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COAL RESOURCE OCCURRENCE AND COAL DEVELOPMENT POTENTIAL MAPS OF THE SOUTHERN PART OF THE CLUBFOOT CREEK QUADRANGLE, ROSEBUD COUNTY, MONTANA

(Report includes 34 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 southern part of the Clubfoot Creek quadrangle, Rosebud County, Montana (plates 1-33) and (2) A coal development potential (CDP) map of the southern part of the Clubfoot Creek quadrangle, Rosebud County, Montana (plate 34). 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). Coal 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/CDP plates 1-34) or included in the resource estimates.

Location

The Clubfoot Creek 7½-minute quadrangle is on the west side of the Tongue River in southern Rosebud County, Montana about 20 miles (32 km) southwest of Ashland. It includes part of the Northern Cheyenne Indian Reservation in its northern part. Cook Creek trends southeastward across the southern part of the quadrangle forming the southern boundary of the reservation. Only about 7 square miles (18 square km) lying outside the reservation are included in the work.

Accessibility

An all-weather county road that forks from Montana Route 212 at Ashland connects Ashland with points to the south along the Tongue River in Montana. This road passes within about 2 miles of the southeastern corner of the quadrangle. Dirt roads and trails branching from this road provide access to the southern part of the quadrangle.

The Burlington Northern Railroad operates and maintains east-west routes through Sheridan, Wyoming, about 50 miles (80 km) to the south, and operates a spur line from Forsyth, Montana southward to Colstrip, Montana, about 35 miles (56 km) to the north.

Physiography

Cook Creek, a southeastward flowing tributary of the Tongue River, occupies a broad valley in the southern part of the quadrangle. The land surface rises southward from Cook Creek in a series of benches held up by resistant sandstone beds or by beds of clinker resulting from burning of coal. Steep-sided gullies and washes intricately dissect the steeper slopes in the quadrangle.

Cook Creek and its tributaries in the southern part of the quadrangle are all intermittent streams.

Climate

Southeastern Montana in the vicinity of the Clubfoot Creek 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 Powder River Basin KRCRA Montana. The Federal Government owns the coal rights in most of the quadrangle south of the Northern Cheyenne Indian Reservation.

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

General geology

Sources of data

The geology in the southern part of the quadrangle is known mainly from the work of Baker (1929) who mapped the part of the quadrangle south of the reservation together with a much larger adjacent area at a scale of 1:62,500. Baker (1929) did not have topographic base maps, and his mapping lacks close vertical control. The surface geology shown on CRO map, plate 1, was compiled by inspection from Baker's (1929) map. Matson and others (1973, pl. 6) outlined areas suitable for stripping of the Wall and Brewster-Arnold coal beds south of Cook Creek. One shallow hole drilled for coal near Cook Creek in the southern part of the Clubfoot Creek quadrangle provides information on the King and Knobloch coal beds.

Coal bed thicknesses shown on the CRO maps are the bed thicknesses reported at outcrops or in the drill hole rounded to the nearest 1 foot, partings excluded.

Stratigraphy

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

The part of the Tongue River Member of the Fort Union remaining in the quadrangle is about 1,900 feet (580 m) thick, and consists of interbedded lenticular beds of yellowish gray to light-gray fine- to very fine grained sandstone, light- or dark-gray siltstone and clayey siltstone, gray shale and claystone, brown carbonaceous shale, and peristent beds of coal. Rocks comprising the Tongue River Member were deposited at elevations of perhaps a few tens of feet above sea level in 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 on the western flank of the Powder River structural basin just west of the basin axis, which trends generally northward. Regional dip is toward the southeast at less than 1^{o}. Structural relief on the Brewster-Arnold coal bed in the southern part of the quadrangle is about 100 feet (30 m), as shown on CRO plate 15.

