Reconnaissance Geology of the Birney-Broadus Coal Field, Rosebud and Powder River Counties Montana

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GEOLOGICAL SURVEY BULLETIN 1072-J

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By W. C. WARREN

CONTRIBUTIONS TO ECONOMIC GEOLOGY

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A description of 15 coal beds and reserves of coal in an area of 850 square miles in southeastern Montana

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RECONNAISSANCE GEOLOGY OF THE BIRNEY-BROADUS COAL FIELD, ROSEBUD AND POWDER RIVER COUNTIES, MONTANA

By W. C. WARREN

ABSTRACT

The Birney-Broadus coal field covers about 850 square miles in Rosebud and Powder River Counties in southeastern Montana. The consolidated sedimentary rocks exposed in the area are about 1,800 to 1,900 feet thick, are nonmarine, and belong to the Fort Union formation of Paleocene age; the Fort Union formation is divided into the Tongue River member and a lower member. All coal beds that were mapped for purposes of reserve calculation are in the Tongue River member. The reserves of coal in the area are estimated to be about 21½ billion short tons, all of which are within about 1,000 feet from the surface in beds 2½ feet or more thick.

INTRODUCTION

This report is the result of part of an investigation of western coal lands by the U.S. Geological Survey for the purpose of classifying public lands and determining their mineral resources and geological features. The field mapping was done during the summers of 1938 and 1939 by W. C. Warren, who was assisted in 1938 by V. R. Chamberlain, J. V. N. Dorr II, D. C. Duncan, G. E. Jacober, R. W. Lemke, R. C. McNamee, and R. R. Wheeler and in 1939 by Dorr and Duncan. The geologic map and coal sections were compiled during the winters of 1938–39 and 1939–40 by Warren, who was assisted by Dorr during the first winter. The estimate of coal reserves was prepared by H. R. Christner in 1948. Marginal parts of the area were examined by W. W. Olive during the fall of 1951 in order to familiarize himself with the geology, and this report was then compiled by Olive from the field notes of Warren and his assistants and from township descriptions prepared by Warren.

PREVIOUS WORK

Coal deposits in an area extending along the Tongue River valley from the Wyoming-Montana boundary through the Birney-Broadus coal field to Brandenburg, Mont., were described by Bass (1924). A report by Renick (1929) on the geology and ground-water resources of central and southern Rosebud County includes about 200 square miles of the western part of the Birney-Broadus coal field.

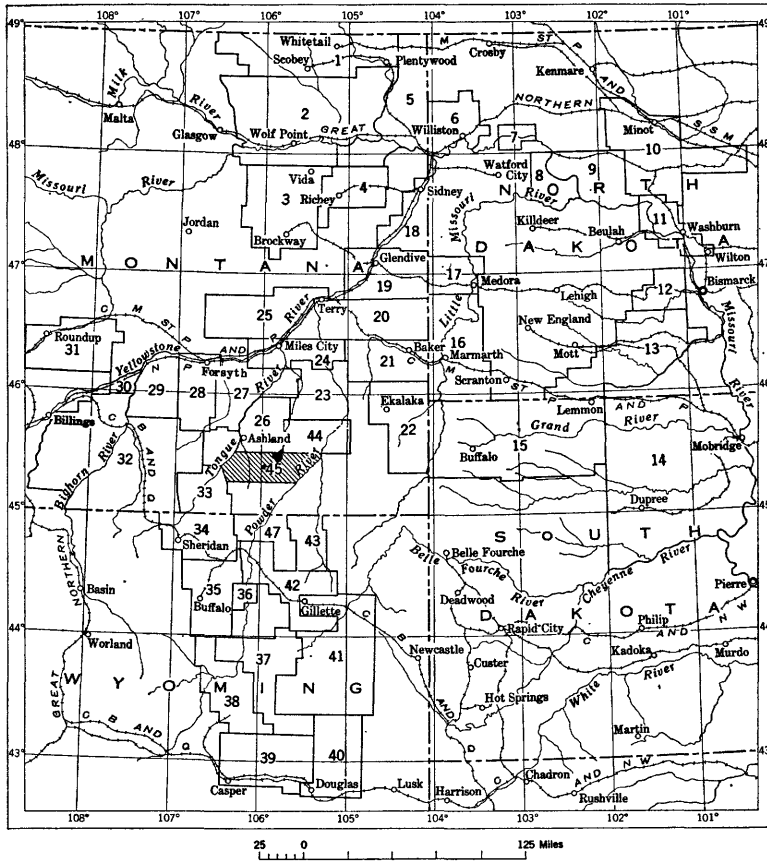

FIGURE 22—Index map showing location of the Birney-Broadus coal field (hachured) and its relation to other coal fields in southeastern Montana and adjacent States.

LOCATION, DRAINAGE, AND TOPOGRAPHY

The Birney-Broadus coal field, which receives its name from the village of Birney, near the west boundary of the area, and from the village of Broadus, near the east edge, includes about 850 square miles in Rosebud and Powder River Counties in southeastern Montana. Much of the central and western parts of the area is in the Ashland division of the Custer National Forest, and a small part of the area west of the Tongue River is in the Tongue River Northern Cheyenne Indian Reservation. The location of the Birney-Broadus coal field and its relation to other coal fields in southwestern Montana, northeastern Wyoming, western South Dakota and eastern North Dakota is shown on the accompanying index map (fig. 22).

About two-thirds of the Birney-Broadus coal field area is drained by the Tongue River, which flows northeast along the west boundary.

Coal fields shown on figure 22 and described in Geological Survey bulletins

Index No.	Coal field or area	U.S. Geol. Survey Bull.
1.	Scobey	751-E
2.	Fort Peck	381-A
3.	McCone County	905
4.	Richey-Lambert	847-C
5.	Culbertson	471-D
6.	Williston	531-E
7.	Nesson Anticline	691-G
8.	Fort Berthold	726-D
9.	Fort Berthold	381-A, 471-C
10.	Minot	906-B
11.	Washburn	381-A
12.	New Salem	726-A
13.	Cannonball River	541-G
14.	Standing Rock and Cheyenne Reservations	575
15.	Northwestern South Dakota	627
16.	Marmarth	775
17.	Sentinel Butte	341-A
18.	Sidney	471-D
19.	Glendive	471-D
20.	Terry	471-D
21.	Baker	471-D
22.	Ekalaka	751-F
23.	Mizpah	906-C
24.	Miles City	341-A
25.	Little Sheep Mountain	531-F
26.	Ashland	831-B
27.	Rosebud	847-B
28.	Forsyth	812-A
29.	Tullock Creek	749
30.	Southwest of Custer	541-H
31.	Bull Mountain	647
32.	Big Horn County	856
33.	Northward extension of Sheridan coal field	806-B
34.	Sheridan	341-B
35.	Buffalo	381-B
36.	Barber	531-I
37.	Pumpkin Buttes	806-A
38.	Sussex	471-F
39.	Glenrock	341-B
40.	Lost Spring	471-F
41.	Gillette	796-A*
42.	Powder River	381-B
43.	Little Powder River	471-A
44.	Coalwood	973-B
45.	Birney-Broadus field (this report)	1072-J
47.	Spotted Horse	1050

*With a chapter on the Minturn district and the northwestern part of the Gillette field by W. T. Thom, Jr.

The rest is drained by the Powder River, which flows northeast and forms the east boundary of the area. Pumpkin, Otter, Odell, and Hanging Woman Creeks are the principal northward-flowing tributaries of the Tongue River, and Mizpah Creek flows northward and enters the Powder River about 50 miles north of the coal field. Most of the smaller tributaries flow southeastward and eastward.

The surface of the area is deeply trenched by long, narrow valleys. Slopes bordering the valleys are precipitous in many places and in other places are interrupted by prominent topographic benches that are formed on resistant clinker produced by burning of the coal. The divide areas in most parts of the field are high and narrow, but in the southwestern part the divide between the Tongue River and Otter Creek is a broad tableland underlain by clinker. Maximum topographic relief within townships ranges from about 300 feet in the northeastern part of the coal field to 1,300 feet in the western part.

The flood plains of the Tongue and Powder Rivers are broad and flat and are bordered by steep slopes rising to benches that range in elevation from about 100 feet above stream level near the northern boundary of the coal field to more than 700 feet in the southern part.

STRATIGRAPHY

The consolidated sedimentary rocks exposed in the Birney-Broadus coal field belong to the Fort Union formation of Paleocene age, which is divided into the Tongue River member and a lower member. Deposits of alluvium of Quaternary age occur in the major stream valleys. The distribution and stratigraphic sequence of the rock units and important coal beds are shown on the geologic map (pl. 19) and in the composite stratigraphic section (pl. 20). Thin terrace deposits of late Cenozoic age are exposed at different levels along the major stream valleys, but they were not mapped.

