to 4 or 5 feet.

CORRELATION WITH OTHER LIGNITE FIELDS.

In order to judge fairly the amount of lignite underlying so large an area as that of the drift-covered portion of the Culbertson field, it is necessary to view the field broadly in its relation to contiguous fields and to consider all facts bearing on the persistency of the lignite beds. In addition to the evidence contained in C. D. Smith's report on the Fort Peck field a number of pertinent facts are now available as a result of examinations of the lignite fields south of Missouri River contemporary with the work in the Culbertson field. Reports on these fields by Eugene Stebinger and others are contained in this volume.

The outcrop of bed F, of the section given above, is prominent in the bluffs south of the Missouri and was traced for approximately 110 miles southeast of these bluffs to a point where it crosses the Montana-North Dakota boundary about 40 miles southeast of Glendive. Although the bed was followed in a reconnaissance way for a distance of 15 to 20 miles south of the Missouri, correct correlation was made possible by the prominent red clinker rim which marks the outcrop and is very conspicuous in the hills and buttes of this region. Throughout the remainder of the distance the bed was studied and mapped in detail and was found to be of apparently uniform quality. The bed ranges from 4 to 10 feet in thickness, but in most localities where measurements were taken it was found to be approximately 6 feet thick.

In the Fort Peck field, bed A of the general section lies immediately above the arbitrarily fixed contact between the yellow Fort Union rocks and the somber-colored Lance beds underlying them. This bed ranges from 5 to 8 feet in thickness and at all exposures is of good quality. In the vicinity of Glendive and southward the arbitrary contact line between the Fort Union and Lance formations was mapped for 350 miles and for the greater part of this distance was marked by the outcrop of a lignite bed 4 to 6 feet in thickness.

A marked similarity exists between the general section measured north of the Missouri and that measured along the Yellowstone 60

to 75 miles farther south. The two sections contain approximately the same number of lignite beds occurring at roughly corresponding stratigraphic distances and having about equal aggregate thicknesses of lignite. It seems highly probable that several of these beds at least are continuous throughout large areas in eastern Montana and in adjacent portions of North Dakota in which the lignite is of Fort Union age.

A report on the Souris River field of eastern Assiniboia, by D. B. Dowling,[1] of the Geological Survey of Canada, furnishes valuable corroborative evidence as to the continuity of the Fort Union lignites. This field lies just north of the international boundary, approximately 45 miles east of the northeast corner of Montana. The geologic section exposed in the Souris River field is composed of approximately 100 feet of light-gray and dark shales interbedded with yellow sandstone. The identification of the fossils contained in these beds as Fort Union forms and the lithologic similarity of the rocks to those of the Culbertson field are sufficient to establish the Fort Union age of the formation practically beyond question. The Souris River section contains three persistent lignite beds, as follows: A 4-foot bed near the top, a bed ranging from 3 to 7 feet in thickness near the middle, and an 8-foot bed near the bottom. A comparison of analyses of these lignites and those of the Culbertson field shows a striking similarity in the chemical composition of the samples from both fields. The lignites of the Souris River field occur at altitudes from 300 to 400 feet lower than those of the nearest beds in the Culbertson field. This difference of altitude, considered in connection with the very slight easterly dip of the strata in the Culbertson field and the practically horizontal position of the beds in the Souris River field seems to warrant the belief that the lignite beds of the latter field may be correlated with some of those exposed in the Culbertson area. The conclusion that the Fort Union lignite beds are persistent throughout the drift-covered portion of the Culbertson field is further borne out by the fact that in the isolated areas between Missouri River and the international boundary, in which the yellow Fort Union rocks are exposed, lignite beds of workable thickness are invariably found.

QUALITY AND PHYSICAL PROPERTIES.

The lignite of the Culbertson field is for the most part of very good quality. Although its calorific value is equal to that of some of the low-grade subbituminous coals, it is still placed well within the class

[1] Dowling, D. B., Coal field of the Souris River, eastern Assiniboia: Ann. Rept. Geol. Survey Canada, vol. 15, pt. F, 1904.

of lignite by its brownish-black color, pronounced woody structure, and high moisture content. The unweathered lignite is usually hard and tough, and breaks most readily along the grain in places where the woody structure is best preserved. It is apparent from the well-defined woody structure of the greater part of the lignite itself, that a large proportion of the material from which it was formed consisted of tree trunks and coarse wood. In several localities silicified wood in fragments of considerable size occurs embedded in the lignite. Upon exposure to the air the lignite becomes very brittle and changes from brownish black to dull black in color. When a considerable quantity of the lignite is exposed to favorable drying conditions it loses moisture so rapidly that slight crackling sounds may be heard as the tension caused by loss of moisture is relieved by the development of many minute irregular cracks. On continued exposure the lignite is reduced to fine slack and finally to powder.

Although the quality as well as the thickness of the different lignite beds varies considerably and the character of a single bed changes from clean hard lignite in one locality to dirty lignite or carbonaceous shale in another, most of such variations are of local rather than of general extent. The lignites of the Culbertson and adjoining fields compare very favorably both as to persistency and quality with the lignites occurring in other formations in different sections of the country. The conditions affecting the formation of the immense marshes in which the Fort Union lignites were formed probably remained constant throughout long periods of time, and the elevations or depressions which brought about land or lakes were probably very gradual and far reaching.

CHEMICAL ANALYSES.

Samples of lignite were collected from all accessible mines and from several of the deepest prospects and other localities in which there seemed to be a minimum of deterioration through weathering.

Owing to the poor stocking quality of the lignite and to the small local demand in summer the few crudely equipped mines of the field are worked intermittently or not at all during the summer months. As a result of this inactivity favorable opportunities for collecting fresh, unweathered samples of the lignite are rare, and not more than half of the twelve samples collected for analysis are representative of the true fuel value. The effect of weathering on lignite is well shown by the analyses of a series of samples collected in a mine near Glendive. (See pp. 274–275.)

In collecting samples the utmost care was exercised to remove all slack and foreign material, such as dirt and burned blasting

powder, from the face of the bed and to channel from top to bottom of the bed to insure a representative sample. After the lignite was pulverized and thoroughly mixed, it was screened through a half-inch mesh and was sealed in a galvanized-iron can, remaining thus sealed until opened in the chemical laboratory.

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

In the table the analyses are given in four forms, marked A, B, C, and D. Analysis A represents the composition of the sample as it comes from the mine. This form is not well suited for comparative purposes, for the amount of moisture in the sample as it comes from the mine is largely a matter of accident; and consequently analyses of the same lignite expressed in this form may vary widely. Analysis B represents the sample after it has been dried at a temperature a little above the normal until its weight becomes constant. This form of analysis is best adapted to general comparisons. Analysis C represents the theoretical condition of the lignite after all the moisture has been eliminated. Analysis D represents the lignite after all moisture and ash have been theoretically removed. This is supposed to represent the true lignite substance, free from the most important impurities. Forms C and D are obtained from the others by recalculation. They should not be used in comparison, for they represent theoretical conditions that never exist.

Analyses of lignite samples from the Culbertson lignite field.

[A. C. Fieldner, chemist in charge.[a]]

Laboratory No.	Location.				No. and plate.	Designation of bed.	Thickness, part sampled.	Air-drying loss.	Form of analysis.	Proximate.				Ultimate.					Heat value.	
	Quarter.	Sec.	T. N.	R. E.						Moisture.	Volatile matter.	Fixed carbon.	Ash.	Sulphur.	Hydrogen.	Carbon.	Nitrogen.	Oxygen.	Calories.	British thermal units.
							Ft. in.													
7059	SW...	8	28	56	140*a*, Pl. XXVI...	E	5	38.7	A	43.2	22.0	29.0	5.8	0.29	.....	.....	.....	.....	3,335	6,000
									B	7.3	35.9	47.3	9.5	.48	.....	.....	.....	.....	5,435	9,790
									C	.....	38.8	51.0	10.2	.51	.....	.....	.....	.....	5,865	10,560
									D	.....	43.2	56.8	.....	.57	.....	.....	.....	.....	6,535	11,760
10724	SW...	8	28	56	140*a*, Pl. XXVI...	E	7	23.6	A	32.6	27.4	30.9	9.10	1.28	6.46	40.35	0.70	42.11	3,730	6,710
									B	11.8	35.9	40.4	11.91	1.68	5.02	52.81	.91	27.67	4,880	8,790
									C	.....	40.7	45.8	13.50	1.90	4.21	59.88	1.04	19.47	5,535	9,960
									D	.....	47.1	52.9	.....	2.20	4.86	69.23	1.20	22.51	6,400	11,520
10725	SW...	34	28	56	40, Pl. XXVI.....	E	6 6	29.2	A	38.9	27.2	27.7	6.23	.75	6.89	36.59	.74	48.80	3,340	6,010
									B	13.7	38.4	39.1	8.80	1.06	5.16	51.68	1.04	32.26	4,720	8,490
									C	.....	44.5	45.3	10.19	1.23	4.20	59.86	1.21	23.31	5,465	9,840
									D	.....	49.6	50.4	.....	1.37	4.68	66.65	1.35	25.95	6,085	10,960
10726	SE...	34	28	56	45, Pl. XXVI.....	F	7	26.3	A	35.3	31.8	25.2	7.73	1.13	6.28	34.98	.83	49.05	3,000	5,400
									B	12.2	43.2	34.1	10.49	1.54	4.56	47.46	1.12	34.83	4,075	7,330
									C	.....	49.2	38.9	11.95	1.75	3.63	54.09	1.28	27.30	4,640	8,360
									D	.....	55.8	44.2	.....	1.99	4.12	61.43	1.45	31.01	5,270	9,490
10727	NE...	3	27	56	48*a*, Pl. XXVI....	DD	4 6	26.0	A	37.5	26.8	29.6	6.06	.32	6.75	39.88	.65	46.34	3,655	6,580
									B	15.6	36.2	40.0	8.19	.43	5.21	53.89	.88	31.40	4,940	8,890
									C	.....	42.9	47.4	9.70	.51	4.13	63.82	1.04	20.80	5,850	10,530
									D	.....	47.5	52.5	.....	.56	4.57	70.67	1.15	23.05	6,475	11,660
10898	NE...	10	28	59	118, Pl. XXVI....	G	5 6	35.3	A	42.8	25.7	26.9	4.64	.24	7.21	36.21	.62	51.08	3,390	6,110
									B	11.6	39.7	41.5	7.17	.37	5.09	55.97	.96	30.44	5,240	9,440
									C	.....	45.0	46.9	8.11	.42	4.28	63.31	1.08	22.80	5,930	10,680
									D	.....	48.9	51.1	.....	.46	4.66	68.90	1.18	24.80	6,455	11,620
10899	SE...	4	31	59	154, Pl. XXVII...	G?	7 6	33.9	A	41.3	25.7	28.2	4.83	.36	7.12	37.18	.65	49.86	3,480	6,260
									B	11.2	38.8	42.7	7.30	.54	5.07	56.25	.99	29.85	5,260	9,470
									C	.....	43.7	48.1	8.23	.61	4.31	63.33	1.11	22.41	5,925	10,660
									D	.....	47.6	52.4	.....	.66	4.70	69.01	1.21	24.42	6,455	11,620

