THE EKALAKA LIGNITE FIELD, SOUTHEASTERN MONTANA.

By CLYDE MAX BAUER.

INTRODUCTION.

This report presents the results of a geologic examination of an area of more than 3,000 square miles in southeastern Montana, including nearly all of Carter County and parts of Fallon and Powder River counties. The physiography of the area and the stratigraphy and structure of the sedimentary rocks are described briefly, and the mineral resources are discussed. The examination was made primarily for the classification of the public land of the area, and as lignite is its chief mineral resource the parts of the field in which lignite was found were consequently studied and mapped in greater detail. Owing to the lapse of several years between the original preparation of this report and its final publication, some changes in road alinements have taken place since the maps published herewith were prepared, some new mines may have been opened, and other minor changes in cultural features have been made.

The field work upon which the present report is based was done in August, September, and October of 1913 and 1914. During the season of 1913 the writer was assisted by C. A. Bonine and R. C. Hay, and in 1914 by E. M. Parks and R. W. Brown. Acknowledgments are made here for many courtesies extended to members of the field parties by the residents in the field.

Prior to the present report very little had been written regarding the geology of this region, although some data concerning it are contained in the writings of Brown,[1] Darton,[2] and Leonard.[3]

[1] Brown, Barnum, The Hell Creek beds of the Upper Cretaceous of Montana: Am. Mus. Nat. Hist. Bull., vol. 23, p. 823, 1907.

[2] Darton, N. H., Geology and underground waters of South Dakota: U. S. Geol. Survey Water-Supply Paper 227, 1909; Preliminary report on the geology and underground water resources of the central Great Plains: U. S. Geol. Survey Prof. Paper 32, 1905.

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

GEOGRAPHY.

LOCATION AND EXTENT OF FIELD.

The area described in this report lies in the southeast corner of Montana, extending northward from the Wyoming State line to the north line of T. 4 N. (See fig. 22.) South of the Montana base line the area extends westward from the South Dakota boundary to Little Powder and Powder rivers; north of the base line it extends westward from the Dakota boundary to the west line of R. 57 E. The western boundary of the field is controlled by the limit of a season's

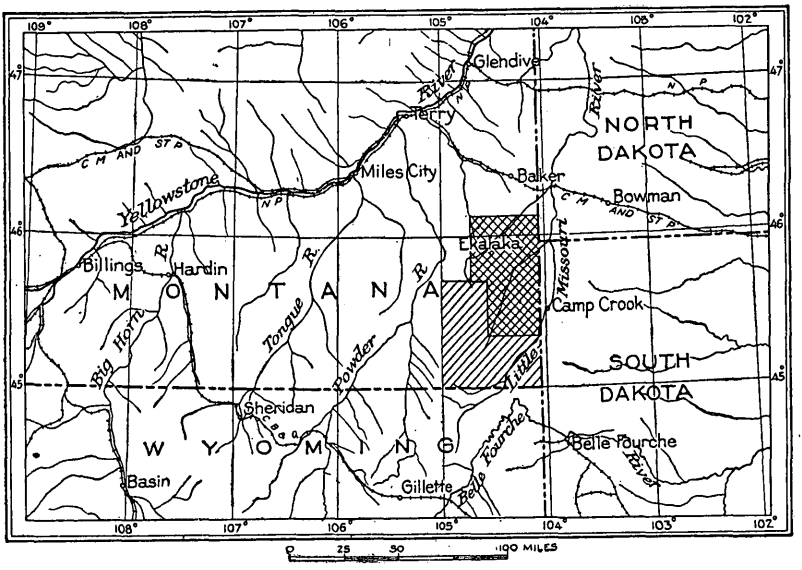


FIGURE 22.—Index map showing location of Ekalaka lignite field, Mont. The area indicated by cross hatching was studied in detail.

work and therefore is arbitrarily fixed as described above. In the course of investigation some observations were made along the divide west of the field as thus outlined. The northeastern part of the field shown on Plate XXX was studied in considerable detail, but the southern and western parts were examined only in rapid reconnaissance.

ACCESSIBILITY.

Different places within the field range between 25 and 100 miles from the nearest shipping point. The nearest railroad station to the northern part of the field is Baker, on the Chicago, Milwaukee & St. Paul Railway, which is 42 miles from Ekalaka. Belle Fourche, S. Dak., on the Chicago & Northwestern Railway, is 25 miles from the southeast corner of the field.

Stage lines that carry mail and passengers run daily between Ekalaka and Baker. Boyes, Piniele, and Alzada are also connected by stage with Belle Fourche. The post offices on Box Elder Creek send and receive mail on alternate days to and from Ekalaka, and those of Ericson and Capitol have stage service from the railroad at Bowman, N. Dak., by way of Camp Crook, S. Dak.

In addition to the county roads from Ekalaka to Baker and from Ekalaka to Camp Crook and several other stage roads that are kept up by the county, the field is traversed by a number of natural trails which make excellent roads with very little care, as the soil, except in the southern shale districts, is of such a consistency as to pack well under ordinary travel. Even in the shale districts the roads are good throughout most of the summer, though practically impassable in wet weather.

TOPOGRAPHIC FEATURES.

The field lies in the northern Great Plains and presents wide tabular surfaces, traversed by the broad valleys of Powder and Little Missouri rivers and locally more or less deeply cut by the narrower valleys of tributaries. Smooth or gently rolling surfaces are characteristic features, but in portions of the field the landscape is diversified by buttes and badlands, or by tree-covered mesas and ridges.

The region as a whole descends in altitude northeastward at about 10 feet to the mile. However, the highest point is in the east-central part of the field, on the A Bar B Buttes. The field presents a variety of topography, as well as considerable difference in altitude. Its highest point is about 4,025 feet above the sea; its lowest point, at the north edge of the field on Little Beaver Creek, is less than 2,900 feet.

Perhaps the most striking features of the topography are the wooded mesas or plateaus, which appear mountainous from a distance and even at close range are rugged and precipitous. The most prominent of these are the Ekalaka Hills, the Long Pine Hills, the Sheep Mountains, the A Bar B Buttes, and the Finger Buttes. These mesas are covered generally with pine trees and present excellent exposures of the geologic strata in cliffs, which are most numerous on their south sides. Many of the lower divides are surmounted by low rocky buttes, some of which are rectangular or pyramidal in form. The Medicine Rocks, on the Little Beaver-O'Fallon Creek divide in T. 3 N., R. 58 E. (see Pl. XXXI, *A*), form an example of the weathering of these rocky buttes, in which the wind is apparently the most active agent.

At the north side of the Ekalaka Hills, along the Box Elder-Little Beaver Creek divide, the country is marked by sandstone ridges and buttes, sparsely covered with pines. These hills diminish in altitude toward the north and are terminated by a line of cliffs facing Little Beaver Creek. Similar tree-covered ridges spread out on the east and north sides of the Long Pine Hills but end more abruptly in an escarpment, which roughly follows the Montana-South Dakota State line. Along this escarpment and to the east barren badland areas stretch for miles. Local badland areas occur in many places throughout the field. Some of the most notable are those of Devils Canyon, in Tps. 1 and 2 S., R. 60 E.; on the north side of T. 2 N., R. 60 E.; and in a large area west of Chalk Buttes along Spring and Timber creeks.

The valleys of the main streams are broad, and the slopes are usually gentle, though the channels of the streams, owing to the torrential rains, are commonly cut 10 to 20 feet into the alluvial plain. In the southern part of the field the general softness of the rocks has lent monotony to the landscape. Except for low mounds, which mark the divides, and small conical hills, known as "tepee buttes," which are scattered here and there in the shale districts, the surface is a featureless rolling plain of dark-gray gumbo.

Farther west along the divide between Little Missouri and Powder rivers the land is rougher and owing to the outcrop of the Fox Hills sandstone presents numerous low hills and sandy flats. Toward Powder River the topography becomes generally more rugged and the relief greater. Locally badlands are developed. The country immediately north of East Fork of Little Powder River is practically treeless. West and south of this area, particularly along the stream courses and on the higher divides, trees add to the increasing variety of the landscape. The divide between Powder and Little Powder rivers, as well as the highland west of Powder River, is very rugged and has a relief of about 1,000 feet. Red clinker-covered hills are common and contrast strongly with the dark green of the pine trees and the light grays and yellows of near-by exposures of the underlying strata.

Powder River itself, although carrying more water than the Little Missouri, does not have so wide a valley, its flood plain being less than a mile in width.

DRAINAGE.

The central and eastern parts of the area here described are drained by Little Missouri River and its tributaries, including Thompson, Cottonwood, Hackberry, and Tie creeks, and farther

north by Box Elder and Little Beaver creeks. The western part of the field is drained westward to Powder and Little Powder rivers, and the northwestern part is drained directly to the Yellowstone by O'Fallon Creek.

A marked feature of the drainage in this region is the direct northeastward course of the principal streams and the northwest-southeast alinement of the tributaries. The direction of the main drainage is common in northern Wyoming also and probably indicates the slope of the ancient plain on which these streams started and which is now represented only by the high mesas. Pleistocene changes in drainage that were profound farther north seem to have had little effect on the streams of this field. However, the capture of the headwaters of the Little Missouri by the Belle Fourche has led to a decrease in erosion by the former, owing to the smaller volume of water which it now carries. Its valley is therefore broad and the gradient relatively low, so that the stream is unable to transport the load of silt, sand, and gravel brought to it by the numerous tributaries, and as a result a broad alluvial flat has been formed along the river. Many of the tributaries of the Little Missouri have likewise silted their valleys, in response to the action of the main stream, and present a contrast to the tributaries of Powder River, whose valleys contain very little alluvium.

GEOLOGY.

STRATIGRAPHY.

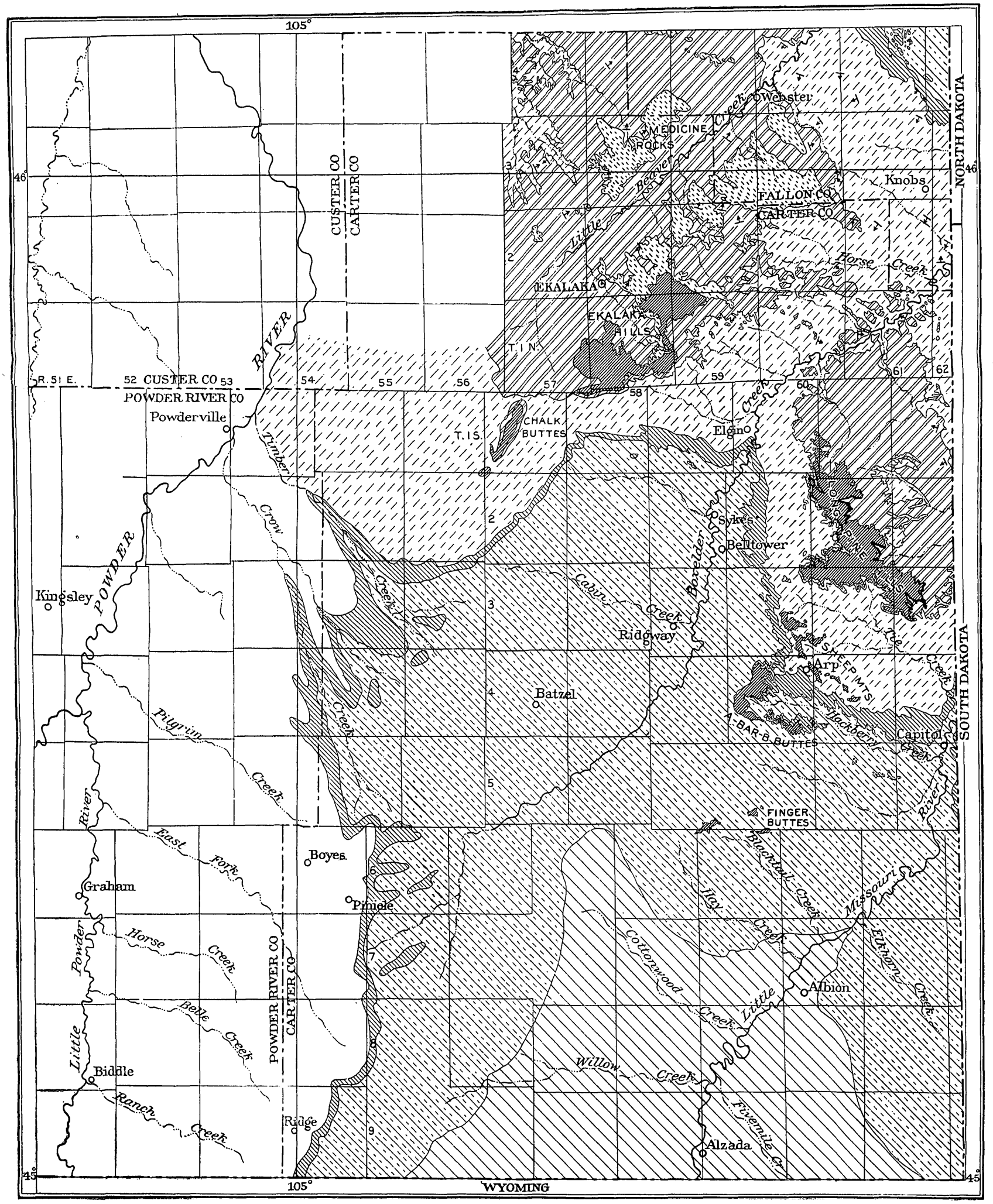
GENERAL SECTION.

