UNITED STATES DEPARTMENT OF THE INTERIOR

GEOLOGICAL SURVEY

Text to accompany:

Open-File Report 79-007

1979

COAL RESOURCE OCCURRENCE AND COAL DEVELOPMENT POTENTIAL MAPS OF THE COLSTRIP SW QUADRANGLE, ROSEBUD COUNTY, MONTANA

[Report includes 17 plates]

By

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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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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 Colstrip SW quadrangle, Rosebud County, Montana, (17 plates; U.S. Geological Survey Open-File Report 79-007). 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 Colstrip SW 7 1/2-minute quadrangle is in central Rosebud County, Montana, about 27 miles (43 km) south of Forsyth, Montana, a town in the Yellowstone River valley about 44 miles (70 km) west-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 town of Colstrip is 0.5 mile (0.8 km) north of the northeast corner of the quadrangle.

Accessibility

The Colstrip SW quadrangle is accessible from the north by paved State Highway 39 which follows northward-flowing Armells Creek and the

East Fork of Armells Creek and intersects U.S. Interstate Highway 94 about 20 miles (32 km) north of the quadrangle. State Highway 39 passes through the northeast corner of the quadrangle. A branch of the Burlington Northern Railroad parallels State Highway 39 and connects the town of Colstrip, the Rosebud (Colstrip) Mine, and the Big Sky Mine in the Colstrip SE quadrangle with the main route of the railroad in the Yellowstone River valley. The Colstrip SW quadrangle is also accessible from the south by way of State Highway 39, which passes very close to the southeast corner of the quadrangle along Rosebud Creek and intersects U.S. Highway 212 some 11 miles (18 km) south of the quadrangle. A number of unimproved roads and trails intersect State Highway 39 and provide access to the interior of the quadrangle.

Physiography

The Colstrip SW quadrangle is within the Missouri Plateau division of the Great Plains physiographic province. The northern part of the quadrangle is dissected and drained by the East Fork of Armells Creek. The southern part of the quadrangle is drained by tributaries of Rosebud Creek, which passes through the southeast corner of the quadrangle, flows northeastward and northward, and joins the Yellowstone River about 10 miles (16 km) east of Forsyth. These two streams and their principal tributaries have narrow valley bottoms, no wider than 0.5 mile (0.8 km). The valley sides are steep, and in places they are eroded into badlands. The interstream divides, which rise 250 to 350 feet (76 to 107 m) above the valley floors, are flat-topped mesas and buttes capped by erosion-resistant beds of reddish-colored clinker formed by the burning of coal beds.

The lowest elevation, about 3,050 feet (930 m), is along Rosebud Creek in the southeast corner of the quadrangle. The highest elevation, 3,720 feet (1,134 m), is on buttes in the northwest part of the quadrangle. Topographic relief is 670 feet (204 m).

Climate

The climate of Rosebud County 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

Most of the Colstrip SW quadrangle is within the Northern Powder River Basin Known Recoverable Coal Resource Area (KRCRA), as shown by the Boundary and Coal Data Map (pl. 2). This map also shows the land ownership status and the Federal lands which were covered by outstanding Federal coal leases as of 1977.

GENERAL GEOLOGY

Previous work

Dobbin (1930) mapped the Colstrip SW quadrangle as part of the Forsyth coal field, Rosebud, Treasure, and Big Horn Counties, Montana. Kepferle (1954) mapped the northern one-third of the quadrangle as part of the

Castle Rock strippable deposit. V. W. Carmichael in 1964 mapped the southern two-thirds of the quadrangle as part of the Colstrip coal deposit (in Matson and Blumer, 1973, pl. 14).

Stratigraphy

A generalized columnar section of the coal-bearing rocks is shown on the Coal Data Sheet (pl. 3) of the CRO maps. All of the exposed bedrock units in the Colstrip SW quadrangle belong to the upper member of the Paleocene Fort Union Formation, the Tongue River Member.

The Tongue River Member of the Fort Union Formation 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 brick-red or reddish-brown slag or clinker. Dobbin (1930) reports that the Tongue River Member is about 1,700 feet (518 m) thick in the Forsyth coal field, but in the Colstrip SW quadrangle the upper part of the member has been removed by erosion so that only about the lower 850 feet (259 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 Colstrip SW quadrangle is in the northwestern part of the Powder River structural basin. The strata dip southward or southeastward at an angle of less than 1 degree. Structure contours on top of the Rosebud, McKay, and Stocker Creek coal beds (pls. 5, 10, and 14) show that the regional dip is in places modified by gentle folding or interrupted by minor faulting.

