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COAL RESOURCE OCCURRENCE AND COAL DEVELOPMENT POTENTIAL MAPS OF THE BLACK SPRING QUADRANGLE, ROSEBUD AND BIG HORN COUNTIES, MONTANA

[Report includes 16 plates]

By

Colorado School of Mines Research Institute

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To convert	Multiply by	To obtain
feet	0.3048	meters (m)
miles	1.609	kilometers (km)
acres	0.40469	hectares (ha)
tons (short)	0.9072	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 Black Spring quadrangle, Rosebud and Big Horn Counties, Montana, (16 plates; U.S. Geological Survey Open-File Report 79-003). 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 1976, 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 Black Spring 7 1/2-minute quadrangle is in southwestern Rosebud County and east-central Big Horn County, Montana, about 35 miles (56 km) south-southwest of Forsyth, Montana, a town in the Yellowstone River valley about 44 miles (70 km) south-southwest of Miles City and 105 miles (168 km) east of Billings. U.S. Interstate Highway 94 and the main east-west routes of the Chicago, Milwaukee, St. Paul, and Pacific Railroad, and the Burlington Northern Railroad follow the Yellowstone River and pass through Forsyth, the county seat.

The Black Spring quadrangle is also about 35 miles (56 km) east of Hardin, Montana, a town in the Bighorn River valley about 43 miles (69 km) east of Billings. U.S. Interstate 90 and a branch line of the Chicago, Burlington, and Quincy Railroad pass through Hardin.

The Black Spring quadrangle is 11 miles (17.6 km) southwest of Colstrip, Montana, a coal-mining town on paved State Highway 39 and on a spur of the Burlington Northern Railroad about 20 miles (32 km) southeast of the Yellowstone

River valley. Approximately the south half of the Black Spring quadrangle is within the Northern Cheyenne Indian Reservation on which the coal resources were not mapped.

Accessibility

The Black Spring quadrangle is accessible from the north by State Highway 39 which passes near the southeast corner of the quadrangle, about 19 miles (30 km) by highway south-southwest of Colstrip. Several unimproved roads intersect State Highway 39, and provide access to the central and northern parts of the quadrangle.

The Black Spring quadrangle is also accessible from the west by U.S. Highway 212 which intersects U.S. Interstate Highway 90 about 15 miles (24 km) southeast of Hardin and passes through the southeast corner of the Black Spring quadrangle about 38 miles (61 km) east of Interstate 90. U.S. Highway 212 intersects State Highway 39 just east of the Black Spring quadrangle. Two unimproved roads intersect U.S. Highway 212 and provide access to the southern part of the quadrangle.

Physiography

The Black Spring quadrangle is within the Missouri Plateau division of the Great Plains physiographic province. The quadrangle is on the slopes between the Little Wolf Mountains just west of the quadrangle and Rosebud Creek just east of the quadrangle. The quadrangle is drained and maturely dissected by southeastward-flowing tributaries of Rosebud Creek. The tributaries are separated by long, narrow, clinker-capped divides, which are about 250 feet (76 m) above the valley bottoms. The reddish-colored clinker makes a resistant caprock and protects dissected remnants of a former extensive clinker-covered plateau. The coals have not been burned in the western part of the quadrangle, and the land is very rugged and inaccessible.

The highest elevation, 4,460 feet (1,359 m), is on a spur of the Little Wolf Mountains in the northwest corner of the quadrangle. The lowest elevation, about 3,200 feet (975 m), is along Rosebud Creek in the southeast quarter of the quadrangle. Topographic relief is about 1,260 feet (384 m).

Climate

The climate of Rosebud and Big Horn 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 north half of the Black Spring quadrangle is within the Northern Powder River Basin Known Recoverable Coal Resource Area, as shown by the Boundary and Coal Data Map (pl. 2). The south half of the quadrangle is within the Northern Cheyenne Indian Reservation in which the coal resources were not mapped. Plate 2 shows the land ownership status of lands north of the Indian Reservation. There were no outstanding Federal coal leases or prospecting permits recorded as of 1977.