The Ekalaka field is in a region of nearly horizontal stratified rocks of Upper Cretaceous and early Tertiary age which lie on the northeast flank of the Black Hills uplift, southwest of the Cedar Creek or Glendive-Baker anticline. In the southern part of the field dips of 3°–4° N. are observable, but north of the Fox Hills escarpment the regional northward dip is more gentle and is modified by local flexures parallel to the Cedar Creek fold. The region affords some excellent exposures for the study of stratigraphic relations and of the variations in the composition of the formations. The sedimentary rocks consist of thick sheets of shale, sandstone, and sandy limestone, all essentially conformable, except for the White River and Arikaree (?) formations, which cap the higher hills and extend across the edges of the older formations. In general the older rock in this field is shale and is softer than the overlying, younger

sandstone. The following table gives a summary of the geologic formations exposed in this region, with their characteristics, range in thickness, and age:

Geologic formations exposed in southwestern Montana.

System.	Series and group.	Formation and member.		Thickness (feet).	Character.
Quaternary.	Postglacial.	Alluvium.		0–30+	Flood-plain deposits.
	–Unconformity–				
Tertiary (?).	Pliocene (?).	Gravel deposits.		0–15+	Terrace gravels.
	–Unconformity–				
Tertiary.	Miocene (?).	Arikaree (?) formation.		0–250	Whitish calcareous sandstone capped by hard green quartzite.
	–Unconformity–				
	Oligocene.	White River formation.		0–134	Basal conglomerate, green and pink calcareous shale, volcanic ash, and pink or cream-colored siliceous limestone.
	–Unconformity–				
	Eocene.	Fort Union formation.	Tongue river member.	125+	Massive yellow sandstone, shale, and lignite.
Tertiary (?).	Eocene (?).	Lance formation.	Ludlow lignitic member.	275–350	Yellowish to gray sandstone, clayey sandstone, shale, and lignite beds, variable in thickness and character.
			Hell Creek member.	400–500	Somber-colored soft shale, brown shale, and gray sandstone, with thin lignite lenses in upper part. Lower half more sandy and contains few lignite bands. Many concretions and thin lenses of iron carbonate. Extremely variable throughout.
Cretaceous.	Upper Cretaceous. Montana group.	Fox Hills sandstone.		60–150	Marine grayish-white to yellowish friable sandstone with concretions.
		Pierre shale.		1,500–2,000	Marine dark shale containing limestone concretions. Gives rise to gumbo soil.
	Upper Cretaceous. Colorado group.	Niobrara shale.		120–225	Light-gray calcareous shale weathering yellow.
		Benton shale.		1,800–2,050	Marine dark shale containing thin sandstones and limestones.
		Dakota sandstone.			



EXPLANATION

Arikaree? formation (Miocene?)	TERTIARY	
White River formation (Oligocene)	TERTIARY	
Fort Union formation (Eocene)	TERTIARY	
Ludlow lignitic member	Lance formation	TERTIARY(?), EOCENE(?)
Hell Creek member	Lance formation	TERTIARY(?), EOCENE(?)
Fox Hills sandstone	Upper Cretaceous	CRETACEOUS
Pierre shale	Upper Cretaceous	CRETACEOUS
Colorado group	Upper Cretaceous	CRETACEOUS

Strike and dip of rocks

MAP SHOWING AREAL GEOLOGY OF THE EKALAKA LIGNITE FIELD, MONT.

COLORADO GROUP.

BENTON SHALE.

The Benton shale, which together with the Niobrara shale composes the Colorado group, crops out in the southern part of the field in the valleys of Little Missouri River and Thompson Creek, where about 1,500 feet of its upper part is exposed.

The Benton as a whole consists of dark marine shale and is divisible into a number of lithologic units. The base of the Benton is not exposed in this field, and no attempt was made to map the members of the formation, as the work in the portion of the field in which they crop out was of a reconnaissance nature. The formation is composed largely of dark-gray and bluish-black shales, which are concretionary throughout. It also contains in its lower portion one sandstone bed from 8 to 50 feet thick, known as the Newcastle sandstone member or Muddy sand, and an impure limestone, 60 to 80 feet thick, about 1,250 feet above its base. Its upper portion contains fossiliferous concretions, which, according to Darton, carry *Prionocyclus woolgari*.

NIOBRARA SHALE.

Overlying the Benton shale conformably is the Niobrara shale, which has an average thickness of about 175 feet and consists in this region of calcareous shale. It is not resistant to erosion, but owing to its yellow color on weathering its outcrop can be traced readily. When fresh the material is light gray to light buff, but on weathering this changes to a rich cream-yellow. According to Darton, the formation includes many thin irregular masses of the fossil *Ostrea congesta*, and this species also occurs scattered through the shale. The upper limit is indefinite, and the overlying Pierre shale is separated from it by a zone of beds that partake of the character of each formation; hence the boundary of the Colorado group as shown on the map (Pl. XXX) is only approximate.

MONTANA GROUP.

PIERRE SHALE.

The Pierre shale consists of about 2,000 feet of dark-green or dark-brown shale, which weathers to a gray or brown gumbo. It crops out over a broad area around the Black Hills, covering a large portion of the central part of this field. A small area of the Pierre is exposed in the extreme northeast corner of the field, on the south end of the Cedar Creek or Baker-Glendive anticline. The

outcrop presents a flat or slightly undulating topography, which is very monotonous and uninteresting. It normally supports a scant growth of grass, though where the soil from it has been mixed with sand from younger formations it supports a rather dense growth of sagebrush and can be farmed with fair success, provided water for irrigation is available without prohibitive cost.

The shale itself is rather soft and thinly bedded, so that its thickness and structure are difficult to determine. It contains concretions throughout its thickness, but they are rather more plentiful at a horizon about 1,000 feet above its base and also near the top. The concretions near the top are composed of impure calcium carbonate; those farther down contain a large percentage of iron carbonate. In the lower part there are zones of harder shale which weather out in reddish-brown flakes.

The areal mapping of the lower limit of the Pierre is only approximate, as simply a rapid reconnaissance of the boundary was made. Its upper limit was mapped in greater detail.

Fossils were collected at a horizon about 400 feet stratigraphically below its upper limit near Ridgway post office, in T. 3 S., R. 58 E., and also from the upper 100 feet of the shale in the northeast corner of the field, in T. 4 N., R. 61 E. These were identified by T. W. Stanton as follows:

T. 3 S., R. 59 E.:
- Ostrea sp. cf. O. inornata Meek and Hayden.
- Inoceramus barabini Morton.
- Lucina occidentalis var. ventricosa Meek and Hayden.
- Baculites ovatus Say.
- Ptychoceras sp.

NE. ¼ sec. 10 and NW. ¼ sec. 11, T. 4 N., R. 61 E.:
- Inoceramus barabini Morton.
- Mactra gracilis Meek and Hayden.
- Scaphites sp.

FOX HILLS SANDSTONE.

The Fox Hills sandstone overlies the Pierre conformably—in fact, the shale below becomes more sandy until it passes into the true sandstone of the middle and upper portions of the Fox Hills. The beds of passage usually occupy a vertical section of about 50 feet. The lower part of the Fox Hills is therefore represented by alternating beds of shale and sandstone, each 6 or 8 inches in thickness. Higher in the formation the shale beds become thinner or disappear entirely. The formation is of marine origin, having been deposited along the shore of the retreating Pierre sea. The sandstone strata are prevailingly light gray, though some portions are orange-yellow and others are light pink. The beds are generally not more than a few inches thick and commonly weather into slabs,

which are more resistant to erosion than either the Pierre or the overlying Lance beds and which therefore produce a rock terrace where conditions are favorable. The Fox Hills sandstone has an average thickness in the northern part of the field of about 75 feet. Farther south it thickens, and near the Wyoming line it is 150 feet thick. However, its upper limit, as well as its lower limit, is rather indefinite in most places. The Lance, which overlies it, is also very sandy in its lower portion. In other localities the upper surface of the Fox Hills is said to have been eroded prior to the deposition of the Lance, but in this field there seems to have been uninterrupted sedimentation from one to the other, and in one place only—on Little Beaver Creek, at the north edge of the field—was any irregularity in the contact noted. At this place the contact is depressed for a few rods to the extent of 3 or 4 feet. *Halymenites major*, a seaweed, the only identifiable fossil collected from the Fox Hills in this field, occurs abundantly in the upper one-third of the formation. The Fox Hills was penetrated between 845 and 920 feet in the well of the Arkansas Natural Gas Co., drilled in the NE. ¼ SW. ¼ sec. 19, T. 3 N., R. 59 E.

LANCE FORMATION.

In this region, as in northwestern South Dakota,[4] the Lance is divisible into two lithologic units, the Hell Creek and Ludlow lignitic members, which are different both in lithology and in lignite content.

HELL CREEK MEMBER.

The Hell Creek member of the Lance formation overlies the Fox Hills and crops out extensively on Little Powder and Powder rivers and across the north-central part of the field, particularly on lower Box Elder Creek and Tie Creek. This member produces a characteristic varied topography of badlands and level areas and ranges from 40 to 500 feet in thickness, consisting of fresh-water and possibly brackish-water deposits of sandstone and shale and thin beds of lignite. The member is more sandy in the lower part and becomes progressively more clayey toward the top. Such lignite as occurs in the Hell Creek member is usually in lenticular beds of small areal extent, in the upper 100 feet. The sandstone beds are commonly clayey or carbonaceous and form interlocking lenses with the shale beds, which are, on the other hand, sandy. As a rule single beds are not traceable more than a few miles, even where exposures are good. The color of the formation is dark gray and buff. In places the strata

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

contain ellipsoidal sandstone concretions of all sizes from an inch or less to 5 or 6 feet in diameter. The concretions are cemented with iron and are usually buff or dirty brown. Thin layers of bog iron ore also occur in the formation.

Fragments of dinosaurian bones were found at several localities about 450 feet above the base of the formation. A tip of horn core of a ceratopsian, probably *Triceratops*, and fragments of *Champsosaurus* sp., collected from a stratum 120 feet from the top, on Devil's Canyon, were identified by C. W. Gilmore. The following plants were collected from the Hell Creek member and identified by F. H. Knowlton:

T. 3 S., R. 62 E., top of member:
Palm, gen. et sp.?
Aralia notata?
T. 2 N., R. 61 E., 50 feet below top of member:
Populus cuneata Newberry.
Populus speciosa Ward.
Sec. 21, T. 4 N., R. 60 E., 60 feet below top of member:
Populus amblyrhyncha Ward.
Populus cuneata Ward.
Platanus sp.?
Celastrus sp.?
Sec. 25, T. 3 N., R. 59 E., 10 feet below top of member:
Taxodium occidentale Newberry.
Celastrus sp.

LUDLOW LIGNITIC MEMBER.