COAL GEOLOGY

Six coal beds, all in the Tongue River Member of the Fort Union Formation, occur in the Colstrip SW quadrangle (pls. 1 and 3). The stratigraphically lowest coal bed, the Robinson coal bed, is about 210 feet (64 m) above the base of the Tongue River Member. The Robinson coal bed is overlain successively by a noncoal interval of 90 feet (27 m), the Stocker Creek coal bed, a noncoal interval of about 30 feet (9 m), the McKay coal bed, a noncoal interval of 15 to 60 feet (4.5 to 18 m), the Rosebud coal bed, a noncoal interval of about 165 feet (50 m), the Popham coal bed, a noncoal interval of about 50 feet (15 m), and the Sawyer coal bed. Three coal beds, the Rosebud, McKay, and Stocker Creek, contain coal resources.

The trace element content of coals in the Colstrip SW 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).

Rosebud coal bed

The Rosebud coal bed was first described by Dobbin (1930, p. 27) after outcrops along Rosebud Creek in the Forsyth coal field.

The Rosebud coal bed crops out along the East Fork of Armells Creek in the northern part of the Colstrip SW quadrangle, and along Rosebud Creek and its tributaries in the southern part of the quadrangle. The coal extends beneath the surface in the central part of the quadrangle where it has been penetrated by a number of coal test holes (pl. 1). In the northern and central parts of the quadrangle, the Rosebud coal ranges in thickness from 20 to 28 feet (6 to 8.5 m). In the southern part of the quadrangle, the Rosebud coal splits into two beds along a line which is shown on the isopach map (pl. 4). In the southern extremity of the quadrangle, the two Rosebud coal beds have a vertical separation of 100 to 120 feet (30 to 37 m). Dobbin (1930) mapped the upper coal bed as the Lee coal bed and the lower bed as the Rosebud coal bed. The correlation of the two coal beds with the Rosebud coal bed in the northern part of the quadrangle is indicated by the coal test holes which were subsequently drilled in the central part of the quadrangle (pls. 1 and 3). The Upper Rosebud coal (Lee coal bed of Dobbin) ranges from about 3 to 12 feet (0.9 to 3.7 m) in thickness, and the Lower Rosebud from 4 to 16 feet (1.2 to 4.9 m). The structure contour map of the Rosebud coal bed (pl. 5)

shows a general southeastward dip of less than a degree, although the contours are quite irregular due to minor folding and faulting and to irregularities in deposition which are characteristic of these continental sedimentary deposits. Overburden on the Rosebud and Upper Rosebud coal bed (pl. 6) ranges from zero to about 360 feet (110 m) in thickness. Overburden on the Lower Rosebud coal bed (pl. 8) ranges from zero to about 400 feet (122 m) in thickness.

A chemical analysis of the Rosebud coal from drill hole RB-56, sec. 30, T. 1 N., R. 41 E. in the Colstrip SW quadrangle shows ash 8.70 percent, sulfur 0.97 percent, and a heating value of 9,060 Btu per pound (21,074 kJ/kg) on an as-received basis (Matson and Blumer, 1973, p. 78). This heating value converts to about 9,815 Btu per pound (22,830 kJ/kg) on a moist, mineral-matter-free basis, indicating that the coal is subbituminous B in rank.

McKay coal bed

The McKay coal bed was described by Dobbin (1930, p. 27) from exposures on the McKay Ranch (Colstrip East quadrangle) in the Forsyth coal field. Dobbin states that the McKay coal bed may be considered a split of the Rosebud coal bed because the interval between them in several places is less than 7 feet (2.1 m). The outcrop of the McKay coal bed follows very closely that of the Rosebud coal bed, and where the Rosebud coal bed has been burned the McKay coal bed is concealed by the Rosebud clinker. For this reason the outcrop of the McKay coal bed was not mapped separately by Dobbin (1930, pl. 7), nor is it shown on the CRO Coal Data Map (pl. 1).