GENERAL GEOLOGY

Previous work

Dobbin (1930) mapped that part of the Black Spring quadrangle north of the Northern Cheyenne Indian Reservation as part of the Forsyth coal field, Rosebud, Treasure, and Big Horn Counties, Montana.

Stratigraphy

A generalized columnar section of the coal-bearing rocks is shown on the Boundary and Coal Data Sheet (pl. 3) of the CRO maps. The exposed bedrock units belong to the upper member of the Paleocene (Tertiary) Fort Union Formation, the Tongue River Member. This member consists of light-colored sandstone, sandy shale, and important coal beds. The thicker coal beds have burned along the outcrop and have fused the overlying rock into slag or clinker. Dobbin (1930, p. 16) reports that the entire Tongue River Member is about 1,700 feet (518 m) thick in the Forsyth coal field. In the Black Spring quadrangle the upper part of the member has been removed by erosion so that probably only about 1,200 feet (366 m) remain.

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 Black Spring quadrangle is in the northwestern part of the Powder River structural basin. The strata in general dip southeastward at an angle of less than 1 degree. In places regional structure is modified by low-relief folds as shown by the structure contour maps on top of the Sawyer, the Rosebud and its

upper split, the Lower Rosebud, and the Robinson coal beds (pls. 4, 8, and 13). Some of the inconsistencies in structure may be due to irregularities in deposition of the coals and other beds as a result of their continental nature.

COAL GEOLOGY

Seven coal beds are exposed at the surface of the Black Spring quadrangle, and two lower beds are encountered in the subsurface in an oil-and-gas test hole in sec. 19, T. 1 S., R. 40 E. All nine coal beds belong to the Tongue River Member of the Fort Union Formation. They are shown in outcrop on the Coal Data Map (pl. 1) and in section on the Coal Data Sheet, plate 3.

The lowermost of the nine beds in the Black Spring quadrangle is the Robinson coal bed which is about 180 feet (55 m) above the base of the Tongue River Member. The Robinson coal bed is overlain successively by a noncoal interval of about 310 feet (94.5 m), the Lower Rosebud coal bed, a noncoal interval of about 4 feet (1.2 m), the Upper Rosebud (Lee) coal bed, a noncoal interval of about 6 feet (1.8 m), a thin local coal bed, a noncoal interval of about 145 feet (44.2 m), the Popham coal bed, a noncoal interval of about 10 feet (3 m), a thin local coal bed, a noncoal interval of about 60 feet (18.2 m), and the Sawyer coal bed. In one area there is a very thin local coal bed about 2 feet (0.61 m) below the Sawyer coal bed and another local coal bed about 15 feet (4.6 m) above the Sawyer coal bed.

The trace element content of coals in the Black Spring 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).

Robinson coal bed

The Robinson coal bed was first described by Dobbin (1930, p. 27) from outcrops on the Robinson Ranch in the Forsyth coal field (McClure Creek quadrangle). This coal bed does not outcrop in the Black Spring quadrangle, but it has been penetrated by an oil and gas test hole in the northwestern part of the quadrangle. The isopach and structure contour map (pl. 13) shows that the Robinson coal bed ranges from about 13 to 18 feet (4.0 to 5.5 m) in thickness, and is folded into a syncline of at least 60 feet (18.2 m) structural relief. Overburden on the Robinson coal bed ranges in thickness from about 80 to 1,250 feet (24 to 381 m), as shown by plate 14. This overburden includes the coal beds which overlie the Robinson coal bed.

There are no known published chemical analyses of the Robinson coal bed. It is assumed that the Robinson coal is similar in rank to associated coal beds in this quadrangle and is subbituminous B.

Rosebud coal bed

The Rosebud coal bed was described by Dobbin (1930, p. 27) from outcrops along Rosebud Creek in the Forsyth coal field. A specific type locality was not given.