The lignite-bearing beds of the Ludlow lignitic member of the Lance overlie the Hell Creek member conformably and consist of strata of fresh-water origin, with local lenses of sand that are probably of eolian origin. Field studies by Thom and Dobbin show that the Ludlow member as developed near Marmarth, N. Dak., is equivalent to the Lebo member of the Fort Union, the Tullock member of the Lance, and the upper part of the Hell Creek member of the Lance of east-central Montana.[5] Although both the Hell Creek and Ludlow members contain lignite in the Ekalaka field, the contrast in composition and texture as well as in color in parts of this area is marked. The most prominent feature of typical Ludlow is the predominance of light-yellow sandstone. In many places this sandstone forms ledges or low bluffs, which are attacked by the wind and eroded still further into pitted surfaces and prismatic columns. Cross-bedding is another characteristic of the sandstones of this member. Careful examination of the cross-bedding revealed several types and predominant characteristics. In every locality examined the false beds dip eastward or northeastward. The thickness of the

[5] Thom, W. T., jr., and Dobbin, C. E., personal communication.

cross-bedded layers ranges from an inch or less to 45 feet, but the maximum, which was found in sec. 20, T. 3 S., R. 62 E., is exceptional, the most common thickness of cross-bedded layers being from 1 to 2 feet. In several places crumpling of cross beds was noted. The upper portion of the Ludlow in this field is very calcareous, containing in some localities from 30 to 40 per cent of lime. This may be due in part to leaching of lime from the White River or other younger formations. The maximum thickness of the Ludlow in this field is about 350 feet.

The following section illustrates the thickness and character of the Ludlow member in the Ekalaka Hills:

Section in secs. 4 and 9, T. 1 N., R. 59 E.

	Ft.	in.
Tongue River member of Fort Union formation:		
Sandstone, gray, calcareous, thin bedded	5+	
Sandstone, greenish gray, calcareous, medium grained; contains carbonaceous material, clay balls, and casts of stems. Appears massive when fresh, but on weathering shows cross-bedding. Cliff former	31	
	36	
Ludlow lignitic member of Lance formation:		
Sandstone, yellowish, soft, alternating with beds of yellow to gray sandy shale (partly covered)	65	
Shale, bluish gray, slightly sandy; contains iron carbonate concretions	59	
Shale, brown, thinly laminated	3	
Shale, bluish gray, stained with limonite	1	6
Sandstone, gray	1	
Shale, brown, lignitic	1	6
Sandstone, gray, fine grained	5	
Sandstone, yellowish, fine grained, with iron carbonate lenses as much as 2 inches thick	5	
Shale, brown, lignitic	2	
Sandstone, gray, fine grained, with some limonite streaks	4	
Shale, sandy, gray, concretionary	11	
Sandstone, light buff, fine grained, micaceous, bedded; a cliff-maker in places	27	
Shale, lignitic		6
Sandstone, gray, containing iron carbonate concretions, the exterior of which weathers to limonite	13	
Shale, lignitic	1	
Shale, gray, sandy	1	6
Shale, brown	2	
Sandstone, gray to yellow, micaceous, with a few thin layers of brown and lignitic shale; contains lignitized tree branches and marcasite concretions	22	
Lignite, poor	1	

	Ft.	in.
Sandstone, yellowish to gray, medium grained, micaceous, with clay balls and pieces of lignite; bedding irregular	18	
Lignite, good, woody	3	4
Bone		4
Lignite, good, woody	2	4
Shale, brown	1	
Sandstone, yellowish gray, fine grained, micaceous; contains limonite concretions; bedding irregular	10	
Covered	13	
Lignite	1±	
Shale, gray, alternating with yellowish and thin brownish streaks; contains small iron carbonate concretions	25	
Sandstone, light lemon-yellow, very fine grained, laminated, micaceous	8	
Shale, brown	1	6
Shale, gray, with brown carbonaceous streaks and yellow sandy streaks, micaceous	12	
Covered (probably shale)	11	
Sandstone, gray, fine grained; contains considerable mica and small limonite concretions; bedded irregularly	11	
Top of Hell Creek member of Lance formation.		
	343	6

The lower sandstone of the Ludlow varies greatly in thickness and character from place to place. It is commonly cross-bedded and contains a few layers of sandstone pellets. These pellets or angular pebbles are usually stratified pieces of sandstone of finer grain than the matrix and indicate shallow-water conditions in which local areas were actually above water for short periods, producing drying cracks and so-called " desiccation pebbles." This condition seems to have been most prevalent while the lower part of the Ludlow was being deposited.

The separation of the Hell Creek and Ludlow members of the Lance and the mapping of the boundary between them in fields adjacent to the Cedar Creek anticline has long presented a difficult problem to geologists, because of the local fallibility of the lithologic and color criteria on which the separation of the two members has commonly been based. Their separation on paleontologic grounds has also been difficult, although dinosaur remains are abundant in the Hell Creek member and are rarely if ever found in the Ludlow member and its equivalents.

In this field the Hell Creek-Ludlow contact was mapped from north to south, the same stratigraphic horizon being traced into the Little Beaver Valley that was mapped by C. F. Bowen in the

Baker field as the base of the Fort Union. Subsequent work has shown that the lignite so mapped by Bowen lies at or near the base of the Lebo shale member of the Fort Union—that is, somewhat above the base of the type Ludlow as mapped by C. J. Hares in southwestern North Dakota. In the Box Elder Creek valley the lithologic contrast between the Hell Creek and the Ludlow is more clearly marked, and the contact as mapped is somewhat lower in the section, corresponding to the base of the light-yellow sandstone, which is traceable into the basal bed of the type Ludlow in northwestern South Dakota. In the southern part of T. 2 N., R. 60 E., the coal bed mapped as the base of the Ludlow farther north has apparently been cut out by stream channeling, and in its place is a coarse massive sandstone. This sandstone transgresses beds beneath it to the extent of about 40 feet, and from this point southward it seemed advisable to follow very closely the base of this sandstone rather than to attempt to maintain a strict stratigraphic position. In T. 1 N., R. 59 E., a siliceous bed was found at the base of this sandstone. Farther east irregularities such as might be due to local channeling at the base of the sandstone were noted in sec. 11, T. 1 N., R. 61 E., and also in the northern part of T. 1 S., R. 62 E. However, at other places along the contact of the Ludlow and Hell Creek members, notably in the eastern part of T. 1 N., R. 60 E., the dark sandy shale of the Hell Creek member grades almost imperceptibly upward into light-yellow sandstone of the Ludlow. The evidence of gradation seems to be fully as common as evidence of channeling. Another example of a gradual change from the dark clayey sandstone of the Hell Creek into light sandy beds of the Ludlow can be well observed on Devils Canyon in the southeastern part of T. 1 S., R. 60 E.

The following fossils collected from the Ludlow member have been identified by F. H. Knowlton:

T. 4 N., R. 57 E.:
- Populus cuneata Newberry.
- Populus amblyrhyncha Ward.
- Populus daphnogenoides Ward.
- Celastrus curvinervis Ward.
- Celastrus pterospermoides Ward.

NW. ¼ sec. 24, T. 3 N., R. 59 E.
- Populus amblyrhyncha Ward.
- Populus cuneata Newberry.
- Populus daphnogenoides Ward.
- Sequoia nordenskiöldi Heer.
- Celastrus sp.
- Platanus haydenii Newberry.

From this list it will be seen that the flora of the Ludlow is of the usual Lance or Fort Union facies, consisting of poplar, bittersweet, redwood, and sycamore.

FORT UNION FORMATION.

TONGUE RIVER MEMBER.

Strata elsewhere classified as the Lebo shale member of the Fort Union formation correspond to the upper part of the Ludlow lignitic member of the Lance of the Ekalaka and adjacent fields. Massive sandstones representative of the lower part of the Tongue River member of the Fort Union are also present and are conspicuously exposed in the Medicine Rocks, on the Little Beaver-O'Fallon Creek divide (see Pl. XXXI, *A*), and in the northern part of the Ekalaka Hills. These Tongue River sandstones constitute all of the Fort Union shown on Plates XXX and XXXIII. Clay pellets and cross-bedding, indicating shallow-water deposition, are common in these sandstones, which also contain local beds of quartzitic sandstone or lignite and are locally slagged by the burning of the lignite (Pl. XXXI, *B*).

The Fort Union as originally mapped in this field included the upper part of the Ludlow lignitic member of the Lance and the Tongue River member, no separation being made in the original field notes, and the boundaries of the Fort Union (Tongue River member) as shown on Plates XXX and XXXIII are at best only approximately correct, being drawn from reconnaissance sketching by W. T. Thom, jr., in 1923, and from notes on the sandstones of the Ekalaka Hills.

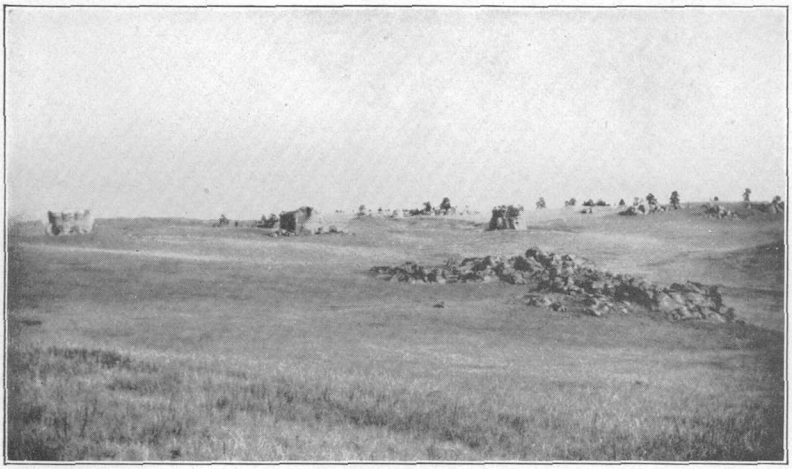
WHITE RIVER FORMATION.

The White River formation, which overlies the Fort Union unconformably, is the next younger formation in this field. It crops out in the Long Pine Hills and may also underlie the Arikaree (?) formation in the Ekalaka Hills, though no positively identifiable fossils were found in the rocks of possible White River age in the latter locality. The White River includes a conglomerate at the base and overlying light-green and light-pink calcareous and tuffaceous beds of varying thickness. In some places the beds are massive pink and cream-colored sandstone; in others they are composed of alternating strata of pale-green clay, marl, chert, and volcanic ash. The formation is apparently largely of lacustrine origin. Its maximum local thickness is 134 feet.

The following fossils collected from the White River formation were identified by J. W. Gidley, of the United States National Museum:

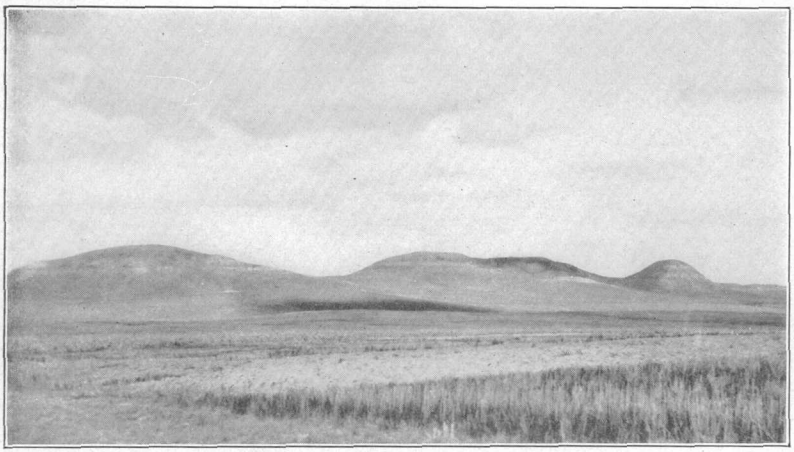
Capitol Rock, SW. ¼ sec. 16, T. 3 S., R. 62 E.:
- Titanothere, portions of lower jaws. The remainder undeterminable fragments.

Buck Point, SW. ¼ sec. 20, T. 3 S., R. 62 E.:
- Teeth of some species of titanothere.
- Incisor tooth, probably of some species of Mesohippus.
- Fragments of a turtle.



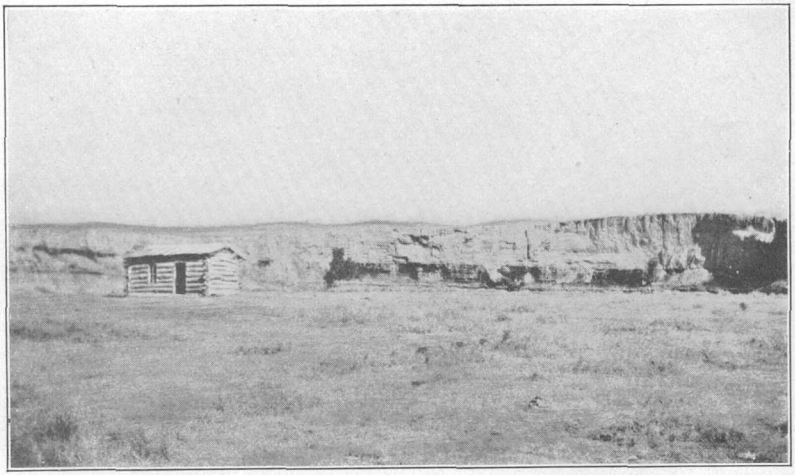
A. PART OF THE MEDICINE ROCKS, NORTH OF EKALAKA, MONT.

