UNITED STATES DEPARTMENT OF THE INTERIOR

GEOLOGICAL SURVEY

Text to accompany:

Open-File Report 79-079

1979

COAL RESOURCE OCCURRENCE AND COAL DEVELOPMENT POTENTIAL MAPS OF THE BEAVER CREEK SCHOOL QUADRANGLE, POWDER RIVER COUNTY, MONTANA

[Report includes 31 plates]

By

Colorado School of Mines Research Institute

CONTENTS

ILLUSTRATIONS

[Plates are in pocket]

Plates 1-30. Coal resource occurrence maps:

1. Coal data map.
2. Boundary and coal data map.
3. Coal data sheet.
4. Isopach and structure contour map of the Ferry coal bed.
5. Overburden isopach and mining-ratio map of the Ferry coal bed.
6. Areal distribution and tonnage map of identified and hypothetical resources of the Ferry coal bed.
7. Isopach and structure contour map of the E coal bed.
8. Overburden isopach and mining-ratio map of the E coal bed.
9. Areal distribution and tonnage map of identified resources of the E coal bed.
10. Isopach and structure contour map of the X coal bed.
11. Overburden isopach and mining-ratio map of the X coal bed.
12. Areal distribution and tonnage map of identified resources of the X coal bed.
13. Isopach and structure contour map of the C and D coal beds.
14. Overburden isopach and mining-ratio map of the C and D coal beds.

Illustrations--Continued

TABLES

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 Beaver Creek School quadrangle, Powder River County, Montana, (31 plates; U.S. Geological Survey Open-File Report 79-079). 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 Beaver Creek School 7 1/2-minute quadrangle is in northwestern Powder River County, Montana, about 49 miles (78 km) south-southwest of Miles City, a town 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 Miles City. The Beaver Creek School quadrangle is 8 miles (13 km) east-northeast of Ashland, Montana, a small town on U.S. Highway 212.

Accessibility

The quadrangle is accessible from Miles City by traveling south on U.S. Highway 312 15 miles (24 km) to the partially paved local Highway 332, the Tongue River Road, and then southwest on this road about 41 miles (66 km) to Goodale Creek, then southeast on the graveled Beaver Creek Road about 10 miles (16 km) to the north edge of the quadrangle. The graveled Beaver Creek Road continues southeastward through the quadrangle and is intersected by a number of unimproved trails and roads which provide access to all except the southernmost part of the quadrangle.

The southern extremity of the quadrangle is accessible from Ashland by going east on U.S. Highway 212 about 5 miles (8 km), then northeastward on the East Fork of Otter Creek Road about 9 miles (14 km) to the southeastern part of the quadrangle. The nearest railroad is 25 miles (40 km) to the northwest at the Big Sky coal mine (Colstrip SE quadrangle). A spur connects this mine with the main line of the Burlington Northern Railroad about 35 miles (56 km) farther to the north.

Physiography

The Beaver Creek School quadrangle is within the Missouri Plateau division of the Great Plains physiographic province. The most conspicuous topographic feature is an unnamed, long, narrow, irregular, flat-topped, eastward-trending ridge in the southern part of the quadrangle. The highest elevation, 4,280 feet (1,305 m), is on this ridge in the southwest quarter of the quadrangle. The ridge forms a prominent drainage divide. The quadrangle surface north of the ridge is drained by tributaries of Beaver Creek, a

northwestward-flowing tributary of the Tongue River. The quadrangle surface south of the ridge is drained by tributaries of Otter Creek, another northwestward-flowing tributary of the Tongue River. The ephemeral streams have cut deep, narrow, steep-sided ravines into the land surface, and in places have carved the intertributary ridges into badlands. Only Beaver Creek in the northern part of the quadrangle flows in a broad valley with gently sloping sides. This valley is bordered at higher elevations by steep slopes and by ledges capped by erosion-resistant, reddish-colored clinker beds formed by the burning of coals. The lowest elevation, 3,020 feet (920 m), is on a tributary of Beaver Creek in the northwest corner of the quadrangle. Topographic relief is about 1,260 feet (384 m).