Most coal test holes in the Colstrip SW quadrangle stop near the base of the Rosebud coal bed, and do not go deep enough to penetrate the McKay coal bed. However, two coal test holes in the north-central part of the quadrangle (pls. 3 and 10) penetrate a coal bed 8 to 9 feet (2.4 to 2.7 m) thick about 60 feet (18 m) below the Rosebud coal bed. This coal bed is correlated with the McKay coal bed in adjacent quadrangles. Structure contours on top of the McKay coal bed (pl. 10) show a general southeastward dip of less than 1 degree which is modified by minor folding and faulting. Overburden on the McKay coal bed (pl. 11) ranges in thickness from near zero (where the coal crops out and is unburned) to about 460 feet (140 m). This overburden includes the Rosebud coal bed.

A chemical analysis of the McKay coal from drill hole RB-58, sec. 5, T. 1 N., R. 41 E., in the Colstrip SW quadrangle (Matson and Blumer, 1973, p. 78) shows ash 6.50 percent, sulfur 1.41 percent, and a heating value of 8,930 Btu per pound (20,771 kJ/kg) on an as-received basis. This heating value converts to about 9,550 Btu per pound (22,213 kJ/kg) on a moist mineral-matter-free basis, indicating that the coal is subbituminous B in rank.

Stocker Creek coal bed

The Stocker Creek coal bed was described by Dobbin (1930, p. 27) after outcrops near the head of Stocker Creek in the Forsyth coal field (Colstrip West and Trail Creek School quadrangles). This coal bed does not crop out in the Colstrip SW quadrangle, but is penetrated at a depth of 159 feet (48 m) in one coal test hole in the southwest quarter of the quadrangle

(pls. 1 and 3). The isopach map (pl. 13) which is based on this measurement and others in adjacent quadrangles shows that the thickness of the Stocker Creek coal bed ranges from about 3 feet (0.9 m) to slightly over 9 feet (2.7 m). Structure contours on top of the Stocker Creek coal bed (pl. 14) show a dip of less than 1 degree southeastward which is modified locally by minor folding and faulting. Overburden on the Stocker Creek coal bed (pl. 15) ranges from about 100 feet (31 m) to about 560 feet (171 m) in thickness. This overburden includes the Rosebud and McKay coal beds.

There are no known published chemical analyses of the Stocker Creek coal. It is assumed that the Stocker Creek coal is similar in rank to the Rosebud and McKay coals in this quadrangle and is subbituminous B.

Other coal beds

The Robinson(?) coal bed was penetrated by an oil-and-gas test hole in the north-central part of the quadrangle. However, because this coal is less than 5 feet (1.5 m) thick, economic coal resources have not been assigned to it.

The Popham coal bed crops out locally in the northern part of the Colstrip SW quadrangle from 160 to 250 feet (49 to 76 m) above the Rosebud coal bed (pls. 1 and 3). The thickness of the Popham coal bed ranges from 2.3 to 3.8 feet (0.7 to 1.2 m). Because of its thinness and local extent, the Popham coal bed has not been assigned economic coal resources.

About 50 feet (15 m) above the Popham coal bed is a clinker bed up to 100 feet (30 m) in thickness which caps all of the highest ridges in the quadrangle. This clinker bed is at the approximate stratigraphic position of the

Sawyer coal bed, and is therefore called the Sawyer clinker bed. The considerable thickness of the Sawyer clinker indicates that the Sawyer coal was at one time of considerable thickness in this area, but it has been entirely burned.

COAL RESOURCES

Data from coal test holes and 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 and the Hypothetical (HYP) part of the Undiscovered Resources, as discussed in U.S. Geological Survey Bulletin 1450-B (1976).

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 for multiple, thin (5 to 40 feet or 1.5 to 2.2 m thick) beds of subbituminous coal in this area.

Estimated coal resources in the Colstrip SW quadrangle were calculated using data obtained from the coal isopach maps (pls. 4, 10, 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 (12,880 metric tons/hectare-meter) for subbituminous coal yields the coal resources in short tons of coal for each isopached coal bed. Reserve Base tonnage values for the Rosebud, the Lower Rosebud, the McKay, and the Stocker Creek coal beds are shown on plates 7, 9, 12, and 15, respectively, and are rounded to the nearest one-hundredth of a million short tons.