FORT UNION FORMATION

In the Birney-Broadus coal field, the Fort Union formation consists of 1,800 to 1,900 feet of nonmarine rocks that crop out throughout almost all the entire area. The formation is divisible into two members: the lower member, which includes the lowermost 250 to 325 feet of the exposed section, and the overlying Tongue River member. This division of the Fort Union formation corresponds to that of the Coalwood coal field (Bryson, 1952, p. 32 and 37), which adjoins the Birney-Broadus field on the north. The lower member is regarded by Bryson as a probable equivalent of the Tullock and Lebo members of the Fort Union formation. The characteristic lithologies of each member and the position of some important coal beds in the Tongue River member are shown in the composite stratigraphic section (pl. 20).

Lower member.—The lower member of the Fort Union formation consists of a series of somber brownish-gray weathering, thin-bedded sandstones, sandy shales, shales, and thin lenticular coal beds, which are exposed in the Powder River drainage area in the easternmost part of the coal field. The coal beds of the lower member are below minimum thickness, 2½ feet, for purposes of mapping and calculation of reserves. The area of outcrop of the lower member is almost barren of timber and presents a desolate landscape of moderate relief.

The base of the lower member is not exposed in the area described in this report. The highest beds of the member intertongue with the lighter colored beds of the Tongue River member. In the Birney-Broadus field, as in the Coalwood field (Bryson, 1952, p. 52), the contact between the two members is placed at the base of the

lowermost thick persistent yellowish-gray-weathering sandstone of Paleocene age. The top of the lower member is 200 to 300 feet above the Powder River in the northeastern part of the coal field. This is due largely to the southwest dip of the strata and the gradient of the river, which is northeastward. The lower member converges southwestward with the valley bottom and passes beneath alluvium that borders the river in the southern part of T. 5 S., R. 50 E.

Tongue River member.—The Tongue River member of the Fort Union formation is composed of beds of sandstone; sandy shale; shale; and coal, some of which are thick and persistent. It is exposed in steep slopes overlooking the Powder River and in most of the area to the west. This member includes all coal beds that were mapped for the purpose of calculating reserves. Yellowish-gray massive, crossbedded sandstone, in beds as much as 100 feet thick is found at different stratigraphic levels and commonly weathers into cliffs, knobs, and pinnacles. The weathered sedimentary rocks are prevailingly yellowish gray, except where they were baked by the burning of underlying coal beds to form clinker, a resistant red rock that is a common feature in areas underlain by the Tongue River member. Clinker caps prominent ridges, mesas, and buttes in most parts of the coal field and forms conspicuous bands along valley walls. The clinker and thick sandstone beds commonly support growths of pine, which are quite dense in the Custer National Forest. The land surface, where underlain by the Tongue River member, is deeply dissected by streams; it presents an area of high relief along the Powder River valley that contrasts sharply with the more subdued topography developed on the lower member.

According to its classification by the Geological Survey, the upper boundary of the Tongue River member of the Fort Union formation is at the top of the Roland coal bed, which was not recognized in the Birney-Broadus field. A sandstone bed about 1,500 feet above the base of the Tongue River member may be equivalent to the fossiliferous sandstone that occurs above and near the top of the Roland in the adjacent northward extension of the Sheridan coal field (Baker, 1929, p. 34). The bed is about 50 feet thick and contains an abundance of fresh-water mollusk shells; it crops out beneath several low buttes that rise above the general level of the divide between Otter and Hanging Woman Creeks near the south boundary of T. 6 S., R. 44 E. Mollusks collected from this bed near U. S. Coast and Geodetic Survey triangulation station Otter, in the NW¼ sec. 36, T. 6 S., R. 44 E., were identified by T. C. Yen, of the Geological Survey, as follows: *Elliptio* cf. *E. priscus* (Meek and Hayden), *Viviparus raynoldsanus* (Meek and Hayden), *Lioplacodes mariana* Yen.

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Yen (oral communication, 1952) states that these forms are known only from the Fort Union formation, but the assemblage is inadequate to form a reliable basis for a more precise age determination.

TERRACE DEPOSITS AND ALLUVIUM

Terrace deposits composed of sand and gravel are exposed at different levels above the Powder and Tongue Rivers and the main tributaries, but they were not mapped.

The gravel along the rivers consists mainly of cobbles and pebbles of quartzite, chert, and igneous rocks. Gravels along the tributaries are composed largely of clinker, sandstone, and ironstone of local origin. Deposits of alluvium consisting of sand, silt, and clay with lenses of gravel and rubble are found in the valley bottoms of the main streams.

STRUCTURE

Strata in the Birney-Broadus coal field lie nearly flat but locally dip as much as 5°. Planetable elevations obtained by Warren on the base of the Broadus coal bed in the northeast part of the map area show that the bed is about 275 feet lower in the southern part of T. 5 S., R. 50 E., than in the north-central part of T. 4 S., R. 51 E., indicating an average southwesterly dip of about 20 feet per mile or less than 1°. Strata exposed in the Tongue River valley in the western part of the area dip gently northwest toward the river. In some parts of the field where thick coal beds, particularly the Knoblock bed, have burned, the strata dip for short distances as much as 20° toward areas underlain by clinker. These dips are produced by the slumping of rocks caused by a reduction in volume attendant to the burning of the coal, and they do not reflect subsurface structure.

The crest of a low anticline trends eastward across Otter Creek in sec. 26, T. 5 S., R. 45 E., where the Knoblock coal bed is exposed about 30 to 40 feet above the creek at the crest and passes below stream level about 1 mile upstream and 5 miles downstream.

Several southeast-trending faults, with displacements ranging from about 40 to 125 feet, were mapped in the eastern part of the coal field in Tps. 4 and 5 S., Rs. 50 and 51 E. A normal fault that strikes east crosses the Tongue River in the western part of the area in secs. 7 and 8, T. 5 S., R. 43 E.

COAL

PHYSICAL AND CHEMICAL PROPERTIES

The coal of the Birney-Broadus field is lignite. It breaks with a conchoidal fracture, is shiny brownish black to black on freshly

exposed surfaces, and has a medium-brown streak. The coal loses moisture rapidly when exposed to the atmosphere and breaks down into small angular particles; thus, it is unsuited for storage in open bins.

Analyses of coal from the Birney-Broadus field and from other fields of southeastern Montana are presented in table 1.

UTILIZATION

Coal has been mined intermittently from short adits at the Indian Service, Alderson, and Knoblock mines, in sec. 18, T. 5 S., R. 43 E., and from the Peerless, Superior, and Black Diamond mines near Broadus. Some coal has also been removed by stripping at the Peerless mine. Small prospect pits and entries throughout the area are worked by residents of the area to supply fuel for domestic use.

Thick coal beds occur at shallow depths throughout large areas in many parts of the field and are adaptable to recovery by strip mining. As the demand for coal increases, such mining in these areas may become economically feasible. Many of these areas, in which coal is beneath 50 feet of overburden or less and might be recovered by stripping methods, are shown on plate 19.

DISTRIBUTION AND CORRELATION OF THE COAL BEDS

The outcrops of coal beds 1½ feet or more in thickness and localities where coal sections were measured are shown on plate 19. All coal beds shown are in the Tongue River member of the Fort Union formation. Several thin stringers of impure coal were noted in the lower member of the Fort Union formation along the Powder River; however, no stringers exceeded the minimum mappable limit. The Knoblock, Sawyer, Wall, Canyon, and Garfield coal beds are correlated with coal beds of the same names which crop out in the northward extension of the Sheridan coal field to the west and southwest and in the Ashland coal field to the north. The Dunning and Ferry beds are correlated with the *E* and *F* beds, respectively, of the Ashland field. Other coal beds, including those named from local geographic features and unnamed beds of local extent, are not correlated with beds outside the area. The lowest persistent coal bed in the area is the Broadus bed, which is exposed in the Powder River valley, and the Knoblock bed, exposed in the Tongue River and Otter Creek valleys. The Garfield bed is the highest persistent coal bed. Relative positions of coal beds exposed in the Birney-Broadus field are shown by townships in figure 23.

