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COAL RESOURCE OCCURRENCE AND COAL DEVELOPMENT POTENTIAL MAPS OF THE BROWNS MOUNTAIN QUADRANGLE, ROSEBUD COUNTY, MONTANA

(Report includes 69 plates)

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This report has not been edited
for conformity with U.S. Geological
Survey editorial standards or
stratigraphic nomenclature.

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COAL RESOURCE OCCURRENCE

Introduction

Purpose

This text is for use in conjunction with two sets of maps: (1) coal resource occurrence (CRO) maps of the Browns Mountain quadrangle, Rosebud County, Montana (plates 1-68), and (2) a coal development potential (CDP) map of the Browns Mountain quadrangle, Rosebud County, Montana (plate 69). The two sets of maps have been prepared as part of a systematic coal resource inventory of Federal coal lands in Known Recoverable Coal Resource Areas (KRCRA's) in the western United States. They are intended to support land-use planning and coal leasing activities of the Bureau of Land Management as required by their Energy Minerals Activities Recommendation System (EMARS). CCoal beds considered in the resource inventory are only those beds 5 feet (1.5 m) or more thick, and under less than 1,000 feet (305 m) of overburden (Reserve Base of subbituminous coals); thinner or deeper beds that are present are not shown by the maps (CRO plates 4-68) or included in the resource estimates.

Location

The Browns Mountain 7 ½ -minute quadrangle is on the east side of the valley of the Tongue River about 20 miles (32 km) south of Ashland, and about a mile (1.6 km) east of the settlement of Birney.

Accessibility

An all-weather county road forks from Montana Route 212 at Ashland and connects Ashland with Birney and other points to the south along the Tongue River in Montana. Branching roads extend from Birney southward up Hanging Woman Creek in the southwestern part of the quadrangle and eastward up the East Fork of Hanging Woman Creek in the south-central part. These roads and connecting roads and trails provide access to most parts of the quadrangle.

The Burlington Northern Railroad operates and maintains east-west routes through Sheridan, Wyoming, about 45 miles (70 km) to the south, and Forsyth, Montana, about 60 miles (100 km) to the north.

Physiography

The quadrangle lies mostly east of the Tongue River and Hanging Woman Creek, a major north flowing tributary of the Tongue River. The land surface rises steeply from the flood plains of these streams and their large tributary streams to a high, dissected plateau, remnants of which form the main interstream divides in the quadrangle. Maximum local topographic relief is in the northern part of the quadrangle and is about 1,060 feet (323 m) from the Tongue River to the top of Browns Mountain.

Climate

Southeastern Montana in the vicinity of the Browns Mountain quadrangle has a semiarid climate. Average annual precipitation at Ashland is about 14 inches (36 cm), and the annual variation in temperature is commonly from 100°F to -30°F (38°C to -34°C).

Land Status

The quadrangle lies in the central part of the Northern Powder River Basin KRCRA. The Federal Government owns most of the coal rights.

In 1977 the quadrangle did not contain outstanding Federal coal leases, prospecting permits, or licenses.

General Geology

Sources of Data

Baker (1929) mapped the southwesternmost part of the Browns Mountain quadrangle as part of the much larger northward extension of the Sheridan coal field, which lies mainly to the southwest, and Warren (1959) mapped the remainder of the area covered by the quadrangle as part of the Birney-Broadus coal field, which lies mainly to the northeast. The work of these men was published at a scale of 1:62,500 and 1:63,360, respectively. Matson and others (1973) have described strippable coal deposits in the Knobloch and Brewster-Arnold coal beds within or adjacent to the western and northern margins of the quadrangle in the valleys of the Tongue River and Hanging Woman Creek. More recently, the quadrangle was remapped by Culbertson and Klett (1976) at a scale of 1:24,000. Culbertson and Kletts' (1976) map, which incorporates the earlier work, is the basis of the present work.

The coal data used are measurements of the coal-bed thicknesses at the outcrop, measurements in four coal test holes, and measurements derived from interpretation of the resistivity log of one oil and gas test hole. The resistivity log is fairly reliable for identifying coal because of the high resistivity of coal beds, although some other beds such as limestone and some kinds of sandstone also have high resistivity, so misinterpretations are possible.

Stratigraphy

All the coal-bearing rocks exposed in the quadrangle, and those present to depths of several hundred feet, belong to the Tongue River member of the Fort Union Formation and are Paleocene in age.

The remaining part of the Tongue River Member of the Fort Union Formation is about 1,900 feet (570 m) thick in the Browns Mountain quadrangle and consists of interbedded lenticular beds of yellowish-gray to light-gray fine- to very fine grained sandstone, light- to dark-gray siltstone and clayey siltstone, gray shale and claystone, brown carbonaceous shale, and persistent beds of coal. Rocks comprising the Tongue River Member were deposited at elevations of perhaps a few tens of feet above sea level in a vast area of shifting flood plains, sloughs, swamps, and lakes that occupied the Northern Great Plains in early Tertiary time.