Produced by erosion of the massive sandstone near the base of the Tongue River member of the Fort Union formation, in central part of T. 3 N., R. 58 E.

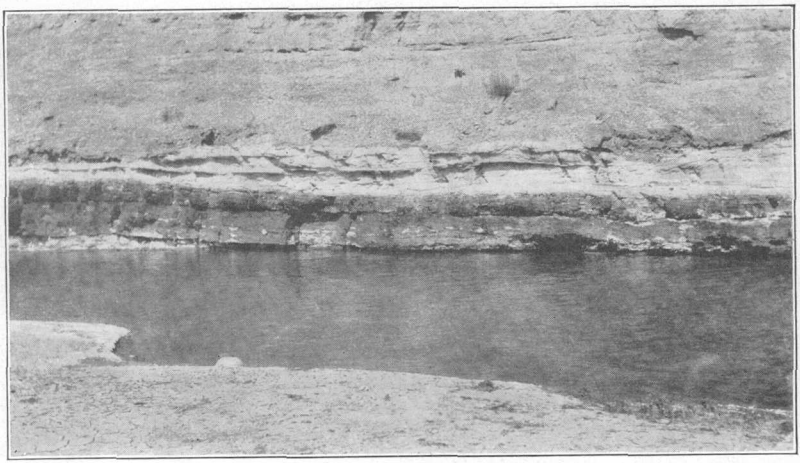


B. CHARACTERISTIC TOPOGRAPHIC FEATURES OF THE NORTHERN PART OF THE EKALAKA LIGNITE FIELD, MONT.

Clinker-capped hills of the Tongue River member of the Fort Union formation and lowlands of the Ludlow lignitic member of the Lance formation, in T. 4 N., R. 59 E.



A. LIGNITE OUTCROP AT McKENZIE PROSPECT, ON SPRING CREEK, LOCATION 2, SEC. 4, T. 4 N., R. 57 E., MONT.



B. LIGNITE OUTCROP IN BLUFFS ON BOXELDER CREEK IN SEC. 9, T. 1 N., R. 61 E., MONT.

In the upper part of the Hell Creek member of the Lance formation, at location 210

ARIKAREE (?) FORMATION.

In this field beds called Arikaree (?) because of their stratigraphic position and lithologic similarity to the Arikaree formation of South Dakota rest upon an eroded surface of the White River formation without angular discordance. These beds are prominent cliff-forming rocks in the Ekalaka and Long Pine hills, as well as in the numerous outliers of Chalk Buttes, Belle Tower, Sheep Mountains, A Bar B Buttes, and Finger Buttes. There is also a small area of coarse conglomerate several feet thick capping a butte in sec. 16, T. 2 N., R. 57 E., which is possibly of the same formation. These strata are composed largely of light-gray or white calcareous sandstone, capped by a few feet of hard green quartzite. The quartzite contains a few small quartz pebbles and is very dense and resistant, forming the cap rock over most of the Long Pine Hills. It is the youngest member of the Arikaree (?) noted. The sandstone is cross-bedded in some places and massive in others. Locally thin layers of shale and limestone are present, and a bed of volcanic ash 3 inches thick, about 60 feet above the base of the formation, was noted in T. 4 S., R. 60 E. The following section of the Arikaree (?) is characteristic of it in this field.

Section of Arikaree (?) formation in sec. 24, T. 1 N., R. 58 E., Ekalaka Hills.

	Feet.
Sandstone, pale greenish gray, massive, coarse-grained, cliff-maker	35
Sandstone, gray, thin-bedded and cross-bedded	38
Sandstone, greenish to white, calcareous, fine-grained, friable, containing nodular sandstone concretions cemented with lime. Massive in fresh exposures, but weathered surfaces show cross-bedding in places. A cliff maker	108
Sandstone, light gray-green to pale green, calcareous, fine-grained. Some parts well cemented, others friable	22
	203

The maximum thickness of the Arikaree (?) in the A Bar B Buttes, in T. 4 S., R. 60 E., is about 250 feet, and at this locality a quartz-pebble conglomerate several feet thick is found at the base in several places. This formation also caps the Finger Buttes.

Fossils in the Arikaree (?) are apparently rare. A few poorly preserved bird and fish bones were collected from the base of the formation in the A Bar B Buttes, in sec. 35, T. 4 S., R. 60 E. These were studied and reported on by R. W. Shufeldt, of the United States National Museum. In T. 1 N., R. 59 E., at locality 238 (see Pl. XXXIII), part of the first upper milk molar of a rhinocerotid, probably *Caenopus*, of Oligocene age, was identified by J. W. Gidley.

This, however, may be an inherited fossil, as it was found very near the base of the Arikaree (?), and its size and character indicate that it might easily have been derived from adjacent White River beds that were being eroded as the Arikaree (?) was being deposited. The fossils therefore merely suggest that these beds, which lie upon known White River beds, are themselves White River or younger. The age of the Arikaree of southern South Dakota, according to its vertebrate fossils, is Miocene. But it can not be said from the data at hand that the Arikaree (?) beds in the Ekalaka field are of the same age, even though they resemble the known Arikaree very closely.

TERRACE GRAVEL.

Scattered widely over the field are remnants of an old plain, which stand 50 to 75 feet above the surrounding surface and are covered with waterworn gravel. Very little can be said of this gravel, except that it is stratified and appears to have been laid down by streams. The gravel ranges in size from sand grains to cobbles 3 or 4 inches in diameter and is composed principally of brown and white quartzite and fossil wood, with some agate, limestone, and sandstone. In some places the terraces abut against the higher hills of the interstream areas, from which they slope away at a decreasing rate to their outward limits. On the hillward side of the terrace near the west end of Sheep Mountain the fragments making up the gravel are angular and have been worn but little by running water. At this place the fragments are composed largely of sandstone derived from the Arikaree (?) of the near-by hills. The maximum known thickness of the gravel is 15 feet.

ALLUVIUM.

Alluvial deposits extend along most of the valleys in this region except in some of the steeper canyons and in the many small badland ravines. The Little Missouri is bordered by alluvial bottom lands of considerable width along nearly all of its course. Owing to numerous meanders of the stream, the bottom lands are cut into small areas, and at the end of nearly every large bend the water is cutting into bedrock. Wide areas of alluvium also occur in Box Elder Creek valley, especially in the shale district which it traverses. The belt of alluvium is markedly narrower where the stream traverses the sandstones of the Lance formation. Powder River is bordered by a bottom land of alluvium from half a mile to a mile in width. The alluvium consists mainly of local materials worked over by the streams and ranges from a thin layer of soil to deposits 20 to 30 feet thick in some of the larger valleys. A well in the Little Missouri

Valley 30 feet deep is sunk entirely in alluvium. The material is largely sand, gravel, and loam, though it merges into talus locally on the slopes adjoining the valleys.

Where the alluvium lies on shale it commonly contains an admixture of sand from some near-by sandstone bed and thus affords some of the best soil of the region.

STRUCTURE.

The dominant structural features of this field are the north end of the Black Hills uplift, the parallel fold of the Cedar Creek or Baker-Glendive anticline, and an intervening broad, shallow syncline, in which minor anticlines and synclines are present.[6] The axis of the plunging north end of the Black Hills uplift passes through T. 6 S., R. 57 E., trending north-northwest, and the Cedar Creek fold crosses the extreme northeast corner of the field. All the formations to and including the Fort Union are deformed about equally. The younger White River, Arikaree (?), terrace gravels, and alluvium lie horizontal, except for depositional slope, on the truncated edges of the older formations. The most pronounced dips in the older strata within the field occur along the southwest flank of the Baker-Glendive anticline. In the northern part of T. 4 N., R. 61 E., the dips in the Fox Hills sandstone average about 2° S. 70° W., whereas in sec. 30 of the same township dips in the Lance reach 4° S. 60° W. Dips on the northeast side of the anticline are as high as 1° NE.

Beds of the Fox Hills sandstone in the central and southern parts of the field dip about 1° along the outcrop. Measurements of the dip of the Pierre and older formations are difficult to obtain, because of the softness and homogeneity of the rock and the thin lamination of the shale. The dip of these strata is presumed to increase slightly toward the south end of the field to a maximum of 4° near Ridge post office.

The minor structural details of the field were not mapped with accuracy, but the dip of the strata at several points in the field is shown on Plate XXX.

ECONOMIC GEOLOGY.

WATER RESOURCES.

The average rainfall in this region ranges from 13 to 16 inches. The amount is noticeably greater in the hills than on the plains. Most of the precipitation falls in the spring and early summer,

[6] Moulton, G. F., and Bass, N. W., Oil and gas prospects in the Cedar Creek anticline and vicinity in Montana, North Dakota, and South Dakota: U. S. Geol. Survey Press Bull. 12051, 1921.

though rains of three or four days' duration are to be expected in September. The snow is commonly light and readily drifted into gullies and canyons. The torrential character of most of the rains and the density of the soils cause a large percentage of the precipitation to run off rapidly and cut deep gullies into the soft formations beneath. Springs are rare on the plains, and most of the streams have water in their channels only a small part of the year. Even some of the larger streams contain only discontinuous pools of water during the summer. Little Missouri and Powder rivers normally contain running water throughout the year, though occasionally during August the flow in places is entirely in the gravel beneath their channels. Box Elder and Little Beaver creeks also contain running water the entire year, though the former is intermittent above Ridgway post office and the latter above the Emerson ranch, T. 3 N., R. 59 E. Many of the smaller streams are reduced to a series of pools during the summer.

The extensive series of sedimentary rocks that underlie this field contain sandstones which are sufficiently porous to be water bearing. These sandstones, some of which do not crop out in the field, reach the surface around the Black Hills, where they obtain their supply of water directly from rains or indirectly from streams that cross their upturned edges. In the southern part of the Ekalaka field, between the Fox Hills outcrop and the Wyoming line, the potential sources of artesian water are the Dakota sandstone and the Lakota sandstone, about 100 feet below the Dakota. These two sandstones furnish artesian water for Belle Fourche, and for a large part of central and eastern South Dakota.[7] The minimum depth to the Dakota at the Wyoming line is about 350 feet, and its depth at the Fox Hills outcrop is about 4,200 feet.

The Fox Hills sandstone is also a potential source of water within that portion of the field which it underlies, though owing to its fineness of grain as well as its gentle dip, it does not produce as abundantly as the Dakota. The sandstones of the overlying Lance formation, though more lenticular, may also prove to be water bearing in parts of the field near Ekalaka and, together with the Fox Hills, are the source of the water now obtained by artesian wells in the Powder River valley.

CEMENT MATERIALS.

Cement-making materials are not so common in this field as might be supposed from the calcareous nature of some of the widespread formations. Many samples of these calcareous rocks were

[7] Darton, N. H., Geology and underground waters of South Dakota: U. S. Geol. Survey Water-Supply Paper 227, 1909.

examined to determine their cement-making qualities, but most of them were found to be too siliceous. A number of calcareous rocks were examined microscopically, and a chemical analysis of one from Capitol Rock was made, as follows:

Partial analysis of rock from T. 3 S., R. 62 E., Fallon County, Mont.

Silica (SiO_2)	24.00
Magnesia (MgO)	1.26
Lime (CaO)	35.79
Loss on ignition	30.02
Total insoluble	28.90
Magnesium carbonate ($MgCO_3$)	2.65
Calcium carbonate ($CaCO_3$)	63.91

This rock is the nearest to "cement rock" of all those examined from this field. All the calcareous rocks tested are from the White River and Arikaree (?) formations, and the chief objection to their use is that they are high in silica, which is commonly in the form of quartz grains and therefore will not submit to calcination at reasonably low temperatures. A test of some of this siliceous limestone was improvised a number of years ago by Mr. D. H. Russell, of Ekalaka, who burned some of the rock in a small kiln in T. 1 N., R. 58 E., south of Ekalaka, for lime. He found that it could be slacked with only moderate success by using hot water.