In some places coal beds and associated sedimentary rocks make up zones within which the coal may show intricate gradations with the other rocks. For example, a zone consisting of an upper layer

TABLE 1. *Analyses of coal from the Birney-Broadus coal field and selected analyses from other fields in southeastern Montana*

Source	Bureau of Mines laboratory sample No. and date of sampling	Air-drying loss	Form of analysis [1]	Moisture	Volatile matter	Fixed carbon	Ash	Sulfur	Heating value (Btu)	Classification of coal [2] by rank
Peerless mine; Broadus coal bed; sec. 23, T. 4 S., R. 50 E., Powder River County.	B-29378 to B-29381 (1938)	25.7	A	33.9	26.6	33.1	6.4	0.2	7,240	Lignite (56–78).[4]
			B	10.9	35.8	44.6	8.7	.3	9,750	
			C	----------	40.2	50.1	9.7	.3	10,650	
			D	----------	44.5	55.5	----------	.4	12,130	
Victor Stabio prospect; Broadus coal bed; sec. 24, T. 4 S., R. 50 E., Powder River County.	B-56504 (1940)[3]	19.2	A	29.0	31.6	31.3	8.1	.3	6,390	Lignite (50–70).[4]
			B	12.1	39.1	38.8	10.0	.4	7,910	
			C	----------	44.5	44.1	11.4	.5	9,010	
			D	----------	50.2	49.8	----------	.5	10,160	
Black Diamond mine; Broadus coal bed; sec. 11, T. 5 S., R. 50 E., Powder River County.	C-75726 (1947)	21.0	A	32.3	29.8	31.4	6.5	.3	7,380	Lignite (52–79).[4]
			B	14.3	37.8	39.7	8.2	.3	9,340	
			C	----------	44.0	46.4	9.6	.4	10,900	
			D	----------	48.7	51.3	----------	.4	12,050	
Superior mine; Broadus coal bed; sec. 14, T. 5 S., R. 50 E., Powder River County.	C-75920 (1947)	20.2	A	33.5	28.3	32.2	6.0	.4	7,290	Lignite (54–78).[4]
			B	16.6	35.4	40.5	7.5	.5	9,140	
			C	----------	42.5	48.5	9.0	.6	10,970	
			D	----------	46.7	53.3	----------	.6	12,050	
Holt mine; Terret coal bed; sec. 10, T. 3 S., R. 44 E., Rosebud County.	A-42289 (1928)	6.8	A	27.3	27.5	41.3	3.9	.4	9,020	Subbituminous C (60–94).[4]
			B	22.0	29.5	44.3	4.2	.4	19,680	
			C	----------	37.8	56.8	5.4	.6	12,400	
			D	----------	40.0	60.0	----------	.6	13,110	
Ash Creek mine; Sawyer coal bed; sec. 35, T. 2 S., R. 49 E., Powder River County.	C-75916 (1947)	23.1	A	35.2	30.6	30.2	4.0	.3	6,930	Lignite (50–72).[4]
			B	15.7	39.8	39.3	5.2	.4	9,020	
			C	----------	47.2	46.6	6.2	.5	10,700	
			D	----------	50.3	49.7	----------	.5	11,410	
Brewster-Arnold mine; Brewster-Arnold coal bed; sec. 23, T. 6 S., R. 42 E., Rosebud County.	95879 (1923)	9.7	A	27.3	28.9	39.2	4.6	.6	8,850	Subbituminous C (59–93).[4]
			B	19.5	32.0	43.4	5.1	.7	9,790	
			C	----------	39.8	53.9	6.3	.8	12,170	
			D	----------	42.5	57.5	----------	.9	12,990	

[1] A, As received; B, air-dried; C, moisture-free; D, moisture- and ash-free.

[2] In accordance with American Society for Testing Materials, Standard specifications for classification of coals by rank (ASTM Designation: D388-38, A.S.A. M20.1—1938): 1939 Book of ASTM Standards, pt. 3, p. 1–6.

[3] Sample of slightly weathered coal.

[4] Parentheses signifies that the contained numbers are on the mineral-matter-free basis. The first number represents fixed carbon on the dry basis, reported to the nearest whole percent. The second number represents hundreds of British thermal units (to the nearest hundred) on the moist basis.

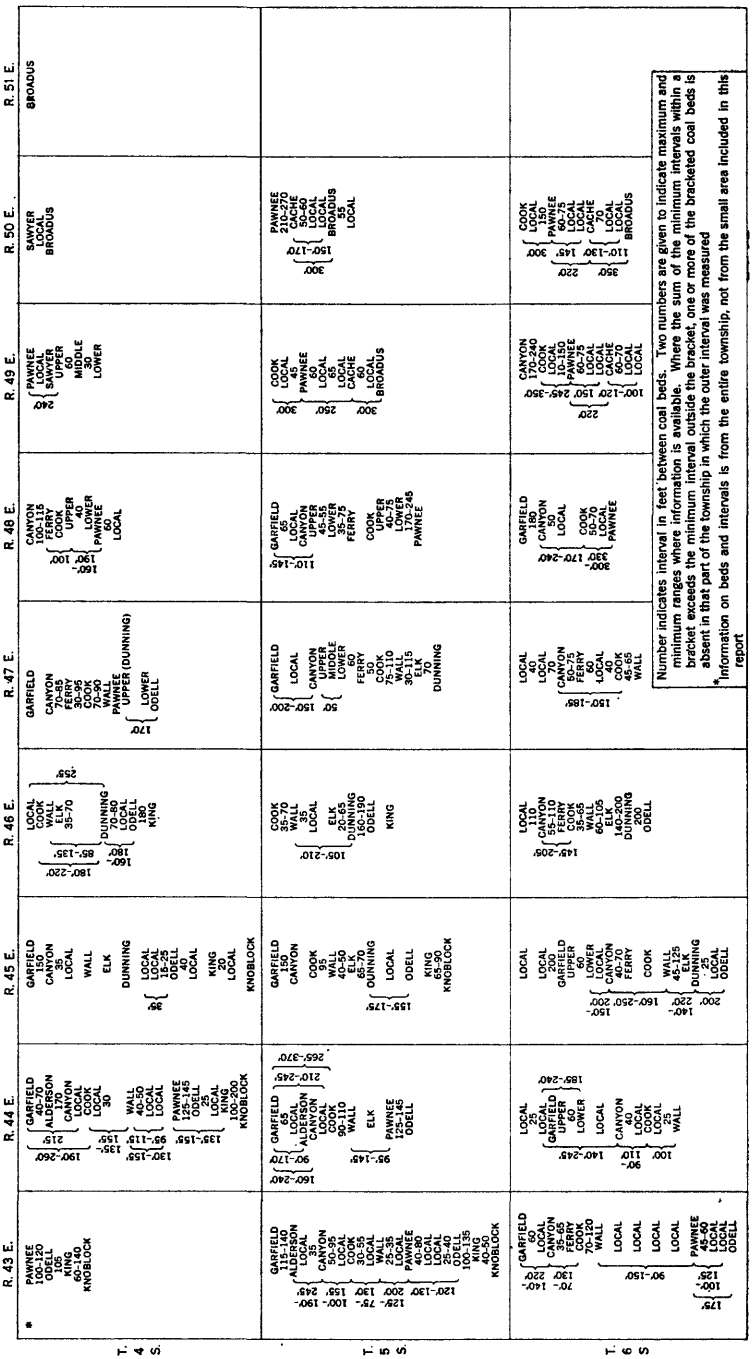

FIGURE 23—Diagram showing intervals between coal beds, by townships, in the Birney-Broadus coal field.

of coal, or bench, and a lower unit of carbonaceous shale may show lateral gradation of both parts so that nearby the zone may consist of an upper unit of carbonaceous shale and a layer of lower coal, or bench; or, a coal zone consisting entirely of coal in one place may grade laterally into an upper and a lower coal bench separated by a unit of carbonaceous shale or carbonaceous sandstone. In some parts of the field the interval between two benches of coal is as much as 50 feet. The cause of such gradations and splitting of coal beds is well explained by Thiadens and Haites (1944, p. 39) who, in regard to similar features in the Netherlands coal measures, wrote as follows:

> At the time that coal seams formed, however, the landscape was an extensive peat bog, with marshy woods, through which large streams meandered. The broad streams changed their course constantly and, in this way, were able to drown and kill extensive areas of peat bog. Sometimes abandoned river beds were again covered by vegetation, and the peat bog invaded the former area of bare river sands and gravels. As a result, we now find sand lenses of various sizes in the coal seams. If this occurred on a larger scale, what we see is a normal splitting of the coal seam.

Because of numerous thick coal beds in the Birney-Broadus area and the paucity of good exposures, tentative correlations established between coal beds across divides and in widely separated parts of the area are subject to revision in the future as more detailed information becomes available. The computation of reserves for each designated bed in each township is based on exposures in the township; thus, it meets with standards of reliability as defined in the section on reserves.

The principal coal resources of the area occur in the coal beds described below. Measured sections of coal beds are shown on plates 21–26. Many local beds as much as 15 feet thick occur at various stratigraphic levels, but these are lenticular and of small areal extent and constitute a very small part of the total reserves.

