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COAL RESOURCE OCCURRENCE AND COAL DEVELOPMENT POTENTIAL MAPS OF THE FOSTER CREEK SCHOOL QUADRANGLE, CUSTER AND POWDER RIVER COUNTIES, MONTANA

[Report includes 14 plates]

By

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ILLUSTRATIONS

[Plates are in pocket]

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Conversion table

To convert	Multiply by	To obtain
feet	0.3048	meters (m)
miles	1.609	kilometers (km)
acres	0.40469	hectares (ha)
tons (short)	0.907	metric tons (t)
short tons/acre-ft	7.36	metric tons/hectare-meter (t/ha-m)
Btu/lb	2.326	kilojoules/kilogram (kJ/kg)

INTRODUCTION

Purpose

This text is for use in conjunction with the Coal Resource Occurrence (CRO) and Coal Development Potential (CDP) maps of the Foster Creek School quadrangle, Custer and Powder River Counties, Montana, (14 plates; U.S. Geological Survey Open-File Report 79-009). This set of maps was compiled to support the land planning work of the Bureau of Land Management in response to the Federal Coal Leasing Amendments Act of 1975, and to provide a systematic coal resource inventory of Federal coal lands in Known Recoverable Coal Resource Areas (KRCRAs) in the western United States. Coal beds considered in the resource inventory are only those beds 5 feet (1.5 m) or more thick and under less than 3,000 feet (914 m) of overburden.

Location

The Foster Creek School 7 1/2-minute quadrangle is in southwestern Custer and northwestern Powder River Counties, Montana, about 38 miles (60.8 km) south of Miles City, Montana. Miles City is on U.S. Interstate Highway 94 and the main lines of the Burlington Northern Railroad and the Chicago, Milwaukee, St. Paul, and Pacific Railroad.

Accessibility

The quadrangle is accessible from Miles City, Montana, by going south on U.S. Highway 312 a distance of 13 miles (21 km) to the intersection with paved local highway 332, and then southwest 23 miles (37 km) to the intersection with Foster Creek Road, and then southeast 13 miles (21 km) to the northwest corner of Foster Creek School quadrangle. The southeastern part of the quadrangle is more readily accessible from Miles City by going south on U.S. Highway 312 a distance of 50 miles (80 km) to the intersection with Pumpkin Creek Road, and then west and southwest a distance of 5 miles (8 km) to the east border of the quadrangle.

Physiography

The Foster Creek School quadrangle is within the Missouri Plateau division of the Great Plains physiographic province. The upland plateau surface, however, has been almost completely dissected by tributaries of the northeasterly flowing Tongue River and its principal tributary, Pumpkin Creek. Foster Creek flows northwesterly to the Tongue River from the north half of the quadrangle, and Little Pumpkin Creek flows northeasterly to Pumpkin Creek from the south half of the quadrangle. A drainage divide oriented northeast-southwest separates the two creek valleys. The highest elevations in the quadrangle, about 3,400 feet (1,036 m) are on the divide near the center of the south half of the quadrangle. The lowest elevation, just under 2,900 feet (884 m) is where Foster Creek flows out of the quadrangle near the northwest corner. Topographic relief is about 500 feet (152 m).

Climate

The climate of Custer and Powder River Counties is characterized by pronounced variations in seasonal precipitation and temperature. Annual precipitation in the region varies from less than 12 inches (30 cm) to 16 inches (41 cm). The heaviest precipitation is from April to August. The largest average monthly precipitation is during June. Temperatures in eastern Montana range from as low as -50°F (-46°C) to as high as 110°F (43°C). The highest temperatures occur in July and the lowest in January; the mean annual temperature is about 45°F (7°C) (Matson and Blumer, 1973, p. 6).

Land status

The Northern Powder River Basin Known Recoverable Coal Resource Area (KRCRA) covers the quadrangle except for the valley bottom of Foster Creek in the northwest quarter of the quadrangle and the valley bottom of Little Pumpkin Creek in the south half of the quadrangle. The Boundary and Coal Data Map (pl. 2) shows the location of the KRCRA tracts and the land ownership status. There were no outstanding Federal coal leases or prospecting permits as of 1977.

GENERAL GEOLOGY

Previous work

Bass (1932) mapped the Foster Creek School quadrangle as part of the Ashland coal field, Rosebud, Powder River, and Custer Counties, Montana. Brown and others (1954) mapped the quadrangle as part of their Foster Creek deposit, in a description of strippable coal in Custer and Powder River Counties, Montana. Gilmour and Williams (1969) mapped the quadrangle as part of the Foster Creek coal deposit. Matson and Blumer (1973) included a revision of the Gilmour and Williams work in their summary of strippable coal, southeastern Montana.

