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COAL RESOURCE OCCURRENCE AND  
COAL DEVELOPMENT POTENTIAL MAPS OF THE  
GARFIELD PEAK QUADRANGLE,  
ROSEBUD COUNTY, MONTANA

[Report includes 13 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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<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 Garfield Peak quadrangle, Rosebud County, Montana, (13 plates; U.S. Geological Survey Open-File Report 79-010). 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 Garfield Peak 7 1/2-minute quadrangle is in south-central Rosebud County, Montana, about 36 miles (58 km) south-southeast of Forsyth, and 54 miles (86 km) south-southwest of Miles City, towns in the Yellowstone River valley of eastern Montana. 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 and Miles City. The small town of Colstrip is 11 miles (17.6 km) northwest of the northwest corner of the quadrangle. The south half of the quadrangle is in the Northern Cheyenne Indian Reservation, and the town of Lame Deer, headquarters for the Reservation, is 8 miles (12.8 km) west of the quadrangle.

## Accessibility

The Garfield Peak quadrangle is accessible from Forsyth by going east on U.S. Interstate Highway 94 about 11 miles (17.6 km) to the partly paved, local Highway 447, the Rosebud Creek Road, and then south on this road about 33 miles (52.8 km) to the graveled Greenleaf Creek Road, then south-southeast on this road about 7 miles (11.2 km) to the north edge of the quadrangle. The Greenleaf Creek Road and intersecting unimproved roads provide access to the northern and western parts of the quadrangle.

The Garfield Peak quadrangle is also accessible from both the east and west by way of U.S. Highway 212, which passes through the southwest quarter of the quadrangle. The quadrangle is about 10 miles (16 km) west of Ashland, and 8 miles (12 km) east of Lame Deer, Montana.

The nearest railroad is a spur of the Burlington Northern Railroad, which runs south about 38 miles (61 km) from the main line, terminating at the Big Sky coal mine in the Colstrip SE quadrangle, about 6.5 miles (10.5 km) northwest of the Garfield Peak quadrangle.

## Physiography

The Garfield Peak quadrangle is within the Missouri Plateau division of the Great Plains physiographic province. The plateau, formed by nearly horizontal strata of unequal hardness, has been maturely dissected by tributaries of Rosebud Creek, west of the quadrangle, and the Tongue River, east of the quadrangle, two northeastward-flowing tributaries of the Yellowstone River. The divide between the two drainages is a narrow forested ridge in the central part of the quadrangle. Garfield Peak, with an elevation of

4,316 feet (1,316 m), is on this divide near the center of the quadrangle. Greenleaf Creek and Miller Creek, major tributaries of Rosebud Creek, dissect the northern and western parts of the quadrangle. Lay Creek, Reservation Creek, and other tributaries of the Tongue River dissect the eastern part of the quadrangle.

The highest elevation in the quadrangle, about 4,368 feet (1,331 m) is on the drainage divide in the south-central part of the quadrangle. The lowest elevation, about 3,100 feet (945 m), is along Miller Creek near the northwest corner of the quadrangle. Topographic relief is about 1,268 feet (386 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  $-50^{\circ}\text{F}$  ( $-46^{\circ}\text{C}$ ) to as high as  $110^{\circ}\text{F}$  ( $43^{\circ}\text{C}$ ). The highest temperatures occur in July and the lowest in January; the mean annual temperature is about  $45^{\circ}\text{F}$  ( $7^{\circ}\text{C}$ ) (Matson and Blumer, 1973, p. 6).

#### Land status

The north half of the Garfield Peak 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 in the Northern Cheyenne Indian Reservation in which the coal resources are

not mapped. Plate 2 shows the 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

Bass (1932) mapped the north half of the Garfield Peak quadrangle, that part outside the Northern Cheyenne Indian Reservation, as part of the Ashland coal field. Kepferle (1954) mapped most of the same area as the Greenleaf Creek coal deposit and part of the Miller Creek coal deposit. Matson and Blumer (1973) mapped the northern part of the quadrangle as the Greenleaf Creek-Miller Creek coal deposit.