Broadus bed.—The Broadus coal bed, which is named from the town of Broadus, is about 100 feet above the base of the Tongue River member. It passes below alluvium in the Powder River valley in sec. 10, T. 6 S., R. 50 E., and probably passes below the level of the Powder River a short distance south of the township. Northward from sec. 10 the coal has burned along much of its outcrop, forming conspicuous clinker which marks the stratigraphic position of the bed along the Powder River and its tributary valleys. In thickness the Broadus coal bed ranges from about 6½ feet, at locality 15 in sec. 27, T. 5 S., R. 50 E., to 22 feet 4 inches, at locality 2 in sec. 23, T. 4 S., R. 50 E. In general, it is thickest near the north boundary of the area.

Knoblock bed.—The Knoblock coal bed was named by Bass (1924) from the Knoblock ranch, on the Tongue River in T. 5 S., R. 43 E. According to Bass (1932, p. 52), this bed is about 300 feet above the base of the Tongue River member of the Fort Union formation along Tongue River valley in the Ashland coal field, and it has an average thickness of about 20 feet. In the Birney-Broadus field the bed occurs near stream level in the valleys of the Tongue River and Otter Creek, where the coal is largely concealed by alluvium and is represented by thick clinker formed from the burning of the coal. No place was found where the bed was completely exposed; however, a log of a well drilled at a point near the boundary between secs. 10 and 15, T. 4 S., R. 43 E., shows 2 layers or benches of coal between depths of 98 and 148 feet. The lower bench is 16 feet thick and is separated by 22 feet of shale from the upper bench, which is 12 feet thick. An incomplete section measured at locality 9, in sec. 8, T. 4 S., R. 44 E., shows 24 feet of coal. At locality 8, across the Tongue River from locality 9, the coal is divided into 2 benches by 20 feet of sedimentary rocks. The upper bench has burned, producing a thick clinker. The lower bench is about 5 feet thick. Incomplete sections measured at other localities show from about 2½ to 23 feet of coal.

King bed.—The King coal bed crops out in and near the base of steep valley walls along the Tongue River and Otter Creek. At several places the position of the bed could not be traced because its clinker merged into the clinker of the underlying Knoblock bed. Throughout most of its extent the King coal bed is less than 5 feet thick. The coal is thickest in T. 5 S., R. 43 E., where it is divided into 2 benches from 20 to 35 feet apart. At localities 14 and 42, in secs. 7 and 17 of this township, the upper bench is about 10 feet thick but contains partings as much as 1 foot 8 inches thick. The lower bench is thickest at locality 44, in sec. 18, T. 5 S., R. 43 E., where 7 feet 9 inches of coal is exposed. Nothward and eastward from T. 5 S., R. 43 E., the coal becomes bony and commonly contains partings.

Sawyer bed.—The Sawyer coal bed consists of 3 lenticular coal beds that crop out in T. 4 S., Rs. 49 and 50 E. The lowest bed reaches a maximum observed thickness of about 5 feet at locality 4, in sec. 15, T. 4 S., R. 49 E.; the middle bed, which is about 30 feet above the lowest bed, has a maximum thickness of 10 feet 3 inches in sec. 3 of the same township; the highest bed, which is about 60 feet above the middle bed, is thickest at locality 12, in sec. 25, T. 4 S., R. 49 E., where 3 feet 2 inches of coal is exposed. All beds thin southward and are less than 1½ feet thick in the adjoining townships to the south.

Cache bed.—The Cache coal bed, which is named for Cache Creek, crops out about 300 to 350 feet above the Broadus bed in the valley walls of the Powder River and its tributaries in the east-central and southeastern parts of the coal field. Elsewhere the coal is less than 1½ feet thick and was not mapped. An incomplete section measured at locality 57 in sec. 36, T. 6 S., R. 49 E., shows about 14½ feet of coal. At many places where the bed was measured, it is split into 2 benches of coal 1½ to 14 feet apart. The upper bench is as much as 8 feet 10 inches thick, and the lower bench has a maximum observed thickness of about 5 feet.

Odell bed.—The Odell coal bed crops out well above stream levels in the northwestern part of the Birney-Broadus coal field and passes below the Tongue River and Otter Creek near the south boundary. It was not recognized east of the Otter Creek drainage area. The bed is thickest at localities 6 and 23, in secs. 5 and 20, T. 6 S., R. 43 E., where measurements show that it is about 11 to 11½ feet thick. In T. 5 S., Rs. 45 and 46 E., and the southern parts of the northern adjoining townships, the coal has an average thickness of about 6 feet. Southward from this area the bed thins to less than 1½ feet and was not mapped. Coal exposed at this stratigraphic position in T. 4 S., R. 44 E., and T. 5 S., R. 43 E., commonly contains much fossilized wood.

Pawnee bed.—The Pawnee coal bed was mapped in the western and eastern parts of the coal field. In these areas the coal has burned along most of its outcrop, and the position of the bed is marked by thick clinker that caps many buttes and forms a conspicuous band along valley walls. The coal is about 5 to 10 feet thick in the western part of the field; it thins in the central part of the field to less than 1½ feet, and thickens again in the eastern part of the field, where it is more than 10 feet thick at many places and reaches a maximum observed thickness of 21 feet 9 inches at locality 25 in sec. 30, T. 5 S., R. 49 E. The bed is split into two benches as much as 45 feet apart in the northern parts of T. 4 S., Rs. 47 and 48 E. The author believes that the upper bench of the Pawnee bed is the same as the Dunning bed that is described below but, since the two benches coalesce eastward, the name Dunning is not used east of the Otter Creek-Pumpkin Creek divide.

Dunning bed.—The Dunning coal bed crops out in steep valley walls in the Otter Creek drainage area and was not recognized in other parts of the coal field. The coal has burned along much of the outcrop and produced a thick conspicuous clinker that marks the stratigraphic position of the bed. East of Otter Creek the bed ranges in thickness from 1 foot 10 inches at locality 3, in sec. 6, T. 5 S., R. 46 E., to 16½ feet at locality 7, in section 22 of the same township; and at many places the coal is more than 5 feet thick.

The coal thins rapidly westward and is mappable only for short distances west of Otter Creek.

Elk bed.—The Elk coal bed occurs as discontinuous lenses that crop out in the steep valley walls along Otter Creek and its tributaries. In the northern part of its extent, the coal is burned or slaked at the outcrop, and few complete sections were measured. The thickest section is at locality 24 in sec. 35, T. 5 S., R. 46 E., where 12 feet 8 inches of coal is exposed. At most outcrops the coal is about 5 feet or less thick.

Wall bed.—The outcrop of the Wall coal bed is almost entirely restricted to the area east of the divide between Pumpkin and Otter Creeks. A thin lens of the Wall coal bed exposed along a tributary of Pumpkin Creek in the northeastern part of T. 4 S., R. 47 E., represents the eastern limit of mappable coal at this horizon. Throughout most of its extent the coal has burned at the outcrop, forming a thick clinker that marks the position of the bed. In general, exposures are poor, and only a few complete sections of the bed were obtained; however, many incomplete sections, most of which show more than 5 feet of coal, were measured. The thickest section was observed at locality 38, in sec. 34, T. 6 S., R. 45 E., where 20 feet 3 inches of coal is exposed; at several other localities east of Otter Creek the coal is more than 10 feet thick. No sections of coal thicker than 10 feet were observed east of Otter Creek, except at locality 45, in sec. 34, T. 6 S., R. 46 E., where the coal bed is 12 feet 3 inches thick.

Cook bed.—The Cook coal bed underlies large areas in the central part of the coal field and is exposed in valley walls along the Tongue River and Odell Creek in the western part. A thick conspicuous clinker marks the stratigraphic position of the bed throughout most of its extent. The Cook coal bed is more than 10 feet thick at many of the outcrops. It reaches a maximum observed thickness of about 25 feet at locality 26 in sec. 36, T. 6 S., R. 48 E. The coal grades laterally into shale at several places in the northern and western parts of the area, and was not mapped. In parts of T. 4 and 5 S., Rs. 47 and 48 E., the coal is split into 2 benches from 40 to 75 feet apart. The upper bench is as much as 16 feet thick at locality 39 in sec. 34, T. 5 S., R. 48 E., and the lower bench is 9 feet thick at locality 18 in sec. 16 of the same township.

Ferry bed.—The Ferry coal bed consists of discontinuous lenses that underlie high divide areas in the central and southwestern parts of the Birney-Broadus field. It contains a very small part of the total reserves of the area. The thickest sections were measured at locality 20 in sec. 18, T. 5 S., R. 48 E., and at locality 12 in sec. 6, T. 4 S., R. 47 E., where the coal is about 11 to 12½ feet thick. At other outcrops the coal is less than 10 feet thick.

