

UNITED STATES DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY

Text to accompany:

Open-File Report 79-006

1979

COAL RESOURCE OCCURRENCE AND
COAL DEVELOPMENT POTENTIAL MAPS OF THE
COLSTRIP SE 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

<u>To convert</u>	<u>Multiply by</u>	<u>To obtain</u>
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 SE quadrangle, Rosebud County, Montana, (17 plates; U.S. Geological Survey Open-File Report 79-006). 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 SE 7 1/2-minute quadrangle is in central Rosebud County, Montana, about 27 miles (43 km) south-southeast of Forsyth, Montana, a town in the Yellowstone River valley about 44 miles (71 km) west-southwest of Miles City and 105 miles (169 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 small town of Colstrip is 1 mile (1.6 km) north of the northwest corner of the quadrangle.

Accessibility

The Colstrip SE 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 Interstate 94 about 29 miles (47 km) north-northwest of the quadrangle and 7 miles (11 km) west of Forsyth. Highway 39 passes through Colstrip, through the Colstrip SE quadrangle, and continues beyond the quadrangle to intersect U. S. Highway 212 about 10 miles (16 km) southwest of the quadrangle at Lame Deer. A branch line of the Burlington Northern Railroad connects the Rosebud (Colstrip) and Big Sky coal mines in the northern and central parts of the quadrangle and the town of Colstrip with the main route of the railroad in the Yellowstone River valley. A number of unimproved roads and trails intersect State Highway 39 and provide access to the remainder of the quadrangle.

Physiography

The Colstrip SE quadrangle is within the Missouri Plateau division of the Great Plains physiographic province. Most of the quadrangle is dissected and drained by tributaries of Rosebud Creek which passes through the southern part of the quadrangle. Only the northwest corner of the quadrangle is drained by a tributary of the East Fork of Armells Creek. Rosebud and Armells Creeks are northward-flowing tributaries of the Yellowstone River. Rosebud Creek has a flood plain 0.5 to 1 mile (0.8 to 1.6 km) in width at an elevation of 2,950 to 3,050 feet (899 to 930 m). The remainder of the quadrangle is maturely dissected by the tributaries forming steep-sided ridges which in places are carved into badlands. Rugged, steep-sided, flat-topped plateau remnants in the western part of the quadrangle rise to elevations above 3,500 and 3,600 feet (1,067 and 1,097 m) and are capped by reddish-colored, erosion-resistant clinker beds formed from the burning of coal beds.

The highest elevation in the quadrangle, slightly over 3,640 feet (1,109 m), is at Miller triangulation station on a flat-topped plateau remnant in the northwest quarter of the quadrangle. The lowest elevation, a little below 2,960 feet (902 m) is along Rosebud Creek at the east border of the quadrangle. Topographic relief is 680 feet (207 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

The Northern Powder River Basin Known Recoverable Coal Resource Area (KRCRA) covers about half of the Colstrip SE quadrangle, 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 an outstanding Federal coal lease as of 1977.

GENERAL GEOLOGY

Previous work

Dobbin (1930) mapped the western part of the Colstrip SE quadrangle as part of the Forsyth coal field, Rosebud, Treasure, and Big Horn Counties,

Montana. The northwest quarter of the quadrangle was mapped by Kepferle (1954) as the South Coal Bank Coulee (presently called Emile Coulee) deposit and part of the southeast quarter as the Miller Creek deposit. V. W. Carmichael in 1964 mapped most 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. The exposed bedrock units belong to the Tongue River Member of the Paleocene Fort Union Formation.

This upper 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 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 SE quadrangle some of the member has been removed by erosion so that only about the lower 900 feet (274 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 SE quadrangle is in the north-central 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 Burley coal beds (pls. 5, 11, and 15) show that the regional dip is in places modified by gentle folding or interrupted by faulting.

COAL GEOLOGY

Four coal beds crop out in the Colstrip SE quadrangle, and a fifth is projected into the subsurface from adjacent quadrangles to the north and east. All five 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 plate 3.

The lowermost of the five coal beds is the Burley coal bed which is about 130 feet (39.6 m) above the base of the Tongue River Member. The Burley coal bed is overlain by a noncoal interval of 130 to 180 feet (40 to 55 m), the Stocker Creek coal bed, a noncoal interval of 30 feet (9 m), the McKay coal bed, a noncoal interval of 7 to 40 feet (2 to 12 m), the Rosebud coal bed, a noncoal interval of about 320 feet (98 m), and the Sawyer coal

bed. The Sawyer coal bed is often burned, forming a thicker clinker bed which, being resistant to erosion, caps the hills.

The Robinson coal bed, which occurs in some of the adjacent quadrangles about 50 feet (15 m) below the Stocker Creek coal bed, may be present in the Colstrip SE quadrangle, but none of the coal test holes of public record went deep enough to reach this horizon.