Coal geology

Thirteen coal beds ranging in thickness from 1 to 20 feet (0.3-6.1 m) were either identified on the surface or in the subsurface in or near the quadrangle (CRO pl. 3). The Terret coal bed is the stratigraphically lowest recognized coal bed. It is successively overlain by a noncoal interval that

averages about 140 feet (43 m) thick; the Flowers-Goodale bed; a noncoal interval about 120 ft (37 m) thick; the Nance coal bed; an interval about 125 feet (38 m) thick containing a thin local coal bed; the Knobloch coal bed; a noncoal interval about 60 ft (18 m) thick, the King coal bed; an interval about 130 ft (40 m) thick containing a local coal bed in the upper part; the Brewster-Arnold coal bed; a noncoal interval about 120 ft (37 m) thick; the Pawnee coal bed; an interval about 120 ft (37 m) thick containing a local coal bed, the Wall coal bed; a noncoal interval about 130 ft (30 m) thick; the Cook coal bed; a noncoal interval about 110 ft (34 m) thick; the Canyon coal bed, and a noncoal interval about 300 ft (92 m) thick which includes clinker as much as 150 ft (46 m) thick resulting from burning of the Anderson and Dietz coal beds, combined.

The nearest locality at which the Terret bed is identified is a well about 3 miles (4.8 km) south of the quadrangle. Information is insufficient for construction of maps or calculation of resources for this coal. The Pawnee, Cook, and all of the local coal beds are too thin to be considered for the purposes of the CRO and CDP maps. The Anderson and Dietz beds have been consumed by burning. CRO plates 4-33 depict the remaining seven beds, which are also described below.

Coals in the Clubfoot Creek quadrangle have not been analyzed; however, based on analyses of coal samples collected at nearby localities, the rank of most of the coal in the quadrangle probably varies from high in the range of subbituminous C to low in the range of subbituminous B. Coals in the Northern Great Plains, including coal in the Fort Union Formation in Montana, generally contain lesser amounts of most elements of environmental concern, than coal beds in other areas of the United States (Hatch and Swanson, 1977, p. 147).

In the past, many of the thicker coal beds have caught fire at the outcrop and 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 thick, and locally caps the high interstream divides.

Canyon coal bed

(CRO pls. 4-8)

Canyon coal bed was named by Baker (1929). It correlates with the coal called the Upper Canyon coal bed by Culbertson and Klett (1976) in the adjacent Browns Mountain quadrangle to the southeast. The bed is marked by a fringe of clinker which has formed by near-surface burning of the coal on the steep hills in the southwestern corner of the quadrangle. The clinker outlines more deeply buried parts of the bed where coal is preserved. An exposure of the Canyon bed in the adjacent part of the Birney quadrangle, a few hundred feet south of the Clubfoot Creek quadrangle, shows a thickness of about 10 feet (3 m) of coal (Baker, 1929; Mapel, 1976). The coal presumably thins from this exposure northward (CRO pl. 4).

Samples for chemical analyses have not been collected from the Canyon bed in the Clubfoot Creek quadrangle.

Wall coal bed

(CRO pls. 9-13)

The Wall coal bed was named by Baker (1929), probably for exposures of the coal along Wall Creek, a tributary to the Tongue River a few miles south of the Clubfoot Creek quadrangle. The Wall bed is present in the southwestern part of the Clubfoot Creek quadrangle, but does not crop out because it has

been extensively burned. The bed contains 17 feet (5.2 m) of coal in the adjacent part of the Birney quadrangle (Baker, 1929), and it appears to be thick and extensive in areas southwest of the Clubfoot Creek quadrangle (Matson and others, 1973, pl. 6). Within the southern part of the Clubfoot Creek quadrangle, only a narrow strip of coal remains in the Wall bed between the back edge of clinker produced by near-surface burning of the coal and the 200-foot (61-m) overburden line; at places the overburden exceeds 400 feet (122 m) (CRO pl. 11).

Analyses of 42 samples of coal from the Wall bed, collected within about 10 miles (16 km) southwest of the Clubfoot Creek 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).

Brewster-Arnold coal bed

(CRO pls. 14-18)

The Brewster-Arnold coal bed was named by Bass (1924) for outcrops at the Brewster-Arnold mine a short distance south of the Clubfoot Creek quadrangle. The bed crops out low in the valley of Cook Creek in the southern part of the Clubfoot Creek quadrangle. It is extensively burned along the outcrop; however, Baker (1929) found 10 feet (3 m) of coal in the Brewster-Arnold bed in a bluff north of Cook Creek in sec. 21, T. 5 S, R. 43 E. It thickens southward to more than 20 feet (6.1 m) in the adjacent part of the Birney quadrangle to the south (Matson and others, 1973, pl. 6; Mapel, 1976). The coal probably underlies all of the southern part of the quadrangle, and is within 200 feet (61 m) of the surface in much of the south-central part (CRO pl. 16).