10900	NE...	19	27	59	102, Pl. XXVI...	G	4	6	33.3	A	41.6	27.1	27.2	4.08	.37	6.83	36.04	.77	51.91	3,185	5,730
										B	12.5	40.7	40.7	6.11	.56	4.69	54.04	1.15	33.45	4,775	8,600
										C	.....	46.4	46.6	6.99	.63	3.77	61.74	1.32	25.55	5,455	9,820
										D	.....	49.9	50.1	.....	.68	4.05	66.38	1.42	27.47	5,865	10,560
11002	NW...	8	34	58	164, Pl. XXVII...	F?	6	6	35.2	A	40.4	24.5	27.6	7.51	.39	6.94	35.15	.57	49.44	3,240	5,830
										B	8.0	37.8	42.6	11.59	.60	4.68	54.25	.88	28.00	5,000	9,000
										C	.....	41.1	46.3	12.60	.65	4.[illegible]	58.99	.96	22.69	5,435	9,780
										D	.....	47.0	53.0	.....	.74	4.70	67.50	1.10	25.96	6,220	11,190
11003	NE...	6	31	56	155, Pl. XXVII...	DD?	3	6	33.2	A	39.3	24.2	30.8	5.74	.53	6.92	37.80	.65	48.36	3,490	6,280
										B	9.1	36.2	46.1	8.60	.79	4.83	56.59	.98	28.21	5,220	9,400
										C	.....	39.8	50.7	9.46	.87	4.20	62.28	1.07	22.12	5,745	10,350
										D	.....	43.9	56.1	.....	.96	4.64	68.79	1.18	24.43	6,350	11,430
11004	NW...	11	29	55	150, Pl. XXVII...	F	7	10	31.3	A	37.8	25.8	30.9	5.51	.75	7.01	39.66	.71	46.36	3,720	6,700
										B	9.1	37.7	45.2	8.05	1.10	5.13	57.90	1.03	26.79	5,435	9,780
										C	.....	41.5	49.7	8.85	1.20	4.53	63.69	1.14	20.59	5,975	10,760
										D	.....	45.5	54.5	.....	1.32	4.97	69.87	1.25	22.59	6,560	10,800
11005	SW...	15	29	55	149, Pl. XXVII...	F	5		35.0	A	40.8	25.2	27.8	6.23	.72	7.11	36.57	.68	48.69	3,415	6,150
										B	8.8	38.8	42.8	9.58	1.10	4.96	56.26	1.04	27.06	5,255	9,460
										C	.....	42.5	47.0	10.51	1.22	4.35	61.71	1.15	21.06	5,765	10,370
										D	.....	47.5	52.5	.....	1.36	4.86	68.95	1.29	23.54	6,440	11,590
11006	SW...	30	33	56	158, Pl. XXVII...	DD?	5	6	35.6	A	41.6	26.7	26.1	5.57	.40	6.81	33.48	.66	53.08	2,930	5,280
										B	9.4	41.4	40.6	8.65	.62	4.42	51.98	1.03	33.30	4,555	8,200
										C	.....	45.7	44.8	9.54	.69	3.73	57.36	1.13	27.55	5,025	9,040
										D	.....	50.5	49.5	.....	.76	4.12	63.41	1.25	30.46	5,555	10,000

[a] All analyses except No. 7059 were made at the laboratory of the Bureau of Mines at Pittsburgh, Pa.

No. 7059.—This sample was taken in 1908 from the Bruegger mine (No. 140*a*, Pl. XXVI) by C. D. Smith. It was cut from the entire thickness of the bed about 200 feet from the mouth of the entry. The lignite was reported dry in the mine.

No. 10724.—From the main entry in the Bruegger mine (No. 140*a*, Pl. XXVI), about 75 feet north of the opening. The mine was idle and the entry floor was covered with water beyond this point. The bed contains no partings of foreign material and consists of hard, black lignite, with the exception of a variable thickness in the central portion, which is soft, and has a slacked appearance. The lignite was probably weathered to considerable extent through long exposure to the air.

No. 10725.—From bed E in the Dempsey mine (No. 40, Pl. XXVI). The sample was taken at the face of the entry, about 60 feet N. 15° W. from the opening. The mine had been idle for a considerable length of time and the lignite was weathered to some extent. The bed was free from shale or bone partings and consisted of alternating hard and soft layers of dry lignite.

No. 10726.—From bed F, in an abandoned prospect about 3½ miles southeast of Culbertson (No. 45, Pl. XXVI). The sample was taken from the face of the entry about 50 feet east of the opening. The lignite bed is 7 feet thick, dry, and free from partings. Although a considerable quantity of lignite was removed from the face of the bed before sampling, it is probable that the sample was considerably weathered and that the calorific value shown in the analysis does not represent the true efficiency of the fuel.

No. 10727.—From bed DD in the Butterfield mine (No. 48*a*, Pl. XXVI), about 3¾ miles southeast of Culbertson. The sample was taken from the face of the entry, about 150 feet north of the mine opening. The bed is free from partings and measures 6 feet in thickness, of which all but the upper 18 inches was sampled. The recently worked face of the lignite was hard and dry, and the sample was fresh and unweathered.

No. 10898.—From bed G at the Red Bank open-cut mine (No. 118, Pl. XXVI). Lignite is dug from the bank only intermittently and at the time this sample was collected the face of the bed had been exposed to the air for several weeks. The lignite was undoubtedly somewhat weathered, although the face was well stripped down before the sample was taken. The bed consists of 5 feet 6 inches of hard, woody lignite, the lower foot of which carries water.

No. 10899.—From the Belgon open-cut mine (No. 154, Pl. XXVII). Considerable lignite is mined here for local use, and at the time the sample was collected the working face of the bed was fresh and practically unweathered. The bed is free from partings and contains 10 feet of tough, brownish black lignite, which is damp throughout and heavily water-bearing near the base. This lignite has much the same general appearance as that of bed G at the Red Bank mine, and it occurs very near the altitude at which that bed should be found at this locality. The Red Bank and Belgon mines are separated by so wide a covered area, however, that the correlation is doubtful.

No. 10900.—From bed G, in an abandoned open-cut mine about 2 miles east and slightly north of Lakeside (No. 102, Pl. XXVI), neighboring farmers had obtained their fuel from this bank during the winter, but at the time the sample was collected no work had been done here for several months, and the surface of the bed was considerably slacked. The bed is covered at this locality by only 10 to 15 feet of sandy shale, and the soft, somewhat dirty condition of the lignite is probably due to the action of surface water.

No. 11002.—This sample was taken from the lignite bed mined in the Coalridge mine (No. 164, Pl. XXVII). It is impossible to definitely correlate this bed with any of those mined farther south because of the wide intervening covered area in which no exposures occur. Assuming that the dip remains constant, however, the elevation of the Coalridge bed indicates its occurrence at about the horizon of beds E or F in the Missouri River section. The Coalridge mine was in operation almost up to the time of sampling, and the working face of the bed from which the sample was taken was fresh and unweathered. The bed contains 10 feet of lignite of which only the central 6½

feet was sampled. This portion of the bed is free from partings and comparatively dry throughout.

No. 11003.—From the lignite bed mined in the Ted Young mine, which overlooks the west end of Medicine Lake (No. 155, Pl. XXVII). Comparative altitudes show that this bed probably corresponds to the bed DD of the general section. The sample was taken from the freshly worked face of the entry and was unaffected by weathering. The bed is 3½ feet thick, free from partings, and exceptionally dry.

No. 11004.—This sample was taken from lignite bed F, which was found at a depth of 30 feet in a new well on the Watts place, about 4 miles southwest of Froid (No. 150, Pl. XXVII). The 30 feet of strata overlying the lignite is composed for the most part of hard and practically impervious clay, and to the character of this material is due the hard, clean, and apparently unaltered condition of the lignite. The bed is dry, free from partings, and measures 7 feet 10 inches in thickness.