Stratigraphy

A generalized columnar section of the coal-bearing rocks is shown on the Coal Data Sheet (pl. 3) of the CRO maps. The exposed bedrock units belong to the Fort Union Formation (Paleocene). The Fort Union Formation is composed of three members: the upper Tongue River Member, the middle Lebo Shale Member, and the lower Tullock Member. Bass (1932, p. 31) considered the Tullock to be a member of the Tertiary(?) Lance Formation, but since 1949 the U.S. Geological Survey has considered the Tullock to be the lowermost member of the Fort Union Formation in Montana.

The Lebo Shale Member composes the lowest outcrops in the quadrangle, occurring as the lowermost beds exposed in the bottom of Foster Creek valley, near the northwest corner of the quadrangle. The Lebo Shale Member is 150 to 160 feet (45.7 to 48.8 m) thick and consists of shale and a few thin, lenticular sandstone, but no mappable coal beds.

The Tongue River Member underlies the rest of the quadrangle and contains the only coal beds of economic interest. This unit is made up mainly of yellow sandstone, sandy shale, carbonaceous shale, and coal. Much coal has burned along outcrops, baking the overlying sandstone and shale and forming thick reddish-colored clinker beds. Originally as much as 1,150 to 1,600 feet (350 to 448 m) thick in this vicinity (Bass, 1932, p. 34), most of the Tongue River Member has been removed by erosion so that only about the lower 500 feet (152 m) remains.

Coal and other rocks comprising the Tongue River Member were deposited in a continental environment at elevations of perhaps a few tens of feet (a few meters) above sea level in a vast area of shifting flood plains, sloughs, swamps, and lakes that occupied the Northern Great Plains in Paleocene (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 U.S. 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 Foster Creek School quadrangle is in the northeastern part of the Powder River structural basin. Regionally, the strata dip about 20 feet per mile (3.8 m per km) to the northwest, but small, shallow, irregular folds interrupt the regional dip, as shown by the structure contours on the Terret coal bed (pl. 11).

COAL GEOLOGY

Four coal beds, all in the Tongue River Member of the Fort Union Formation, were mapped on the surface in this quadrangle (pl. 1) and are shown in section on plate 3. The lowest of these is a local, unnamed coal bed, which lies about 100 feet (30 m) above the base of the Tongue River Member. This local coal bed is overlain by a noncoal interval of 40 feet (12 m); the Terret coal bed, a noncoal interval of 70 feet (21 m), the

Flowers-Goodale coal bed, a noncoal interval of 100 feet (30 m), and the Knobloch coal bed. The Terret, Flowers-Goodale, and Knobloch coal beds contain economic coal reserves.

The coal found along the eastern flank of the Powder River basin in Montana increases in rank from lignite, located along the outcrop areas in the east, to subbituminous C, B, and A located in the deeper parts of the basin to the west. Lignite A is a coal having a heating value of 6,300 to 8,300 Btu per pound (14,654 to 19,306 kJ/kg) on a moist, mineral-matter-free basis. Subbituminous C coal has a heating value of 8,300 to 9,500 Btu per pound (19,306 to 22,097 kJ/kg) on a moist, mineral-matter-free basis. All coal analyses data available at the present time for this and adjacent quadrangles were considered in making our decision to assign a rank of lignite to the coal in this quadrangle. The lignite-subbituminous boundary may fall within the quadrangle close to the western border, but not enough data is presently known to allow our drawing that boundary line through the quadrangle with certainty. Therefore, it is drawn along the western boundary of the quadrangle, and a rank of lignite has been arbitrarily assigned by us to all of the coal in the entire quadrangle. Additional data to be obtained in the future may make a more precise determination of the location of this boundary line possible.

The trace element content of coals in the Foster Creek School quadrangle has not been determined; however, coals in the Northern Great Plains, including those in the Fort Union Formation in Montana, have been found to 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).