Climate

The climate of Powder River 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

Plate 2 shows the land ownership status of lands within the quadrangle. All of the land in the south half of the quadrangle, and much of the land in the north half, is Federal coal land. The Northern Powder River

Basin Known Recoverable Coal Resource Area covers all but a small area in the northwest quarter of the quadrangle. There were no outstanding Federal coal leases or prospecting permits recorded as of 1977.

GENERAL GEOLOGY

Previous work

Bass (1932) mapped all of the Beaver Creek School quadrangle as part of the Ashland coal field, Rosebud, Treasure, and Big Horn Counties, Montana. Matson and Blumer (1973) mapped most of the northern part of the quadrangle as the Beaver Creek-Liscom Creek coal deposit, and most of the southern part of the quadrangle as the Ashland 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, 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 baked and fused the overlying rock into reddish-colored slag and clinker. The Tongue River Member is about 1,650 feet (503 m) thick in the Beaver Creek School quadrangle even though the uppermost strata have been removed by erosion.

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 Beaver Creek School quadrangle is in the northeastern part of the Powder River structural basin. The strata in general dip southward at an angle of less than 1 degree. In places the regional structure is modified by low-relief folds, as shown by the structure contour maps on top of the coal beds, (pls. 4, 7, 10, 13, 17, 22, 25, and 28). Some of the nonuniformity in structure may be due to irregularities in deposition of the coals and other beds as a result of their continental origin.

COAL GEOLOGY

Nine named coal beds and several additional local, thin coal beds are exposed at the surface in the Beaver Creek School quadrangle. They are shown in outcrop on the Coal Data Map (pl. 1) and in section on the Coal Data Sheet (pl. 3). Eight of the named coal beds have coal resources. All the coal beds belong to the Tongue River Member of the Paleocene Fort Union Formation.

The lowermost of the coal beds is the Terret coal bed which is about 140 feet (43 m) above the base of the Tongue River Member. The Terret is overlain by a noncoal interval of about 40 feet (12 m), the Flowers-Goodale coal bed, a noncoal interval of about 75 feet (23 m), a local coal bed, a noncoal interval of about 35 to 65 feet (11 to 20 m), the Knobloch coal bed, a noncoal interval of about 80 to 120 feet (24 to 37 m), a local coal bed, a noncoal interval of 30 to 40 feet (9 to 12 m), the Lower Sawyer coal bed, a noncoal interval of about 10 feet (3 m), a local coal bed, a noncoal interval of 30 to 70 feet (9 to 21 m), the Upper Sawyer coal bed, a noncoal interval of about 100 feet (30 m), the C and D coal beds, a noncoal interval of 40 to 50 feet (12 to 15 m), the X coal bed, a noncoal interval of about 75 feet (23 m), a local coal bed, a noncoal interval of about 55 feet (17 m), the E coal bed, a noncoal interval of about 125 feet (38 m), a local coal bed, a noncoal interval of about 55 feet (17 m), the Lower Cook coal bed, a noncoal interval of about 200 feet (61 m), the Ferry coal bed, a noncoal interval of about 100 feet (30 m), and the Garfield clinker bed formed by the burning of a 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).

Terret coal bed

The Terret coal bed was first described by Bass (1932, p. 51) from a small coal mine on the Terret Ranch (Cook Creek Reservoir quadrangle),

just west of the Beaver Creek School quadrangle. The Terret coal bed crops out near the northwest corner of the Beaver Creek School quadrangle. Because there are no thickness measurements of this coal in this quadrangle, its thickness has been projected into the quadrangle from the adjacent quadrangles. This projection (pl. 28) indicates that the Terret coal bed is 5 to 9 feet (1.5 to 2.7 m) thick in the northern fourth of the Beaver Creek School quadrangle. The bed dips southward at an angle of less than 1 degree. Overburden on the Terret coal bed ranges from zero at the outcrop to about 760 feet (232 m) in thickness (pl. 29).