Canyon bed.—The Canyon coal bed lies beneath shallow cover in the Powder-Tongue River divide area, and is exposed in high interstream areas in the western part of the field. At most places the outcrop is concealed by thick clinker formed from the burning of the bed. The coal is more than 5 feet thick throughout most of its extent, reaching a maximum observed thickness of about 13 feet at locality 19 in sec. 29, T. 6 S., R. 48 E., and thinning to less than 1½ feet in the southeastern part of T. 4 S., R. 44 E. In T. 5 S., Rs. 47 and 48 E., the Canyon coal is a zone split into 2 benches 45 to 55 feet apart. The upper bench is the more persistent. Both are locally more than 10 feet thick.

Alderson bed.—The Alderson coal bed consists of thin lenses of small areal extent which crop out near divide levels in Tps. 4 and 5 S., R. 44 E. The coal is nowhere more than 5 feet thick and constitutes an almost insignificant part of the total reserves of the area.

Garfield bed.—The Garfield coal bed, the highest persistent coal bed mapped in the field, has burned throughout large areas in the western part of the area to form abundant clinker which underlies broad high surfaces. West of Otter Creek the bed is limited to several small patches of coal that crop out near the head of Pumpkin Creek in the south-central part of the field. Two coal beds, about 60 feet apart, were mapped as the Garfield beds in the southern parts of T. 6 S., Rs. 44 and 45 E. Sections measured on the upper bed show about 5 to 16 feet of coal at localities 22 and 23 in sec. 33, T. 6 S., R. 44 E., and the lower bed is about 18 feet thick at locality 34 in sec. 30, T. 6 S., R. 45 E. Neither of these beds was found to be exposed elsewhere in the area west of Otter Creek. Near the head of Pumpkin Creek the Garfield coal bed is of little importance because it is thin, lenticular, and generally bony.

ESTIMATE OF COAL RESERVES

The reserves of coal in the Birney-Broadus field are estimated to be about 21½ billion short tons. These reserves are contained in beds 2½ feet or more thick and are within about 1,000 feet of the surface. Table 2 shows the reserves classified by township, bed, thickness range, and by categories based on abundance and reliability of data. Measured and indicated reserves include coal in bands 2 miles wide that are parallel and adjacent to the outcrop line; inferred reserves include, in general, coal more than 2 miles from the outcrop line. Average thicknesses of coal beds were determined from measurements at outcrops, trenches, and mine workings. Coal of all classes within the specified thickness limits is assumed to underlie a semicircular area whose radius is equal to half the length of the outcrop. Areas defined in this manner were measured on the map by using a polar planimeter, and tonnages were com-

puted assuming that 1 acre-foot of lignite weighs 1,770 short tons (Combo and others, 1949, p. 17).

TABLE 2.—*Estimated reserves of coal in the Birney-Broadus coal field*

Coal bed	Average thickness (feet)	Area (acres)	Reserves, in millions of short tons, in beds of thickness shown— Measured and indicated 2½–5 ft	5–10 ft	>10 ft	Total, measured and indicated	Inferred 2½–5 ft	5–10 ft	>10 ft	Total, inferred	Grand total
T. 5 S., R. 42 E. (fractional)											
Wall	4.2	8	0.06			0.06					0.06
Pawnee	8.4	30		0.45		.45					.45
Odell	3.6	110	.70			.70					.70
	5.5	60		.58		.58					.58
Knoblock	11.0	2,750			53.54	53.54					53.54
Total			0.76	1.03	53.54	55.33					55.33
T. 4 S., R. 43 E. (fractional) (pl. 21)											
Pawnee	8.0	20		0.28		0.28					0.28
Odell	3.6	100	0.64			.64					.64
King	3.4	80	.48			.48					.48
Knoblock	20.0	700			24.78	24.78					24.78
Total			1.12	0.28	24.78	26.18					26.18
T. 5 S., R. 43 E. (pl. 22)											
Alderson	3.5	370	2.29			2.29					2.29
Canyon	7.4	2,180		28.55		28.55					28.55
	10.2	140			2.53	2.53					2.53
Cook	4.2	1,790	13.31			13.31					13.31
	7.2	2,330		29.69		29.69					29.69
	10.7	55			1.04	1.04					1.04
Wall	3.8	4,550	30.60			30.60					30.60
	5.4	1,990		19.02		19.02					19.02
Pawnee	7.4	10,900		142.77		142.77					142.77
Odell	4.4	11,045	85.89			85.89					85.89
King (West of Tongue River) upper bench	2.8	50	0.25			0.25					0.25
	8.0	15		0.21		.21					0.21
lower bench	4.6	1,010	8.22			8.22					8.22
	6.0	160		1.70		1.70					1.70
King (East of Tongue River)	4.5	2,240	17.93			17.93					17.93
	6.2	810		8.87		8.87					8.87
Knoblock	9.9	1,780		31.19		31.19					31.19
	12.1	11,310			242.36	242.36					242.36
Local beds	3.8	1,550	9.68			9.68					9.68
	5.4	1,296		2.29		2.29					2.29
Total			168.17	264.29	245.93	678.39					678.39

TABLE 2.—*Estimated reserves of coal in the Birney-Broadus coal field*—Continued

Coal bed	Average thickness (feet)	Area (acres)	Reserves, in millions of short tons, in beds of thickness shown— Measured and indicated 2½–5 ft	5–10 ft	>10 ft	Total, measured and indicated	Inferred 2½–5 ft	5–10 ft	>10 ft	Total, inferred	Grand total
T. 6 S., R. 43 E. (pls. 24 and 26)											
Canyon	5.9	9,640	-------	100.67	-------	100.67	-------	-------	-------	-------	100.67
Cook	3.5	3,570	22.12	-------	-------	22.12	-------	-------	-------	-------	22.12
	3.5	15	-------	-------	-------	-------	0.94	-------	-------	0.94	0.94
	5.3	1,770	-------	16.60	-------	16.60	-------	-------	-------	-------	16.60
	6.4	290	-------	-------	-------	-------	-------	3.28	-------	3.28	3.28
Wall	4.2	9,630	71.59	-------	-------	71.59	-------	-------	-------	-------	71.59
	6.6	3,480	-------	50.46	-------	50.46	-------	-------	-------	-------	50.46
	11.2	40	-------	-------	0.79	0.79	-------	-------	-------	-------	.79
Pawnee	4.9	6,300	54.64	-------	-------	54.64	-------	-------	-------	-------	54.64
	4.9	1,410	-------	-------	-------	-------	12.23	-------	-------	12.23	12.23
	7.2	5,700	-------	72.20	-------	72.20	-------	-------	-------	-------	72.20
	7.7	2,420	-------	-------	-------	-------	-------	32.98	-------	32.98	32.98
Odell	7.1	6,470	-------	81.16	-------	81.16	-------	-------	-------	-------	81.16
	7.1	6,570	-------	-------	-------	-------	-------	82.57	-------	82.57	82.57
	10.7	180	-------	-------	3.41	3.41	-------	-------	-------	-------	3.41
Knoblock	12.3	3,350	-------	-------	72.93	72.93	-------	-------	-------	-------	72.93
	12.3	5,830	-------	-------	-------	-------	-------	-------	126.39	126.39	126.39
Local beds	4.5	3,480	26.55	-------	-------	26.55	-------	-------	-------	-------	26.55
	6.0	495	-------	5.23	-------	5.23	-------	-------	-------	-------	5.23
Total	-------	-------	174.90	326.32	77.13	578.35	13.17	118.83	126.39	258.39	836.74
T. 4 S., R. 44 E. (pl. 21)											
Canyon	6.2	85	-------	0.93	-------	0.93	-------	-------	-------	-------	0.93
Cook	5.0	650	-------	5.75	-------	5.75	-------	-------	-------	-------	5.75
Wall	3.8	1,050	7.06	-------	-------	7.06	-------	-------	-------	-------	7.06
	6.5	1,450	-------	16.68	-------	16.68	-------	-------	-------	-------	16.68
	11.2	590	-------	-------	11.70	11.70	-------	-------	-------	-------	11.70
Elk	3.8	580	3.90	-------	-------	3.90	-------	-------	-------	-------	3.90
Pawnee	6.6	5,770	-------	67.40	-------	67.40	-------	-------	-------	-------	67.40
Odell	3.7	6,300	41.26	-------	-------	41.26	-------	-------	-------	-------	41.26
	5.7	3,570	-------	35.70	-------	35.70	-------	-------	-------	-------	35.70
King	3.9	6,890	46.98	-------	-------	46.98	-------	-------	-------	-------	46.98
Knoblock	5.0	70	-------	.62	-------	.62	-------	-------	-------	-------	.62
	23.0	10,970	-------	-------	446.59	446.59	-------	-------	-------	-------	446.59
	23.0	5,320	-------	-------	-------	-------	-------	-------	216.58	216.58	216.58
Local beds	3.8	60	.40	-------	-------	.40	-------	-------	-------	-------	.40
	6.4	55	-------	.63	-------	.63	-------	-------	-------	-------	.63
Total	-------	-------	99.60	127.71	458.29	685.60	-------	-------	216.58	216.58	902.18