### 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, which is the uppermost member of the Fort Union Formation (Paleocene). 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 reddish-colored slag or clinker. The entire Tongue River Member is about 1,700 feet (518 m) in thickness (Dobbin, 1930, p. 16), but in the Garfield Peak quadrangle, the upper part of the member has been removed by erosion; probably about 1,400 feet (427 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 Garfield Peak quadrangle is in the north-central part of the Powder River structural basin. The strata in general dip southward at an angle of less than 1 degree. In places regional structure is modified by low-relief folds, as shown by the structure contour map on top of the Upper Rosebud and Lower Rosebud coal beds (pl. 10). 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 origin.

#### COAL GEOLOGY

Four named coal beds crop out in the Garfield Peak quadrangle. In addition to these, several thin, local beds crop out for short distances or were penetrated in drill holes. All the coal beds belong to the Tongue River Member of the Fort Union Formation (Paleocene). They are shown in

outcrop on the Coal Data Map (pl. 1) and in section on the Coal Data Sheet (pl. 3).

The lowermost of the four named coal beds in the Garfield Peak quadrangle is the McKay coal bed. It is about 320 feet (98 m) above the base of the Tongue River Member, and is overlain successively by a noncoal interval of about 30 feet (9 m), the Rosebud coal bed, a noncoal interval of about 80 feet (24 m), the Knobloch coal bed, a noncoal interval of about 175 feet (53 m), and the Sawyer coal bed.

The trace element content of coals in this 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).

#### McKay coal bed

The McKay coal bed was first described by Dobbin (1930, p. 27) from exposures on the McKay Ranch (Colstrip East quadrangle) in the Forsyth coal field, about 10 miles (16 km) northwest of the Garfield Peak quadrangle. The McKay coal bed may be considered a lower split of the Rosebud coal bed because the interval between them in several places is less than 7 feet (2.1 m) (Dobbin, 1930, p. 27).

In the Garfield Peak quadrangle, the McKay coal bed crops out only in the extreme northwest corner of the quadrangle, and for a distance of only about 100 feet (30 m). The McKay coal is not present in a drill hole in the Badger Peak quadrangle less than 1 mile (1.6 km) south-southwest of

the outcrop. Because of its very limited occurrence, the McKay coal bed has not been assigned coal resources in the Garfield Peak quadrangle.

#### Rosebud coal bed

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

The Rosebud coal bed crops out for a limited distance in the northwest corner of the quadrangle (pl. 1). It was penetrated by a drill hole about 2.6 miles (4.2 km) south-southeast of the northwest corner (pls. 1 and 3), where it has a thickness of 14 feet (4.3 m). Based on this and on other control points in adjacent quadrangles, the Rosebud coal bed probably extends throughout the north half of the quadrangle (pl. 1). The Rosebud coal bed has a thickness of 8 to 22 feet (2.4 to 6.7 m), as shown by the isopach map (pl. 10). Structure contours on the Rosebud coal bed (pl. 10) show a general southward dip of less than 1 degree, although this dip is modified by local, minor folding. Overburden on the Rosebud coal bed (pl. 11) ranges from zero at the outcrop to 800 feet (244 m) in thickness.

There are no known publicly available chemical analyses of the Rosebud coal bed in the Garfield Peak quadrangle. However, a chemical analysis of the Rosebud coal bed from drill hole SH-70101, sec. 24, T. 1 S., R. 42 E., in the Badger Peak quadrangle about 150 feet (46 m) west of the Garfield Peak quadrangle border shows ash 6.75 percent, sulfur 0.70 percent, and a heating value of 8,590 Btu per pound (19,980 kJ/kg) on an as-received basis (Matson and Blumer, 1973, p. 125). This heating value converts to about

9,212 Btu per pound (21,427 kJ/kg) on a moist, mineral-matter-free basis, indicating that the Rosebud coal bed is subbituminous C in rank.