There are no known publicly available chemical analyses of the Terret coal in the Beaver Creek School quadrangle. Terret coal from 38 to 44 feet (11.6 to 13.4 m) in drill hole SH-7094, sec. 16, T. 1 N., R. 45 E., in the Brandenberg quadrangle, 6.5 miles (10.4 km) north-northwest of the Beaver Creek School quadrangle shows ash 5.767 percent, sulfur 0.691 percent, and a heating value of 8,170 Btu per pound (19,003 kJ/kg) on an as-received basis (Matson and Blumer, 1973, p. 121). This heating value converts to about 8,670 Btu per pound (20,166 kJ/kg) on a moist, mineral-matter-free basis, indicating that the Terret coal in the Brandenberg quadrangle is subbituminous C in rank. Because the Brandenberg and Beaver Creek School quadrangles are adjacent and have a similar position in the basin, it is assumed that the Terret coal in the Beaver Creek School quadrangle is similar and is subbituminous C in rank.

Flowers-Goodale coal bed

The Flowers-Goodale coal bed was described by Bass (1932, p. 53) from two small mines located in the Brandenberg quadrangle, about 4.5 miles (7.2 km) north-northwest of the Beaver Creek School quadrangle. The Flowers-Goodale coal bed crops out near the northwest corner of the Beaver Creek School quadrangle. The thickness measurements here are not definitive but the coal bed is believed to range from about 5 to 9 feet (1.5 to 2.7 m) in thickness and to dip westward at an angle of less than 1 degree (pl. 25). The Flowers-Goodale coal bed is projected into the southwestern part of the quadrangle where it is believed to range from about 5 to 6.5 feet (1.5 to 2.0 m) in thickness, and dip southward at an angle of less than 1 degree based on measurements in the adjacent quadrangles. Overburden on the Flowers-Goodale coal bed in the northwestern part of the quadrangle ranges from zero at the outcrops to about 520 feet (158 m) in thickness; and in the southwestern part of the quadrangle the overburden ranges from about 420 to 1,250 feet (128 to 381 m) in thickness (pl. 26).

There is no known publicly available chemical analysis of the Flowers-Goodale coal bed in the Beaver Creek School quadrangle. An analysis of this coal from a depth of 54 to 61 feet (16 to 19 m) in drill hole SH-7084, sec. 36, T. 1 N., R. 45 E. in the Hayes Point quadrangle, about 3 miles (4.8 km) north of the Beaver Creek School quadrangle shows ash 5.560 percent, sulfur 0.380 percent, and a heating value of 8,271 Btu per pound (19,238 kJ/kg) on an as-received basis (Matson and Blumer, 1973, p. 121). This heating value converts to about 8,758 Btu per pound (20,371 kJ/kg) on a

moist, mineral-matter-free basis, indicating that the Flowers-Goodale coal at this location is subbituminous C in rank. Because this location is close to the Beaver Creek School quadrangle and has a similar position in the basin, it is assumed that the Flowers-Goodale coal in the Beaver Creek School quadrangle is similar and is subbituminous C in rank.

Knobloch coal bed

The Knobloch coal bed was named by Bass (1924) from a small coal mine on the Knobloch Ranch in the Tongue River valley in the Birney Day School quadrangle, about 22 miles (35 km) southwest of the Beaver Creek School quadrangle. In the latter quadrangle, the Knobloch coal bed is about 110 to 140 feet (34 to 43 m) above the Flowers-Goodale coal bed. The Knobloch coal bed crops out in the northern part of the quadrangle (pl. 1), and extends throughout most of the quadrangle (pl. 22). Its thickness increases from about 8 feet (2.4 m) in the northern part of the quadrangle to about 52 feet (15.9 m) in the southern part of the quadrangle (pl. 22). The bed dips southward or westward at an angle of less than 1 degree (pl. 22). Overburden on the Knobloch coal bed ranges in thickness from zero at the outcrops to about 1,100 feet (335 m) near the southwest corner of the quadrangle (pl. 23).

A chemical analysis of the Knobloch coal from a depth of 85 to 95 feet (26 to 29 m) in drill hole SH-7080, sec. 34, T. 1 S., R. 46 E., in the Beaver Creek School quadrangle shows ash 7.501 percent, sulfur 0.279 percent, and a heating value of 7,933 Btu per pound (18,452 kJ/kg) on an as-received basis (Matson and Blumer, 1973, p. 121). This heating value

converts to about 8,576 Btu per pound (19,948 kJ/kg) on a moist, mineral-matter-free basis, indicating that the Knobloch coal in this quadrangle is subbituminous C in rank.