Representative samples of the sedimentary rocks overlying and interbedded with minable coal beds in the eastern and northern Powder River Basin have been analyzed for their trace element content by the U.S. Geological Survey and the results summarized by the Department of Agriculture and others (1974) and by Swanson (in Mapel and others, 1977, pt. A, p. 42-44). The rocks contain no greater amounts of trace elements of environmental concern than do similar rock types found throughout other parts of the western United States.

Structure

The quadrangle is in the trough of the Powder River structural basin just about on the basin axis, which in Montana trends generally northward. Regional dip is generally toward the south at less than 1°. Structural relief within the quadrangle exemplified on the Knobloch coal bed, is about 260 feet (79 m), as shown on CRO plate 50.

Coal geology

Twenty-three coal beds ranging in thickness from 1 foot to an estimated 54 feet (0.3-16.5 m) were identified on the surface or in the subsurface in the Browns Mountain quadrangle (CRO plate 3). Of these, seven are thin, unnamed local coal beds. The uppermost coal bed, which has burned across most of the quadrangle, is the Anderson coal bed or the Anderson and Dietz beds, combined. This coal is successively underlain by an interval about 170 ft (52 m) thick that contains the thin Cox bed and an underlying local coal bed; the Upper Canyon coal bed; a noncoal interval about 40 ft (12 m) thick; the Lower Canyon coal bed; an interval about 40-110 ft (12-34 m) thick containing a local coal in the lower part; the Cook coal bed; and interval 30-80 ft (9-24 m) thick containing a thin local coal bed; the Upper Otter coal bed; a noncoal interval 5-30 ft (1.5-9 m) thick; the Lower Otter coal bed; a noncoal interval about 40 ft (12 m) thick; the Wall coal bed; an interval about 70-100 ft (21-30 m) thick containing a local coal bed in the lower part; the Pawnee coal bed; an interval about 100 ft (30 m) thick containing a local coal bed near the middle; the Poker Jim coal bed; a noncoal interval 40-60 ft (12-18 m) thick; the Brewster-Arnold coal bed; a noncoal interval about 30 ft (9 m) thick; the Odell coal bed; an interval about 160 ft (49 m) thick containing a local coal bed in the lower part; the King coal bed; a noncoal interval about 40 feet (12 m) thick; the Knobloch coal bed; a noncoal interval about 100-140 ft (31-43 m) thick; the Nance coal bed; an interval about 120 ft (37 m) thick; the Flowers-Goodale coal bed; a noncoal interval about 220 ft (67 m) thick containing a local coal bed near the top; and the Terret coal bed.

Of the 17 named coals identified in the quadrangle, the Cox and Odell beds are the only ones too thin to contain Reserve Base coal. A local coal bed below the Flowers-Goodale coal bed tentatively identified in the Hose-Austin, no. 1 Bones Bros. well, sec. 21, T. 6 S., R. 43 E. (hole 6, CRO pl. 3), is estimated to be 8 ft (2.4 m) thick, and a local bed at about the horizon of the King bed in a shallow drill hole in sec. 32, T. 6 S., R. 43 E., is 6 ft (1.8 m) thick (CRO pl. 3). Information is insufficient to determine the lateral extent of these coals, and resources have not been calculated for them.

Coal-bed thicknesses shown on the CRO maps are the bed thicknesses reported at outcrops or in the drill holes rounded to the nearest foot, partings excluded. The coal beds generally are free of partings. For detailed measurements of beds exposed at the outcrop, see Culbertson and Klett (1976).

In the past, many of the thicker coal beds have caught fire at the outcrop, and have burned underground for varying distances, some for a mile (1.6 km) or more. The heat from the burning coal has baked and fused the overlying rocks to form a resistant reddish rock called clinker (also called scoria, red shale, and other names locally). In this quadrangle clinker is as much as 150 feet (45.7 m) thick and caps many of the high interstream divides.

The only analyses of fresh coals in the Browns Mountain quadrangle are from drill cores of the Brewster-Arnold bed in sec. 20, T. 6 S., R. 43 E.(Matson and others, 1973, p. 43). Analyses of weathered coal have been made for samples collected at outcrops of five of the beds (tables 1-3). Based on these analyses and on analyses of coal samples collected at nearby localities, the rank of the coal in the quadrangle varies from high in the range of subbituminous C to low in the range of subbituminous B. Coals in the Northern Great Plains, including those in the Fort Union Formation in Montana, contain, in general, appreciably lesser amounts of most elements of environmental concern than coals in other areas of the United States (Hatch and Swanson, 1977, p. 147). The trace element content of coals in the Browns Mountain quadrangle are given on table 2.

Table 1.--Description of coal samples collected for analysis from the Fort Union Formation, Browns Mountain quadrangle, Rosebud County, Montana.

(Samples are channel samples of outcrops or chips from a dug pit.)