It is probable that the tepee buttes of the Pierre formation contain the proper constituents for cement material, though no tests of this limestone were made by the writer.

The Niobrara formation, which is exposed beneath the Pierre shale in the southern portion of this field (see Pl. XXX), is known generally in the States farther south as a "cement rock," but in this field it contains too large a proportion of clay to be suitable for cement manufacture.

CLAY.

Clay for the manufacture of brick, tile, or earthenware occurs at a number of horizons in the Lance, and a bed from 10 to 12 feet thick is present along the escarpment of the Ekalaka Hills in T. 1 N., R. 58 E. This bed contains a small percentage of lime, apparently leached from the overlying Arikaree (?). It is light green and burns to a gray color. This clay may be used for brick or tile, and by the addition of a small amount of iron oxide red or brown brick may be made from it.

SOILS.

The soils of the Ekalaka field are largely residual—that is, they are derived from the formations upon which they lie. In the southern part of the field the soils are mostly clay and clay loam. On the

outcrop of the Fox Hills formation the soils are decidedly sandy, and the Pierre soil is a well-known gumbo. The soil of the Lance is variable, contains alkali in patches, and in general is thin, being good only where it is mixed with material from the contiguous formations. The areas underlain by soil from the Fort Union, White River, and Arikaree (?) are small and lie on the highest hills. This soil supports luxuriant grass and most of the forest growth. Owing to its position on the high land it is too thin in many places for cultivation, but where it is tillable it is a rich dark loam of excellent quality. A study of the distribution of the formations as shown on the map (Pl. XXX) will indicate the general distribution of the several soil types mentioned.

The still smaller areas of gravel are generally too stony to be satisfactory farming land, though they support considerable grass. Probably the best farming lands of the region are the belts of alluvium along the main streams, provided water for irrigation can be obtained economically. The alluvium is a mixture of sand, gravel, and clay and owing to its depth and character is tillable throughout the area shown on Plate XXXIII. Because of its porosity, however, it requires more water than the soils of greater density.

LIGNITE.

DISTRIBUTION.

The lignite of the Ekalaka field occurs in the Lance and Fort Union formations, which are preserved only in the northeastern part of the area, in the vicinity of the Ekalaka and Long Pine hills. Plate XXXIII shows the area examined for lignite in the Ekalaka field. The Ludlow lignitic member of the Lance formation contains the principal local lignite reserves, although minor deposits are present in the Hell Creek member of the Lance and in the remnants of the Tongue River member of the Fort Union. There are several prominent lignite horizons in the field, whose vertical distribution is about as follows:

	Feet.
Wilder bed.	
Interval, shale and sandstone	90–110
Elder zone.	
Interval, shale and sandstone	60–75
Keefer, Spillman, Herman, and probably Emerson beds.	
Interval, shale and sandstone	60
Coal Bank bed and McKenzie bed.	
Interval, shale and sandstone	15
Horner bed.	

Local lenses of lignite occur at several other horizons, and all the lignite beds are irregular in thickness, the valuable lignite occurring in comparatively small areas.

The Coal Bank bed crops out on Coal Bank Creek in T. 2 N., R. 61 E., where it reaches a maximum thickness of over 15 feet. (See section 179, Pl. XXXIV.) Within a distance of 2 miles to the north this bed is less than 2 feet thick, but southward the decrease in thickness is somewhat more gradual. The same horizon is probably represented by the Horner and McKenzie lignites, which lie within a few feet of each other on the southeast end of the Long Pine Hills. These beds have been mined in several places in T. 3 S., R. 62 E., and T. 2 S., R. 62 E. The lower or Horner bed has a maximum thickness of about 5 feet at the Horner mine, in sec. 10, T. 3 S., R. 62 E. The McKenzie bed is mined in sec. 15 of the same township at the Kerr mine, where it is about 5½ feet thick, and also in sec. 23 of the township immediately to the north at the Moody mine, where it is 5 feet thick. On Spring Creek near the north line of T. 4 N., R. 57 E., another lens at the McKenzie horizon also shows a maximum thickness of 9 feet. (See Pl. XXXII, *A*.) In each of these localities the thickness decreases from the maximum to less than 2 feet within a comparatively short distance. The Emerson bed, which probably lies about at the horizon of the Keefer, Spillman, and Herman beds, or 60 feet above the McKenzie, is present on Little Beaver Creek in the vicinity of the Emerson ranch, in T. 3 N., R. 59 E., where it reaches a maximum thickness of over 9 feet of bone and coal (section 95, Pl. XXXIV). The Elder bed or group of beds is extensively developed in the vicinity of Ekalaka, where it attains an observed maximum thickness of about 6 feet. The Wilder bed also attains a thickness of about 4 feet at several places in the plateau east of Ekalaka and in the hills north of Little Beaver Creek. Other more local beds are also exploited to some extent. One nearly 3 feet thick is mined in the hills about 2 miles south of the town at the Parks mine. Another is mined about 1 mile east of the Parks mine. The latter bed contains much carbonaceous shale and bone but has an aggregate thickness of lignite amounting to over 4 feet.

The ash content of the lignite of this field is variable and in places high, relatively pure lenses of lignite grading through bony coal into carbonaceous shale or sandstone. It is probable that the heating value of the lignite increases slightly from north to south, owing to the greater regional metamorphism near the Black Hills uplift. At present the lignite of the Ekalaka field is mined for local domestic use only.

PHYSICAL PROPERTIES.

The lignite of the Ekalaka field is similar in general character to that of North Dakóta and adjacent fields of eastern Montana. It is

black or almost black, though yielding a brown powder, and may show either a bright black luster or be lusterless. In some of it the texture of the carbonized wood is still clearly visible, and some layers in the lignite beds show the hardness, black color, and well-developed cleavage of subbituminous coal.

On exposure to the air lignite loses a considerable part of its moisture, shrinks and soon falls to pieces, a characteristic which makes shipping it in open cars to distant markets almost impossible, unless it is to be used after briquetting or as powdered fuel.

CHEMICAL CHARACTER.

The first three analyses of the table on page 253 give a suggestion of the quality and chemical character of the lignite of the Ekalaka field. All the samples were somewhat weathered, however, and so the analyses are of doubtful value. Six representative analyses of Dakota lignite are also given and may be accepted as showing fairly accurately the probable composition of the lignite in this area.

In the table the analyses are given in four forms, marked A, B, C, and D. Form A is the analysis of the lignite exactly as it comes from the mine. Form B represents the sample after it has been dried at a temperature a little above the normal until its weight has become constant. Form C is a theoretical analysis of the sample after all moisture has been eliminated. Form D is also computed and is the analysis of the sample after all moisture and ash have been theoretically removed. Neither of the two conditions last mentioned exists in nature, but form C is used by mechanical engineers and form D is valuable for comparing the quality of the pure lignite substance and the effect on its heating value of the impurities present, and it is also used by petroleum geologists as an index of the degree of regional metamorphism at the point of sampling.

Analyses of lignite from the Ekalaka field, Mont., and fields in North and South Dakota.

[Made by the Geological Survey and Bureau of Mines; E. E. Somermeier, F. M. Stanton, and A. C. Fieldner, chemists.]

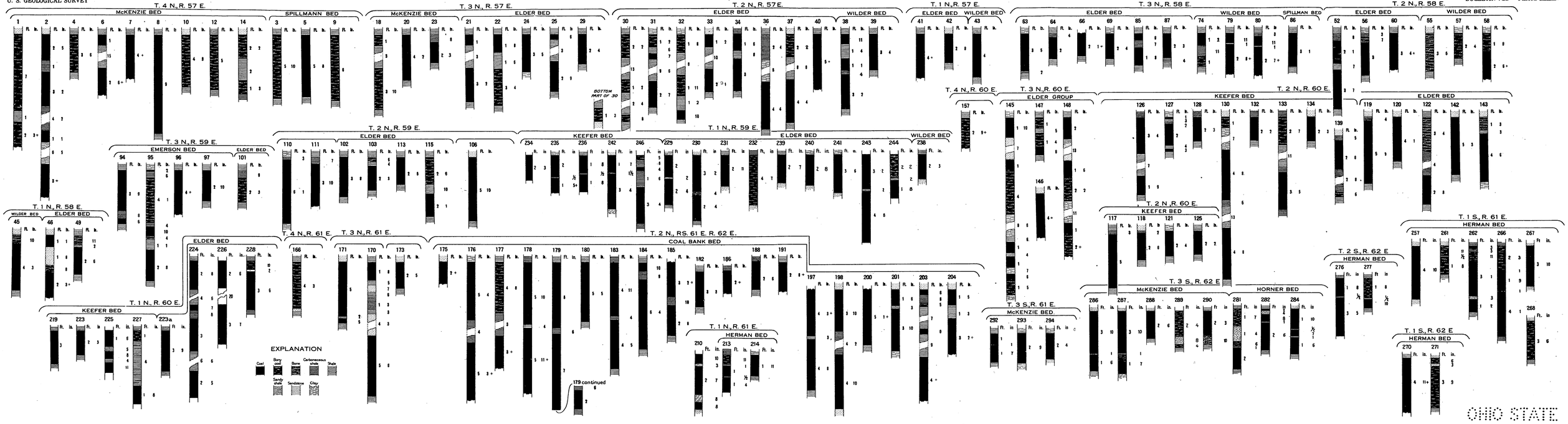
Source of sample.	Location.				Laboratory No.	Air drying loss.	Form of analysis.	Proximate.			Ultimate.					Heating value.	
	Quarter.	Section.	Township.	Range.				Moisture.	Volatile matter.	Fixed carbon.	Ash.	Sulphur.	Hydrogen.	Carbon.	Nitrogen.	Oxygen.	Calories.	British thermal units.
Coal Bank prospect, Ekalaka field	-------	34	6 N.	57 E.	10910	26.2	A	38.7	27.0	25.1	9.21	0.30	-------	-------	-------	-------	3,345	6,020
							B	16.9	36.6	34.0	12.48	0.41	-------	-------	-------	-------	4,530	8,160
							C	-------	44.1	40.9	15.02	0.49	-------	-------	-------	-------	5,455	9,820
							D	-------	51.9	58.2	-------	0.58	-------	-------	-------	-------	6,420	11,550
Kerr mine, Ekalaka field	-------	15	3 S.	62 E.	20372	33.5	A	39.0	22.6	23.9	14.47	1.60	-------	-------	-------	-------	3,110	5,600
							B	8.4	34.0	35.9	21.75	2.41	-------	-------	-------	-------	4,680	8,420
							C	-------	37.1	39.1	23.73	2.62	-------	-------	-------	-------	5,100	9,190
							D	-------	48.7	51.3	-------	3.44	-------	-------	-------	-------	6,690	12,050
Horner mine, Ekalaka field	-------	11	3 S.	62 E.	20370	34.3	A	41.3	24.6	26.9	7.19	0.62	-------	-------	-------	-------	3,440	6,190
							B	10.6	37.2	40.9	10.95	0.95	-------	-------	-------	-------	5,240	9,430
							C	-------	42.0	45.8	12.25	1.06	-------	-------	-------	-------	5,860	10,550
							D	-------	47.8	52.2	-------	1.21	-------	-------	-------	-------	6,680	12,020
Phillips mine, Perkins County, S. Dak.	SW.	7	17 N.	11 E.	12488	30.1	A	42.5	23.2	25.3	9.00	1.16	7.07	35.22	0.62	46.93	3,310	5,950
							B	17.7	33.2	36.2	12.88	1.66	5.33	50.39	.88	28.86	4,735	8,520
							C	-------	40.4	44.0	15.64	2.02	4.08	61.21	1.08	15.97	5,750	10,350
							D	-------	47.8	52.2	-------	2.39	4.84	72.56	1.28	18.93	6,815	12,270
Jones mine, Perkins County, S. Dak.	NW.	35	19 N.	10 E.	12453	26.0	A	39.2	24.7	27.8	8.35	2.22	6.60	38.02	.53	44.28	3,505	6,310
							B	17.8	33.3	37.6	11.28	3.00	5.02	51.38	.71	28.61	4,735	8,520
							C	-------	40.6	45.7	13.72	3.65	3.70	62.49	.87	15.57	5,760	10,370
							D	-------	47.2	52.8	-------	4.23	4.29	72.43	1.01	18.04	6,675	12,020
Newcomb mine, Harding County, S. Dak.	SW.	10	20 N.	9 E.	15062	23.6	A	34.7	27.2	29.0	9.1	.95	-------	-------	-------	-------	3,475	6,250
							B	11.1	37.1	39.4	12.4	1.29	-------	-------	-------	-------	4,735	8,520
							C	-------	41.7	44.4	13.9	1.46	-------	-------	-------	-------	5,325	9,580
							D	-------	48.3	51.7	-------	1.70	-------	-------	-------	-------	6,185	11,140
Washburne Lignite Coal Co.'s mine, Wilton, N. Dak.	-------	1	142 N.	80 W.	1935	32.3	A	40.5	27.1	27.4	5.0	.76	-------	-------	-------	-------	3,690	6,640
							B	12.1	39.9	40.4	7.5	1.12	-------	-------	-------	-------	5,450	9,810
							C	-------	45.5	46.0	8.5	1.28	-------	-------	-------	-------	6,205	11,170
							D	-------	49.7	50.3	-------	1.40	-------	-------	-------	-------	6,785	11,210
Consolidated Coal Co.'s mine, Lehigh, N. Dak.	-------	8	139 N.	95 W.	1971	35.6	A	42.1	24.5	25.7	7.7	1.13	-------	-------	-------	-------	3,420	6,160
							B	10.0	38.1	40.0	11.9	1.75	-------	-------	-------	-------	5,310	9,560
							C	-------	42.4	44.4	13.2	1.95	-------	-------	-------	-------	5,905	10,630
							D	-------	48.8	51.2	-------	2.25	-------	-------	-------	-------	6,805	12,250
U. S. Bureau of Reclamation mine, Williston, N. Dak.	-------	7	154 N.	100 W.	19367	32.8	A	44.1	23.8	36.3	5.76	.56	7.28	36.11	.63	49.66	3,355	5,040
							B	16.9	35.4	39.1	8.58	.84	5.40	53.74	.94	30.50	4,990	8,980
							C	-------	42.6	47.1	10.32	1.00	4.25	64.68	1.13	18.62	6,005	10,810
							D	-------	47.5	52.5	-------	1.12	4.74	72.11	1.26	20.77	6,665	12,060