TABLE 2.—*Estimated reserves of coal in the Birney-Broadus coal field*—Continued

Coal bed	Average thickness (feet)	Area (acres)	Reserves, in millions of short tons, in beds of thickness shown— Measured and indicated 2½–5 ft	5–10 ft	>10 ft	Total, measured and indicated	Inferred 2½–5 ft	5–10 ft	>10 ft	Total, inferred	Grand total
T. 5 S., R. 44 E. (pl. 23)											
Alderson	3.5	1,190	7.41			7.41					7.41
Canyon	4.1	2,500	18.14			18.14					18.14
	7.3	6,290		80.67		80.67					80.67
	10.7	1,360			25.76	25.76					25.76
Cook	7.7	12,150		165.59		165.59					165.59
	10.7	1,590			30.11	30.11					30.11
Wall	3.8	180	1.21			1.21					1.21
	7.4	13,770		180.36		180.36					180.36
	7.4	130						1.70		1.70	1.70
	12.9	4,680			106.86	106.86					106.86
Elk	3.2	2,260	12.80			12.80					12.80
	4.6	1,930					15.51			15.51	15.51
	6.6	5,150		60.16		60.16					60.16
Pawnee	7.4	16,010		209.70		209.70					209.70
	7.4	4,260						55.80		55.80	55.80
Odell	4.9	7,920	68.69			68.69					68.69
	4.9	10,740					93.15			93.15	93.15
	5.5	4,900		47.70		47.70					47.70
Knoblock	16.0	3,410			96.57	96.57					96.57
	16.0	20,250							573.48	573.48	573.48
Local beds	3.9	530	3.62			3.62					3.62
	5.3	450		4.21		4.21					4.21
Total			111.87	748.39	259.30	1,119.56	108.66	57.50	573.48	739.64	1,859.20
T. 6 S., R. 44 E. (pl. 25)											
Garfield	17.2	4,930			150.09	150.09					150.09
Canyon	4.3	180	1.37			1.37					1.37
	6.5	1,070						12.31		12.31	12.31
	7.3	19,469		91.18		91.18					91.18
Ferry	3.5	130	.81			.81					.81
	3.5	2,470					15.30			15.30	15.30
Cook	6.4	3,050						34.55		34.55	34.55
	7.7	6,690		91.18		91.18					91.18
Wall	4.4	5,860	45.64			45.64					45.64
	7.6	1,940		26.26		26.26					26.26
	6.8	9,650						133.44		133.44	133.44
	13.2	970			22.62	22.62					22.62
	14.7	1,670							43.45	43.45	43.45
Elk	4.6	2,980					24.26			24.26	24.26
Pawnee	7.4	180		2.36		2.36					2.36
	7.4	11,070						144.99		144.99	144.99
Odell	4.9	16,740					145.19			145.19	145.19
Knoblock	16.8	9,300							263.38	263.38	263.38
Local beds	2.8	1,630	8.04			8.04					8.04
Total			55.86	210.98	172.71	439.55	184.75	325.29	306.83	816.87	1,256.42

TABLE 2.—*Estimated reserves of coal in the Birney-Broadus coal field*—Continued

Coal bed	Average thickness (feet)	Area (acres)	Reserves, in millions of short tons, in beds of thickness shown— Measured and indicated: 2½–5 ft	5–10 ft	>10 ft	Total, measured and indicated	Inferred: 2½–5 ft	5–10 ft	>10 ft	Total, inferred	Grand total
T. 4 S., R. 45 E. (pl. 21)											
Wall	10.0	650	-------	11.51	-------	11.51	-------	-------	-------	-------	11.51
Elk	3.8	580	3.90	-------	-------	3.90	-------	-------	-------	-------	3.90
Pawnee	6.6	2,680	-------	26.00	-------	26.00	-------	-------	-------	-------	26.00
	6.6	1,100	-------	-------	-------	-------	-------	12.85	-------	12.85	12.85
Odell	3.6	950	6.05	-------	-------	6.05	-------	-------	-------	-------	6.05
	6.1	2,570	-------	27.68	-------	27.68	-------	-------	-------	-------	27.68
King	3.1	4,730	25.89	-------	-------	25.89	-------	-------	-------	-------	25.89
Knoblock	18.7	16,520	-------	-------	546.80	546.80	-------	-------	-------	-------	546.80
	18.7	2,170	-------	-------	-------	-------	-------	-------	71.82	71.82	71.82
Local beds	3.2	75	.42	-------	-------	.42	-------	-------	-------	-------	.42
Total	-------	-------	36.26	65.19	546.80	648.25	-------	12.85	71.82	84.67	732.92
T. 5 S., R. 45 E. (pl. 23)											
Canyon	6.8	40	-------	0.48	-------	0.48	-------	-------	-------	-------	0.48
Cook	5.9	440	-------	4.60	-------	4.60	-------	-------	-------	-------	4.60
Elk	3.6	780	4.97	-------	-------	4.97	-------	-------	-------	-------	4.97
	6.5	2,160	-------	24.85	-------	24.85	-------	-------	-------	-------	24.85
Dunning	4.0	610	4.32	-------	-------	4.32	-------	-------	-------	-------	4.32
	5.6	65	-------	.64	-------	.64	-------	-------	-------	-------	.64
Pawnee	6.6	110	-------	1.29	-------	1.29	-------	-------	-------	-------	1.29
	6.6	7,850	-------	-------	-------	-------	-------	91.70	-------	91.70	91.70
Odell	5.7	9,110	-------	91.91	-------	91.91	-------	-------	-------	-------	91.91
Knoblock	18.7	1,270	-------	-------	42.04	42.04	-------	-------	-------	-------	42.04
	18.7	6,110	-------	-------	-------	-------	-------	-------	202.23	202.23	202.23
Total	-------	-------	9.29	123.77	42.04	175.10	-------	91.70	202.23	293.93	469.03
T. 6 S., R. 45 E. (pl. 25)											
Garfield	17.2	460	-------	-------	14.00	14.00	-------	-------	-------	-------	14.00
Canyon	3.0	70	0.37	-------	-------	.37	-------	-------	-------	-------	.37
	8.2	13,020	-------	188.97	-------	188.97	-------	-------	-------	-------	188.97
Ferry	3.7	11,480	75.18	-------	-------	75.18	-------	-------	-------	-------	75.18
	5.3	380	-------	5.56	-------	5.56	-------	-------	-------	-------	5.56
Wall	7.4	430	-------	5.63	-------	5.63	-------	-------	-------	-------	5.63
	7.4	110	-------	-------	-------	-------	-------	1.44	-------	1.44	1.44
	12.9	14,020	-------	-------	320.12	320.12	-------	-------	-------	-------	320.12
Elk	3.9	7,440	51.36	-------	-------	51.36	-------	-------	-------	-------	51.36
	4.6	6,470	-------	-------	-------	-------	104.04	-------	-------	104.04	104.04
	5.9	4,620	-------	48.25	-------	48.25	-------	-------	-------	-------	48.25
Dunning	3.4	740	-------	-------	-------	-------	4.45	-------	-------	4.45	4.45
	3.6	7,650	48.75	-------	-------	48.75	-------	-------	-------	-------	48.75
	5.5	95	-------	.93	-------	.93	-------	-------	-------	-------	.93
Pawnee	6.6	4,340	-------	-------	-------	-------	-------	50.70	-------	50.70	50.70
Odell	4.9	960	8.33	-------	-------	8.33	-------	-------	-------	-------	8.33
	4.9	6,920	-------	-------	-------	-------	60.02	-------	-------	60.02	60.02
	5.7	520	-------	5.25	-------	5.25	-------	-------	-------	-------	5.25