Sample No.	U.S. Bur. Mines Lab. No.	Locality Sec.	Locality T.	Locality R.	Bed name	Bed thickness in feet	Part of bed sampled
D177820	K-64928	Ctr 1	7 S.	43 E.	Upper Canyon	8.0	lower 7.0 ft
D177821	K-64929	NE¼ 25	6 S.	43 E.	Upper Otter	10.0	upper 10.0 ft
D177822	K-64930	NE¼ 5	6 S.	43 E.	Poker Jim	6.4	all
D177823	K-64931	SW¼ 4	6 S.	43 E.	Wall	7.2	all
D177824	K-64932	NW¼ 22	6 S.	43 E.	Pawnee	4.7	all

Table 2.--Major, minor, and trace-element composition of five coal samples from Browns Mountain quadrangle, Mt., reported on whole-coal basis

[Values are in either percent or parts per million. Si, Al, Ca, Mg, Na, K, Fe, Mn, Ti, P, Cl, Cd, Cu, Li, Pb, and Zn values were calculated from analysis of ash. As, F, Hg, Sb, Se, Th, and U values are from direct determinations on air-dried (32°C) coal. The remaining analyses were calculated from spectrographic determinations on ash. L after a value means less than the value shown, N means not detected, and B means not determined]

Sample	Si %	Al %	Ca %	Mg %	Na %	K %	Fe %	Mn ppm	Ti %	P ppm
D177820	0.27	0.33	0.70	0.701	0.221	0.012	0.20	23 L	0.028	396
D177821	1.6	.71	.73	1.01	.449	.052	.18	43 L	.054	489 L
D177822	.51	.55	.49	.500	.678	.033	.15	28 L	.031	314 L
D177823	.74	.22	.36	.170	.355	.014	.091	19 L	.022	209 L
D177824	.93	.56	.64	.571	.357	.014	.30	59	.041	440

Sample	Cl %	As ppm	Cd ppm	Cu ppm	F ppm	Hg ppm	Li ppm	Pb ppm	Sb ppm	Se ppm
D177820	0.012L	1	0.06L	3.4	85	0.05	0.9	1.8	0.2	0.5
D177821	.022L	1	.11L	7.3	155	.12	3.2	2.8	.5	.7
D177822	.014L	1	.07L	3.7	85	.03	2.9	2.5	.3	.3
D177823	.010L	1	.05L	3.3	50	.01	1.5	1.2	.2	.2
D177824	.015L	1	.08	6.0	135	.02	1.4	1.9L	.3	.5

Sample	Th ppm	U ppm	Zn ppm	B ppm-S	Ba ppm-S	Be ppm-S	Ce ppm-S	Co ppm-S	Cr ppm-S	Ga ppm-S
D177820	3.0L	0.2L	3.7	30	500	0.5	N	0.7 L	1	1
D177821	3.0L	2.5	23.9	30	500	.7	N	2	3	1.5
D177822	3.0L	.2L	15.6	50	500	.5	N	.7	1.5	2
D177823	3.0L	.3	1.9	50	150	.5	N	.5	1.5	1
D177824	3.0L	.5	38.3	50	500	1	N	2	2	1.5

Sample	Ge ppm-S	La ppm-S	Mo ppm-S	Nb ppm-S	Ni ppm-S	Sc ppm-S	Sr ppm-S	V ppm-S	Y ppm-S	Yb ppm-S	Zr ppm-S
D177820	N	N	1	N	1	1	100	5	1.5	0.15	7
D177821	N	10 L	1.5	2 L	3	1.5	100	7	5	.5	15
D177822	N	7 L	1.5	1.5 L	2	1	70	7	3	.3	10
D177823	N	N	N	1	1.5	.7	50	3	2	.15	7
D177824	N	7 L	1	1.5	7	1	70	5	5	.5	15

Table 3.--Proximate, ultimate, Btu, and forms-of-sulfur analyses of outcrop samples of coal, Browns Mountain quadrangle, Rosebud County, Mont.

[All analyses except Btu are in percent. Original moisture content may be slightly more than shown because samples were collected and transported in plastic bags to avoid metal contamination. Form of analyses: A, as received; B, moisture free; C, moisture and ash free. All analyses by Coal Analysis Section, U.S. Bureau of Mines, Pittsburgh, Pa.]

		Proximate analysis				Ultimate analysis					Btu	Forms of sulfur		
[1] Sample No.	Form of analysis	Moisture	Volatile matter	Fixed carbon	Ash	H	C	N	O	S		Sulfate	Pyritic	Organic
D177820	A	36.3	30.0	29.3	4.4	6.1	38.7	0.9	49.4	0.5	5860	0.20	0.01	0.25
	B	----	47.1	46.1	6.8	3.3	60.7	1.4	27.1	.7	9190	.31	.01	.39
	C	----	50.6	49.4	---	3.5	65.2	1.5	29.0	.8	9860	.34	.01	.42
D177821	A	38.4	27.3	26.8	7.5	6.1	35.6	0.6	49.5	0.5	5350	0.28	0.01	0.17
	B	----	44.3	43.6	12.1	3.0	57.8	1.2	25.2	.7	8690	.46	.01	.27
	C	----	50.5	49.5	----	3.4	65.8	1.4	28.6	.8	9890	.52	.01	.31
D177822	A	34.7	30.3	29.5	5.5	5.9	38.9	0.9	48.3	0.5	5880	0.16	0.01	0.31
	B	----	46.4	45.2	8.4	3.2	59.7	1.3	26.7	.7	9010	.24	.01	.47
	C	----	50.7	49.3	---	3.4	65.1	1.4	29.3	.8	9840	.26	.01	.52
D177823	A	26.3	31.4	38.8	3.5	6.2	50.5	0.9	38.6	0.3	8470	0.01	0.01	0.30
	B	----	42.5	52.7	4.7	4.4	68.5	1.2	20.8	.4	11490	.01	.01	.41
	C	----	44.8	55.2	---	4.6	71.9	1.3	21.7	.5	12060	.01	.01	.43
D177824	A	34.2	30.6	29.8	5.4	5.9	39.1	1.0	48.1	0.5	5890	0.07	0.02	0.39
	B	----	46.4	45.4	8.2	3.2	59.4	1.6	26.9	.7	8940	.11	.02	.60
	C	----	50.6	49.4	---	3.5	64.7	1.7	29.3	.8	9740	.12	.03	.65