DETAILS BY TOWNSHIPS.

Details concerning the lignite resources of each township in the region examined are given below. The descriptions are presented in geographic order, beginning at the northwest corner of the field (see Pl. XXXIII) and proceeding from north to south along each range. Many of the measurements of lignite beds 2 feet or more in thickness are shown graphically on Plate XXXIV with numbers corresponding to those used on the map (Pl. XXXIII). Other sections are given in the text.

T. 4 N., R. 57 E.—Near the top of the Hell Creek member is a lignite bed known as the McKenzie bed, which crops out along Spring (see Pl. XXXII) and O'Fallon creeks in T. 4 N., R. 57 E., and was measured at locations 1, 2, 4, 6, 7, 8, 10, 12, 13, and 14. The bed is variable in thickness and locally consists mainly of bone. The observed thicknesses of the bed are shown graphically on Plate XXXIV. East and south of location 14 the bed is generally too thin to be of any value. The Spillman bed, which is higher than the McKenzie and separated from it by about 60 feet of sandy shale and sandstone, was mapped in secs. 1, 2, 3, 11, and 17 and measured at locations 3, 5, and 9. This bed averages 5½ feet in thickness but is more variable in quality than the McKenzie bed. Another local lignite lens occurs between the McKenzie and Spillman beds and was measured at location 11, in sec. 15, where it contains 2 feet 8 inches of lignite. The general structure of the coal-bearing rocks in this township indicates a slight dip to the north of about 20 feet to the mile.

T. 3 N., R. 57 E.—The McKenzie lignite bed was mapped across T. 3 N., R. 57 E., and was measured at locations 17, 18, 20, 23, and 26. The greatest thickness of the bed is in the northeast corner of the township, where it is 4 feet 2 inches thick, as shown by the measurements at locations 18 and 20 (Pl. XXXIV). Southeast of this locality the bed is less than 3 feet in thickness, as shown by the following measurements: At location 17 it is 1 foot 4 inches thick; at location 23, 2 feet 3 inches; at location 26, 1 foot 8 inches. A lignite bed lower in the stratigraphic section, but unimportant in this township, was measured at locations 15 and 16, in sec. 5, where it measures 10 inches and 1 foot 2 inches, respectively. The Elder bed, which lies 120 to 135 feet above the McKenzie bed, crops out in some high hills in secs. 16, 21, and 27, as well as in the bluffs about the base of Wilder Butte. This bed becomes thicker toward the west. Measurements of it were obtained at locations 19, 21, 22, 24, 25, 27, 28, and 29. Some of these measurements are shown graphically on Plate XXXIV. At location 19 there is 1 foot 5 inches of lignite; at location 27, 1 foot 8 inches; at location 28, 1 foot 8 inches. At location 29



SECTIONS OF LIGNITE BEDS IN EKALAKA LIGNITE FIELD, SOUTHEASTERN MONTANA

two benches of lignite, separated by about 4 feet of shale, gave measurements of 1 foot 10 inches for the upper bench and 2 feet 4 inches for the lower bench. Another measurement, obtained on the same bed about a quarter of a mile west of the northwest corner of sec. 31, showed a thickness of 5 feet 11 inches. The Wilder lignite, which is of commercial value in certain parts of the field, lies about 100 feet above the Elder bed and crops out in Wilder Butte but was not measured in this township. The strata within this township dip northward about 10 feet to the mile.

T. 2 N., R. 57 E.—In the extreme northeastern part of T. 2 N., R. 57 E., the beds of the coal-bearing formation dip northeastward about 35 feet to the mile for a short distance. Elsewhere in the township the strata are more nearly flat. The Elder bed of lignite was measured at locations 30, 31, 32, 33, 34, 35, 36, 37, and 40. In general these measurements show that the bed becomes thicker toward the west. The quality of the lignite in this bed is in general very good. All these measurements except No. 35 are shown on Plate XXXIV. The Wilder bed was measured at locations 38 and 39.

T. 1 N., R. 57 E.—The stratified rocks lie nearly flat in T. 1 N., R. 57 E. However, a lignite bed, probably the Elder bed, crops out in sec. 2 at location 41 and in sec. 7 at location 42. The mapping of the outcrop of this bed in this township was exceedingly difficult, and in most places the inferred boundary is merely a topographic contour line, based on instrumental elevations and configuration of the surface. In mapping such boundaries, the line is placed far enough back from the supposed weathered outcrop to include only areas believed to be underlain by solid lignite. Location 42 is at a strip pit where the lignite is 2 feet 8 inches thick. About a quarter of a mile down the ravine a measurement on the same bed also showed 2 feet 8 inches of lignite. In another strip pit at location 41 the lignite is more than 4 feet thick. A higher bed measured at locations 43 and 44 is at about the same stratigraphic position as the Wilder bed and shows thicknesses of 4 feet and 1 foot 2 inches, respectively.

T. 4 N., R. 58 E.—Many thin beds of lignite crop out at several places in T. 4 N., R. 58 E., but none of them contain more than 2 feet of lignite. Those measured are at about the same horizons as the Spillman and Elder beds and may be their local representatives. At location 88, in sec. 33, 1 foot 7 inches of lignite is exposed near the water in Spring Creek. At location 89, 8 inches of lignite was found; at location 90, 1 foot 6 inches. The southwestern part of the township is underlain by the McKenzie lignite bed, which is within 300 feet of the surface and thick enough to warrant the classification of this portion of the township as coal land.

T. 3 N., R. 58 E.—The McKenzie lignite bed probably underlies most of T. 3 N., R. 58 E., but does not crop out within its boundaries.

However, its thickness and quality in the township immediately to the west warrant classifying parts of secs. 5, 7, 8, 18, and 19 and all of sec. 6 as coal land. The Spillman bed, which lies next above the McKenzie, was measured at locations 86 and 76, in secs. 4 and 7, where the thicknesses found were respectively 3 feet 1 inch and 9 inches. The Elder bed also crops out in this township and is of sufficient thickness in sec. 31 to warrant classifying a part of this section as coal land. Measurements on this bed were obtained at locations 63, 64, 65, 66, 69, 85, and 87. These measurements are given on Plate XXXIV, except the one at location 65, where the bed is only 1 foot 2 inches thick, and one made about a quarter of a mile west of location 64, where the bed contains about 2 feet of lignite. The Wilder bed, named from Wilder Butte, around which it is exposed, was measured at locations 62, 67, 68, 70, 71, 73, 74, 77, 79, 80, 81, 82, and 83. At location 62 the bed carries 1 foot 8 inches of lignite; at 67, 1 foot 7 inches; at 68, 1 foot 11 inches; at 70, 6 inches; at 71 the entire bed is carbonaceous shale; at 73, 1 foot 6 inches; at 74, 1 foot 2 inches; at 77, 1 foot 5 inches; at 79, more than 3 feet 6 inches; at 80, more than 3 feet 5 inches; at 81, 1 foot 5 inches; at 82, 1 foot; and at 83 lignite probably belonging to the same bed was found in a spring, but no section could be obtained at this place. The measurements made at locations 74, 79, and 80 are shown graphically on Plate XXXIV. The greatest thicknesses of the Wilder bed, as will be seen from these measurements, are in secs. 19 and 20, where a small area has been classified as coal land on the basis of this bed. Several thin beds were noted at other places in the township, such as locations 75 and 78, but as the beds are very thin and the lignite poor, they are considered of no value. The strata higher in the section form the sandstone ridges and buttes of the divide.

T. 2 N., R. 58 E.—The Elder lignite bed was mapped across T. 2 N., R. 58 E., and sections of it were obtained at locations 52, 56, and 60. A well in the SW. ¼ sec. 2 is reported to have struck lignite. All the measurements on this bed are shown in Plate XXXIV. The bed averages about 4 feet of lignite throughout the township so far as could be determined from its exposures. The basis for mapping this lignite bed in the northwestern part of the township is largely hypothetical. Contour lines drawn at the elevation of the lignite bed indicate the probable position of the outcrop. At several places thin beds higher in the section were measured, the most valuable of which is the Wilder bed. This bed was measured at locations 53, 54, 55, 57, 58, and 61. At location 58 this bed contains more than 4 feet 2 inches of lignite. The other measurements indicate that the bed is valueless elsewhere in this township. At location 53 the bed

measures 1 foot 8 inches. At location 56 no lignite was found, but a carbonaceous shale containing some streaks of lignite indicates the horizon of the bed. At location 61 about 1 foot 2 inches of lignite was found. Other measurements on the bed are given on Plate XXXIV.

T. 1 N., R. 58 E.—The lowest bed of lignite exposed in T. 1 N., R. 58 E., apparently is the Keefer bed, measured at location 45 C, in sec. 36, where it carries 2 feet 5 inches of dirty lignite. The Elder lignite bed crops out at several places around the head of the Russell Creek valley and was measured at locations 46, 47, 48, and 49. The entire thickness of the bed could not be obtained at location 47 but probably is only slightly greater than the measurement obtained, which was 2 feet 1 inch. At location 48 the bed contains about 2 feet 6 inches of dirty lignite, and at location 49 the bed is divided into several benches, the larger one of which contains 2 feet 6 inches of lignite. This bed was also measured at location 45 B, where it carries 2 feet 11 inches in the lower bench and 2 feet in an upper bench. A higher bed of lignite, probably the Wilder bed, was measured at locations 45, 45 A, and 50; at location 45 the bed carries 4 feet 3 inches of rather poor lignite; at location 45 A it contains about 3 feet of weathered lignite; and at location 50 the bed is much weathered and apparently contains only carbonaceous shale.

T. 4 N., R. 59 E.—Several outcrops of thin lignite beds were found in T. 4 N., R. 59 E., but none of them are of sufficient thickness to be considered valuable. The following section was obtained in a butte at location 91, in sec. 5:

Section of beds exposed at location 91, sec. 5, T. 4 N., R. 59 E.