No. 11005.—From bed F in the main entry of the Astrope mine (No. 149, Pl. XXVII). The lignite was sampled at the working face of the entry, and as the mine was in operation at the time the sample was fresh and unweathered. The bed contains 5 feet of clean, hard lignite overlain by 1 foot of soft shaly carbonaceous material. The lower part of the bed carries considerable water.

No. 11006.—From a 7-foot lignite bed worked in the Jones mine, about 6 miles northeast of Medicine Lake (No. 158, Pl. XXVII). The sample was taken from the freshly worked face of the entry and was unweathered. The bed consists of alternating hard and soft layers of lignite, but is free from partings of shale or bone. The sample represents only the lower 5½ feet of the bed as the upper part is left for a roof. Although the altitude of the Jones mine is slightly higher than that of the Ted Young mine, slight local changes of dip would be sufficient to cause the difference, and it is highly probable that these two mines are on the same lignite bed.

DESCRIPTIONS BY TOWNSHIPS.

Although the lignite-bearing rocks in the larger part of the Culbertson field are covered with glacial material and many whole townships are without a single exposure, the townships in which the beds of lignite outcrop will be considered individually so that the important facts may be most easily grasped by those interested in the field. The extent, continuity, and general relations of the lignite outcrops are shown in Plates XXVI and XXVII in as great detail as the exposures in the field permit. By reference to these maps and to the lignite sections in Plate XXV the details of the following township descriptions may be so fitted together as to give a broad view of the field without sacrifice of details. Beginning at the south side of the field each tier of townships is considered from west to east.

T. 26 N., R. 59 E.—In this township the principal lignite bed exposed north of Missouri River is bed G of the general section. It occurs near the top of the badland bluffs in secs. 1, 2, and 3. It is thin in sec. 1, ranging from 20 inches at location 72 to 27 inches thick at locations 73 and 74. At location 75, sec. 2, it is 2 feet 7 inches thick and at location 83, sec. 3, it is 3 feet thick. The lignite is thinner and of poorer quality than the same bed in the two townships north of this one. The decrease in thickness and change in quality of this bed is apparent between the exposures a few miles

to the northwest, where the lignite is of good quality and about 4 feet thick, and the exposures in this township, where the lignite is slacked and dirty and 3 feet or less in thickness.

In sec. 1, a higher lignite bed, probably bed H of the general section, outcrops for a short distance. Variations are evident in the thickness and quality of this bed, which also outcrops in the township to the north, similar to the variation described in bed G. The records of two wells, one drilled in the SE. ¼ sec. 11 and the other near the center of sec. 13, indicate the presence of a lignite bed not far below river level. In the first well a 7-foot bed of hard lignite was drilled through at a depth of 165 feet and in the second well a 4-foot bed was pierced at a depth of about 90 feet.

T. 27 N., R. 56 E.—In the portion of this township lying north of the Missouri four beds of lignite outcrop along the river bank and in the adjacent bluffs. (See Pl. XXVI.) Beginning with the lowest, these beds are equivalent to the beds designated CC, DD, E, and F in the general lignite section. The outcrops of beds CC and DD extend across secs. 2, 3, and 12, and are almost coincident with each other. The lower bed CC has a thickness of 5 feet 6 inches at location 48, sec. 3, as shown in Plate XXV. It holds the same thickness and character at location 51, sec. 2, but southeast of the last-mentioned place it decreases rapidly, showing two beds 18 inches thick separated by 6 feet of shale at location 59, 19 inches at location 60, and 24 inches at location 61. The quality is also variable, ranging from hard black lignite through shaly lignite to carbonaceous shale. Bed DD, which is fairly persistent, generally ranges between 3 and 5 feet in thickness, and at the Butterfield mine, No. 48*a*, reaches its maximum measured thickness of 6 feet. Eastward from the mine the thickness of the bed decreases to 2 feet 9 inches at location 50 and less than 1½ feet at the east township line. The lignite in the Butterfield mine is of very good quality.

Beds E and F outcrop near the tops of the steep hills and ridges in secs. 1, 2, 3, and 12. In this area bed E is extremely impure. It is well represented by sections 44, 54, and 57 in Plate XXV. It was also measured at other places along the outcrop, showing 6 feet 8 inches thick at location 47, 6 feet at location 49, 7 feet at location 56, and 6 feet 10 inches at location 58. Bed F is slightly thinner, as shown by sections 46, 52, and 55. It was also measured at location 53, where the bed has the same thickness that it has at location 52. These beds are apparently very similar in quality, and though somewhat variable each has an average thickness of 6 to 7 feet in this township and in the adjoining sections of the township to the north. The higher fuel value of bed E (analysis No. 10725) over that of bed F (analysis No. 10726), at localities 40 and 45 in the township north, is probably due

to the thinness of cover over the upper bed and also to its continued exposures in the shallow prospect in which the sample was collected.

Beds DD, E, and F are burned along their outcrops in many localities in this township. Where combustion has taken place, thick beds of red slag and baked shale plainly mark the position of the lignite, and owing to their hardness and resistance to erosion are prominent as the cap rocks of many of the small buttes and ridges.

In the south bank of the Missouri, near the ferry south of Culbertson, a 6-foot bed of lignite outcrops within 10 feet of water level. This bed was observed from the north river bank, and as it was not sampled nor examined closely the quality is not known. In the alluvial flat occupying the western part of the township north of the river this bed is probably not present, having been cut away by the stream before the river shifted to its present channel. It is probably present, however, near or slightly below the river level in secs. 1, 2, 3, and 12.

T. 27 N., R. 57 E.—Bed CC, which is the lowest outcropping lignite in this township, occurs near the base of the river bluffs just above the valley floor. It ranges in thickness from 6 feet at location 62, in sec. 18 (Pl. XXVI), to 2 feet 6 inches and 2 feet 10 inches at locations 64 and 66, and to 1 foot 9 inches at location 63, in sec. 17. Southeast of location 66, sec. 20, the bed soon passes below the limit of 30 inches and beyond the center of sec. 27 its outcrop could not be traced.

The outcrop of bed DD was followed across the corner of sec. 7, and halfway across sec. 18, east of which it could not be found.

Beds E and F are the most important and most persistent of those outcropping in the township. They are exposed at many localities in the bluffs facing the river, and although they are almost entirely grass covered along the north slope of the ridge which separates the Missouri from its abandoned valley on the north the horizon was carefully followed and the boundaries of the beds are probably approximately correct as mapped. Sections 67, 69, and 70 show that bed E maintains a fairly uniform thickness of nearly 7 feet across this township. Sections 65 and 68 show that bed F holds a similar thickness wherever it was measured. These beds are burned along their outcrops over much of the sharply dissected territory north and east of the Diamond ranch, and their positions are plainly marked by the thick beds of red slag and baked shale.

According to reports of a well which was drilled some years ago near the northwest corner of sec. 35 a bed of lignite 20 feet thick was pierced by the drill at a depth of about 90 feet below the surface. This report was verified by ranchmen of the community who express the opinion that the lignite lies approximately 75 feet below river level.

T. 27 N., R. 58 E.—Exposures are almost entirely lacking in this township, and very little information concerning the lignite is available. The outcrops of beds E and F were found in places across sec. 31, and exposures of bed F or the slag formed by its burning were found in secs. 28 and 32. The outcrops of these two beds were followed along the west side of Little Muddy Creek Valley, thence northwestward several miles into the adjoining township and back into sec. 6 of the township under discussion. (See Pl. XXVI.) The inferred positions of these outcrops were sketched from planetable stations on a traverse and level line carried along the horizon of the lignite bed. The line between secs. 13 and 24 lies along the top of a ridge, the altitude of which is sufficient to admit of the presence of lignite beds E and F. The inferred boundary of bed F is mapped around the point of this ridge and is believed to be approximately correct as the line of outcrop is connected with exposures of this bed which occur at places in the surrounding territory. Bed E, however, is covered in this vicinity, and the mapping of its probable outcrop was discontinued in the township to the north.

That the township is underlain by a lignite bed at considerable distance below bed E is indicated by the following reports of wells drilled in and near the township: In the N. ½ sec. 22 a lignite bed about 8 feet thick was penetrated at a depth of about 175 feet below the surface; in the SE. ¼ sec. 31 of the next township north a lignite bed 12 feet thick was encountered about 185 feet below the surface; and in the NE. ¼ sec. 7 of the township east a lignite bed approximately 15 feet thick was found at a depth of 180 feet. The depth at which the lignite is reported to occur in these wells, considered in connection with surface altitudes, indicates the presence of a persistent lignite horizon, probably that of bed DD, about 150 to 200 feet stratigraphically lower than bed E. The only definite measurement of lignite recorded in this township was made in an abandoned prospect at location 71 near the center of sec. 32, at which point bed F contains 6 feet of brownish-black lignite. Although considerably weathered and somewhat dirty, the lignite is apparently of fair quality.

T. 27 N., R. 59 E.—Beds F, G, and H of the general section (p. 149), outcrop in the escarpments and on the slopes of the large mesa or plateau which occupies the central and eastern part of the township. Two partial exposures of bed F were found at locations 110 and 111. The 28-inch and 36-inch measurements taken at these localities represent only a part of the bed, complete measurement being impracticable because of the quantity of water present.

In Rip Rap Coulee, secs. 28 and 33, the outcrops of two thin lignite beds were found between the F and G horizons and were followed for a short distance along the stream bed. Stratigraphically, these beds

occur 55 and 85 feet, respectively, above bed F. The lower bed measures 14 inches at location 88 and 22 inches at location 89, and the upper bed measures 22 inches at location 85. The absence of these beds in an exposure of the same horizon a short distance farther west is proof of their lenticular character.