[1] Table 1 gives descriptions of the samples.

Anderson coal bed, and Anderson and Dietz coal beds, combined

The Anderson and Dietz coal beds are prominent coals 40-90 feet (13-27 m) apart, stratigraphically, in areas south of the Browns Mountain quadrangle (Baker, 1929; Bryson and Bass, 1973; Matson and others, 1973). The two coals merge northward, and in most parts of the Browns Mountain quadrangle they are combined, and are extensively burned forming clinker that caps most of the high divides. The combined Anderson and Dietz coals were called the Garfield coal bed or the Garfield coal zone by Warren (1959).

Unburned coal thought to represent the Anderson bed underlies an area of a few acres around hole 10 in sec. 5, T. 7 S., R. 44 E., with a thickness of 34 ft (10.4 m)(CRO pl. 1). Depth to the top of the coal ranges from about 15-70 feet (4.6-21 m). The Dietz coal which would normally be expected below the Anderson in this vicinity, either is combined with the Anderson or is missing.

A small area of unburned coal underlies parts of secs. 8 and 17, T.6 S., R. 44 E. Coal in this area is estimated to be 54 feet (16.5 m) thick in the combined Anderson and Dietz beds, based on the log of a drill hole nearby to the east (Matson and others, 1973, pl. 8, hole SH-8). Depth to the top of the coal is a maximum of about 200 feet (61 m).

Analyses of eight coal samples from the Anderson bed, collected within about 5 miles (8 km) east of the Browns Mountain quadrangle have a sulfur content of 0.18-0.88 percent, an ash content of 4.1-8.9 percent, and a heat value of 7,637-8,374 Btu per pound on an as-received basis (Matson and others, 1973, p. 47).

CRO maps have not been made for the Anderson and the Anderson and Dietz beds, combined, because of the small size of the areas of coal that remain unburned.

Upper Canyon coal bed
(CRO pls. 4-8)

The Upper Canyon coal bed, as it is referred to by Culbertson and Klett (1976), is the coal called the Canyon coal bed by most other workers in areas to the south and southeast (Baker, 1929; Bryson and Bass, 1973; Matson and others, 1973). It is thin or missing in the northern part of the quadrangle but it ranges in thickness from 5 to 18 feet (1.5-5.5 m) in the southeastern part along the East Fork Creek of Hanging Woman Creek (CRO pl. 4). Overburden on the Upper Canyon bed is less than 300 feet (91 m) thick.

Coal samples collected from a drill hole about 1 1/2 miles(2.4 km) southeast of the quadrangle contained 0.165-0.660 percent sulfur, 3.8-7.3 percent ash, and had heat values of 7,862-8,801 Btu per pound on an as-received basis (Matson and others, 1973, p. 47). Table 3 shows the analysis of coal from an outcrop of the bed in the quadrangle (sample D177820).

Lower Canyon coal bed
(CRO pls. 9-13)

The Lower Canyon coal bed, as it is referred to by Culbertson and Klett (1956), is the coal called the Canyon bed in much of the area of the Browns Mountain quadrangle by Warren (1959). The Lower Canyon bed is commonly 5-6 feet (1.5-1.8 m) thick in the quadrangle, thickening to as much as 11 feet (3.4 m) in the northeastern corner (CRO pl. 5). It is typically exposed on steep-sided divides and the area suitable for strip mining is generally confined to a narrow band along the outcrop (CRO pl. 6).

Analyses have not been made of coal in the Lower Canyon bed. The quality is probably like that of other coals in the upper part of the Tongue River Member of the Fort Union Formation in nearby areas.

Cook coal bed (CRO pls. 14-18)

The Cook coal bed (Culbertson and Klett, 1976), is 5 feet (1.5 m) or more thick only along the eastern and southern margins of the quadrangle. In the southeastern part it thickens rapidly southeastward from 5 feet (1.5 m) to an estimated 15 feet (4.6 m) in the southeastern corner (CRO pl.14). Several small areas are under sufficiently shallow overburden to have a good potential for strip mining (CRO pl. 16).

Coal analyses are not available for the Cook bed in or near the Browns Mountain quadrangle.