	Ft.	in.
Clinker	20±	
Sandstone, yellow, friable	16	
Sandstone, forming hard ledge	3	
Covered	9	
Shale, drab	2	
Lignite		8
Clay, gray	18	
Sand, yellow	1	
Clay, gray	3	6
Ash and shale, probably from thin lignite bed		2
Shale, gray	4	
Sandstone, light yellow, friable	6	
Shale, carbonaceous		1½
Shale, light gray	10	
Sandstone, forming ledge	3+	
Total section	96	5½±
Total lignite		8

At location 92, in sec. 21, a bed of lignite crops out in a spring from which no measurement could be obtained. However, it was reported that the bed was about 2½ feet thick. A well in the SW. ¼ sec. 2 is reported to have struck 2 feet of lignite. Wells in the southern part of the township from 30 to 50 feet deep were dug through sand and sandstone for the entire depth. A small portion of secs. 32, 33, and 34 is classified as coal land on the basis of the Emerson bed, which crops out in the township to the south and undoubtedly underlies this area.

T. 3 N., R. 59 E.—The Emerson lignite bed is the most valuable bed of lignite that crops out in T. 3 N., R. 59 E., and is probably equivalent to the Keefer and Spillman beds, although it is possibly to be correlated with the McKenzie bed. At the Emerson mine, at location 95, in sec. 15, this bed attains a thickness of 7 feet. This bed was examined and measured at locations 94, 95, 96, and 97 (see Pl. XXXIV), and probably also at 99 and 100. At location 94 an incomplete section shows 3 feet 9 inches of lignite; at 95, 7 feet; at 96, 4+ feet; at 97, 2 feet 10 inches; at 99, 1 foot 9 inches; and at 100, 1 foot 2 inches. A lignite bed partly exposed in the channel of Little Beaver Creek at location 93 was found to contain at least 1 foot 8 inches of lignite. Southward from this place on both sides of Little Beaver Creek this bed passes immediately under a thick cover of alluvium, so that no complete section could be obtained, and its correlation is uncertain. It may represent the Emerson bed but probably is a lower one. A higher bed of lignite, possibly the Elder bed, was found at location 101 and contains 2 feet 3 inches of bony lignite at that place. Above this bed stratigraphically the formation becomes decidedly sandy and the higher hills show a notably large proportion of sandstone. At location 98 a bed of gray siliceous rock 1 foot 3 inches thick crops out. The bed is found on both sides of Fletcher Creek and extends northward from location 98, in sec. 24, to the northern part of sec. 13. This bed contains the casts and molds of plant remains, none of which could be identified. The origin of the deposit is still somewhat a matter of speculation, although it is probably similar to that of flint clays found in other coal fields. It is also reported that 5 feet of lignite was struck at a depth of 50 feet in the Arkansas Natural Gas Co.'s well drilled in the NE. ¼ SW. ¼ sec. 19, but it is not known what horizon was represented by this bed.

T. 2 N., R. 59 E.—The lignite beds in T. 2 N., R. 59 E., are exceedingly variable in quality and thickness. The lowest bed exposed, probably belonging to the basal part of the Elder zone, crops out along Coal Creek and was measured in sec. 23 at locations 110 and 111. The bed contains 6 feet 1 inch of lignite at location 110 and

at least 3 feet 10 inches at location 111. The top part of the bed is exposed about a quarter of a mile east of location 111, where 2 feet of the bed lies above the water in the creek. The same bed is reported to contain 5 feet of good lignite at location 116, in sec. 35. The next higher lignite, the main Elder bed, occurs in the northern and southeastern parts of the township and was measured at locations 102, 103, 105, 108, 113, 114, and 115. At location 102 the bed carries 3 feet 8 inches of lignite; at 103, 2 feet 3 inches; at 105 the entire bed is composed of carbonaceous shale; at 108, 1 foot 7 inches; at 113, 2 feet 6 inches; at 114, 10 inches; at 115, 4 feet 7 inches of lignite in two benches. (See Pl. XXXIV.) The next higher bed of lignite was measured at location 106 and carries 5 feet 10 inches of lignite at that point. A bed higher in the section was measured at locations 104 and 109, where it carries 2 feet 1 inch and 1 foot 2 inches of lignite, respectively.

T. 1 N., R. 59 E.—The Keefer lignite, stratigraphically the lowest bed of lignite in T. 1 N., R. 59 E., is in the Lance formation about 25 feet below the top of the Hell Creek member. This bed crops out in the central part of the township and was measured at locations 234, 235, 236, 242, 245, and 246. The bed averages a little more than 3 feet where measured, but it is very inconstant in quality. It thins toward the east and is of no value in the eastern part of the township, and it is only 8 inches thick at location 245. Measurements of it are shown graphically on Plate XXXIV. A small lens was found a short distance below this bed near the Kennedy ranch, in sec. 30, but the thickness and extent of this lens are not known. An incomplete measurement at location 249 shows 1 foot 10 inches of lignite. A lower bench of the Elder bed, which is about 50 feet above the base of the Ludlow member in this township, was measured at location 233, where it contains 1 foot of lignite, and at location 247, where 1 foot 2 inches of lignite in an upper bench is separated by 2 inches of gypsum from 1 foot 8 inches in a lower bench. The Elder bed proper, about 15 feet higher stratigraphically, was mapped across the entire township and was measured at locations 229, 230, 231, 232, 237, 239, 240, 241, 243, and 244. In this township the main Elder bed reaches a maximum thickness of about 8 feet at location 243. (See Pl. XXXIV.) A measurement at location 237 showed a thickness of 1 foot of lignite. The next higher bed of lignite exposed in this township is correlated with the Wilder bed, which was measured also in the township immediately to the west, near the forest-ranger station. In this township it was measured at location 238, where it contains 2 feet 3 inches of lignite.

Tps. 1, 2, 3, 4, and 5 S., R. 59 E.—No lignite beds are known to underlie the northern part of T. 1 S., R. 59 E., and the surface rocks of the southern part of this township and of Tps. 2, 3, 4, and 5 S., R.

59 E., belong to the Pierre shale and Arikaree (?) formation, which are barren of lignite in this field.

T. 4 N., R. 60 E.—All the lignite beds that crop out in T. 4 N., R. 60 E., are comparatively thin, and the attempt to correlate them from one outcrop to another is difficult and uncertain. Measurements were obtained at locations 150, 151, 152, 154, 156, 157, 158, and 159. In the SW. ¼ sec. 32 at location 151 a thin bed partly burned, carrying only 1 foot 3 inches of lignite, was found. It is reported that in a well in the SE. ¼ of the same section 3 feet of lignite was struck at a depth of about 30 feet. At location 150 about 1 foot of lignite could be seen, but owing to the swampy condition of the land around the outcrops the section is incomplete. At location 152, 1 foot of lignite crops out; at 154, 1 foot 4 inches; at 156, 1 foot 1 inch; at 157, 2 feet 9 inches; at 158, 1 foot 3 inches; and at 159, 4 inches. At none of these localities, except possibly 157, is the lignite sufficiently thick to be of any value.

T. 3 N., R. 60 E.—Three beds of lignite are known to crop out in T. 3 N., R. 60 E., and lie near the base of the Ludlow member as mapped. This group of lignite beds probably represents the Elder zone but is not persistent and can not be certainly correlated with beds in other townships. Measurements made near the Youghley strip pit, in sec. 3, show them to be of fair quality and thickness. Measurements were also obtained on these beds at locations 144, 145, 146, 147, and 148. At location 144 fragments of lignite found in a spring indicate the presence of a lignite bed, but no section could be obtained. At location 145 the following section was measured:

Section at location 145, in the NE. ¼ sec. 23, T. 3 N., R. 60 E.

	Ft.	in.
Sandstone, hard, concretionary	18	
Shale, gray, sandy	50	
Lignite, good	1	10
Sandstone, yellow, friable	7	
Lignite, good	1	
Lignite, dirty	4	
Shale, sandy	8	6
Shale, drab		6
Lignite, good	1	
Shale, drab		4
Lignite, good	1	
Shale, drab, sandy		7
Lignite, good		6
Lignite, dirty	1	5
Sandstone, light yellow, top shaly	1	5
Shale, somber.		
	97	1

At location 146 the middle bed of this group contains over 4 feet of lignite, the bottom of the bed being below water level. At loca-

tion 147 the upper bed of this group contains 8 inches of lignite, the remainder of it being bone. At location 148 three beds were measured, the upper one containing 2 feet of lignite, the middle bed 3 feet 8 inches of lignite and bone, and the lower bed 3 feet of lignite and bone, as shown in the section on Plate XXXIV. At a section measured at location 149 no lignite was found. Clinker occurring on high hills in secs. 22, 23, and 26 indicates that a bed of lignite higher in the stratigraphic section was once continuous over this township but has been eroded and burned, so that only the massive clinker remains.

T. 2 N., R. 60 E.—The Keefer lignite, which is the lowest valuable bed exposed in T. 2 N., R. 60 E., crops out along the South Fork of Horse Creek. It was measured at locations 126, 127, 128, 130, 131, 132, 133, 134, and 139. At location 126 the bed carries 1 foot 9 inches of lignite in a lower bench and 3 feet 4 inches in an upper bench; at 127, 2 feet 9 inches; at 128, 2 feet 3 inches; at 131, 3 feet in a lower bench and 3 feet 2 inches in an upper bench; at 132, 2 feet 2 inches; at 133, 3 feet 5 inches; at 134, 2 feet 3 inches; at 139, 2 feet 8 inches. This lignite is thickest at location 130, where it occurs in two benches of 4 feet 8 inches each, as shown on Plate XXXIV. This bed is not definitely known to crop out elsewhere in this township but is correlated with the Keefer bed on the basis of its stratigraphic relations. Two beds of lignite separated by about 15 feet of sandy shale crop out in the high hills on the divide between Horse Creek and Coal Creek. The lower one of these beds was measured at locations 117, 118, 121, 124, and 136. At location 117 it is 5 feet thick; at 118, 2 feet 6 inches; at 121, 2 feet 4 inches; at 124, 2 feet 8 inches; and at 136, more than 5 feet 6 inches. The higher bed is correlated with the main Elder bed and was measured at locations 119, 120, 122, 125, 142, and 143. At location 119 the bed contains 5 feet 9 inches of lignite; at 120, 4 feet 1 inch; at 122, 3 feet 4 inches of very poor lignite; at 125, 2 feet 2 inches of fair lignite; at 142, 5 feet 3 inches; and at 143, 4 feet 6 inches.

T. 1 N., R. 60 E.—An isolated outcrop of lignite was found in the Hell Creek member of the Lance at location 222, in sec. 26, T. 1 N., R. 60 E., on Box Elder Creek, a measurement there showing 2 feet 1 inch of lignite. The bed could not, however, be traced for any great distance in either direction. It is probably the same lignite bed as that of the Hell Creek member, mapped in the township immediately to the east. The lowest bed of lignite in the Ludlow lignitic member occurs very near its base and is tentatively correlated with the Keefer bed. Sections of it measured at locations 219, 223, 225, and 227 are shown graphically on Plate XXXIV. At locations 220 and 221 the bed at the Keefer horizon contains no lignite, and at

location 224 the Keefer is represented by only 1 foot 5 inches of lignite. A bed about 45 feet higher was mapped in the northern part of the township and was measured at locations 223–a, 224, 226, and 228. It may be the same as the Elder bed of the township immediately to the west. The sections measured are shown graphically on Plate XXXIV.

T. 1 S., R. 60 E.—No lignite of commercial importance is known to occur in T. 1 S., R. 60 E., although a thin bed of carbonaceous sandstone containing some lignite was measured in sec. 25, at location 251, as indicated below:

Section at location 251, sec. 25, T. 1 S., R. 60 E.

	Ft.	in.
Sandstone, light green, calcareous.		
Sandstone, carbonaceous, black		3
Lignite, very dirty	2	2
Shale, carbonaceous, sandy		6
Lignite, fair		6
Shale, brown		6
Sandstone, gray		4
Total lignite	2	8

This bed is near the top of the Ludlow. In secs. 35 and 36 two beds are measured, one near the base of the Ludlow and the other about 60 feet below. The upper bed, at location 252, sec. 36, contains 2 feet 3 inches of lignite and the lower, at location 253, sec. 35, 2 feet 1 inch.

Tps. 2, 3, 4, and 5 S., R. 60 E.—It is believed that Tps. 2 to 5 S., R. 60 E., are devoid of commercially valuable lignite, their surface rocks consisting chiefly of the Pierre shale, Fox Hills sandstone, and Arikaree (?) formation, which are not lignite-bearing within the Ekalaka field.