TABLE 2.—*Estimated reserves of coal in the Birney-Broadus coal field*—Continued

Coal bed	Average thickness (feet)	Area (acres)	Reserves, in millions of short tons, in beds of thickness shown— Measured and indicated 2½–5 ft	5–10 ft	>10 ft	Total, measured and indicated	Inferred 2½–5 ft	5–10 ft	>10 ft	Total, inferred	Grand total
T. 6 S., R. 45 E.—Continued											
Knoblock	18.7	540			17.87	17.87					17.87
	18.7	7,440							246.26	246.26	246.26
Local beds	2.5	30	0.13			.13					.13
	7.3	220		2.84		2.84					2.84
	15.3	1,020			27.62	27.62					27.62
Total			184.12	257.43	379.61	821.16	168.51	52.14	246.26	466.91	1,288.07
T. 4 S., R. 46 E. (pl. 21)											
Wall	6.9	1,060		12.95		12.95					12.95
Elk	3.3	2,000	11.68			11.68					11.68
	5.3	20		.19		.19					.19
Dunning	3.7	10	.06			.06					.06
	7.1	200		2.51		2.51					2.51
	10.5	5,720			106.31	106.31					106.31
Odell	4.0	2,730	19.33			19.33					19.33
	6.9	11,820		144.36		144.36					144.36
King	2.6	270	1.24			1.24					1.24
Knoblock	19.4	2,470			84.81	84.81					84.81
	19.4	18,990							652.08	652.08	652.08
Local beds	2.7	20	.10			.10					.10
	6.0	13		.14		.14					.14
Total			32.41	160.15	191.12	383.68			652.08	652.08	1,035.76
T. 5 S., R. 46 E. (pl. 23)											
Cook	4.0	85	0.60			0.60					0.60
	7.5	95		1.26		1.26					1.26
	13.8	1,070			26.14	26.14					26.14
Wall	6.1	2,240		24.19		24.19					24.19
Elk	3.5	2,710	16.69			16.69					16.69
	8.9	810		12.76		12.76					12.76
	11.1	2,730			53.64	53.64					53.64
Dunning	3.0	40	.22			.22					.22
	14.0	9,470			234.67	234.67					234.67
Odell	6.5	14,370		165.33		165.33					165.33
	6.5	2,640					30.37			30.37	30.37
Knoblock	18.7	5,570			184.36	184.36					184.36
	18.7	16,330							540.51	540.51	540.51
Total			17.51	203.54	498.81	719.86	30.37		540.51	570.88	1,290.74

TABLE 2.—*Estimated reserves of coal in the Birney-Broadus coal field*—Continued

Coal bed	Average thickness (feet)	Area (acres)	Reserves, in millions of short tons, in beds of thickness shown— Measured and indicated 2½–5 ft	5–10 ft	>10 ft	Total, measured and indicated	Inferred 2½–5 ft	5–10 ft	>10 ft	Total, inferred	Grand total
T. 6 S., R. 46 E. (pl. 25)											
Canyon	3.1	750	4.12			4.12					4.12
	6.7	350		4.13		4.13					4.13
Ferry	4.1	2,390	17.34			17.34					17.34
Cook	3.5	890	5.51			5.51					5.51
	7.5	1,780		23.63		23.63					23.63
	12.7	4,400			98.91	98.91					98.91
Wall	7.5	7,430		98.63		98.63					98.63
	10.3	2,470			45.03	45.03					45.03
Elk	4.2	4,820	35.83			35.83					35.83
	6.5	2,510		28.88		28.88					28.88
	11.1	240			4.72	4.72					4.72
Dunning	4.7	4,930	41.01			41.01					41.01
	6.9	3,860		47.14		47.14					47.14
	6.9	1,120						13.75		13.75	13.75
	12.5	4,570			101.11	101.11					101.11
Odell	5.7	7,070		71.33		71.33					71.33
	5.7	6,300						63.56		63.56	63.56
Knoblock	18.7	1,360			45.01	45.01					45.01
	18.7	3,160							104.59	104.59	104.59
Total			103.81	273.74	294.78	672.33		77.31	104.59	181.90	854.23
T. 4 S., R. 47 E. (pl. 21)											
Canyon	6.8	470		5.62		5.62					5.62
Ferry	3.8	1,520	10.22			10.22					10.22
	6.2	4,810		52.78		52.78					52.78
	11.2	120			2.38	2.38					2.38
Cook	3.9	3,810	26.23			26.23					26.23
	6.5	9,770		114.13		114.13					114.13
	11.2	240			4.76	4.76					4.76
Wall	3.6	10,620	67.67			67.67					67.67
	8.2	5,890		85.26		85.26					85.26
	8.2	330						4.79		4.79	4.79
Dunning	3.7	3,250	21.28			21.28					21.28
	3.7	1,600					10.48			10.48	10.48
	6.7	60						.71		.71	.71
	7.1	9,480		119.14		119.14					119.14
	10.5	1,650			30.67	30.67					30.67
Pawnee	6.1	5,810		62.30		62.30					62.30
	6.1	560						6.05		6.05	6.05
Odell	4.0	1,170	8.28			8.28					8.28
	6.3	3,500		39.03		39.03					39.03
	6.3	2,880						32.14		32.14	32.14
Knoblock	10.0	24,560							434.71	434.71	434.71
Total			133.68	478.26	37.81	649.75	10.48	43.69	434.71	488.88	1,138.63

TABLE 2.—*Estimated reserves of coal in the Birney-Broadus coal field*—Continued

Coal bed	Average thickness (feet)	Area (acres)	Reserves, in millions of short tons, in beds of thickness shown— Measured and indicated 2½–5 ft	5–10 ft	>10 ft	Total, measured and indicated	Inferred 2½–5 ft	5–10 ft	>10 ft	Total, inferred	Grand total
T. 5 S., R. 47 E. (pl. 23)											
Garfield	3.1	80	0.44			0.44					0.44
Canyon (2 beds)	4.1	3,770	27.29			27.29					27.29
	7.0	6,160		76.54		76.54					76.54
	10.9	970			18.73	18.73					18.73
Ferry	4.1	1,290	9.36			9.36					9.36
	5.0	3,160		27.97		27.97					27.97
	10.2	810			14.62	14.62					14.62
Cook	3.7	5,450	35.69			35.69					35.69
	7.4	3,410		44.51		44.51					44.51
	13.9	9,030			222.17	222.17					222.17
	13.9	430							10.58	10.58	10.58
Wall	6.1	16,270		175.67		175.67					175.67
	6.1	2,370						25.26		25.26	25.26
Elk	3.5	240	1.49			1.49					1.49
	8.9	3,180		50.09		50.09					50.09
Dunning	7.2	1,980		25.23		25.23					25.23
	7.2	2,980						37.98		37.98	37.98
	12.1	8,800			186.91	186.91					186.91
	12.1	3,560							75.61	75.61	75.61
Pawnee	6.1	8		.08		.08					.08
	7.5	6,300						52.29		52.29	52.29
	17.1	720							21.79	21.79	21.79
Odell	6.5	3,260		37.51		37.51					37.51
	6.5	15,470						177.98		177.98	177.98
Knoblock	10.0	13,750							243.38	243.38	243.38
Local bed	5.4	360		3.44		3.44					3.44
Total			74.27	441.04	442.43	957.74		293.51	351.36	644.87	1,602.61
T. 6 S., R. 47 E. (pl. 25)											
Canyon	3.8	5,100	34.32			34.32					34.32
	6.4	9,310		105.46		105.46					105.46
Ferry	4.1	2,750	19.96			19.96					19.96
Cook	11.8	18,460			385.56	385.56					385.56
	11.8	4,510							94.20	94.20	94.20
Wall	7.1	16,830		211.50		211.50					211.50
	7.1	6,840						85.96		85.96	85.96
Elk	8.9	1,360		21.42		21.42					21.42
	14.0	750			18.59	18.59					18.59
Dunning	4.8	2,680					22.77			22.77	22.77
	7.2	40		.51		.51					.51
	7.2	8,360						106.54		106.54	106.54
	12.1	2,780			59.54	59.54					59.54
	12.1	4,960							106.73	106.73	106.73
Pawnee	7.5	5,630						74.74		74.74	74.74
Odell	6.5	30		.35		.35					.35
	6.5	12,860						147.95		147.95	147.95
Knoblock	18.7	40							1.32	1.32	1.32
Local beds	3.5	840	5.26			5.26					5.26
Total			59.54	339.24	463.69	862.47	22.77	415.19	202.25	640.21	1,502.68