Upper and Lower Otter coal beds (CRO pls. 19-23)

The Upper and Lower Otter beds are names used by Culbertson and Klett (1976) for a pair of coal beds 5 to 30 feet (1.5-9 m) apart in outcrops in the Browns Mountain quadrangle. The Lower Otter exceeds 5 feet (1.5 m) in thickness only in the norheastern part of the quadrangle (CRO pl. 19), where it contains one or more thin shale partings. The Upper Otter coal bed is thin in the northern part of the quadrangle, but abruptly thickens southeastward to 14 feet (4.3 m) or more of coal in the southern part at an abandoned mine (CRO pl. 1) in the valley of the East Fork of Hanging Woman Creek. An area along the valley bottom about 0.3 to 0.4 mile (0.5 to 16 km) wide is underlain by the Upper Otter coal under less than 200 feet (61 m) of overburden in this vicinity. The coal in this area has good potential for surface mining.

Coal from an outcrop of the Upper Otter bed near the abandoned mine along the East Fork of Hanging Woman Creek was analyzed with the results shown on tables 2 and 3 (sample D177821). Sulphur was 0.5 percent, ash, 7.5 percent, and heat value 5,350 Btu per pound on an as-received basis for the slightly weathered sample (table 3).

Wall coal bed
(CRO pls. 24-28)

The Wall coal bed was named by Baker (1929) probably for outcrops of the bed along Wall Creek in the adjacent Birney quadrangle to the west. The coal is known to be more than 5 feet (1.5 m) thick only in the northern part of the quadrangle, and in two small isolated localities in the western part. A maximum thickness of 7 feet (2.1 m) was measured in the northwestern part of the quadrangle. Resources available for stripping are relatively low (CRO pl. 24).

Analyses of 42 samples of coal from the Wall bed, collected within about 12 miles (19 km) west of the Browns Mountain quadrangle, show a range in sulfur content from 0.12 to 1.06 percent, ash content from 2.5 to 12.6 percent, and heat value from 7,637 to 9,566 Btu per pound on an as-received basis (Matson and others, 1973, p. 38-40). Analyses of an outcrop sample of the Wall coal is given on tables 2 and 3 (sample D177823).

Pawnee coal bed
(CRO pls. 29-33)

The Pawnee coal bed as mapped by Culbertson and Klett (1976) is thin in most of the quadrangle, but ranges from 5 to 8 feet (1.5-2.4 m) thick in bluffs along Hanging Woman Creek in the southwestern corner, not including one or more shale partings (CRO pl. 29). The Pawnee coal bed in this vicinity is stratigraphically higher than the coal identified as the Pawnee coal bed by Warren (1959) in the northern part of the area of the Browns Mountain quadrangle, according to Culbertson and Klett (1976). Resources of coal in the Pawnee bed available for stripping are small. Analyses have not been made of the Pawnee coal bed in the quadrangle.

Poker Jim coal bed
(CRO pls. 34-38)

The Poker Jim coal bed was named by Culbertson and Klett (1976) for exposures along Poker Jim Creek in the northern part of the Browns Mountain quadrangle. The same coal was called the Pawnee bed by Warren (1959) in the Poker Jim Creek drainage, but as already noted, a stratigraphically higher coal is called the Pawnee coal bed in this report.

The Poker Jim bed attains a maximum measured thickness of 10 feet (3.0 m) in the northwestern part of the quadrangle and thins irregularly from this area southward to less than 5 feet (1.5 m) in the central and southern parts. It locally contains one or more shale partings in its lower part. The coal is under shallow enough cover to be available for stripping in fairly large areas along the northern edge of the quadrangle (CRO pl. 36).

Chemical analyses of an outcrop sample of the coal are given in tables 2 and 3 (sample D177822).

Brewster-Arnold coal bed
(CRO pls. 39-43)

The Brewster-Arnold coal bed was named by Bass (1924) for the coal bed at the Brewster-Arnold mine a short distance west of the Browns Mountain quadrangle. The bed crops out near the flood plain of the Tongue River in the northwestern part of the quadrangle. It has a maximum known thickness of 11 feet (3 m) in an incomplete measurement in sec. 20, T. 6 S.,

R. 43 E. It thins from this point northward and southward along its outcrop (CRO pl. 39), and is assumed to thin eastward, also, in the subsurface.

A coal bed estimated to be as much as 10 feet (3 m) thick may extend into the subsurface in the southeastern corner of the quadrangle from areas where it was identified farther to the east (CRO pl. 39). This coal is tentatively correlated with the Brewster-Arnold bed. Information is lacking to establish definitely the thickness and distribution of this coal, or to trace it westward in the subsurface to outcrops along the Tongue River. Depth to the coal exceeds 400 feet (122 m).

The Brewster-Arnold bed contains large resources of coal beneath less than 200 feet (61 m) of overburden adjacent to its outcrop in the northwestern part of the quadrangle (CRO pl. 41).

Analyses of two samples of coal collected from drill cores of the Brewster-Arnold coal bed in sec. 20, T. 6 S., R. 43 E. show the following average values, on an as-received basis: sulfur, 0.30 percent; ash, 6.58 percent; and heat value, 8,702 Btu per pound (Matson and others, 1973, p. 43).