An analysis of coal from a drill core collected in sec. 28, T. 5 S., R. 42 E., contains 0.55 percent sulfur, 12.5 percent ash, and has a heat value of 7,879 Btu per pound on an as-received basis (Matson and others, 1973, p. 40). Other samples of coal collected from the Brewster-Arnold bed farther to the south contain 0.24-0.29 percent sulfur, 4.0-8.3 percent ash, and have a heat value of 8,786-9,417 Btu per pound on an as-received basis (Matson and others, 1973, p. 43).

King coal bed

(CRO pls. 19-23)

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 east of the Clubfoot Creek 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 Clubfoot Creek quadrangle, and was called the Upper Knobloch bed by Culbertson and Klett (1976) and by Mapel (1976) in the adjacent Browns Mountain and Birney quadrangles to the southeast and south. 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 60 feet (18 m) apart in the southern part of the Clubfoot Creek quadrangle, converge northward along the valley of the Tongue River and join to form the Knobloch coal bed north of secs. 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 east of the Clubfoot Creek quadrangle lead to a different interpretation; namely, that the King bed does not join the Knobloch bed, but instead is continuous northeastward with the Sawyer coal bed as mapped 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 7 feet (2.1 m) thick in a drill hole in sec. 27, T. 5 S., R. 42 E., in the southeastern part of the Clubfoot Creek quadrangle. Regional thickness relations suggest that the coal thins southwestward to less than 5 feet (1.5 m) thick in the southwestern part of the quadrangle as shown on CRO plate 19. The coal lies beneath less than 200 feet (61 m) of overburden in the lower valley of Cook Creek in the southeastern part of the quadrangle (CRO pl. 21).

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. 24-28)

The Knobloch coal bed (spelled Knoblock in early reports) was named by Bass (1924) for exposures along the Tongue River a few miles east of the Clubfoot Creek 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). Coal in the Knobloch is 19 feet (5.8 m) thick, where drilled south of Cook Creek in sec. 27, T. 5 S., R. 42 E., in the southeastern part of the Clubfoot Creek quadrangle (CRO pls. 1 and 3). Based on regional thickness relations, the coal thins generally southwestward across the southern part of the quadrangle (CRO pl. 24); however, information is not available within the quadrangle to show accurately local variations in the thickness of the coal.

Matson and others (1973, p. 64-65) sampled the Knobloch (called by them the middle bench of the Knobloch) in sec. 7, T. 6 S., R. 43 E., about 3 miles

(5 km) south of the Clubfoot Creek quadrangle. Their analyses show 0.16 percent sulfur, 5.9 percent ash, and a heat value of 8,963 Btu per pound on an as-received basis. A summary of analyses of the Knobloch coal bed near Ashland are given in table 1. The coal is subbituminous C in rank.

Nance coal bed

(CRO pls. 4-8)

The Nance coal bed is named for its occurrence in a hole drilled by Mr. Marcus Nance and Dr. Arthur Hayes in sec. 25, T. 5 S., R. 42 E., about 3/4 mile (1.2 km) southeast of the Clubfoot Creek quadrangle. It is 10 feet (3 m) thick and occurs at a depth of 242 feet (74 m) in this drill hole. (See Culbertson and Klett, 1976, locality 1). 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 has also been referred to as the Lower Knobloch bed in reports on the Birney quadrangle by Mapel (1976) and on the Browns Mountain quadrangle by Culbertson and Klett (1976), following a modification of the usage of Matson and others (1973).

The Nance coal bed was identified in the logs of oil and gas tests and in holes drilled for coal in the adjacent Birney, Browns Mountain, and Birney Day School quadrangles, and is projected into the southeastern part of the Clubfoot Creek quadrangle on this basis.

The Nance bed is estimated to be 5-9 feet (1.5-2.7 m) thick in the southeastern part of the Clubfoot Creek quadrangle, thinning westward to less than 5 feet (1.5 m) thick in the southwestern part (CRO pl. 4). Overburden is estimated to be slightly less than 200 feet (61 m) in the southeastern part of the quadrangle where the coal is thickest, increasing generally westward (CRO pl. 6).