Sawyer coal bed

The Sawyer coal bed was first 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 31 miles (49.6 km) west of the Beaver Creek School quadrangle. The Sawyer coal bed crops out in the central part of the Beaver Creek School quadrangle where it is 70 to 120 feet above the Knobloch coal bed (pl. 1). In the southern part of the quadrangle, the Sawyer coal is a single coal bed 8 to 16 feet (2.4 to 4.8 m) thick (pl. 16). To the north the Sawyer coal splits into two coal beds approximately along a line shown on plate 16. The Upper Sawyer coal bed ranges from 5 to 22.7 feet (1.5 to 6.9 m) in thickness. The Lower Sawyer coal bed ranges from about 2 to 13.5 feet (0.6 to 4.1 m) in thickness; and the unsplit Sawyer coal bed ranges from 8 to 16 feet (2.4 to 4.9 m) in thickness (pl. 16). The Sawyer beds dip southward at an angle of less than 1 degree (pl. 17). Overburden on the Sawyer coal bed ranges from zero at the outcrop to about 900 feet (274 m) in thickness (pls. 18 and 20).

There is no known publicly available chemical analysis of the Sawyer coal bed in the Beaver Creek School quadrangle. A chemical analysis of the Sawyer coal from a depth of 82 to 92 feet (25 to 28 m) in drill hole SH-7066, sec. 36, T. 2 S., R. 45 E., in the Coleman Draw quadrangle, about 1 mile (1.6 km) south of the Beaver Creek School quadrangle, shows ash 4.672

percent, sulfur 0.297 percent, and a heating value of 8,015 Btu per pound (18,643 kJ/kg) on an as-received basis (Matson and Blumer, 1973, p. 73). This heating value converts to 8,408 Btu per pound (19,557 kJ/kg) on a moist, mineral-matter-free basis, indicating that the Sawyer coal at this location is subbituminous C in rank. Because this location is so close to the Beaver Creek School quadrangle and has a similar position in the basin, it is assumed that the Sawyer coal in the Beaver Creek School quadrangle is similar and is subbituminous C in rank.

C and D coal beds

The C and overlying D coal beds were first described by Bass (1932, p. 55) from exposures in the Ashland coal field, possibly from the Beaver Creek School quadrangle, although a type locality was not given. The two closely spaced beds have been combined and mapped together for purposes of this report. They are represented on plate 1 by a single outcrop line, as shown by Bass (1932, pl. 3). Ninety percent or more of this combined coal unit is composed of the D coal bed alone. Bass (1932, p. 55) says that the C bed is of little economic importance because it contains an abundance of silicified, partly carbonized tree stumps and fragments of logs that destroy the value of the bed. The C and D beds crop out across the central part of the quadrangle, along its southern border, and near the northeast corner of the quadrangle. The beds are about 100 feet (30 m) above the Sawyer coal bed. The combined coal unit ranges from 2.2 to 18.2 feet (0.67 to 5.5 m) in thickness, and dips southward at an angle of less than 1 degree (pl. 13). Overburden on the combined C and D beds ranges from zero at the outcrops to about 490 feet (149 m) in thickness (pl. 14).

There are no known publicly available chemical analyses of the C and D coal beds. It is assumed that the C and D coal beds are similar in rank to the closely associated coal beds in the Beaver Creek School quadrangle and are subbituminous C in rank.

X coal bed

The X coal bed was first described by Bass (1932, p. 55) from exposures in the Ashland coal field, and probably from the Beaver Creek School quadrangle where it is well exposed, although a type locality is not given. The X coal bed occurs about 40 to 50 feet (12 to 15 m) above the D coal bed and crops out in the central and southern parts of the quadrangle. The X bed ranges from about 4 to 7.5 feet (1.2 to 2.3 m) in thickness and is practically flat (pl. 10). Overburden on the X bed ranges from zero at the outcrops to about 580 feet (177 m) in thickness (pl. 11).

There is no known publicly available chemical analysis of the X coal bed. It is assumed that the X coal is similar to the closely associated coals in the Beaver Creek School quadrangle and is subbituminous C in rank.