In the Rough Draw quadrangle, north of the Black Spring quadrangle, the Rosebud coal bed splits into two beds. Dobbin (1930) mapped the upper split as the Lee coal bed and the lower split as the Rosebud coal bed. Test holes drilled later showed that the Lee coal bed correlates with the upper part of the unsplit Rosebud coal bed. The Upper Rosebud (Lee) coal bed crops out in the northeastern part of the Black Spring quadrangle (pls. 1 and 3). The upper and lower splits have been penetrated by the oil and gas test hole in the northwestern part of the quadrangle. As shown by the isopach map (pl. 7), the upper split ranges from 2.1 to 20 feet (0.6 to 6.1 m) in thickness, and the lower split

ranges from about 5 to 8 feet (1.5 to 2.4 m) in thickness. The unsplit Rosebud coal bed in the western part of the quadrangle ranges from about 24 to 30 feet (7.3 to 9.1 m) in thickness. The structure contour map (pl. 8) shows that the Rosebud coal is folded into a low-relief syncline in the western part of the quadrangle. Overburden on the Rosebud coal bed and its upper split (pl. 9) ranges from zero at the outcrops to about 1,000 feet (305 m) in thickness.

There are no known published chemical analyses of the Upper Rosebud (Lee) or Lower Rosebud coal beds in the Black Spring quadrangle. A chemical analysis of the Rosebud coal bed from drill hole RB-69, sec. 5, T. 1 N., R. 40 E. about 8 miles (13 km) to the north in the Rough Draw quadrangle (Matson and Blumer, 1973, p. 79) shows ash 9.34 percent, sulfur 0.95 percent, and a heating value of 8,800 Btu per pound (20,469 kJ/kg) on an as-received basis. This heating value converts to about 9,707 Btu per pound (22,578 kJ/kg) on a moist, mineral-matter-free basis, indicating that the coal is subbituminous B in rank. Since the Black Spring quadrangle has a similar position in the basin, it is assumed that the Rosebud coal in the Black Spring quadrangle is similar and is subbituminous B in rank.

Popham coal bed

The Popham coal bed was first described by Dobbin (1930, p. 28) from exposures in the Rough Draw quadrangle, just north of the Black Spring quadrangle, although an exact type locality was not given. In the Black Spring quadrangle, the Popham coal bed crops out at only one locality which is in the northwest quarter of the quadrangle. Here the Popham is about 175 feet (53 m) above the Upper Rosebud (Lee) coal bed and is 3.6 feet (11 m) thick, as shown on plates 1 and 3. Because of the thinness of the Popham coal bed, economic coal resources do not exist and no estimates of coal resources were made.

Sawyer coal bed

The Sawyer coal bed was described by Dobbin (1930, p. 28) from exposures in the foothills of the Little Wolf Mountains in the Forsyth coal field (Rough Draw and Black Spring quadrangles).

The Sawyer coal bed crops out in a broad zone in the foothills of the Little Wolf Mountains extending from the north border of the Black Spring quadrangle to the limits of mapping at the Northern Cheyenne Indian Reservation (pl. 1). The thickness of the Sawyer coal ranges from about 5 to 8.4 feet (about 1.5 to 2.6 m), as shown by the isopach map, plate 4. Structure contours on top of the Sawyer coal bed (pl. 4) show a slight northward dip of less than 1 degree, but the number of control points is insufficient to adequately map the structure. Overburden on the Sawyer coal bed (pl. 5) ranges from zero to about 300 feet (91 m) in thickness.

A chemical analysis of the Sawyer coal from the small abandoned mine in sec. 30, T. 1 N., R. 40 E. about 4 miles (6.4 km) north of the Black Spring quadrangle in the Rough Draw quadrangle (Gilmour and Dahl, 1967, p. 16) shows ash 6.8 percent, sulfur 1.8 percent, and a heating value of 8,080 Btu per pound (18,794 kJ/kg). This heating value converts to about 8,670 Btu per pound (20,177 kJ/kg) on a moist, mineral-matter-free basis, indicating that the coal is subbituminous C in rank. Because of the proximity of this location to the Black Spring quadrangle, it is assumed that the Sawyer coal in the Black Spring quadrangle is similar and is subbituminous C in rank.