Table 1.--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

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

Chemical analyses are not available for coal in 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 Clubfoot Creek quadrangle.

Flowers-Goodale coal bed

(CRO pls. 29-33)

The Flowers-Goodale bed is mapped beneath all of the southern part of the Clubfoot Creek quadrangle with a thickness ranging from about 9 to 12 feet (2.7-5.8 m) (CRO pl. 29). The name is from a coal that crops out in the Ashland coal field to the north (Bass, 1932, p. 53-54). The Flowers-Goodale bed is projected into the southern part of the Clubfoot Creek quadrangle on the basis of its identification in oil and gas tests in the neighboring Birney and Birney Day School quadrangles to the south and east respectively. The coal is probably thickest in the southeastern corner of the quadrangle where the depth to the coal is as little as 300 feet (92 m).

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 Clubfoot Creek quadrangle, sulfur ranged from 0.36-0.77 percent, ash from 7.27-9.03 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 1.

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 that is 5 feet (1.5 m) or more thick, under 1000 feet (305) or less 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 of 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 to a distance of 3/4 mile from the measurement, and Inferred coal extends 2 1/4 miles (7.2 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 Reserve Base.

The total Reserve Base for federally owned coal in the southern part of the Clubfoot Creek quadrangle in beds thicker than 5 feet (1.5 m), which lie 1,000 ft (305 m) or less below the land surface is estimated to be about 240 million short tons as shown by table 2 and CRO plate 2. Of this amount 1 percent (2 million short tons) is Measured, 20 percent (48 million short tons) is Indicated, and 79 percent (190 million short tons) is Inferred.

Table 2.--Estimated Reserve Base for Federal coal lands in the southern part of the Clubfoot Creek quadrangle.

(In thousands of short tons, rounded. Multiply by 0.907 to convert to metric tons)

Coal bed name	Overburden 0-200 feet (0-61 m)				Overburden 200-1,000 ft (61-305 m)				Grand total (rounded)
	Measured	Indicated	Inferred	Total (rounded)	Measured	Indicated	Inferred	Total (rounded)	
Canyon	-----	400	2,400	2,800	-----	-----	900	900	3,700
Wall	-----	6,000	17,000	23,000	-----	2,100	11,000	13,000	36,000
Brewster-Arnold	-----	14,000	23,000	37,000	-----	650	24,000	25,000	62,000
King	640	5,100	5,500	11,000		1,200	9,300	11,000	22,000
Knobloch	1,300	12,000	7,300	21,000	330	5,700	43,000	49,000	70,000
Nance	-----	-----	40	40	-----	-----	10,000	10,000	10,000
Flowers-Goodale	-----	-----	-----	-----	-----	-----	39,000	39,000	39,000
Total (rounded)	1,900	38,000	55,000	95,000	330	9,700	138,000	148,000	240,000

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 coal is 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 0-10, 10-15, and greater than 15, as shown on CRO pls. 6, 11, 16, 21, and 26. 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 estimates for federally owned coal in the various development-potential categories for surface mining methods are shown in table 3. Each quarter section or tract in the southern part of the quadrangle is classified according to its development potential for surface mining methods on CDP plate 34.

Development potential for underground mining methods

Reserve Base for federally owned coal beneath 200-1,000 feet (61-305 m) of overburden is estimated to be 148 million short tons, as shown on table 2. 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 is unknown.

Table 3.---Potential for surface mining of the estimated Reserve Base, southern part of the Clubfoot Creek quadrangle.

(Development potentials are based on mining ratios (cubic yards of overburden/ton of underlying coal). To convert short tons to metric tons, multiply by 0.907; to convert mining ratios in yd^3/ton coal to m^3/t, multiply by 0.84)

Coal bed	High development potential (0-10 mining ratio)	Moderate development potential (10-15 mining ratio)	Low development potential (>15 mining ratio)	Total
Canyon	1,400,000	870,000	570,000	2,800,000
Wall	19,000,000	4,000,000	---------	23,000,000
Brewster-Arnold	30,000,000	6,800,000	490,000	37,000,000
King	3,400,000	1,800,000	6,000,000	11,000,000
Knobloch	15,000,000	5,700,000	---------	21,000,000
Nance	--------	-------	40,000	40,000
Total (rounded)	69,000,000	19,000,000	7,100,000	95,000,000

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