The total Reserve Base tonnage of federally owned surface-minable and underground-minable coal in the Colstrip SW quadrangle is calculated to be 310.69 million short tons (281.86 million t). The total tonnage of federally owned Hypothetical coal resources, all of which is surface-minable, is calculated to be 15.39 million tons (13.96 million t). The Reserve Base (RB) and Hypothetical (HYP) 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 percent of the Reserve Base tonnage is classed as Measured, 44 percent as Indicated, and 48 percent as 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
0.911 = conversion factor (cu. yds./ton)

Areas of high, moderate, and low development potential for surface-mining methods are defined as areas underlain by coal beds having less than

500 feet (152 m) of overburden and having respective mining-ratio values of 0 to 10, 10 to 15, and greater than 15. Mining-ratio contours and the stripping-limit overburden isopach which serve as boundaries for these development-potential areas are shown on plates 6, 8, and 11. The 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 (pl. 17) included 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 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 mining-ratio values of 10 to 15) 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 often is 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 500 feet or 152 m of overburden) is shown on the Coal Development Potential map (pl. 17). Most of the Federal lands in the quadrangle have a high development potential for surface mining due to the presence of the thick Rosebud coal bed and its splits. As shown on plate 6, the Rosebud coal bed has mainly a high development potential in the north two-thirds of the quadrangle, i.e., the area north of the split line of the Rosebud coal bed. South of the split line the Upper Rosebud coal has a high development potential only in relatively narrow bands above the outcrops on the valley sides. Above these bands are narrow bands of moderate development potential, adjacent to wide areas of low potential covering the interstream ridges. Near the southeast quarter of the quadrangle where the coal bed is less than 5 feet (1.5 m) thick, the Upper Rosebud coal bed has no development potential. The Lower Rosebud coal bed, which is present in the southern third of the quadrangle, has a high development potential in a moderately wide band above the outcrops of the sides of valleys (pl. 8). Above this is a very narrow band of moderate development potential, and above this is a wide area of low development potential on the tops of the interstream ridges.

The McKay coal bed which underlies the Rosebud coal bed is of Reserve-Base thickness in the northeast quarter of the quadrangle (pl. 11). The McKay coal has a small area of high development potential in a valley near the northeast corner of the map and a larger area of moderate development potential higher in the valley. In the remainder of its area of occurrence, the McKay coal bed has a low development potential, or no development potential where it is less than 5 feet (1.5 m) thick.

The Stocker Creek (pl. 15) coal bed has Reserve Base thickness only in the west half of the quadrangle. Because the Stocker Creek coal bed is relatively thin (pl. 13) and is covered by considerable overburden, its development potential for surface mining is low, except for small areas along the north border of the quadrangle where the development potential is moderate (pl. 15).

Of the unleased Federal coal lands in the quadrangle 84 percent have a high development potential for surface mining, 6 percent have a moderate potential, 6 percent have a low potential, and 4 percent have 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. An estimate of the tonnage of underground-minable coal is listed in table 2 by coal bed and by coal development-potential category. The Stocker Creek coal bed contains an estimated total of 2.32 million short tons (2.10 million t) of underground-minable Reserve Base coal. There are no underground-minable 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.

Table 1.--Surface-minable coal resource tonnage by development-potential category for Federal coal lands (in short tons) in the Colstrip SW quadrangle, Rosebud County, 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 Upper Rosebud	139,600,000	44,780,000	23,290,000	207,670,000
Lower Rosebud	11,760,000	5,250,000	21,230,000	38,240,000
McKay	90,000	90,000	8,590,000	8,770,000
Stocker Creek	0	900,000	52,790,000	53,690,000
Total	151,450,000	51,020,000	105,900,000	308,370,000
Hypothetical Resource tonnage				
Stocker Creek	0	0	15,390,000	15,390,000
Total	0	0	15,390,000	15,390,000
Grand Total	151,450,000	51,020,000	121,290,000	323,760,000

Table 2.--Underground-minable coal resource tonnage by development-potential category for Federal coal lands (in short tons) in the Colstrip SW quadrangle, Rosebud County, 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				
Stocker Creek	0	0	2,320,000	2,320,000
Total	0	0	2,320,000	2,320,000

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