Terret coal bed

The Terret coal bed was described by Bass (1932, p. 51) from a small mine on the Terret Ranch (Cook Creek Reservoir quadrangle) in the Ashland coal field, about 16 miles (26 km) southwest of the Foster Creek School quadrangle. The Terret coal crops out in the valleys of Foster, Flat Butte, and Lone Tree Creeks, and underlies the intervening divides (pl. 1). The bed ranges from less than 3 to 16 feet (0.9 to 4.9 m) in thickness, and is of Resource Base thickness (5 feet or 1.5 m or more) only in approximately the northern two-thirds of the quadrangle (pl. 10). The Terret coal bed dips regionally to the southwest at about 20 feet per mile (3.8 m per km), but this dip is interrupted by several broad, shallow folds (pl. 11). The overburden on the Terret coal bed ranges from zero to over 400 feet (122 m) in thickness (pl. 12). Where thickest, the overburden includes the Flowers-Goodale and Knobloch coal beds.

The Montana Bureau of Mines and Geology drilled and cored the Terret coal in drill hole FC-16 (sec. 17, T. 1 N., R. 48 E.) in the northeast quarter of the Foster Creek School quadrangle. An analysis of coal from depths of 53 to 62 feet (16.1 to 18.9 m) shows a heating value of 7,820 Btu per pound (18,189 kJ/kg), ash 5.14 percent, and sulfur 0.21 percent, on an as-received basis (Matson and Blumer, 1973, p. 86). This analysis converts to a moist, mineral-matter-free heating value of about 8,244 Btu per pound (19,176 kJ/kg) and determines the coal rank to be lignite A. An analysis of the Terret coal from drill hole FC-32 (sec. 25, T. 1 N., R. 47 E.) near the center of the Foster Creek School quadrangle shows a heating value of 7,630 Btu per pound (17,747 kJ/kg), ash 6.24 percent, and sulfur 0.20 percent, on an as-received basis (Matson and Blumer, 1973, p. 86). This analysis converts to about 8,138 Btu per pound (18,929 kJ/kg) on a moist, mineral-matter-free basis and likewise determines the Terret coal in this quadrangle to be lignite A in rank.

Flowers-Goodale coal bed

The Flowers-Goodale coal bed was described by Bass (1932, p. 53) from two small mines located in the Brandenberg quadrangle, about 12 miles (19 km) west of the Foster Creek School quadrangle.

The Flowers-Goodale coal bed underlies the divide which runs northeasterly across the quadrangle separating the Foster Creek and Little Pumpkin Creek drainages. The coal bed thickness ranges from 4 to 17 feet (1.2 to 5.2 m), generally becoming thicker in a westward direction (pl. 7). There is a slight dip northwestward, less than 40 feet per mile (7.62 m/km), as is shown on plate 7. The overburden on the Flowers-Goodale coal bed ranges from zero to over 200 feet (61 m) in thickness (pl. 8). Where thickest (local areas on the crest of the drainage divide, see plate 8), the overburden includes the Knobloch coal bed.

The Montana Bureau of Mines and Geology drilled and cored the Flowers-Goodale coal bed in drill hole FC-32 (sec. 25, T. 1 N., R. 47 E.) near the center of the Foster Creek School quadrangle. An analysis of coal from depths of 83 to 95.5 feet (25.3 to 29.1 m) shows a heating value of

7,540 Btu per pound (17,538 kJ/kg), ash 7.27 percent, and sulfur 0.36 percent, on an as-received basis (Matson and Blumer, 1973, p. 86). This analysis converts to a moist, mineral-matter-free heating value of about 8,130 Btu per pound (18,910 kJ/kg), and determines the coal rank to be lignite A.

Knobloch coal bed

The Knobloch coal bed was described by Bass (1932). The coal-bed name was taken from the Knobloch Ranch and coal mine in the Birney Day School quadrangle located about 34 miles (54 km) southwest of the Foster Creek School quadrangle.

The Knobloch coal bed is present in a number of local areas on the crest of the drainage divide extending northeastward across the Foster Creek School quadrangle (pls. 1, 4). The regional dip of the Knobloch coal bed is northwestward about 40 feet per mile (7.62 m/km), and the thickness of the coal bed ranges from about 7 to 17 feet (2.1 to 5.2 m), as shown on plate 4. The overburden covering the Knobloch coal bed ranges from zero to about 150 feet (46 m) in thickness, and the mining ratio is less than 10 throughout the quadrangle (pl. 5). Analyses of the Knobloch coal are not available in the Foster Creek School quadrangle; however, the Montana Bureau of Mines and Geology cored the Knobloch coal in drill hole FC-11 (sec. 3, T. 1 S., R. 47 E.) in the North Stacey School quadrangle about 2 miles (3.2 km) west of the Foster Creek School quadrangle boundary. An analysis of the coal from depths 84 to 100 feet (25.6 to 30.5 m) shows a heating value of 7,500 Btu per pound (17,445 kJ/kg), ash 8.36 percent, and sulfur 0.32 percent, on an as-received basis (Matson and Blumer, 1973, p. 86). This heating value converts to about 8,190 Btu per pound (19,050 kJ/kg) on a moist, mineral-matter-free basis, and determines the rank of the coal to be lignite A. Since this drill hole is located so close to the Foster Creek School quadrangle, it is assumed that the Knobloch coal in the Foster Creek School quadrangle is similar and is also lignite A in rank.