Beds G and H, which outcrop in the badland slopes near the top of the bluffs, are in many localities exposed to view throughout distances ranging from a few feet to several hundred feet. These are the most easily accessible and at present the most important beds in the township. Bed G occurs approximately 200 feet above bed F and its thickness where exposed and measured in this township is given in the following table:

Thickness of lignite bed G in T. 27 N., R. 59 E.

No.	Quarter section.	Thickness.
		Ft. in.
76	NE. ¼ sec. 35	3
77	NE. ¼ sec. 35	2 10
78	NW. ¼ sec. 35	2 8
79	SW. ¼ sec. 35	2 8
80	NE. ¼ sec. 34	2 10
81	NE. ¼ sec. 34	2 8
82	SE. ¼ sec. 34	2 10
84	SE. ¼ sec. 33	4 4
86	SE. ¼ sec. 28	3 4
87	SE. ¼ sec. 28	4 6
90	NW. ¼ sec. 28	4
91	SW. ¼ sec. 28	4
92	SW. ¼ sec. 28	3 4
93	NW. ¼ sec. 33	3 8
94	SW. ¼ sec. 28	3 6
95	SW. ¼ sec. 28	4 2
96	SE. ¼ sec. 29	4 2
97	NE. ¼ sec. 29	4
98	NW. ¼ sec. 28	4 2
99	NE. ¼ sec. 29	4
100	SE. ¼ sec. 20	4
102	NE. ¼ sec. 19	4 6
103	NE. ¼ sec. 19	4
104	NE. ¼ sec. 19	4
106	SE. ¼ sec. 18	4 8
107	NW. ¼ sec. 17	4 6
108	SE. ¼ sec. 8	3 8
109	SE. ¼ sec. 8	4
112	NW. ¼ sec. 15	3+
113	SE. ¼ sec. 15	8
114	NE. ¼ sec. 14	4

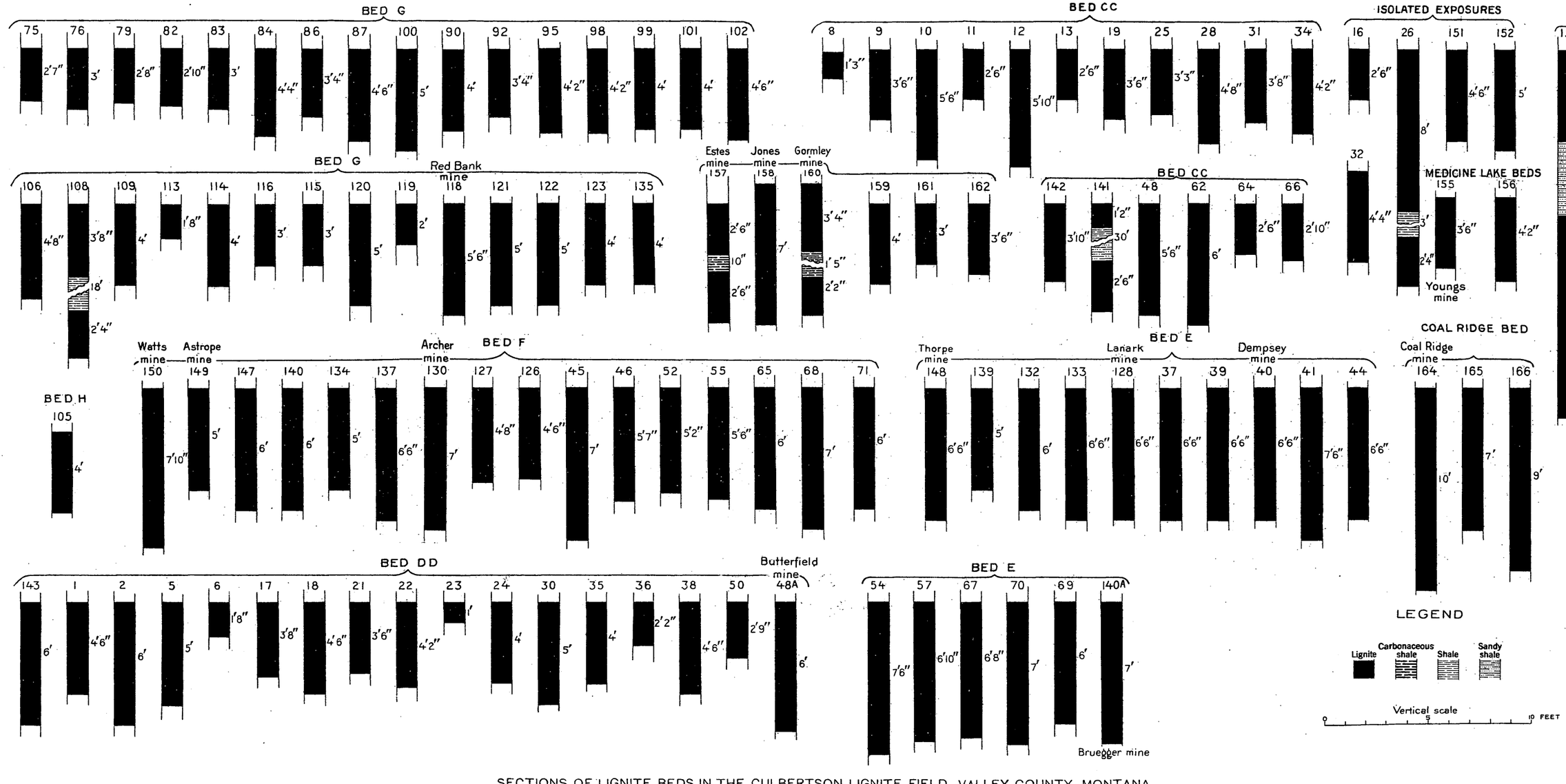
The quality of this lignite is not perceptibly different from that of bed CC. It has a shaly appearance on the outcrop and is very much slacked by long exposure to the weather. The analysis (laboratory No. 10900) of a sample from this bed, taken at location 102 in sec. 19, is shown in the table of analyses on page 336. The sample had undoubtedly suffered much deterioration through weathering, so the analysis does not represent the true fuel value of the unaltered lignite. Bed H lies about 70 feet stratigraphically above bed G at locality 105 and is the uppermost lignite bed in the entire section. It is 4 feet thick

and is apparently very similar to bed G in physical characteristics and quality.

T. 28 N., R. 55 E.—The lowest lignite beds in the Culbertson field outcrop along the face of the bluff which overlooks the Missouri and Big Muddy Creek valleys. The lowest of these, lying almost on the level of the valley floor, is represented by sections 16, 26, and 32, in Plate XXV. These measurements show a great increase in thickness of the bed toward the south, but the presence of a section only 27 inches thick at location 29 shows that this increase is irregular and that the bed is very lenticular. The lignite is very soft and dirty and is of doubtful commercial value.

Next above this bed, and separated from it by a stratigraphic distance of about 125 feet, is the bed designated CC in the general section. Its outcrop was found at places, crossing the township in a northwest-southeast direction. Its thickness is shown in Plate XXV by sections 8, 9, 10, 11, 12, 13, 19, 25, 28, 31, and 34. These show the bed increasing from a thickness of 15 inches at location 8, sec. 6, to 5 feet 6 inches at location 10 and 5 feet 10 inches at location 12. Curiously, at location 11, which is midway between two locations showing a good thickness, the bed is thin. A similar condition holds at location 13, but beyond this place it gradually increases in thickness to 4 feet 8 inches at location 28, sec. 35, and 4 feet 2 inches at location 34, sec. 36. At location 33, near the west line of sec. 36, the bed is 4 feet thick. Where observed along the outcrop this bed was considerably weathered and appeared somewhat slacked and dirty. The unweathered lignite, however, is probably of very fair quality. It has been mined to some extent near the center of sec. 25 and the quality of the fuel is said to be fairly good. At the time the Culbertson field was examined this mine was not accessible.

Bed DD, which is the highest workable lignite in the township, occurs approximately 70 feet stratigraphically above bed CC. Its outcrop was found only along the bluff in the SE. ¼ of the township and across the corner of sec. 6. The bed is decidedly lenticular, as shown by the sections in Plate XXV. At location 1, on the north line of the township, in sec. 6, the thickness of the bed is 4 feet 6 inches. This increases to 6 feet at location 2 but drops down to 5 feet at locations 3, 4, and 5. South of the last-mentioned location the bed thins to 20 inches at location 6, and 6 inches at location 7. Beyond this place it was not noted for several miles along the outcrop line, except at locations 14 and 15, sec. 16, where measurements of 10 and 18 inches respectively were obtained. At location 7, sec. 27, the bed is 3 feet 8 inches thick, but increases to 4 feet 6 inches at location 18. It drops down to 4 feet 2 inches at location 20, and for the remainder of the distance across the township shows the thicknesses given in sec-



SECTIONS OF LIGNITE BEDS IN THE CULBERTSON LIGNITE FIELD, VALLEY COUNTY, MONTANA

tions 21, 22, 23, 24, 30, and 35, except that at location 27 it is 3 feet 6 inches thick.