T. 4 N., Rs. 61 and 62 E.—The surface rocks of T. 4 N., R. 61 E., belong to the Pierre shale, Fox Hills sandstone and Lance formation, which dip 2°–4° SW. Of these formations only the Lance contains lignite of any importance. At location 166 a bed of much weathered, impure lignite 4 feet 3 inches thick was measured.

The structural conditions in this township and the one adjoining it on the east are interesting, inasmuch as the axis of the long Baker-Glendive anticline crosses these townships in a northwesterly direction. There are several domes on this anticline, from which gas has been obtained at a depth of 600 to 800 feet, and deeper drilling may develop oil. One of these domes, perhaps the highest one structurally on the anticline, has its apex near sec. 18, T. 4 N., R. 62 E.,[8] and is

[8] Moulton, G. F., and Bass, N. W., Oil and gas prospects in the Cedar Creek anticline and vicinity, in Montana, North Dakota, and South Dakota: U. S. Geol. Survey Press Bull. 12051, 1921.

now being drilled jointly by the Absaroka Oil Development Co. and the Florence Oil & Gas Co.

T. 3 N., Rs. 61 and 62 E.—The lowest bed of lignite known in T. 3 N., Rs. 61 and 62 E., is the Coal Bank bed, which was measured at location 173, where it contains 2 feet 5 inches of lignite. This bed crops out extensively along Coal Bank Creek in the township immediately to the south but is not exposed elsewhere in these townships. Beds of lignite about 6 inches thick were measured at locations 169 and 172, and a higher bed of lignite was measured at locations 170 and 171, where it contains 5 feet and 5 feet 5 inches of lignite, respectively. (See Pl. XXXIV.) A bed of lignite about 15 feet stratigraphically above this one was measured at locations 167, 167–a, and 168. At location 167 this bed contains 2 feet 5 inches of lignite; at 167–a, 10 inches; at 168, 2 feet 5 inches.

T. 2 N., Rs. 61 and 62 E.—The Coal Bank lignite bed is the commercially important one of T. 2 N., Rs. 61 and 62 E., and was measured at locations 174, 175, 176, 177, 178, 179, 180, 183, 184, 185, 188, 191, 192, 193, 194, 195, 196, 197, 198, 199, 200, 201, 203, and 204. Most of these measurements are shown on Plate XXXIV. At location 174 the bed carries 9 inches of lignite; at 192, 1 foot; at 193 the bed is divided into three benches by partings, the upper containing 10 inches of lignite, the middle 9 inches, and the lower 10 inches; at 194 only one of these benches was measured, and it contains 9 inches of lignite; at 195 the bed carries 1 foot of lignite; at location 196, 10 inches; at location 197, 1 foot 2 inches; and a measurement on the north side of Boxelder Creek a quarter of a mile east of location 200 shows the bed to contain 4± feet of lignite. The maximum thickness of this bed is at location 179, where it carries 15 feet of lignite. It is a somewhat irregular lens of local extent. A lower bed of lignite, which is relatively of minor value, was measured at locations 181, 182, 186, and 187. At location 181 this bed contains 1 foot 8 inches of lignite; at 182, 3 feet 3 inches; at 186, 2+ feet; and at 187, 9 inches. A range of clinker hills in the central part of T. 2 N., R. 61 E., has been formed by the spontaneous burning of higher lignite beds. A stratigraphic section measured at location 190 showed only two beds of lignite, 10 and 14 inches thick.

T. 1 N., Rs. 61 and 62 E.—A lenticular bed of lignite in the Hell Creek member of the Lance formation, possibly representative of the Coal Bank horizon, crops out in T. 1 N., Rs. 61 and 62 E., along Boxelder Creek. It was measured at locations 210, 211, 212, 215, 216, and 217. Its maximum thickness is about 4 feet, at location 210 (see Pl. XXXII, *B*), where it has been taken out by the local farmers in small quantities. Even at this place, however, the bed is separated by partings of shale and sandstone. At location 211

its thickness is 1 foot 1 inch; at location 212, 1 foot 2 inches; at location 215 it consists of an upper bench 1 foot thick separated by 8 feet of sandstone from a lower bench containing 1 foot 3 inches of lignite; at location 216 it contains 1 foot of lignite; and at location 217 only 10 inches of dirty lignite was found. A higher bed of lignite, probably at the Herman horizon, belonging to the Ludlow lignitic member of the Lance, crops out in the southern part of these townships along Spring Creek, and sections of it were measured at locations 213 and 214 (see Pl. XXXIV) and also at a number of places in the township to the south. In the creek bank at location 218, sec. 7, four thin beds of lignite were found, separated by brown shale and fine-grained gray sandstone, and none of them over 18 inches thick.

T. 1 S., R. 61 E.—The lignite of T. 1 S., R. 61 E., is found entirely in the Ludlow member of the Lance. The lower beds are irregular in thickness and inconstant. Several of these thin beds, which are stratigraphically only a few feet above the base of the Ludlow, were measured at locations 263, 264, 265, 258, and 259, in secs. 24, 25, 26, and 27. At location 263 the thickness is 1 foot 3 inches; at 264, 10 inches; at 265, 1 foot 3 inches; at 258, 2 feet 1 inch of very dirty lignite; and at 259, 2 feet 8 inches, with a 5-inch shale parting. One of these lenticular beds showed a thickness of 1 foot 3 inches at location 254, in sec. 5.

The next higher bed of lignite is about 40 to 60 feet above the base of the Ludlow member of the Lance and is known as the Herman bed. This bed may be the same as the Keefer bed of the area about the Ekalaka Hills, but as the bed is not continuous between these two areas the correlation is uncertain. Measurements of the Herman lignite bed were obtained at locations 256, 257, 261, 262, 266, 267, and 268. At location 256 it contains 1 foot 3 inches of lignite; measurements at the other locations are shown graphically on Plate XXXIV.

A stratigraphic section measured in the center of sec. 27 illustrates the character and position of the beds in the lower part of the Ludlow lignitic member of the Lance in this township.

Stratigraphic section at location 260, sec. 27, T. 1 S., R. 61 E.

	Ft.	in.
Sandstone	10	
Lignite, poor		8
Shale, brown		2
Lignite, weathered, of fair quality (Herman bed)	2	5
Shale and sandstone	72	
Sandstone, fine grained, yellowish	2	
Lignite, containing about 30 per cent of ash	1	10
Shale, brown	5	
Lignite		10

	Ft.	in.
Shale and sandstone	38	
Lignite, containing 30 per cent of ash	1	
Bone		2
Lignite		5
Shale		1
Lignite (probably marks base of Ludlow lignitic member)		8
Sandstone, carbonaceous	5	
	140	1

Beds of lignite higher in the Ludlow are thin and nonpersistent. One of these was measured in sec. 20 at location 255, where it shows the following section:

Section at location 255, sec. 20, T. 1 S., R. 61 E.

Sandstone, light yellow.	Ft.	in.
Shale, nearly white		5
Bone, sandy		6
Shale, light gray		2
Lignite, dirty		4
Shale, brown		3
Lignite, sandy, weathered	1	9
Shale, sandy.		
Total lignite	2	1

This bed is about 20 feet below identifiable Arikaree (?) strata.

T. 2 S., R. 61 E.—About 450 feet of the upper part of the Lance formation is exposed in T. 2 S., R. 61 E., and is apparently devoid of valuable lignite. The overlying White River and Arikaree (?) formations are likewise barren of lignite.

T. 3 S., R. 61 E.—A bed of lignite at about the McKenzie horizon occurs at the contact of the Hell Creek and Ludlow members of the Lance as mapped in the eastern part of T. 3 S., R. 61 E., and was measured at locations 292, 293, 294, 295, and 296. It is thickest in this township at location 293, where it contains 2 feet 9 inches of weathered lignite. It is stated by ranchers who have lived long in this locality that lignite has been prospected here, but the present indications are that the bed is not thick enough to warrant extensive mining. Measurements of this bed at locations 292, 293, and 294 are shown graphically on Plate XXXIV. Those at locations 295 and 296 showed, respectively, 10 inches and 11 inches of lignite. West of location 296 the bed is thin or absent.

Tps. 4 and 5 S., R. 61 E.—The surface rocks of Tps. 4 and 5 S., R. 61 E., belong to the Pierre shale, Fox Hills sandstone, Hell Creek member of the Lance formation, and Arikaree (?) formation and are barren of valuable lignite.

T. 1 S., R. 62 E.—The following stratigraphic section indicates the character and succession of the beds in the eastern part of T. 1 S., R. 62 E.:

Stratigraphic section in the NE. ¼ sec. 4, T. 1 S., R. 62 E.

	Ft.	in.
Sandstone, buff, cross-bedded, forming cliff, base of the Ludlow lignitic member	20+	
Sandstone, thin bedded, friable	4	4
Shale, dark gray, flaky	2	6
Lignite		7
Shale, brown		3
Shale, dark, sticky when wet	5	8
Sandstone, argillaceous, soft, yellowish	6	5
Shale, light gray	3	
Bone		6
Shale, carbonaceous	1	
Shale, light brown, sandy	10	6
Lignite		6
Shale, gray, containing streaks of iron concretions	26	3
Lignite		8
Shale, dark gray	7	
Shale, light gray	11+	
	95	

Only one valuable bed of lignite is exposed in this township, though several thin beds were measured—one at location 272, where 2 feet 2 inches was found, and another at location 273, where 2 feet of good lignite is exposed. The Herman bed of lignite, about 50 feet above the base of the Ludlow, crops out along Spring Creek and was measured at locations 270 and 271. (See Pl. XXXIV.) Its maximum thickness is at location 266, in the township immediately to the west, where it is 8 feet thick and has been mined for local use, and it is also mined at location 270. A thin bed about 15 feet above the Herman bed, containing 14 inches of lignite, was measured at location 269. As no lignite of importance is known below the Herman bed in this vicinity, areas not underlain by it are probably barren of valuable lignite.

T. 2 S., R. 62 E.—The only bed of lignite of economic importance known in T. 2 S., R. 62 E., is the Herman bed, which is worked at the Moody mine, in sec. 23, near the State line, and is tentatively correlated with the Keefer and Spillman lignites. It is stratigraphically about 50 feet above the base of the Ludlow, as in the township immediately to the north. The bed in this township seems to lie in a little basin and thins equally in all directions from the Moody mine at location 276. Measurements on this bed were taken at locations 274, 275, 276, 277, and 278, within the township (see Pl. XXXIV), and at locations 279 and 280, in South Dakota, about

half a mile east of the Montana line. At location 274 the Herman bed contains only carbonaceous shale; at location 275 no lignite was found; at location 280, 2 feet of lignite; at location 278, 2 feet 10 inches; and at location 279, 2 feet 10 inches.

T. 3 S., R. 62 E.—Two beds of lignite, separated by about 15 feet of shale, have been mapped in T. 3 S., R. 62 E. They occur very near the contact of the Hell Creek and Ludlow members of the Lance—in fact, the upper of these two beds, which is correlated with the McKenzie bed, has been used as a contact marker in the western and central portions of the township. It was measured at locations 286, 287, 288, 289, 290, and 291. It is irregular in thickness and quality, as is shown by Plate XXXIV, and is of no practical value in the western part of the township. In secs. 15, 16, and 21 it averages over 5 feet in thickness and has been mined in a small way at the Kerr and Chuning mines, locations 286 and 287. An analysis of lignite from the Kerr mine is given on page 253. The Chuning mine was not being operated at the time the examination was made. At location 291 only 6 inches of very dirty lignite was found.

The Horner lignite, which is about 15 feet below the McKenzie bed, was measured at locations 281, 282, 283, 284, and 285. This bed is also lenticular, and its thickest portion lies in sec. 10. It is being mined at location 284, and the analysis of a sample obtained at this place is given on page 253. Measurements of this lignite bed made at locations 281, 282, and 284 are shown graphically on Plate XXXIV. That at location 283 showed 3 feet 8 inches of lignite with a 4-inch parting of bone near the middle; and at location 285 only 11 inches of lignite was found.

Tps. 4 and 5 S., R. 62 E.—Tps. 4 and 5 S., R. 62 E., lie in the broad, featureless valley of the Little Missouri and are underlain chiefly by the Pierre shale and Fox Hills sandstone, which are barren of lignite. In the northern part of T. 4 S. strata belonging to the basal 150 feet of the Lance formation are present but contain no valuable deposits of lignite.