COAL RESOURCES

Data from drill holes as well as from all publicly available surface mapping by others (see list of references) were used to construct outcrop, isopach, and structure contour maps of the coal beds in this quadrangle.

Coal resource tonnages shown in this report are the Reserve Base (RB) part of the Identified Resources found within 3 miles (4.8 km) of a point of coal-bed measurement, as discussed in U.S. Geological Survey Bulletin 1450-B. Hypothetical Resources, located more than 3 miles (4.8 km) from a coal measurement point, are not present in the quadrangle.

The Reserve Base for lignite is lignite that is 5 feet (1.5 m) or more thick, under 1,000 feet (305 m) or less of overburden, and located within 3 miles (4.8 km) of a point of coal-bed measurement. Reserve Base is further subdivided into reliability categories according to their nearness to a measurement of the coal bed. Measured coal is coal within 0.25 mile (0.4 km) to a measurement, Indicated coal extends 0.5 mile (0.8 km) beyond Measured coal to a distance of 0.75 mile (1.2 km) from the measurement point, and Inferred coal extends 2.25 miles (3.6 km) beyond Indicated coal to a distance of 3 miles (4.8 km) from the measurement point.

Hypothetical Resources are undiscovered coal resources in beds that may reasonably be expected to exist in known mining districts under known geologic conditions. In general, Hypothetical Resources are located in broad areas of coal fields where no points of observation are present and the evidence for the coal's existence is from distant outcrops, drill holes, or wells that are more than 3 miles (4.8 km) away. Hypothetical Resources are located beyond the outer boundary of the Inferred part of Identified Resources in areas where the assumption of continuity of the coal bed is supported only by a projection of geologic evidence.

Reserves are the recoverable part of the Reserve Base coal. For surface-minable coal in this quadrangle, the coal reserves are considered to be 85 percent (the recovery factor for this area) of that part of the Reserve Base that is beneath 200 feet (61 m) or less of overburden. This depth of overburden is the stripping limit for beds of lignite in this area.

Estimated coal resources in this quadrangle were calculated using data obtained from the coal isopach maps (pls. 4, 7, and 10) for the Knobloch, Flowers-Goodale, and Terret coal beds, respectively. The coal-bed acreage (measured by planimeter) multiplied by the average isopached thickness of the coal bed times a conversion factor of 1,750 short tons of coal per acre-foot (12,880 metric tons/hectare meter) for lignite yields the lignite resources in short tons for each isopached bed. Reserve Base and Reserve tonnage values for the Knobloch, Flowers-Goodale, and Terret coal beds are shown on plates 6, 9, and 13, respectively, and are rounded to the nearest one-hundredth of a million short tons.

The estimated total Reserve Base tonnage of federally owned, surface-minable lignite in this quadrangle is calculated to be 261.63 million short tons (237.30 million t). Of this total, 222.00 million short tons (201.35 million t) are considered to be surface minable (table 1), and 39.63 million short tons (35.94 million t) are considered to be underground minable (table 2). The Reserve Base tonnage totals per section are shown in the northwest corner of each section on CRO plate 2 and by development-potential category in tables 1 and 2. All numbers are rounded to the nearest one-hundredth of a million short tons. About 8.8 percent of the total surface-minable and underground-minable Reserve Base tonnage is classed as Measured, 45.6 percent as Indicated, and 45.6 percent as Inferred.

COAL DEVELOPMENT POTENTIAL

Areas where coal beds are 5 feet (1.5 m) or more thick and are overlain by 200 feet (61 m) or less of overburden are considered to have potential for surface mining and are 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-ratio values for lignite is as follows:

$$MR = \frac{t_o\ (0.922)}{t_c\ (rf)}$$

where MR = mining ratio

t_o = thickness of overburden

t_c = thickness of lignite

rf = recovery factor = 0.85

0.922 = conversion factor (cu. yds./ton)

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 5, 8, and 12 for the Knobloch, Flowers-Goodale, and Terret coal beds, respectively. These mining-ratio values for each development-potential category are based on economic and technological criteria and were provided by the U.S. Geological Survey. Estimated tonnages in each development-potential category (high, moderate, and low) for surface mining are shown in table 1.