T. 28 N., R. 56 E.—In Diamond Coulee, about a mile northwest of Culbertson, two lignite beds outcrop in a cut bank of the creek. The lower of these, which occurs partly below the bed of the stream at location 142, is 46 inches thick, and the upper, 30 feet higher, at location 141, is only 14 inches thick. Although the outcrop of the lower bed could not be followed continuously from this exposure to the mine on bed CC in sec. 25 of the township west, in all probability it marks the eastward continuation of bed CC. The 14-inch bed probably represents bed DD of T. 28 N., R. 55 E., although its occurrence only 30 feet above the lower bed makes the correlation somewhat doubtful. The only additional exposures of either of the lower lignite beds in this township are on bed DD at locations 36, 38, 42, and 43 in secs. 33 and 34. Sections 36 and 38 are shown on Pl. XXV. At locations 42 and 43 the lignite is 4 feet 6 inches thick, the same as at location 38. The gentle eastward dip of the formation considered in connection with comparative altitudes and the similarity in character of the lignite is sufficient evidence for the correlation of this bed with the DD bed described in T. 28 N., R. 55 E. The position of the covered outcrop of the bed in the valley east of Culbertson is dependent upon the depth and profile of the valley before it began to fill with sediment washed down from the surrounding country.

The outcrops of beds E and F which cross the township in the north-central part are burned in many places and are marked by conspicuous beds of red slag and baked shale. These beds are separated by a stratigraphic interval ranging between 50 and 70 feet. Bed E outcrops across the township just north of the center and also around the point of the highland in secs. 33, 34, and 35. In the last-mentioned locality it is represented in Plate XXV by sections 37, 40, and 41. It was also measured at location 39, but its thickness is the same as that at location 37. In the northern part of the township bed E was measured at four places and its thickness is shown by sections 132, 133, 139, and 140*a*. The section last mentioned was measured at the Bruegger mine, in sec. 8, from which considerable lignite has been mined for local use. Bed F was measured at one place only in the southern part of the township and its thickness at this place is shown in section 45, Plate XXV. In the northern part it is represented at locations 134, 137, and 140. It was also measured at location 138, but its thickness here is the same as at location 137. In practically all of the exposures the lignite is badly weathered and near the surface is very dirty. When the slacked portion is removed, however, the less weathered lignite is found to be tough and rubbery, brownish black to black in color, and lustrous in streaks. Nos. 10724, 10725, and 10726 in the table of analyses (p. 336) indicate that

bed E is of slightly better quality than bed F, although the difference is not apparent in the physical characteristics and appearance of the two beds. In sec. 9 the outcrop of a lignite bed was found about 75 feet stratigraphically above bed F, which from its relation to that bed probably should be correlated with bed G of T. 27 N., R. 59 E. At location 135 this bed measures 4 feet (Pl. XXV) and at location 136 lignite 2 feet 6 inches thick is exposed, but the bottom of the bed is inaccessible.

T. 28 N., R. 57 E.—Only beds E and F outcrop in this township and for the most part these outcrops are concealed by a cover of soil and grass. Bed E is exposed at only one place in this township and that is the Lanark mine, location 128, on the line between secs. 22 and 27. This mine is at present abandoned, and the section shown in Plate XXV was measured only a short distance in from the mouth of the tunnel. The quality of the bed is probably much better beyond the zone of weathering, its muddy appearance being no doubt due to long exposure to circulating air and surface water. In sec. 28, near Lanark station, there are still evidences of an opening on bed E known as the Old Government mine, in which lignite is reported to have been mined years ago. Measurement of the bed at this point is impossible, as the lignite is no longer accessible.

Three openings were found on bed F, one at location 129 in the west side of sec. 17, in which 6 feet of lignite was measured without reaching the bottom of the bed, and two others at locations 130 and 131 (Pl. XXVI) in sec. 18, in each of which complete measurements of 7 feet were made. The opening near the center of sec. 18 is known as the Archer mine, and at this locality considerable mining has been done by stripping off the shale which overlies the lignite.

The lignite beds are traceable in the western part of the township by their relation to more or less prominent exposures of sandstone and shale baked to a brownish-red color by the burning of the lignite along its outcrop.

T. 28 N., R. 58 E.—Although the lignite outcrops are entirely concealed over most of this township the lines along which the outcrops should occur, were they not covered by soil and grass, are indicated on Plates XXVI and XXVII by broken lines. The supposed outcrops of both bed E and bed F were mapped along the south and west sides of Shotgun Creek valley. Mapping of the inferred outcrop of bed E was discontinued east of Shotgun Creek because of the uncertainty as to its location. Owing to the easterly dip of the formation, bed E in this locality is well down in the valley floor. Lignite was found in three localities along the supposed outcrop of bed F, which follows the north side of Shotgun Creek valley, across the township in a northwest-southeast direction. In a prospect at

location 127, in sec. 7, the bed measures 4 feet 8 inches in thickness and appears shaly and very much weathered. At location 126, in the south side of sec. 9, the same bed contains 4 feet 6 inches of lignite very similar to that exposed in sec. 7. At what is supposed to be the horizon of bed F, near the southeast corner of sec. 24 (location 125), a bed of lignite is exposed in a small excavation made around a spring. The lignite carries much water and is the source of supply of several springs in the immediate vicinity. Owing to the presence of water a satisfactory measurement of the bed could not be obtained and it is probable that the 14 inches of lignite measured does not include the entire bed.

An outcrop supposed to be that of bed G, which outcrops prominently in the next township east, was mapped for several miles in the northeast quarter of the township, but no exposure of the bed could be found. At location 124, in the south half of sec. 12, a lignite bed 1 foot 11 inches thick occurs about 60 feet stratigraphically above the horizon of bed G. This position makes possible its correlation with bed H, as that bed is exposed in T. 27 N., R. 59 E.

T. 28 N., R. 59 E.—The occurrence of lignite exposures along the outcrop of the horizon of bed F, to the west and south of this township is a strong indication that, although completely obscured by surface cover, bed F underlies that part of the township in which the surface elevations are sufficiently high to admit of its presence. The approximate location of the covered outcrop of the bed is indicated on Plate XXVI by the broken line bordering the valleys of Red Bank and Little Muddy creeks. Bed G, which is described in connection with T. 27 N., R. 59 E., also outcrops prominently in the much-dissected badlands in the north half of this township. In much of this area the bed is burned along its outcrop, which is well marked by conspicuous remnants of brick-red clinker beds and baked shale. The thickness of this bed is well shown by sections 115, 116, 118, 119, 120, 121, 122, and 125 in Plate XV. At location 117 only the upper part of the bed, measuring 2 feet 6 inches, is visible. The thickness of the lignite ranges from 3 to 5½ feet, with a probable average of about 4 feet. The quality of lignite exposed in the open cut known as the Red Bank mine (No. 118) is comparatively good. Although somewhat weathered it is very hard and tough and has a lustrous black color. Analysis No. 10898 in the table on page 154 represents a sample from this mine.

T. 29 N., R. 54 E.—The outcrops of beds CC and DD, which are described in connection with T. 28 N., R. 55 E., occur along the east side of Big Muddy Creek valley.

An abandoned prospect on a bed at location 146*a*, in sec. 9 (Pl. XXVII), is caved in and no longer accessible. It is reported that a fair quality of lignite several feet in thickness was formerly mined at

that locality. The outcrop of the bed was mapped for a few miles near the creek southward from the vicinity of Helmers ranch, but it could not be connected with the outcrop of bed CC near the river with which it has been correlated.

The outcrop of bed DD is exposed nearly across the township on the east side of Big Muddy Creek. Its thickness at location 143 is indicated in Plate XXV. At location 144 it holds the same thickness of 6 feet, but farther north complete sections could not be obtained. At location 145 3 feet of lignite was measured and at location 146 2 feet, but in both places the bottom of the bed was concealed. The quality of bed DD is apparently only fair. The lignite is soft and in places somewhat shaly. Settlers who have dug this lignite from the bank in the south part of the township report that it is a fairly satisfactory domestic fuel.

T. 29 N., R. 55 E.—Two lignite beds of considerable thickness outcrop in the west-central part of the township along intermittent stream courses. Although these outcrops are separated from the nearest exposure of beds E and F in T. 28 N., R. 56 E., by 5 or 6 miles of drift-covered territory, they are correlated with those beds on the basis of corresponding altitude, stratigraphic distance apart, and thicknesses of bed. At location 147 (Pl. XXVII) in the NE. ¼ sec. 19, on George Damm's place, a prospect pit has been dug through 6 feet of soft dirty lignite which probably represents bed F and lies only a few feet below the surface of the ground. The bed at this locality contains so much shale and has so deteriorated through the action of surface water that it has practically no fuel value. In the Thorpe mine, location 148, in the NE. ¼ sec. 20, the total thickness of bed E is 6½ feet. At a distance of 80 feet in from the mouth of the drift the upper half of the bed consists of soft slacked lignite. The lower half is hard brownish-black lignite apparently of fair quality. The Astrope mine, location 149, in the SW. ¼ sec. 15, is probably in bed F, although the covered condition of the outcrops in this vicinity makes accurate correlation impossible. The bed contains 5 feet of hard black lignite overlain by 1 foot of soft shaly carbonaceous material and has a hard sandy clay roof and clay floor. The quality of the lignite in this mine is comparatively good as shown by analysis No. 11005 in the table. At location 150 in the NW. ¼ sec. 11, a bed of lignite 7 feet 10 inches thick was found at a depth of 30 feet in a shaft dug on the Watts place. This lignite underlies a hard almost impervious clay and is apparently unaffected by weathering.