#### Knobloch coal bed

The Knobloch coal bed was described by Bass (1924) from a small mine on the Knobloch Ranch on the Tongue River in the Birney Day School quadrangle, about 15 miles (24 km) south of the Garfield Peak quadrangle. In the Garfield Peak quadrangle, the Knobloch coal bed lies about 80 feet (24 m) above the Rosebud coal bed and 175 feet (53 m) below the Sawyer coal bed (pl. 3). The Knobloch coal bed crops out extensively in the northern and eastern parts of the quadrangle, where it ranges from about 5.5 to 24 feet (1.7 to 7.3 m) in thickness (pl. 7). Structure contours on top of the Knobloch coal bed (pl. 7) show a southward or southeastward dip of less than 1 degree except where modified by minor local folding. Overburden on the Knobloch coal bed (pl. 8) ranges from zero at the outcrop to about 850 feet (259 m) in thickness.

A chemical analysis of the Knobloch coal from drill hole SH-70100, sec. 36, T. 1 S., R. 42 E., in the northwest quarter of the quadrangle, shows ash 5.5 percent, sulfur 0.4 percent, and a heating value of 8,935 Btu per pound (20,783 kJ/kg) on an as-received basis (Matson and Blumer, 1973, p. 124). This heating value converts to about 9,455 Btu per pound (21,992 kJ/kg) on a moist, mineral-matter-free basis, which indicates that the Knobloch coal is subbituminous C in rank.

#### 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), about 16 miles (25.7 km) west of the Garfield Peak quadrangle.

In the Garfield Peak quadrangle, the Sawyer coal bed has burned extensively, forming a clinker bed that reaches 100 feet (30 m) in thickness in places on the interstream divides (pl. 1). The isopach map of the Sawyer coal bed (pl. 4) shows that the coal bed ranges from 7.3 to 20.5 feet (2.2 to 6.2 m) in thickness. Structure contours on top of the Sawyer coal bed (pl. 4) show a northeastward dip of less than 1 degree which is modified in places by minor local folding and faulting. Overburden on the Sawyer coal bed (pl. 5) ranges in thickness from about zero near the outcrops to 600 feet (183 m).

A chemical analysis of the Sawyer coal bed from drill hole SH-7099, sec. 6, T. 2 S., R. 43 E., near the center of the west boundary of the quadrangle, shows ash 5.89 percent, sulfur 0.02 percent, and a heating value of 8,805 Btu per pound (20,480 kJ/kg) on an as-received basis (Matson and Blumer, 1973, p. 124). This heating value converts to about 9,356 Btu per pound (21,762 kJ/kg) on a moist, mineral-matter-free basis, indicating that the Sawyer coal here is subbituminous C in rank.

#### Local coal beds

A few thin coal beds of local extent crop out in places on the surface or are penetrated in wells in the quadrangle (pls. 1 and 3). Because of their limited occurrence and thinness they have not been assigned economic coal resources. A thick clinker bed caps Garfield Peak at the southern border of the mapped area. This clinker is evidence that there was once an additional, unnamed coal bed above the Sawyer coal bed, but it has been entirely burned.

## COAL RESOURCES

Data from all publicly available drill holes and from 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 resources in the Garfield Peak quadrangle were calculated using data obtained from the coal isopach maps (pls. 4, 7, and 10). 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/hectare-meter) 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 Sawyer, Knobloch, and Rosebud coal beds are shown on plates 6, 9, and 12, respectively, and are rounded to the nearest one-hundredth of a million short tons.