Odell coal bed

The Odell coal bed was named by Warren (1959, p. 572). A coal identified as the Odell bed in the Browns Mountain quadrangle (Culbertson and Klett, 1976) crops out about 30-40 feet (9-12 m) below the Brewster-Arnold coal bed near the flood plain of the Tongue River in the western part of the quadrangle (not shown on the geologic map, CRO pl. 1). The coal is slightly less than 5 feet (1.5 m) thick in a drill hole in sec. 17, T. 6 S., R. 43 E. (shown rounded to 5 feet on CRO pls. 1 and 3), and is 3-4 feet (.09-1.2 m) thick at most other places where measured in the quadrangle.

Chemical analyses have not been made of the Odell coal bed, and resources have not been calculated.

King coal bed
(CRO pls. 44-48)

The King coal bed was named by Warren (1959, p. 571) presumably for outcrops of the bed along King Creek, a tributary of the Tongue River about 8 miles (13 km) north of the Browns Mountain quadrangle. The same coal bed was called the upper bench of the Knobloch coal bed by Matson and others (1973, pls. 11A and 33) along the Tongue River in the vicinity of the Browns Mountain quadrangle, and it was called the Upper Knobloch bed by Culbertson and Klett (1976) in the northern part of the Browns Mountain quadrangle. According to Matson and others (1973), the King and Knobloch beds (or upper and middle benches of the Knobloch bed in their nomenclature), which are about 35 feet (11 m) apart in the northern part of the Browns Mountain quadrangle, converge northward along the valley of the Tongue River and join to form the Knobloch coal bed north of sec. 29 and 30, T. 4 S., R. 44 E. Regional subsurface relations, the mapping done by Warren (1959), and unpublished mapping done by W. C. Culbertson in 1977, along the Tongue River north of the Browns Mountain quadrangle indicate a different interpretation of the stratigraphic relations; namely, that the King bed does not join the Knobloch bed but instead is continuous with the Sawyer coal bed as shown in the Ashland area by Bass (1932) and McKay (1976). The Sawyer bed lies as much as 225 feet (69 m) above the Knobloch bed near Ashland (Bass, 1932, p. 52).

The King bed is about 7 feet (2.1 m) thick in a drill hole in sec. 25, T. 5 S., R. 42 E., and probably extends as a continuous bed 5 feet (1.5 m) or more thick across the northern part of the quadrangle (CRO pl. 44). The bed has possibilities for strip mining in the northwestern corner of the quadrangle (CRO pl. 46).

Matson and others (1973, p. 65) report that a sample of coal from the King bed (upper bench of the Knobloch of their nomenclature), collected in sec. 30, T. 5 S., R. 43 E., contains 0.59 percent sulfur, 4.8 percent ash, and has a heat value of 9,135 Btu on an as-received basis.

Knobloch coal bed
(CRO pls. 49-53)

The Knobloch coal bed (spelled Knoblock in early reports) was named by Bass (1924) for exposures along the Tongue River about 2 miles (3.2 km) north of the Browns Mountain quadrangle. The coal bed identified in this report as the Knobloch was called the middle bench of the Knobloch by Matson and others (1973, pls. 11A and 33), and the Middle Knobloch bed by Culbertson and Klett (1976).

Coal in the Knobloch bed is 18 feet (5.5 m) thick in a drill hole in sec. 25, T. 5 S., R. 42 E., in the northwestern corner of the quadrangle; and it is 16 feet (4.9 m) thick in an oil and gas well in sec. 21, T. 6 S., R. 43 E., in the west-central part (CRO pl. 49). The bed could not be identified in the log of a well less than a mile south of the quadrangle in sec. 30, T. 6 S., R. 43 E.

A very irregularly shaped area of about 1 1/2 square miles (4 sq. km) in underlain by substantial resources of coal in the Knobloch bed at depths of less than 200 feet (61 m) east of the Tongue River (CRO pl. 51) in the northwestern corner of the quadrangle.

Matson and others (1973, p. 64) sampled the Knobloch (called by them the middle bench of the Knobloch) in sec. 7, T. 6 S., R. 43 E., about 1/2 mile (1 km) west of the Browns Mountain quadrangle. Their analyses shows 0.16 percent sulfur, 5.9 percent ash, and a heat value of 8,963 Btu per pound on as received basis. A summary of analyses of the Knobloch coal bed about 20 miles (16 km) northeast of the quadrangle near Ashland are given in table 4. The rank of the coal is subbituminous C.

Table 4.--Composition of coal in the Knobloch and Flowers-Goodale beds, Ashland area, Montana.

(Analyses by Coal Analysis Section, U.S. Bureau of Mines, Pittsburgh, Pa. based on standard coal analyses (proximate, ultimate, Btu, and forms-of-sulfur analyses, reported in percent on as-received basis.)