The fresh lignite is fairly hard and black and except for several thin dull streaks it has a shiny luster. As shown by analysis No. 11004 in the table, the lignite is of excellent quality and is said to be a first-class domestic fuel. It is reported that, in drilling wells in the southeastern part of the township, thicknesses of 5 to 6½ feet of

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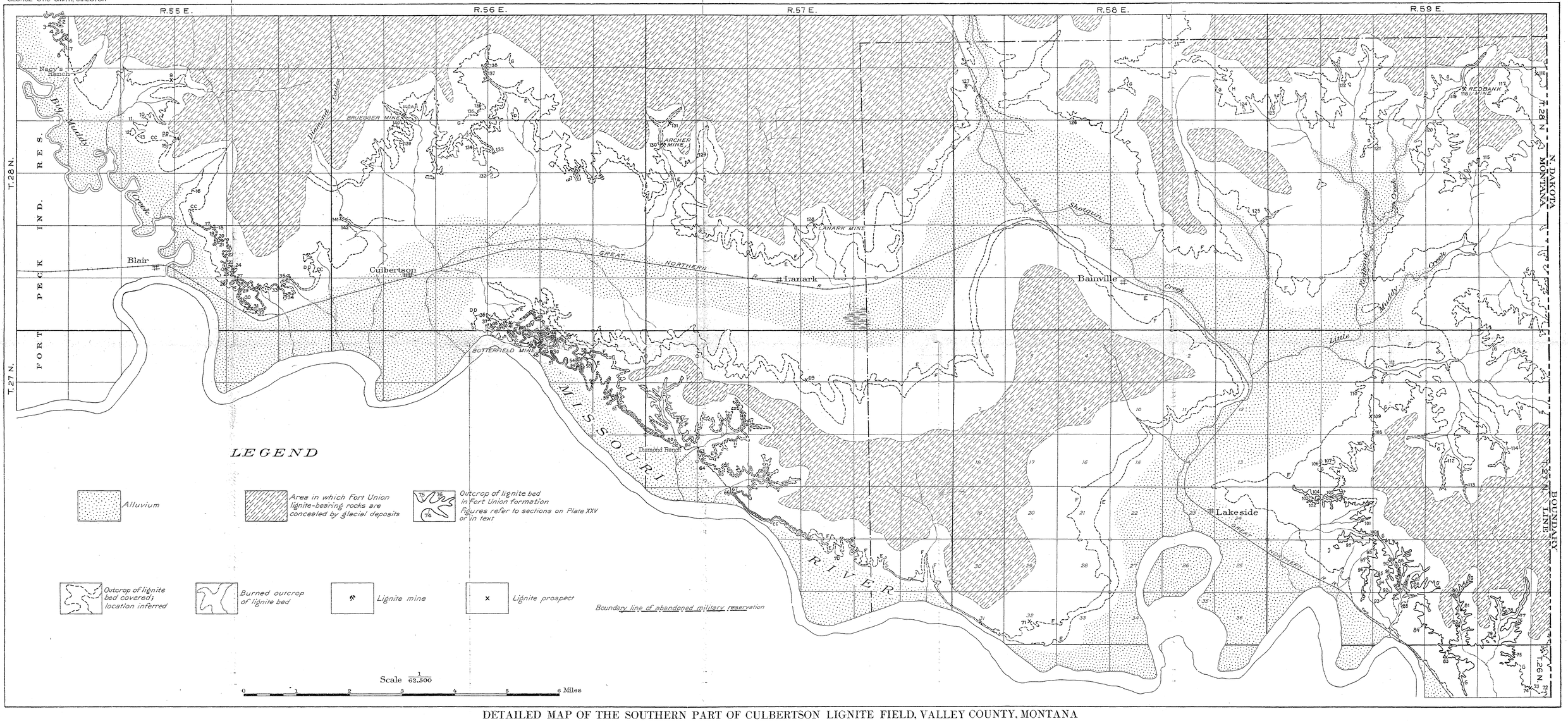
GEORGE OTIS SMITH, DIRECTOR



DETAILED MAP OF THE SOUTHERN PART OF CULBERTSON LIGNITE FIELD, VALLEY COUNTY, MONTANA

By A. L. Beekly

1912

lignite were encountered in four localities at what seems to be roughly the same stratigraphic horizon. These reports indicate the continuity and persistent thickness of bed F beneath the covered area between the outcrop in this township and that in T. 28 N., R. 56 E.

T. 29 N., R. 58 E.—At the Reynolds ranch, near the northeast corner sec. 10, locality not definitely determined, a bed of lignite 5 feet thick occurs just above and at the edge of the spring which furnishes the water for the ranch. This bed has never been mined, and and its quality can only be estimated from the appearance and physical characteristics of the weathered surface. The bed consists of layers of fairly hard clean-looking lignite alternating with softer and more shaly layers. The bank is wet and the lignite is considerably water-soaked near the surface. It is probable that this bed would yield a fair quality of fuel, if opened up beyond the zone of weathering. This exposure is isolated and the position of the bed is not definitely known. Its most probable correlation, however, is with bed H of T. 27 N., R. 59 E., which occurs approximately 70 feet above bed G. The Reynolds lignite is estimated to be 50 to 100 feet higher in the section than bed G, the horizon of which is mapped for a short distance in secs. 32 and 33.

T. 30 N., R. 56 E.—In the west bank of a small coulee, about 3 miles east of Froid, location 151, a bed of lignite 4½ feet thick is exposed in an abandoned prospect drift. The outcrop could be traced only a few hundred feet. The weathered lignite is very soft and shaly, and the bed probably has very little fuel value, a conclusion borne out by the fact that attempts to mine it have been commercial failures.

T. 30 N., R. 58 E.—At location 152, about 3 miles north of Dwyer post office, a bed of lignite 5 feet thick has been opened, and a small amount of mining has been done by stripping off 10 to 15 feet of glacial material which covers the bed. The lower part of the bed bears much water and is the source of a small but rapid stream which flows continually from the bank. The lignite is soft and muddy on the surface and apparently contains considerable shale. It has been used to some extent for domestic purposes, but in general is said to have been unsatisfactory.

T. 31 N., R. 56 E.—Two lignite beds outcrop in the bluff overlooking the western part of Medicine Lake. The lower of these, which occurs almost at water level near the east quarter corner of sec. 9, has been opened at location 156, and 4 feet 2 inches of lignite is exposed. The bottom of the bed was not uncovered, but the prospector reported the total thickness to be 5 feet. The lignite is soft and shaly and apparently of poor quality, although the effect of exposure to air and surface water should be taken into consideration. The upper bed outcrops along the face of the bluff 40 to 50 feet strati-

graphically above the lower one and is mapped for a distance of 3 to 4 miles along the border of the lake. This bed is 3½ feet thick in the Young mine at location 155 near the center of sec. 6, and its quality is comparatively good. It is very hard, black, and dry, and is free from partings. Graphic representations of the outcrops of lignite beds in this township and of measured thicknesses are shown on Plate XXV.

T. 31 N., R. 59 E.—Two exposures of lignite are known in this township, one at the Belgon mine at location 154 near the north line of sec. 9, and another in an abandoned mine at location 153 in the S. ½ sec. 16. These exposures occur at the same altitude, and in all probability represent the same bed. The abandoned mine in sec. 16 is an opening on a lignite bed 10 feet thick. The lignite has long been exposed to the air and is considerably slacked near the surface. The bed is made up of brownish-black woody lignite containing what appear to be lenses of carbonaceous shale. This bed is overlain by 3 feet 8 inches of sandy shale, above which is a bed of shaly lignite 4½ feet thick, in which are embedded a great many fragments of silicified wood. The same sequence of beds is exposed at the Belgon mine, in which the lower bed is 11 feet thick and is separated from the upper bed by 3 feet of sandy shale. Mining is carried on by stripping 5 to 15 feet of cover off the large bed, which leaves the freshly worked face of the lignite well exposed and easily accessible. The lignite of the lower bed is clean, hard, and bright, and of very good quality. An analysis of this lignite is contained in the table on page 154. The upper bed contains 2 feet of soft shaly lignite, which is discarded in mining. The line along which it is assumed these beds would outcrop were it not for the glacial and talus cover was mapped between the two mines and for some distance on either side of them.

T. 32 N., R. 56 E.—A bed containing 5 feet of lignite outcrops in the north bank of a coulee near the north line of sec. 4 of this township. The Estes mine (location 157) worked this bed, which here contains 10 inches of shale near the middle of the bed, leaving 2 feet 6 inches of lignite below the parting and the same thickness above. The entry is accessible for only 50 feet, and throughout this distance the lignite is considerably air-slacked and its shaly appearance indicates a high ash content. The bed is exposed at a locality several hundred feet farther northeast, just across the township line in sec. 31, T. 33 N., R. 56 E. A section of the bed measured here shows that the thickness of the lignite and the thickness and position of the shale parting is practically the same as in the abandoned Estes mine. It is reported that a bed of hard lignite 6 feet thick underlies the exposed bed, from which it is separated by 3 feet of clay. No opportunity was offered, however, to corroborate this report. In a well located in the NW. ¼ sec. 10 it is reported that a lignite bed 7 feet

thick was drilled through at a depth of about 115 feet. Aside from the exposures occurring in sec. 4 the outcrops of lignite beds in this township are completely covered by talus and glacial material.

T. 33 N., R. 56 E.—Lignite exposures occur at several localities along the face of the low bluff or bench facing Big Muddy Creek valley in the western part of the township. These exposures occur at practically the horizon of the lignite bed described in connection with T. 32 N., R. 56 E., and probably represent that bed. The outcrop of this bed was mapped instrumentally across the township. In the Estes mine near the south line of sec. 31 the bed contains 5 feet of lignite with a 10-inch shale parting in the middle of the bed. In the Jones mine (location 158), near the southwest corner of sec. 30 the bed is 7 feet thick and consists of alternating hard and soft layers of somewhat dirty lignite with the softer layers predominating. The lignite is damp throughout and dripping wet in many places in the mine. It is said to make fairly good domestic fuel after it has air-dried to some extent. Measurements made along the outcrop farther north give the following results: At location 159 in the NE. ¼ sec 7, a bed of soft somewhat shaly lignite 4 feet thick is exposed. In the Gormley mine, location 160 in the SW. ¼ sec. 5, a bed is exposed containing 3 feet 4 inches of lignite at the top and 2 feet 2 inches of lignite at the bottom, separated by a shale parting 1 foot 5 inches thick. The roof of the entry is of lignite, so the total thickness above the parting is not known. This part of the bed is somewhat soft and shaly, and its quality is probably below the average of the field. Below the parting, however, the lignite is hard and black and although it contains considerable water in the lower part it is apparently of good quality.