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

Only the Rosebud, McKay, and Burley coal beds are known to contain economic coal resources.

Rosebud coal bed

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

Clinker beds caused by the burning of the Rosebud coal bed crop out in the areas of higher elevation throughout most of the Colstrip SE quadrangle (pl. 1). In the northern part of the quadrangle, the coal bed is a single unit and is about 25 to 29 feet (7.6 to 8.8 m) thick (pl. 4). In the southern part of the quadrangle, the Rosebud coal bed splits into two beds along the line indicated on the isopach map, plate 4. The two beds are designated

Upper and Lower Rosebud, respectively. The Upper Rosebud split ranges from 5 to 12 feet (1.5 to 3.7 m) in thickness, and the Lower Rosebud split ranges from 1.3 to 16 feet (0.4 to 4.9 m) in thickness. The two splits are separated by as much as 100 feet (30 m) of sandstone and sandy shale (pl. 3). Dobbin (1930) identified the upper split as the Lee coal bed and the lower split as the Rosebud coal bed, but holes drilled for coal correlations since 1930 demonstrate the equivalence of the Lee coal bed and the upper part of the Rosebud coal bed.

The Rosebud coal bed and its splits dip southeastward less than 1 degree (pl. 5), but the regularity of dip is interrupted by minor local folds. Overburden on the Rosebud coal bed (or Upper Rosebud coal bed where applicable) ranges from zero to about 360 feet (110 m), as shown on plate 6, and the overburden on the Lower Rosebud coal bed ranges from zero to about 400 feet (122 m), in thickness, as shown on plate 8.

A chemical analysis of the Rosebud coal from drill hole RB-46, sec. 15, T. 1 N., R. 41 E., in the Colstrip SE quadrangle (Matson and Blumer, 1973, p. 78) shows ash 8.67 percent, sulfur 0.77 percent, and a heating value of 9,090 Btu per pound (21,143 kJ/kg) on an as-received basis. This heating value converts to about 9,953 Btu per pound (23,151 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 first described by Dobbin (1930, p. 27) after exposures on the McKay Ranch (Colstrip East quadrangle) in the Forsyth coal

field. Dobbin (1930, p. 27) 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 is burned, the McKay coal bed is usually 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 continuously on the CRO Coal Data Map (pl. 1). The thickness of the McKay coal bed ranges from 2.3 to 10 feet (0.7 to 3.0 m), as shown on the isopach map (pl. 10). Structure contours on top of the McKay coal bed (pl. 11) show a general south or southeast dip of less than 1 degree which is modified by minor local folding. Overburden on the McKay coal bed (pl. 12) ranges from zero to 430 feet (131 m) in thickness. This overburden includes the Rosebud coal bed.

A chemical analysis of the McKay coal from drill hole RB-46, sec. 15, T. 1 N., R. 41 E., in the Colstrip SE quadrangle shows ash 7.75 percent, sulfur 1.87 percent, and heating value 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 9,821 Btu per pound (22,844 kJ/kg) on a moist, mineral-matter-free basis, indicating that the coal is subbituminous B in rank.

Burley coal bed

The Burley coal bed was first described by Dobbin (1930, p. 27) after outcrops at the Burley Ranch in the Forsyth coal field (Colstrip East

quadrangle). There are no outcrop or drill-hole data points of control for the Burley coal bed in the Colstrip SE quadrangle. The bed thickness and attitude are projected into the quadrangle from adjacent quadrangles to the east and northeast. The projected thickness of the Burley coal bed in the Colstrip SE quadrangle ranges from less than 4 feet (1.2 m) to over 7 feet (2.1 m), as shown on plate 14. The dip of the bed is southeastward less than 1 degree (pl. 14). Overburden on the Burley coal bed ranges from about 100 feet (30 m) to slightly more than 300 feet (91 m) in thickness, as shown on plate 15. This overburden includes the McKay and Rosebud coal beds.

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

COAL MINES

Rosebud (Colstrip) coal mine

The Rosebud coal mine is in the northern part of the Colstrip SE quadrangle.

The Northern Pacific Railway opened the mine in 1924 and stopped production in 1958 as diesel fuel supplemented coal for locomotives. Montana Power Company purchased the property in 1959, and its coal producing subsidiary, Western Energy Company, has operated the mine to the present time. Only the Rosebud coal bed is mined. Its average thickness is about 25 feet (7.6 m). Average ash content is 8.45 percent, sulfur 0.8 percent, and heating value 8,750 Btu per pound (20,352 kJ/kg) on an as-received basis.