TABLE 2.—*Estimated reserves of coal in the Birney-Broadus coal field*—Continued

Coal bed	Average thickness (feet)	Area (acres)	Reserves, in millions of short tons, in beds of thickness shown— Measured and indicated: 2½–5 ft	5–10 ft	>10 ft	Total, measured and indicated	Inferred: 2½–5 ft	5–10 ft	>10 ft	Total, inferred	Grand total
T. 4 S., R. 48 E. (pl. 22)											
Ferry	4.2	15	0.11			0.11					0.11
	8.1	150		2.15		2.15					2.15
Cook	3.8	2,345	15.91			15.91					15.91
	6.7	1,430		16.90		16.90					16.90
Pawnee	4.8	190	1.61			1.61					1.61
	6.6	8,380		98.02		98.02					98.02
	13.8	1,240			30.29	30.29					30.29
Knoblock	7.0	21,400						265.15		265.15	265.15
Sawyer	2.5	920	4.07			4.07					4.07
Broadus	3.8	9,280					62.42			62.42	62.42
	8.3	6,990						102.69		102.69	102.69
Local beds	2.8	600	3.13			3.13					3.13
Total			24.83	117.07	30.29	172.19	62.42	367.84		430.26	602.45
T. 5 S., R. 48 E. (pl. 24)											
Garfield	3.8	670	5.39			5.39					5.39
	5.4	180		1.72		1.72					1.72
Canyon	3.5	9,420	58.76			58.76					58.76
	6.7	2,660		31.54		31.54					31.54
	10.9	230			4.44	4.44					4.44
Ferry	2.7	1,210	5.78			5.78					5.78
	4.8	545		4.66		4.66					4.66
	10.1	2,380			42.55	42.55					42.55
Cook	3.8	5,150	34.40			34.40					34.40
	7.5	12,830		17.03		17.03					17.03
	10.7	6,090			115.34	115.34					115.34
	10.7	620							11.74	11.74	11.74
Pawnee	7.4	6,270		82.12		82.12					82.12
	7.5	4,250						56.42		56.42	56.42
	17.1	6,900							208.84	208.84	208.84
	18.0	5,940			189.25	189.25					189.25
Knoblock	7.0	2,050						25.40		25.40	25.40
Broadus	3.8	5,660					39.07			39.07	39.07
	8.3	1,540						22.62		22.62	22.62
Total			104.33	137.07	351.58	592.98	39.07	104.44	220.58	364.09	957.07
T. 6 S., R. 48 E. (pl. 26)											
Canyon	7.8	12,170		168.02		168.02					168.02
	11.0	120			2.34	2.34					2.34
Cook	13.3	4,690							110.41	110.41	110.41
	15.9	14,780			415.95	415.95					415.95
Wall	6.1	2,080						22.46		22.46	22.46
Pawnee	7.5	1,160						15.40		15.40	15.40
	16.8	17,360							516.22	516.22	516.22
	16.8	4,670			138.87	138.87					138.87
Local beds	2.6	55	0.25			.25					.25
	8.6	100		1.52		1.52					1.52
Total			0.25	169.54	557.16	726.95		37.86	626.63	664.49	1,391.44

TABLE 2.—*Estimated reserves of coal in the Birney-Broadus coal field*—Continued

Coal bed	Average thickness (feet)	Area (acres)	Reserves, in millions of short tons, in beds of thickness shown— Measured and indicated 2½–5 ft	5–10 ft	>10 ft	Total, measured and indicated	Inferred 2½–5 ft	5–10 ft	>10 ft	Total, inferred	Grand total
T. 4 S., R. 49 E. (pl. 22)											
Knoblock	5.0	6,970						61.68		61.68	61.68
Sawyer	3.5	9,310	58.11			58.11					58.11
Broadus	8.3	2,370						34.82		34.82	34.82
	14.7	21,090							548.74	548.74	548.74
	16.7	310			9.27	9.27					9.27
Local beds	3.9	190	1.31			1.31					1.31
Total			59.42		9.27	68.69		96.50	548.74	645.24	713.93
T. 5 S., R. 49 E. (pl. 24)											
Cook	3.8	140	0.94			0.94					0.94
	5.0	75		0.66		.66					.66
	10.9	110			2.12	2.12					2.12
Pawnee	8.0	40		.57		.57					.57
	18.2	1,920			61.85	61.85					61.85
Cache	3.7	2,040	13.36			13.36					13.36
	6.3	1,590		17.73		17.73					17.73
Broadus	3.8	2,370					15.94			15.94	15.94
	8.3	2,720		39.96		39.96					39.96
	8.3	11,800						173.35		173.35	173.35
	12.4	120			2.63	2.63					2.63
	12.4	6,250							137.76	137.76	137.76
Local beds	3.1	3,855	21.53			21.53					21.53
	5.5	180		1.75		1.75					1.75
Total			35.83	60.67	66.60	163.10	15.94	173.35	137.76	327.05	490.15
T. 6 S., R. 49 E. (pl. 26)											
Canyon	7.4	35		0.46		0.46					0.46
Cook	16.0	340			9.63	9.63					9.63
Pawnee	16.7	9,550			282.29	282.29					282.29
Cache	7.6	8,240		110.84		110.84					110.84
	11.1	4,510			88.61	88.61					88.61
Broadus	3.8	1,590					10.69			10.69	10.69
	8.1	150						2.15		2.15	2.15
Local beds	3.7	11,120	74.62			74.62					74.62
	6.1	3,400		38.04		38.04					38.04
Total			74.62	149.34	380.53	604.49	10.69	2.15		12.84	617.33
T. 4 S., R. 50 E. (pl. 22)											
Cache	4.3	880	6.70			6.70					6.70
Sawyer	2.7	10	.05			.05					.05
Broadus	16.9	9,780			292.55	292.55					292.55
	16.9	4,760							142.39	142.39	142.39
Total			6.75		292.55	299.30			142.39	142.39	441.69

TABLE 2.—*Estimated reserves of coal in the Birney-Broadus coal field*—Continued

Coal bed	Average thickness (feet)	Area (acres)	Reserves, in millions of short tons, in beds of thickness shown— Measured and indicated: 2½–5 ft	5–10 ft	>10 ft	Total, measured and indicated	Inferred: 2½–5 ft	5–10 ft	>10 ft	Total, inferred	Grand total
T. 5 S., R. 50 E. (pl. 24)											
Cache	4.3	6,890	52.44			52.44					52.44
Broadus	8.6	3,340		50.84		50.84					50.84
	12.4	7,620			167.24	167.24					167.24
	12.4	4,040							88.67	88.67	88.67
Local beds	3.6	300	1.93			1.93					1.93
Total			54.37	50.84	167.24	272.45			88.67	88.67	361.12
T. 6 S., R. 50 E. (fractional) (pl. 26)											
Cache	4.3	70	0.53			0.53					0.53
	8.4	2,520		37.47		37.47					37.47
	10.7	530			10.04	10.04					10.04
Broadus	3.8	1,030	6.93			6.93					6.93
	3.8	850					5.72			5.72	5.72
	8.1	2,830		40.57		40.57					40.57
	8.1	500						7.17		7.17	7.17
Local beds	3.6	1,265	10.41			10.41					10.41
	6.5	5,010		57.64		57.64					57.64
	11.4	55			1.11	1.11					1.11
Total			17.87	135.68	11.15	164.70	5.72	7.17		12.69	177.59
T. 4 S., R. 51 E. (fractional) (pl. 22)											
Broadus	8.5	65		0.98		0.98					0.98
	18.9	160			5.35	5.35					5.35
Total				0.98	5.35	6.33					6.33

TABLE 3.—*Summary of estimated reserves of coal in Birney-Broadus coal field, by coal beds (in millions of short tons)*

Coal bed	Measured and indicated reserves in beds of thickness shown— 2½–5 ft	5–10 ft	>10 ft	Total	Inferred reserves in beds of thickness shown— 2½–5 ft	5–10 ft	>10 ft	Total	Total measured, indicated, and inferred
Garfield	5.83	1.72	164.09	171.64					171.64
Alderson	9.70			9.70					9.70
Canyon	144.37	1,043.75	53.80	1,241.92		12.31		12.31	1,254.23
Ferry	138.76	93.12	59.55	291.43	15.30			15.30	306.73
Cook	154.71	571.16	,311.73	2,037.60	.94	37.83	226.93	265.70	2,303.30
Wall	223.83	918.12	507.12	1,649.07		275.05	43.45	318.50	1,967.57
Elk	142.62	246.60	76.95	466.17	143.81			143.81	609.98
Dunning	115.64	196.10	719.21	1,030.95	37.70	158.98	182.34	379.02	1,409.97
Pawnee	56.25	765.54	702.55	1,524.34	12.23	593.92	746.85	1,353.00	2,877.34
Odell	239.17	747.89	3.41	990.47	328.73	504.20		832.93	1,823.40
Cache	73.03	166.04	98.65	337.72					337.72
Sawyer	62.23			62.23					62.23
King	100.99	10 78		111.77					111.77
Knoblock		31.81	1,857.66	1,889.47		352.23	3,676.73	4,028.96	5,918.43
Broadus	6.93	132.35	477.04	616.32	133.84	342.80	917.56	1,394.20	2,010.52
Local beds	167.38	117.73	28.73	313.84					313.84
Total	1,641.44	5,042.71	6,060.49	12,744.64	672.55	2,277.32	5,793.86	8,743.73	21,488.37

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