In the vicinity of the Gormley mine and northward three thin lignite beds outcrop—one above the Gormley mine, near the top of the bluff, and the other two almost on the level of the valley floor. The two upper beds have thicknesses of only a few inches, and the lower, measured in several localities, has a maximum thickness of 3 feet at location 161.

T. 34 N., R. 56 E.—The outcrop of the principal lignite bed described in connection with T. 33 N., R. 56 E., is mapped through secs. 19, 30, and 31 of this township. Mapping of the two thin beds occurring above and below the main bed was continued for some distance in sec. 31, but was later discontinued because of absolute concealment of the bed by glacial material and alluvium. Near the center of sec. 31 a 10-inch lignite bed outcrops about halfway up the bluff. The covered condition of the lignite zone in this vicinity, however, makes it very doubtful which bed is represented by this outcrop. So far as known, no other outcrops of lignite occur in the township.

T. 34 N., R. 58 E.—Several exposures of lignite occur along practically the same horizon in this township, and these were mapped as one bed as indicated on Plate XXVII. The fact that all of the exposures occur at closely corresponding altitudes, indicates that they represent a single lignite bed. In the Coalridge mine (location 164) in the NW. ¼ sec. 8, the lignite ranges in thickness from 10 to 14 feet. The bed is mainly made up of fairly hard and clean lignite, though in many places it contains soft layers and lenticular masses of shaly material. The same bed is exposed at location 165, about three-fourths of a mile northeast of the mine, and contains 7 feet of soft, dirty-looking lignite. In this locality the lower part of the bed is water-bearing and the upper part is weathered to such an extent that it is difficult to make an estimate of the quality. At location 163 in the SW. ¼ sec. 20 the lignite bed was partially uncovered and is apparently very similar in quality to that in the Coalridge mine. The bed is more than 4 feet thick here, although the base was not reached and a complete measurement could not be made. About a mile west of this locality indications of lignite are visible on the surface at the same horizon, but the bed was not prospected. The inferred outcrop of the bed is mapped for approximately 2 miles south of the southernmost lignite exposure and more than 1 mile north and east of the exposure farthest north. In digging a well on the Hueth place, several hundred feet west of the township line, near the southeast corner of sec. 13, a bed of lignite was struck at a depth of 50 feet. After 5 feet of the lignite had been taken out, the well filled with gas over night and one of the workmen was overcome and lost his life when lowered into it the next morning. The well was abandoned, and although the complete thickness of the lignite was never ascertained its occurrence at approximately the horizon of the Coalridge lignite seems to warrant its correlation with that bed.

T. 35 N., R. 56 E.—At location 162 in the NE. ¼ sec. 36 several lignite exposures occur along the north fork of Antelope Creek. In the new Damsgaard prospect, at a distance of 20 feet from the mouth of the entry, the bed contains 3 feet 6 inches of clean hard lignite. In a prospect about 500 feet farther east the thickness of lignite is about the same, but here the bed is soft and apparently thoroughly slacked for a distance of 60 feet from the opening. This slacked condition of the lignite prevails in the several other exposures in the vicinity, besides which no other exposures of lignite are known to occur in the township.

T. 35 N., R. 58 E.—In the north-central part of this township a bed of lignite lies very near the surface throughout a comparatively flat area several square miles in extent, over which there are abundant indications of lignite, such as bloom and coaly-looking prairie-dog mounds. It is probable that the thickness of cover does not exceed

DOMINION OF CANADA

R.53 E. R.54 E. R.55 E. R.56 E. R.57 E. R.58 E.

T.37 N. T.36 N. T.35 N. T.34 N. T.33 N. T.32 N. T.31 N. T.30 N. T.29 N. T.28 N. T.27 N. T.26 N.

Ueland's Ranch
AMBROSE ROAD
Johnson's Ranch
Hammer's Ranch
166
PIERCE MINE
Plentywood
162
165
164
Coalridge
Antelope Cr.
Antelope
HUETH WELL
163
161
160
CORMLEY MINE
159
Reserve
Dagmar
158
JONES MINE
157
ESTES MINE
Lake Cr.
Medicine Lake
YOUNG MINE
155
MEDICINE LAKE
156
BELGON MINE
154
153
Homestead
Muddy Creek
GREAT NORTHERN
Froid
151
Enterprise
Dwyer
Helmers Ranch
150
WATTS MINE
146A
146
148
149
ASTROPE MINE
145
147
THORPE MINE
McCabe
144
143
Miller's Ranch
BRUEGGER MINE
ARCHER MINE
Culbertson
Lanark
Bainville
Redbank Creek
BUTTERFIELD MINE
Muddy
Little
Diamond Ranch
Lakeside
Mondak
152

FORT PECK IND. RES.

Big

MISSOURI RIVER

N. DAKOTA
MONTANA

R.56 E. R.57 E. R.58 E. R.59 E.

LEGEND

Area in which the lignite-bearing rocks are concealed by glacial deposits

Outcrops of lignite beds; lignite underlies dotted side of outcrop

Lignite mine

Lignite prospect

6	5	4	3	2	1
7	8	9	10	11	12
18	17	16	15	14	13
19	20	21	22	23	24
30	29	28	27	26	25
31	32	33	34	35	36

DIAGRAM OF TOWNSHIP

Scale 1/250,000
0 1 2 3 4 5 6 7 8 9 10 MILES

MAP OF THE CULBERTSON LIGNITE FIELD, VALLEY COUNTY, MONTANA

By A. L. Beekly

1912

10 feet over most of this area and that the lignite is thoroughly slacked, probably to the extent of decay. In several localities, however, the cover is sufficiently thick to have preserved the lignite, and in one of these (No. 166), known as Three Man Butte, near the east quarter corner of sec. 10, the lignite bed is exposed and a small amount of development work has been done. In this prospect the lignite bed is 9 feet thick and is made up of fairly hard clean layers alternating with softer layers containing considerable shale. Very little work had been done here, and the freshest lignite exposed is considerably weathered. It is probable that further development may show the quality of the unweathered lignite to be very good. The area, however, in which the cover is sufficiently thick to protect the bed is not more than a few acres in extent. The outcrop line, as shown on Plate XXVII, is for the most part theoretical, although a number of definite exposures of the outcrop were located. No other outcrops of lignite are known to occur in the township.

NOTES ON RECONNAISSANCE EXAMINATION OF PLENTYWOOD DISTRICT.

No detailed work was done in the townships west of range 56, but the following facts, gathered in the course of a few days of reconnaissance work in the vicinity of Plentywood, are presented in connection with this report because of their close relation to the field.

Lignite beds outcrop in many localities along the valleys of Big Muddy Creek and tributary streams. In the area between Antelope station and Plentywood a number of lignite exposures occur along the east side of the valley, and these, on the basis of relative altitudes, are thought to be on the same lignite bed. The following measured section of the bed mined in the Pierce mine, 3 miles northeast of Plentywood, corresponds very closely with a reported section said to have been measured a short distance northwest of Antelope.

Section of lignite bed at Pierce mine.

	Ft.	in.
Sand, clayey.		
Clay and lignite, alternating in thin layers	2	
Lignite, mostly soft, contains harder lenses	2	6
Clay and lignite, alternating in thin layers	1	2
Lignite, hard, brownish black	4	4
Total lignite	6	10

The Pierce mine supplies most of the fuel used in Plentywood and in the surrounding territory, which is largely taken up by settlers. Mining was carried on by stripping off the materials which cover the lignite, but owing to increasing thickness of cover a change to the entry system of operation was contemplated by the owner at the time this investigation was made.

In the small areas of badlands, along the face of the valley terraces west of Plentywood, lignite beds are known to outcrop in several localities. At one place, about 5 miles southwest of Plentywood, two beds outcrop separated by 26 feet of sandy shale. The upper bed contains 2 feet 10 inches of fairly good lignite and the lower contains 3 feet 2 inches of practically the same quality. A small quantity of lignite has been mined at this locality by the open-cut method.

Numerous reports indicate that exposures of lignite occur at intervals along Big Muddy Creek as far north as the international boundary line. These reports, together with observations by the writer, point to a gradual thinning of the lignites toward the northwest.

DEVELOPMENT.

The comparatively small local demand for the lignite of the Culbertson field, together with its lack of stocking and shipping qualities, has prevented the development of mines on an extensive scale. Brief descriptions of the principal mines of the field are contained in the following notes. It should be borne in mind that figures used in these descriptions represent conditions as they existed in the summer of 1910.

Butterfield mine.—Location 48*a*, NE. ¼ sec. 3, T. 27 N., R. 56 E. Drift mine; entry extends 150 feet north; roof hard sandy shale; floor clay; lignite bed 6 feet 4 inches thick, hard, clean, black, and dry; production, 6 to 10 tons a day in winter; owned and operated by Butterfield & Englebright, Culbertson.

Bruegger mine.—Location 140*a*, SW. ¼ sec. 8, T. 28 N., R. 56 E. Drift mine; from opening entry extends 200 to 300 feet north; roof shale; floor shale; lignite bed 7 feet thick, hard and clean at top and bottom, central portion softer; production, about 8 tons a day in winter; owned and operated by Mr. Bruegger, Culbertson.