Local coal beds

There are three thin, local coal beds of very limited extent which occur in places from 6 to 16 feet (1.8 to 4.9 m) above the Upper Rosebud, the Popham, and the Sawyer coal beds (pls. 1 and 3). They range from 1.8 to 4.4 feet (0.5 to 1.3

m) in thickness. Because of the thinness of these local coal beds, economic coal resources have not been assigned to them.

COAL RESOURCES

Data from all publicly available drill holes and 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 and the Hypothetical (HYP) part of the Undiscovered Resources, as discussed in U.S. Geological Survey Bulletin 1450-B.

The Reserve Base for subbituminous coal is coal that is 5 feet (1.5 m) or more thick, under 3,000 feet (914 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) of 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 extrapolation of geologic evidence. For purposes of this report, tonnages were calculated for only those

Hypothetical coal resources in beds that are estimated to be 5 feet (1.5 m) or more thick and to be under less than 3,000 feet (914 m) of overburden.

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 500 feet (152 m) or less of overburden, the stripping limit of multiple, thin (5 to 40 feet or 1.5 to 12 m thick) beds of subbituminous coal in this area.

Estimated resources in the Black Spring quadrangle were calculated using data obtained from the coal isopach maps (pls. 4, 7, and 13). The coal-bed acreage (measured by planimeter) multiplied by the average isopached thickness of the coal bed times a conversion factor of 1,770 short tons of coal per acre-foot (13,028 metric tons per hectare-meter) for subbituminous coal yields the coal resources in short tons of coal for each isopached coal bed. Reserve Base, Reserve, and Hypothetical tonnage values for the Sawyer, Rosebud and its upper split, Lower Rosebud, and the Robinson coal beds are shown on plates 6, 10, 12, and 15, and are rounded to the nearest one-hundredth of a million short tons.

As shown by table 1, the total Reserve Base tonnage of federally owned, surface-minable coal in the Black Spring quadrangle is calculated to be 261.08 million short tons (236.85 million t), and the total tonnage of surface-minable Hypothetical coal is estimated to be 121.25 million short tons (110.00 million t). As shown by table 2, the total tonnage of underground-minable Reserve Base coal is 69.59 million short tons (63.13 million t), and the total tonnage of underground-minable Hypothetical coal is 2.90 million short tons (2.63 million t). The Reserve Base and Hypothetical tonnage totals per section are shown in the northwest corner of each section of 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 1 percent of the surface-minable Reserve Base tonnage is classed as Measured, 14 percent as Indicated, and 85 percent as Inferred. About 1 percent of the underground-minable Reserve Base coal is measured, 19 percent Indicated, and 80 percent Inferred.

COAL DEVELOPMENT POTENTIAL

Areas where coal beds are 5 feet (1.5 m) or more thick and are overlain by 500 feet (152 m) or less of overburden are considered to have potential for surface 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-ratio values 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
cf = conversion factor (cu. yds./ton)

Areas of high, moderate, and low development potential are here defined as areas underlain by coal having respective mining-ratio values of 0 to 10, 10 to 15, and greater than 15, as shown on CRO maps, plates 5, 9, 11, and 14 for the Sawyer, Rosebud and its upper split, Lower Rosebud, and Robinson 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), of both Reserve Base and Hypothetical coal, for surface mining are shown in table 1. Estimated tonnages for underground mining are shown in a like manner in table 2.

Development potential for surface-mining methods

The Coal Development Potential (CDP) map included in this series of maps pertains only to surface mining. It 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.

The coal development potential for surface-mining methods (less than 500 feet or 152 m of overburden) is shown on the CDP map (pl. 16). Most of the Fed-coal lands have a high development potential for surface mining, but there are also numerous small tracts of moderate and low development potential.