E coal bed

The E coal bed was first described by Bass (1932, p. 55) from exposures in the Ashland coal field. An exact type locality was not given. This bed occurs in the southern part of the Beaver Creek School quadrangle about 100 to 140 feet (30 to 43 m) above the X coal bed (pl. 1). The E coal bed ranges from about 6 to 16 feet (1.8 to 4.9 m) in thickness and dips southward or southwestward at an angle of less than 1 degree (pl. 7).

Overburden on the E bed ranges from zero at the outcrop to about 620 feet (189 m) in thickness (pl. 8).

There is no known publicly available chemical analysis of the E coal bed. It is assumed that the E coal bed is similar to closely associated coals in the Beaver Creek School quadrangle and is subbituminous C in rank.

Lower Cook coal bed

The name Cook coal bed was first used by Bass (1932, p. 59-60) for a coal bed in the Cook Creek Reservoir quadrangle, just west of the Beaver Creek School quadrangle in the Ashland coal field. At some localities there is an Upper and a Lower Cook coal bed; but in the Beaver Creek School quadrangle only the Lower Cook coal bed is present. The Lower Cook coal bed crops out about 200 feet (61 m) above the E coal bed. The coal is exposed only for a distance of about 1.5 miles (2.5 km) in the southwestern part of the quadrangle where it has a thickness of 3.3 to 4.4 feet (1 to 1.3 m), as shown on plate 1. Because of its thinness it has not been assigned economic coal resources.

Ferry coal bed

The Ferry coal bed was first described by Warren (1959, p. 573) after exposures in the central and southwestern parts of the Birney-Broadus coal field. A type locality was not given. In the Beaver Creek School quadrangle, the Ferry coal bed is present in the southern part of the quadrangle (pl. 1). However, the coal is generally burned at the outcrop. There are no thickness measurements of this coal within this quadrangle; and the thickness of 3 to 6 feet (0.9 to 1.8 m) shown on the isopach and structure map

(pl. 4) has been projected into the quadrangle from adjacent quadrangles. Regional structural contours on top of the coal indicate that the bed is nearly flat or dips westward at an angle of less than 1 degree (pl. 4). Overburden on the Ferry coal is about 40 feet (12 m) in thickness (pl. 5).

There are no known publicly available chemical analyses for the Ferry coal bed. For calculation of coal resources, the Ferry coal has been assigned a rank of subbituminous C in accordance with the rank of other closely associated coal beds in this quadrangle.

Local coal beds

There are a number of thin, local coal beds shown on plates 1 and 3. Because of their limited areal extent and thinness (not over 5 feet or 1.5 m thick) they have not been assigned economic coal resources.

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.

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 Beaver Creek School quadrangle were calculated using data obtained from the coal isopach maps (pls. 4, 7, 10, 13, 16, 22, 25, and 28). 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 Ferry, E, X, C and D, Upper Sawyer, Lower Sawyer, Knobloch, Flowers-Goodale, and Terret coal beds are shown on plates 6, 9, 12, 15, 19, 21, 24, 27, and 30, 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 Beaver Creek School quadrangle is calculated to be 1,278.74 million short tons (1,159.82 million t), and the total Hypothetical tonnage of surface-minable coal is calculated to be 12.53 million short tons (11.36 million t), as shown in table 1. The underground-minable Reserve Base tonnage is 673.2 million short tons (610.59 million t), and the Hypothetical underground-minable tonnage is 72.10 million short tons (65.39 million t), as shown in table 2. All numbers are rounded to the nearest one-hundredth of a million short tons. About 3 percent of the Reserve Base tonnage is classed as Measured, 20 percent as Indicated, and 77 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 here 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 5, 8, 11, 14, 18, 20, 23, 26, and 29 for the Ferry, E, X, C and D, Upper Sawyer, Lower Sawyer, Knobloch, Flowers-Goodale, and Terret coal beds, respectively. 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), 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 on federally owned coal land is shown on the CDP map (pl. 31). Most of the Federal coal lands in the Beaver Creek School quadrangle have a high development potential for surface mining. There is a narrow band across the southern part of the quadrangle in which these lands have a moderate or low development potential due to thick overburden. Except for the lands in this band, all of the Federal coal lands have a high potential for surface mining.