Coal production during 1977 was 9,773,676 short tons (8,864,724 t). All of the coal was produced by surface-mining methods. The principal use of the coal is for generation of electric power. Large power plants are near the mine, and coal is also shipped by unit train to power plants at Billings, Montana, and to states to the east.

Big Sky coal mine

The Big Sky coal mine, in the west-central part of the Colstrip SE quadrangle, is owned and operated by Peabody Coal Company. The Rosebud and McKay coal beds are mined. Average ash content of the coal is 10.4 percent, sulfur 0.75 percent, and heating value 8,450 Btu per pound (18,894 kJ/kg) on an as-received(?) basis. The mine was opened in 1969. Cumulative production through 1977 was 11,404,225 short tons (10,343,632 t). During 1977 2,343,877 short tons (2,125,896 t) was produced. The coal is shipped by unit train to Minnesota and used for electric power generation.

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 12 m thick) beds of subbituminous coal in this area.

Estimated coal resources in the Colstrip SE quadrangle were calculated using data obtained from the coal isopach maps (pls. 4, 10, and 14). 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 t/ha-m) for subbituminous coal yields the coal resources in short tons of coal for each isopached coal bed. Reserve Base and Reserve tonnage values for the Rosebud, McKay, and Burley coal beds are shown on plates 7, 13, and 16, respectively, and are rounded to the nearest one-hundredth of a million short tons.

The total Reserve Base tonnage of federally owned coal in the Colstrip SE quadrangle is calculated to be 157.16 million short tons (142.54 million t), and the Hypothetical Resource tonnage is calculated to be 16.62 short tons (15.07 million t). The Reserve Base tonnage totals and the Hypothetical Resource tonnage totals per section are shown in the northwest corner of each section on CRO plate 2 and by development-potential category in table 1. All numbers are rounded to the nearest one-hundredth of a million short tons. About 7 percent of the Reserve Base tonnage is classed as Measured, 35 percent as Indicated, and 58 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 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 maps, plates 6, 8, 12, and 15 for the Rosebud, Lower Rosebud, McKay, and Burley 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 (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 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 ratios) 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). The coal development potential of leased Federal coal lands has not been evaluated. The remainder of the Federal land has either a high development potential or no development potential. The lands having no development potential are where the coal beds have been removed by erosion along Rosebud Creek and its principal tributaries, such as Miller, Hay, and Lee Coulees.

The area of high development potential south of Rosebud Creek in the southeast quarter of the quadrangle is formed by the Lower Rosebud split of the Rosebud coal bed and by the McKay coal bed. The Lower Rosebud coal bed has a considerable area between the outcrops and the 10 mining-ratio contour where the development potential is high (pl. 8). Northeast of this Lower Rosebud area is a small area where the McKay coal bed is greater than 5 feet (1.5 m) thick and has a high development potential.

The other lands with high development potential, all north of Rosebud Creek, owe their high development potential to the superimposition of several coal beds. The lowest bed, the Burley coal bed, has only a small area along the bottom of Cow Creek near the northeast corner of the quadrangle where the overburden is sufficiently thin to form an area of high development potential (pl. 15). In most places the Burley coal bed has mining ratios above 15 and low development potential. However, about 160 to 210 feet (49 to 64 m) above the Burley coal bed is the McKay coal bed. The McKay coal bed has wide areas along the sides of valleys where the development potential is high (pl. 12). Adjacent to these areas of high development potential and overlapping them in places are wide areas of high development potential formed by the Rosebud coal bed and its splits (pl. 6) about 7 to 40 feet (2 to 12 m) above the McKay coal bed. The Rosebud coal bed and its splits have only narrow areas of moderate and low development potential at the tops of ridges.

About 71 percent of the unleased Federal lands in the quadrangle has a high development potential for surface mining, and 29 percent has no development potential for surface mining.

Development potential for underground mining and in-situ gasification

All known minable coal in the Colstrip SE quadrangle is within surface-minable depths. Because there are no known underground coal resources below the stripping limit, a Coal Development Potential map for underground mining and estimates of underground resources were 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 SE 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	Moderate development	Low development	Total
	potential (0-10 mining ratio)	potential (10-15 mining ratio)	potential (>15 mining ratio)	
Reserve Base tonnage				
Rosebud and Upper Rosebud	54,630,000	9,060,000	9,400,000	73,090,000
Lower Rosebud	16,360,000	2,810,000	7,240,000	26,410,000
McKay	27,630,000	12,490,000	17,280,000	57,400,000
Burley	60,000	130,000	70,000	260,000
Total	98,680,000	24,490,000	33,990,000	157,160,000
Hypothetical Resource tonnage				
Burley	1,610,000	940,000	14,070,000	16,620,000
Total	1,610,000	940,000	14,070,000	16,620,000
Grand Total	100,290,000	25,430,000	48,060,000	173,780,000

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