	Knobloch Bed[1] (22 samples)		Flowers-Goodale Bed[1] (3 samples)	
	Arithmetic mean	Range	Arithmetic mean	Range
Moisture	30.3	26.0-35.1	27.6	26.4-28.8
Vol. matter	28.8	26.4-32.5	27.6	26.2-28.7
Fixed C	35.2	31.3-37.9	36.6	34.4-39.1
Ash	5.7	4.0-7.4	8.2	5.8-11.9
Hydrogen	6.7	6.4-6.9	6.2	5.6-6.5
Carbon	47.6	43.3-49.8	48.4	45.8-51.2
Nitrogen	.7	.6-.8	.8	.7-.9
Oxygen	39.2	37.4-41.7	35.9	35.0-37.2
Sulfur	.2	.1-.3	.5	.4-.6
Btu/lb	8,140	7,270-8,480	8,240	7,790-8,710
Sulfate S	0.01	0.00-.07	0.01	0.01-.01
Pyritic S	.06	.01-.12	.10	.07-.15
Organic S	.10	.01-.26	.36	.29-.43

[1]Sample data from U.S. Bureau of Land Management, 1975.

Nance coal bed
(CRO pls. 54-58)

The Nance coal bed is named for its occurrence in the Nance and Hayes drill hole at locality 2 (CRO pl. 1), sec. 25, T. 5 S., R. 42 E., where the coal is 10 feet (3 m) thick and occurs at a depth of 242 feet (74 m). A coal at about the same horizon in holes drilled in the valley of the Tongue River was regarded by Matson and others (1973, pl. 33) as a lower bench of the Knobloch bed. The coal bed is referred to as the Lower Knobloch bed by Culbertson and Klett (1976) following a modification of the usage of Matson and others (1973).

The Nance bed is estimated to be as much as 12 feet (3.7 m) thick in the northern part of the Browns Mountain quadrangle, thinning generally southward (CRO plate 54). Overburden is estimated to be slightly less than 200 feet (61 m) in the northwestern part of the quadrangle in the area where the coal is thickest (CRO pl. 56).

Chemical analyses of coal are not available for the Nance bed, or for the lower bench of the Knobloch as the coal is referred to by Matson and others (1973). Presumably the coal is similar in quality to other coals in the lower part of the Fort Union Formation in the vicinity of the Browns Mountain quadrangle.

Flowers-Goodale coal bed
(CRO pls. 59-63)

The Flowers-Goodale coal bed was named by Bass (1932, p. 53-54) for outcrops in the Ashland coal field more than 20 miles (16 km) north of the Browns Mountain quadrangle. A 20-foot (6-m) thick coal bed identified in the log of hole 6 (CRO pl. 1) is believed to be the same bed. The electric logs of a few widely scattered oil and gas holes suggests that the coal extends across the quadrangle in the subsurface with a thickness in the range of 17-20 feet (5.2-6.1 m)(CRO pl. 59). Much additional information will be needed to determine accurately local variations in thickness. The coal is beneath more than 1,000 feet (305 m) of overburden in much of the eastern part of the quadrangle, and it is nowhere under less than 200 feet (61 m) of overburden (CRO pl. 61).

Matson and others (1973, p. 86) report that in three samples of coal from the Flowers-Goodale bed collected in the Ashland coal field about 30 miles (50 km) northeast of the Browns Mountain quadrangle, sulfur ranged from 0.36-0.77 percent, ash from 7.27-9.02 percent, and heat value from 7,540 to 7,570 Btu per pound on an as-received basis. Other analyses of coal found in drill holes near Ashland are summarized on table 4.

Tarret coal bed
(CRO pls. 64-68)

The lowest identified coal bed, the Terret bed (CRO pl. 1, hole 6), is correlated with a coal bed of the same name that crops out in the Ashland coal field to the north. Subsurface information is very sparse on which to demonstrate continuity of the coal between the Browns Mountain quadrangle and outcrops of the Terret bed in the Ashland coal field 20 miles (32 km) or more to the north; the correlation, therefore, is regarded as tentative.

Based on the identification of the bed in hole 6 (CRO pl. 1) and on the identification of coal at about the same stratigraphic level in wells adjacent to the quadrangle, the Terret bed is an estimated 5-10 feet (1.5-3.0 m) thick, and lies beneath 500 feet (153 m) to more than 1,000 feet (305 m) of overburden in the northern part of the quadrangle (CRO pls. 59 and 60).

Matson and others (1973, p. 86) give three analyses of the Terret coal from samples collected a few miles northeast of Ashland in which the sulfur content is 0.20-0.24 percent, the ash content is 5.14-6.25 percent, and the heat value is 7,630-7,860 Btu per pound on an as-received basis.

Coal Resources

Coal resource estimates in this report are restricted to the Reserve Base part of the Identified Coal Resource, which is the part most likely to be developed in the foreseeable future. (See U.S. Geol. Survey Bull. 1450-B for a discussion of these terms). The Reserve Base for subbituminous coal is coal 5 feet (1.5 m) or more thick, under less than 1000 feet (305 m) of overburden, and within 3 miles (4.8 km) of a complete measurement of the coal bed. Reserve Base coal is further subdivided into categories according to its nearness to a measurement cf the coal bed. Measured coal is coal within 1/4 mile (0.4 km) of a measurement, Indicated coal extends 1/2 mile (0.8 km) beyond Measured coal, and Inferred ccal extends 1 1/4 miles (2 km) beyond Indicated coal to a distance of 3 miles (4.8 km) from the measurement.