The Terret coal bed (pl. 29) has a fairly extensive area of high development potential (mining-ratio values of 0 to 10) and moderate development potential (mining-ratio values of 10 to 15) in the lower part of the Beaver Creek valley in the northern part of the quadrangle. However, most of this coal is on non-Federal coal land. The Terret coal under the Federal coal lands has mainly a low development potential (mining-ratio values greater than 15).

The Flowers-Goodale coal bed (pl. 26) has areas of coal development potential in the southwest and in the northwest quarters of the quadrangle. In the southwest quarter, the development potential is mainly for underground-mining as the overburden is greater than 500 feet (152 m) in thickness. There is a limited area of low development potential for surface mining where the overburden is less than 500 feet (152 m) in thickness. In the northwest quarter of the quadrangle, most of the Flowers-Goodale coal under Federal land has a low development potential for surface mining (mining-ratio values greater than 15).

The Knobloch coal bed (pl. 23) has wide areas of high development potential (mining-ratio values 0 to 10) at low elevations on the sides of the Beaver Creek valley and its tributary valleys in the northern part of the quadrangle. There are smaller areas of high development potential near the southern border of the quadrangle. Above these areas are quite wide bands of moderate development potential (mining-ratio values 10 to 15) higher in the valleys. There is an extensive area of low development potential in the central part of the quadrangle extending from the 15-mining-ratio contour to the stripping limit at the 500-foot (152-m) overburden isopach near the crests of the intertributary divides.

The Lower Sawyer coal bed (pl. 20) has an area of development potential for surface mining bounded by the outcrops and the 5-foot (1.5-m) coal isopach in the west-central part of the quadrangle. There is a relatively narrow area of high development potential between the outcrops and the 10-mining-ratio contour along the sides of the ephemeral stream valleys.

Above this is a very narrow band of moderate development potential (mining-ratio values 10 to 15). Still higher is a wide area of low development potential (mining-ratio values greater than 15) extending to the crests of the hills or to the stripping limit at the 500-foot (152-m) overburden isopach.

The Sawyer coal bed and the upper split of the Sawyer coal bed (pl. 18) has a potential for surface development except in the northern part of the quadrangle where the coal has been removed by erosion and in a zone across the southern part of the quadrangle where the overburden is greater than 500 feet (152 m) in thickness. There is a relatively wide band of high development potential extending from the outcrops to the 10 mining-ratio contour. Above this is a narrow band of moderate development potential (mining-ratio values 10 to 15) and a wide area of low development potential (mining-ratio values greater than 15).

The combined C and D coal beds (pl. 14) have small local areas of coal development potential in the south-central, central, and northeastern parts of the quadrangle. Over most of the quadrangle these beds have no development potential for surface mining, because the beds have either been removed by erosion, or are less than 5 feet (1.5 m) thick. Both the areas of high development potential (mining-ratio values 0 to 10) and the areas of moderate development potential (mining-ratio values 10 to 15) are quite limited. The areas of low development potential are large and extend to the crests of the intertributary divides.

The X coal bed (pl. 11) has a circular area of development potential for surface mining in the south-central part of the quadrangle. Elsewhere

in the quadrangle this coal bed has no development potential, as it either has been removed by erosion or is less than 5 feet (1.5 m) in thickness. The areas of high development potential (mining-ratio values 0 to 10) and moderate development potential (mining-ratio values 10 to 15) are limited to narrow bands on the sides of the valleys. There is a large area of low development potential (mining-ratio values greater than 15) extending to the 500-foot (152-m) stripping limit, close to the crests of the divides.

The E coal bed (pl. 8) has an area of development potential for surface mining extending across the southern part of the quadrangle from the outcrops to the crests of the hills. The areas of high development potential are quite narrow bands; and the areas of moderate development potential are very narrow bands. Most of the area has a low development potential extending from the 15 mining-ratio contour to the crests of the hills. Only limited areas are above the 500-foot (152-m) overburden isopach and hence have no development potential for surface mining. The E bed also has a small area of development potential for surface mining near the northeast quarter of the quadrangle.

The Ferry coal bed (pl. 5) has four very small areas of development potential for surface mapping in the southeast quarter of the quadrangle extending from the outcrops to the crests of the hills. These areas consist of very narrow bands of high, moderate, and low development potential. Elsewhere in the quadrangle the bed has no development potential, as it has either been removed by erosion or is less than 5 feet (1.5 m) thick.