The Sawyer coal bed (pl. 5), where it is more than 5 feet (1.5 m) thick in the north-central part of the quadrangle, has limited areas of high development potential on the lower slopes of the hills between the boundary of the coal and the 10 mining-ratio contour. There are narrow bands of moderate development (mining-ratio values 10 to 15) higher on the hill slopes, and larger areas of low development potential extending from the 15 mining-ratio contour to the crests of the hills.

The Rosebud coal bed and the upper split of the Rosebud coal bed (pl. 9) have quite large areas of high development potential in the bottoms of the stream valleys between the boundary of the coal and the 10 mining-ratio contour, particularly in the southern part of the mapped area. There are narrow to wide bands of moderate development potential (mining-ratio values 10 to 15) higher on the valley slopes. Generally wide areas of low development potential (mining-ratio values greater than 15) underlie the interstream divides.

The lower split of the Rosebud coal bed (pl. 11) has limited areas of high development potential (mining-ratio values less than 10) in the bottoms of the valleys in the southern part of the mapped area. Higher in these valleys there are wider areas of moderate development potential (mining-ratio values 10 to 15). There are very wide areas of low development potential extending from the 15 mining-ratio contour to the crests of the hills.

The Robinson coal bed (pl. 14) has limited areas of high development potential (mining-ratio values less than 10) in bottoms of the valleys of Cottonwood Creek and Slough Grass Creek near the eastern border of the mapped area. There are narrow areas of moderate development potential (mining-ratio values 10 to 15) higher in these valleys. A wide area of low development potential extends from the 15 mining-ratio contour to the 500-foot overburden isopach, the arbitrarily assigned stripping limit, or to the crests of the lower hills.

Approximately 57 percent of the Federal coal lands in the quadrangle has a high development potential for surface mining, 26 percent has a moderate development potential, 15 percent has a low development potential, and 2 percent has no development potential.

Development potential for underground mining and in-situ gasification

Coal beds 5 feet (1.5 m) or more in thickness lying more than 500 feet (152 m) but less than 3,000 feet (914 m) below the surface of this quadrangle are considered to have development potential for underground mining. Estimates of the tonnage of underground-minable coal are listed in table 2 by coal bed and by coal development-potential category. The Robinson coal and the Rosebud coal bed and its upper split have an estimated total of 72.49 million short tons (65.76 million t) of underground-minable Reserve Base and Hypothetical coal resources.

Coal is not currently being mined by underground methods in the Northern Powder River Basin because of poor economics. Therefore, the coal development potential for underground mining of these resources is rated 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 surface-mining limit in this area is rated as low, and a Coal Development Potential map for underground mining was not made.

Table 1.--Surface-minable coal resource tonnage (in short tons) by development-potential category for Federal coal lands in the Black Spring quadrangle, Rosebud and Big Horn 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				
Rosebud and its upper split	39,810,000	46,450,000	61,130,000	147,390,000
Lower Rosebud	0	4,420,000	40,200,000	44,620,000
Robinson	140,000	3,930,000	65,000,000	69,070,000
Total	39,950,000	54,800,000	107,830,000	261,080,000
Hypothetical Resource tonnage				
Rosebud and its upper split	3,650,000	3,180,000	1,950,000	8,780,000
Lower Rosebud	3,280,000	8,820,000	15,650,000	27,750,000
Robinson	13,150,000	15,690,000	55,880,000	84,720,000
Total	20,080,000	27,690,000	73,480,000	121,250,000
Grand Total	60,030,000	82,490,000	181,310,000	382,330,000

Table 2.--Underground-minable coal resource tonnage (in short tons) by development-potential category for Federal lands in the Black Spring quadrangle, Rosebud and Big Horn 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				
Rosebud and its upper split	0	0	5,350,000	5,350,000
Robinson	0	0	64,240,000	64,240,000
Total	0	0	69,590,000	69,590,000
Hypothetical Resource tonnage				
Robinson	0	0	2,900,000	2,900,000
Total	0	0	2,900,000	2,900,000
Grand Total	0	0	72,490,000	72,490,000

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