Reserves are the recoverable part of the Reserve Base. For strippable coal in this quadrangle the coal reserve is considered to be 85 percent of the part of the Reserve Base that is under less than 200 feet (61 m) of overburden.

The total Reserve Base for Federally owned coal is estimated to be about 1.9 billion short tons (CRO pl. 2). Only about 3 percent of this large amount is classified as Measured; 19 percent is Indicated; and 78 percent is Inferred as shown by the tabulation below:

Reserve Base for Federal coal lands.
according to overburden category and reliability of
the estimates, Browns Mountain quadrangle.

(In millions of short tons (rounded); to convert to metric tons, multiply by 0.9072.)

Overburden 0-200 feet			Overburden 200-1,000 feet		
Measured	Indicated	Inferred	Measured	Indicated	Inferred
40	140	60	20	210	1,420

COAL DEVELOPMENT POTENTIAL

Development potential for surface mining methods

Areas where the coal beds are more than 5 feet (1.5 m) thick and are overlain by 200 ft (61 m) or less of overburden are considered to have potential for strip mining and were assigned a high, moderate, or low development potential based on the mining ratio (cubic yards of overburden per ton of recoverable coal). The formula used to calculate mining ratios for subbituminous coalis as follows:

$$MR = \frac{t_o\ (0.911)}{t_c\ (rf)}$$

where MR = mining ratio

t_o = thickness of overburden

t_c = thickness of coal

rf = recovery factor (0.85)

Areas of high, moderate, and low development potential are here defined as areas underlain by coal beds having respective mining-ratio values of 0 to 10, 10 to 15, and greater than 15, as shown on CRO plates 6, 11, 16, 26, 31, 36, 41, 46, 51, and 56. These mining-ratio values for each development-potential category are based on economic and technological criteria; they are applicable only to this quadrangle, and were derived in consultation with A. F. Czarnowsky, Area Mining Supervisor, U.S. Geological Survey.

Reserve Base for federally owned coal beneath less than 200 feet (61 m) of overburden in the various development-potential categories total 240 million short tons, as shown in table 5.

Each quarter section or lot underlain by federally owned coal is classified according to its development potential for surface mining methods on plate 69.

Development potential for underground mining methods

The Reserve Base for federally owned coal beneath 200-1,000 feet (61-305 m) of overburden is estimated to be 1.65 billion short tons, as shown on Table 6. Coal at these depths is available for underground mining. Coal is not now being mined underground in the Powder River Basin, and recovery factors have not been established. The development potential was not evaluated.

Table 5. - Estimated Reserve Base for surface mining methods (0-200 feet overburden) for Federal coal lands in the Browns Mountain quadrangle, Rosebud County, Montana.

[In short tons. Development potentials are based on mining ratios (cubic yards of overburden/ton of underlying coal). To convert short tons to metric tons, multiply by 0.9072; to convert mining ratios in yd^3/ton coal to m^3/t, multiply by 0.842]

Coal bed	High development potential (0-10 mining ratio)	Moderate development potential (10-15 mining ratio)	Low development potential (>15 mining ratio)	Total (rounded)
Anderson[1]	780,000	-----	-----	780,000
Anderson and Dietz, combined[2]	770,000	-----	-----	770,000
Upper Canyon	5,280,000	5,680,000	16,900,000	27,900,000
Lower Canyon	14,300,000	10,200,000	32,500,000	57,000,000
Cook	1,990,000	1,080,000	5,540,000	8,610,000
Upper and Lower Otter	8,000,000	5,040,000	5,210,000	18,300,000
Wall	5,700,000	4,000,000	9,900,000	19,600,000
Pawnee	4,060,000	1,950,000	3,090,000	9,100,000
Poker Jim	5,450,000	8,640,000	21,800,000	35,900,000
Brewster-Arnold	12,400,000	8,100,000	15,200,000	35,700,000
King	1,810,000	744,000	3,790,000	6,340,000
Knobloch	13,600,000	5,630,000	-----	19,200,000
Nance	-----	-----	2,420,000	2,420,000
Total (rounded)	74,000,000	51,000,000	116,000,000	240,000,000

[1] Coal preserved in sec. 5, T. 7 S., R. 44 E.; thickness 34 feet.

[2] Coal preserved in secs. 6 and 7, T. 6 S., R. 44 E.; estimated thickness 54 feet.

Table 6.--Estimated Reserve Base for underground mining methods (200-1,000 feet overburden) for Federal coal lands in the Browns Mountain quadrangle, Rosebud County, Montana.

(In short tons. To convert to metric tons, multiply by 0.9072.)

Coal bed name	Reserve Base
Upper Canyon	33,200,000
Lower Canyon	78,000,000
Cook	49,100,000
Upper Otter	49,900,000
Lower Otter	6,100,000
Wall	21,700,000
Pawnee	3,000,000
Poker Jim	47,300,000
Brewster-Arnold	94,000,000
King	28,800,000
Knobloch	509,000,000
Nance	171,000,000
Flowers-Goodale	464,000,000
Terret	87,100,000
Total (rounded)	1,650,000,000

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