Development potential for surface-mining methods

The Coal Development Potential (CDP) map, plate 14, in this series of maps depicts the highest coal development-potential category which occurs within each smallest legal subdivision of land (normally about 40 acres or 16.2 ha). If such a 40-acre (16.2-ha) tract of land contains areas of high, moderate, and low development potential, the entire tract is assigned to the high development-potential category for CDP mapping purposes, etc.

In areas of moderate to high topographic relief, the area of moderate development potential for surface mining of a coal bed (area having 10 to 15 mining-ratio values) is often restricted to a narrow band between the high and low development potential areas. In fact, due to the 40-acre (16.2-ha) minimum size of coal development-potential increments, the narrow strip of moderate development-potential area is often absorbed into the 40-acre (16.2-ha) tracts of high development-potential category. The Coal Development Potential (CDP) map then shows areas of low development potential abutting against areas of high development potential.

The coal development potential for surface-mining methods (less than 200 feet or 61 m of overburden) is shown on the Coal Development Potential map (pl. 14). Most of the Federal coal lands in the quadrangle have a high development potential for surface mining due to the superimposed Terret, Flowers-Goodale, and Knobloch coal beds.

The Terret coal bed (pl. 12) has wide bands of high development potential along the valleys in the north two-thirds of the quadrangle, extending from the outcrops to the 10 mining-ratio contours. Above this is a narrow band of moderate development potential extending to the 15 mining-ratio contour, and wide areas of low development potential under the ridges where the overburden is thickest. This overburden in most places contains the Flowers-Goodale coal bed.

The Flowers-Goodale coal bed (pl. 8) has wide areas of high development potential (mining-ratio values 0-10) in a zone extending diagonally from the southwest to the northeast quarters of the quadrangle. Above this are narrow bands of moderate development potential (mining-ratio values 10-15) and areas of low development potential (mining-ratio values greater than 15) under the ridges.

The Knobloch coal bed (pl. 5), which is about 100 feet (30 m) above the Flowers-Goodale coal bed, occurs principally in the southwest quarter of the quadrangle. All of the Knobloch coal has a high development potential (mining-ratio values 0-10). About 80 percent of the Federal coal land in this quadrangle has a high development potential for surface mining, 2 percent has a moderate potential, and 18 percent has no development potential.

Development potential for underground mining and in-situ gasification

The Terret coal bed contains some coal below the stripping limit of 200 feet (61 m), and this is shown in table 2 by development-potential category. Coal is not being mined currently by underground methods in the Northern Powder River Basin because of poor economics. For this reason the development potential for all the underground-minable coal resource tonnage listed in table 2 is classified as low, and a coal development-potential map for underground mining was not made.

In-situ gasification of coal on a commercial scale has not been done in the United States. Therefore, the development potential for in-situ gasification of coal found below the stripping limit in this area is rated as low.

Table 1.--Surface-minable coal resource tonnage by development-potential category for Federal coal lands (in short tons) in the Foster Creek School quadrangle, Custer and Powder River Counties, Montana

[Development potentials are based on mining ratios (cubic yards of overburden/short ton of recoverable coal). To convert short tons to metric tons, multiply by 0.9072]

Coal bed	High development potential (0-10 mining ratio)	Moderate development potential (10-15 mining ratio)	Low development potential (>15 mining ratio)	Total
Reserve Base tonnage				
Knobloch	35,440,000	20,000	0	35,460,000
Flowers-Goodale	54,430,000	24,710,000	7,840,000	86,980,000
Terret	37,400,000	29,460,000	32,700,000	99,560,000
Total	127,270,000	54,190,000	40,540,000	222,000,000

Table 2. --Underground-minable coal resource tonnage by development-potential category for Federal coal lands (in short tons) in the Foster Creek School quadrangle, Custer and Powder River Counties, Montana

[To convert short tons to metric tons, multiply by 0.9072]

Coal bed	High development potential	Moderate development potential	Low development potential	Total
Reserve Base tonnage				
Flowers-Goodale	0	0	3,660,000	3,660,000
Terret	0	0	35,970,000	35,970,000
Total	0	0	39,630,000	39,630,000

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