The total Reserve Base tonnage of federally owned, surface-minable coal in the Garfield Peak quadrangle is calculated to be 387.29 million short tons (351.35 million t), and the total Hypothetical tonnage of surface-minable coal is calculated to be 25.99 million short tons (23.59 million t), as shown

in table 1. The underground-minable Reserve Base tonnage is 13.31 million short tons (12.07 million t), and the Hypothetical underground-minable tonnage is 4.31 million short tons (3.91 million t), as shown in table 2. 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, 25.6 percent as Indicated, and 67.4 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 5, 8, and 11, for the Sawyer, Knobloch, and Rosebud 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.

The coal development potential for surface-mining methods (less than 500 feet or 152 m of overburden) is shown on the CDP map (pl. 13). All of the Federal coal lands have a high development potential for surface-mining methods, except two 40-acre (16.2-ha) tracts which have a moderate development potential, and one 40-acre (16.2-ha) tract which has no development potential.

Three superimposed coal beds, the Rosebud, Knobloch, and Sawyer, all have areas of high development potential. The lowermost coal bed, the Rosebud, (pl. 11) has a high development potential in an irregular band between the outcrops and the 10 mining-ratio contours across the northern and eastern parts of the quadrangle. Just south and west of this band is a relatively narrow band of moderate development potential. Adjacent to this to the south

and west is a wide band of low development potential extending to the arbitrarily assigned stripping limit at the 500-foot (152 m) overburden isopach near the Northern Cheyenne Indian Reservation boundary. The overburden in that area, however, includes the Knobloch coal bed.

The Knobloch coal bed (pl. 8), about 80 feet (24 m) above the Rosebud coal bed, likewise has high development potential in an irregular band across most of the northern and eastern parts of the quadrangle north of the Northern Cheyenne Indian Reservation. Directly south and west of this is a wide band of moderate development potential. Farther southwest is a relatively narrow band of low development potential extending to the stripping limit at the 500-foot (152-m) overburden isopach. The overburden in that area includes the Sawyer coal bed, which is about 175 feet (53 m) above the Knobloch.

The Sawyer coal bed (pl. 5) has a considerable area of high development potential in the southern part of the mapped area north of the Northern Cheyenne Indian Reservation. This is succeeded to the south and west by a narrow band of moderate development potential, and then a narrow band of low development potential.

Because the high-development-potential areas of the three coal beds are adjacent and partially overlapping, practically all of the Federal coal lands in the Garfield Peak quadrangle have a high development potential for surface mining, as shown by plate 13.

## 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 development-potential category for each coal bed. 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 Garfield Peak 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
<b>Reserve Base tonnage</b>				
Sawyer	32,100,000	7,460,000	• 4,930,000	44,490,000
Knobloch	88,340,000	39,930,000	42,530,000	170,800,000
Rosebud	93,410,000	24,460,000	54,130,000	172,000,000
Total	213,850,000	71,850,000	101,590,000	387,290,000
<b>Hypothetical Resource tonnage</b>				
Rosebud	9,740,000	5,690,000	10,560,000	25,990,000
Total	9,740,000	5,690,000	10,560,000	25,990,000
<b>Grand Total</b>	<b>223,590,000</b>	<b>77,540,000</b>	<b>112,150,000</b>	<b>413,280,000</b>

Table 2. --Underground-minable coal resource tonnage by development-potential category for Federal coal lands (in short tons) in the Garfield Peak 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
<b>Reserve Base tonnage</b>							
Sawyer	0	0	0	300,000	0	300,000	300,000
Knobloch	0	0	0	8,560,000	0	8,560,000	8,560,000
Rosebud	0	0	0	4,450,000	0	4,450,000	4,450,000
Total	0	0	0	13,310,000	0	13,310,000	13,310,000
<b>Hypothetical Resource tonnage</b>							
Rosebud	0	0	0	4,310,000	0	4,310,000	4,310,000
Total	0	0	0	4,310,000	0	4,310,000	4,310,000
<b>Grand Total</b>							
	0	0	0	17,620,000	0	17,620,000	17,620,000

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