The superimposed coal beds in the Beaver Creek School quadrangle have areas of high development potential for surface mining which are adjacent or slightly overlapping. For this reason the various areas of high development potential spread across the quadrangle and cover most of the Federal coal lands. As shown by plate 31, about 88 percent of the Federal coal lands in the Beaver Creek School quadrangle have a high development potential for surface mining, 6 percent have a moderate development potential, and 6 percent have a low 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 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 Beaver Creek School quadrangle, Powder River 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				
E	40,500,000	18,080,000	81,070,000	139,650,000
X	11,480,000	6,720,000	59,320,000	77,520,000
C and D	8,040,000	7,550,000	19,290,000	34,880,000
Sawyer and Upper Sawyer	66,320,000	44,010,000	209,890,000	320,220,000
Lower Sawyer	5,880,000	4,870,000	48,170,000	58,920,000
Knobloch	171,510,000	297,390,000	150,440,000	619,340,000
Flowers-Goodale	2,350,000	3,550,000	7,210,000	13,110,000
Terret	140,000	1,030,000	13,930,000	15,100,000
Total	306,220,000	383,200,000	589,320,000	1,278,740,000
Hypothetical Resource tonnage				
Ferry	520,000	370,000	160,000	1,050,000
Knobloch	0	2,110,000	1,420,000	3,530,000
Terret	0	0	7,950,000	7,950,000
Total	520,000	2,480,000	9,530,000	12,530,000
Grand Total	306,740,000	385,680,000	598,850,000	1,291,270,000

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

[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				
E	0	0	1,510,000	1,510,000
X	0	0	710,000	710,000
Sawyer and Upper Sawyer	0	0	72,480,000	72,480,000
Lower Sawyer	0	0	3,630,000	3,630,000
Knobloch	0	0	578,880,000	578,880,000
Flowers-Goodale	0	0	6,690,000	6,690,000
Terret	0	0	9,260,000	9,260,000
Total	0	0	673,220,000	673,220,000
Hypothetical Resource tonnage				
Knobloch	0	0	66,820,000	66,820,000
Flowers-Goodale	0	0	4,580,000	4,580,000
Terret	0	0	700,000	700,000
Total	0	0	72,100,000	72,100,000
Grand Total	0	0	745,320,000	745,320,000

REFERENCES

Bass, N. W., 1924, Coal in Tongue River valley, Montana: U.S. Geological Survey Press Memoir 16748.

_____ 1932, The Ashland coal field, Rosebud, Powder River, and Custer Counties, Montana: U.S. Geological Survey Bulletin 831-B, p. 19-105.

Dobbin, C. E., 1930, The Forsyth coal field, Rosebud, Treasure, and Big Horn Counties, Montana: U.S. Geological Survey Bulletin 812-A, p. 1-55.

Hatch, J. R., and Swanson, V. E., 1977, Trace elements in Rocky Mountain coals, in Proceedings of the 1976 symposium, Geology of Rocky Mountain coal, 1977: Colorado Geological Survey, Resource Series 1, p. 143-163.

Mapel, W. J., Swanson, V. E., Connor, J. J., Osterwald, F. W., and others, 1977, Summary of the geology, mineral resources, environmental geochemistry, and engineering geologic characteristics of the northern Powder River coal region, Montana: U.S. Geological Survey Open-File Report 77-292.

Matson, R. E., and Blumer, J. W., 1973, Quality and reserves of strippable coal, selected deposits, southeastern Montana: Montana Bureau of Mines and Geology Bulletin 91, 135 p.

U.S. Bureau of Mines and U.S. Geological Survey, 1976, Coal resource and classification system of the U.S. Bureau of Mines and U.S. Geological Survey: U.S. Geological Survey Bulletin 1450-B, 7 p.

U.S. Department of Agriculture, Interstate Commerce Commission, and U.S. Department of the Interior, 1974, Final environmental impact statement on proposed development of coal resources in the eastern Powder River coal basin of Wyoming: v. 3, p. 39-61.

Warren, W. C., 1959, Reconnaissance geology of the Birney-Broadus coal field, Rosebud and Powder River Counties, Montana: U.S. Geological Survey Bulletin 1072-J, p. 561-585.