Red Bank mine.—Location 118, S. ½ NE. ¼ sec. 10, T. 28 N., R. 59 E. Open-cut mine; lignite bed 5 feet 6 inches thick, hard, clean, black, wet near base; shale cover 3 to 10 feet; floor clay; production, probably 3 to 5 tons a day in winter; operated by settlers; ownership unknown.

Thorpe mine.—Location 148, SE. ¼ NE. ¼ sec. 20, T. 29 N., R. 55 E. Drift mine; from opening entry extends 80 feet west; roof shale; floor shale; lignite bed 6 feet 6 inches thick, lower 3 feet hard and of fair quality, upper part slacked; development work, no lignite marketed; owned and operated by Mr. Thorpe, Froid.

Astrope mine.—Location 149, SE. ¼ SW. ¼ sec. 15, T. 29 N., R. 55 E. Drift mine; from opening entry extends about 115 feet north; one cross entry 65 feet; roof sandy clay; floor clay; lignite bed 5 feet thick, lower 4 feet hard and black, remainder of bed slacked and

muddy; production, 3 to 5 tons a day; owned and operated by C. E. Astrope, Froid.

Watts mine.—Location 150, NE. ¼ NW. ¼ sec. 11, T. 29 N., R. 55 E. Shaft mine; shaft 40 feet deep; roof clay; floor clay; lignite bed 7 feet thick, clean, hard, black, and dry; in process of development, no lignite marketed; owned and operated by Mr. Watts, Froid.

Young mine.—Location 155, SE. ¼ NW. ¼ sec. 6, T. 31 N., R. 56 E. Drift mine; from opening entry extends about 200 feet south; roof shale; floor clay; lignite bed 3 feet 6 inches thick, hard, black, clean, and free from partings; production variable, 5 to 30 tons a week; owned and operated by Ted Young, Medicine Lake.

Belgon mine.—Location 154, SW. ¼ SE. ¼ sec. 4, T. 31 N., R. 59 E. Open-cut mine; lignite bed 11 feet thick, hard, brownish black, and free from partings, overlain by 3 feet of drab sandy shale, which is in turn overlain by 2 feet of shaly lignite; cover sand 3 to 15 feet thick; floor clay; production variable, 2 to 10 tons a day; owned and operated by John Belgon, 20 miles east of Medicine Lake.

Estes mine.—Location 157, NE. ¼ NW. ¼ sec. 4, T. 32 N., R. 56 E. Drift mine; entry caved in at distance of 50 feet from opening; lignite bed 6 feet thick, contains shale parting near center of bed ranging from 8 inches to 2 feet in thickness; upper part of bed dry and shaly, lower part wet; roof glacial till; floor clay; mine not producing; new entry started 500 feet northeast; operated by Daniel Estes, Medicine Lake.

Jones mine.—Location 158, SE. ¼ SW. ¼ sec. 30, T. 33 N., R. 56 E. Drift mine; from opening entry extends about 250 feet south; roof shale; floor clay; lignite bed 7 feet thick, damp, made up of hard clean layers and soft shaly layers alternating; production, 3 to 5 tons a day in winter; operated by Mr. Jones, Medicine Lake.

Coalridge mine.—Location 164, SE. ¼ NW. ¼ sec. 8, T. 34 N., R. 58 E. Drift mine; entry extends northwest 150 feet, southwest 100 feet, and west 150 feet; roof shale; floor clay; lignite bed ranges from 10 to 14 feet in thickness, brownish black, contains soft shaly lenses, dry; production, about 1,500 tons a year; owned and operated by George L. Onstad, Coalridge.

Prospects.—In addition to these mines, there are many prospects and abandoned drifts in the field. In nearly all the easily accessible lignite outcrops small openings have been made by farmers, who prefer to dig their own supply of fuel rather than haul it from one of the established mines.

ESTIMATED TONNAGE.

The following estimates of the amount of lignite in the Culbertson field are based upon the thicknesses of lignite beds measured along Missouri River and in the scattered rock exposures of the field. (See

general section, p. 331.) The known persistency of the thicker of these beds throughout a large area south of the Culbertson field is taken into consideration in making the estimates. In a large area of so few rock exposures, however, the figures here presented, although based upon all available data, should at best be considered only a very general estimate.

Two estimates are presented—one of the amount of lignite lying within 500 feet of the surface, which is considered the limit of workable depth of lignites under the Interior Department's present scheme of land classification, and the other of the total tonnage of lignite contained in the Fort Union formation in this field. The former is based upon surface altitudes considered in connection with the known thicknesses and stratigraphic positions of the lignite beds of the upper part of the section. The southern part of the field, in which exposures were most abundant, is divided for computation purposes into three areas which are estimated to be underlain by lignite within 500 feet of the surface as follows: The first area, of 36 square miles, by 20 feet of lignite; the second area, of 164 square miles, by 17 feet of lignite; and the third area, of 252 square miles, by 14 feet of lignite. These thicknesses represent the estimated composite sections of lignite beds underlying the separate areas and are mainly based upon the average thicknesses measured in each area. In addition to the three areas described above the field contains 255 square miles in which the thickness of lignite lying within 500 feet of the surface is estimated at 8 feet. Measurements made in localities well scattered over this area were considered in making this estimate. The specific gravity of the lignite is such that a bed of it 1 acre in extent and 1 foot in thickness contains 1,800 short tons or 1,152,000 short tons to the square mile. On this basis the tonnage of lignite lying within 500 feet of the surface of the Culbertson field is equal to 16,911,752,000 short tons. It should be borne in mind, however, that these figures represent the gross tonnage and that the prevailing percentage of recoverable coal in many mining regions is approximately 55 per cent of the total. Accepting this figure arbitrarily as applicable to the Culbertson field, the amount of recoverable lignite is equal to about 9,395,400,000 short tons.

The following estimate of the total tonnage of lignite in the Fort Union formation of this field is based upon the thickness of lignite beds contained in the general section with a reduction for uncertainty as to the persistence which is thought to be sufficient to render the figures rather too low than too high. In the southern part of the field nearest the locality in which the general section was measured there is evidence to support the assumption that an area of 441 square miles is underlain by at least 30 feet of lignite. North of this an area of 596 square miles is estimated to be underlain by at least 20 feet of

lignite. This area lies at considerable distance from the localities in which the lower lignite beds of the series are known to be present, but in fixing the thickness of lignite for this area the uncertainty as to the persistency of the lower beds is counterbalanced in large measure by the exposure, in several localities within the area, of lignite beds ranging from 6 to 14 feet in thickness. The thickness of lignite in the remaining 370 square miles in the northern part of the field is placed at 10 feet mainly for the reason that in several localities in and near the area 6 to 9 foot beds of lignite are exposed. The presence of the lower beds in this area is too much a matter of doubt to be allowed to raise the total thickness of lignite very much above that which may be seen in the field.

The estimated total tonnage of Fort Union lignite in the field, calculated from the above figures is 33,235,200,000 short tons, and of this amount, using the common percentage of recovery under ordinary mining conditions, 18,464,000,000 short tons may be considered recoverable. As previously stated, the above tonnage estimates should be considered only as a guess, based upon as many facts as are available. In the opinion of the writer, however, the figures are very conservative.

FUTURE DEVELOPMENT.

The Culbertson district is almost entirely destitute of timber, as a result of which the settlers and towns people are rendered dependent upon either the small mines of the field or upon imported fuel. As a domestic fuel the lignite is fairly satisfactory, but it is only by the use of large quantities that a high degree of heat can be maintained. For this reason it must be sold at a very low price or the consumers will buy Sand Coulee, or other west-central Montana coal, which, though higher priced, gives more heat and is much cleaner. The demand for fuel in this region, though very small at present, will no doubt be stimulated somewhat as the country fills with settlers. The frequent recurrence of droughts with attendant loss of crops, however, tends to retard the agricultural development of the country, a condition which makes it impossible to foresee a large local market in the near future. Under present conditions a number of mines which have been opened in recent years have been abandoned as unprofitable because of small demand and difficulties of mining. The sandy clays and shales which almost invariably overlie the lignites crumble badly and in general make very poor roofs, a difficulty emphasized greatly by the total lack of timber except in a few scattered localities along Missouri River.

Attempts have been made to market the lignite as a domestic fuel in localities at some distance from the field, but because of the poor shipping quality of the lignite these have not been successful. Be-

cause of the high moisture content of the lignite it air-slacks rapidly and the cars were found to contain practically nothing but slack when their destination was reached.

The lignite has been proven too light for satisfactory fuel in ordinary locomotives, although fairly good results have been obtained by its use in engines constructed with fire boxes especially designed for burning lignite. When the supply and availability of high-grade coal is considered, however, it is evident that only a few railroads can be economically equipped with lignite-burning engines.

Although lignite has shown high efficiency in gas producers, the Culbertson area is too far remote from activities requiring power plants for that use of the lignite to appear promising in the near future. Lignite briquets have proven a very satisfactory and good stocking fuel, but when the location of the field, the difficulties of mining, and the added cost of briquetting are considered it seems improbable that lignite of the Culbertson field would be able to compete in outside markets with the more easily minable and higher-grade coal which occurs in immense quantities in other sections of Montana and Wyoming.

It is probable that until such time as industries may spring up in this region, creating a need for power, or until the supply of high-grade coal is sufficiently diminished to render lignite economical for steaming fuel or profitable when made into briquets, the lignite of the Culbertson field will be in demand only for local domestic use.