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COAL RESOURCE OCCURRENCE AND COAL DEVELOPMENT POTENTIAL MAPS OF THE COOK CREEK RESERVOIR QUADRANGLE, POWDER RIVER AND ROSEBUD COUNTIES, MONTANA

[Report includes 35 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 Cook Creek Reservoir quadrangle, Powder River and Rosebud Counties, Montana, (35 plates; U.S. Geological Survey Open-File Report 79-084). 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 Cook Creek Reservoir 7 1/2-minute quadrangle is in southeastern Rosebud County and northwestern Powder River County, 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 quadrangle is about 2.5 miles (4 km) northeast of Ashland, a small town on the Tongue River and on U.S. Highway 212, 44 miles (70.1 km) west-northwest of Broadus, Montana.

Accessibility

The quadrangle is accessible from Ashland by going eastward on U.S. Highway 212 for 0.8 mile (1.3 km) and thence northward on an unimproved road about 3 miles (4.8 km) to the southern border of the quadrangle; or by going 3 miles (4.8 km) eastward from Ashland and then northward on an unimproved road 3.9 miles (6.2 km) to the southern border of the quadrangle.

The nearest railroad is a spur of the Burlington Northern Railroad which runs southward about 38 miles (61 km) from the main line in the Yellowstone River valley, terminating at the Big Sky coal mine (Colstrip SE quadrangle) which is about 18 miles (29 km) west-northwest of the Cook Creek Reservoir quadrangle.

Physiography

The Cook Creek Reservoir quadrangle is within the Missouri Plateau division of the Great Plains physiographic province. The land surface is maturely dissected, rugged, and forested. The most conspicuous topographic feature, the Cook Mountain in the southeast quarter of the quadrangle, is a group of intricately dissected ridges capped by erosion-resistant, reddish-colored clinker formed by the burning of coal beds. The northern part of the quadrangle drains northward from the mountains into Beaver Creek, a tributary of the Tongue River. The western part drains westward and northwestward through other tributaries of the Tongue River which is about 2 miles (3.2 km) west of the quadrangle and flows northeastward to join the Yellowstone River at Miles City. The southern part of the quadrangle drains southward from the mountains into Cook Creek and other tributaries of Otter Creek, which joins the Tongue River at Ashland. The streams carry water only part of the year in their narrow, gorge-like channels, wedged between precipitous slopes. The highest point in the mountains, Cook triangulation station, has an elevation of 4,369 feet (1,332 m). The lowest elevation, about 2,940 feet (896 m), is along Bringoff Creek at the northwestern border of the quadrangle. Topographic relief within the quadrangle is 1,429 feet (436 m).

Climate

The climate of Powder River and Rosebud Counties is characterized by pronounced variations in seasonal precipitation and temperature. Annual precipitation in the region varies from less than 12 inches (30 cm) to 16 inches (41 cm). The heaviest precipitation is from April to August. The largest average montly 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 covers all of the Cook Creek Reservoir quadrangle except a small area along its west border, as shown by the Boundary and Coal Data Map (pl. 2). The Federal Government owns the coal rights for all lands in the southeastern part of the quadrangle, and approximately every other section in the remainder of the quadrangle. There were no outstanding Federal coal leases or prospecting permits recorded as of 1977.

GENERAL GEOLOGY

Previous work

Wegemann (1910) made a reconnaissance of the quadrangle and made notes on the coal of the Custer National Forest. Bass (1932) mapped the entire quadrangle as part of the Ashland coal field, Rosebud, Powder River, and Custer Counties, Montana. Matson and Blumer (1973) mapped the southern part of the quadrangle as part of 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. Only the uppermost member of the Paleocene Fort Union Formation, the Tongue River Member, is exposed in the Cook Creek Reservoir quadrangle. The member is presently about 1,600 feet (488 m) thick in the quadrangle; an unknown amount at the top has been removed by erosion. The unit is composed of light-colored sandstone, sandy shale, carbonaceous shale, and coals. These strata were deposited in a continental environment a few tens of feet (a few meters) above sea level in a large area of shifting flood plains, sloughs, swamps, and lakes. The Tongue River Member contains the coal beds of greatest economic interest. Much of the coal has burned along the outcrops forming, thick, reddish-colored clinker beds of baked and fractured sandstone and shale.

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 Cook Creek Reservoir 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 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, 16, 20, 25, 29, and 32). 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

The coal beds that occur in the Cook Creek Reservoir quadrangle are shown in outcrop on the Coal Data Map (pl. 1) and in section on the Coal Data Sheet (pl. 3). All of 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 200 feet (61 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 20 to 90 feet (6 to 27 m) that includes in places a local bed, the Knobloch coal bed, a noncoal interval of 200 to 250 feet (61 to 76 m) that includes in places a local coal bed, the Sawyer coal bed, a noncoal interval of 120 to 150 feet (37 to 46 m), the C and D coal beds, a noncoal interval of about 50 to 90 feet (15 to 27 m), the E coal bed, a noncoal interval of about 120 to 190 feet (37 to 58 m) that includes in places a local coal bed, the Cook coal bed, a noncoal interval of about 100 feet (30 m) that includes in places a local coal bed, the Ferry coal bed, a noncoal interval of about 100 feet (30 m), and the Garfield clinker 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 described by Bass (1932, p. 51) from a small coal mine on the Terret Ranch in the northern part of the Cook Creek Reservoir quadrangle (pl. 1). The Terret coal bed crops out only in the northern part of the quadrangle. It is thickest, 9 feet (2.7 m) plus, at the Terret mine and is believed to decrease in thickness southward to less than 5 feet (1.5 m), as shown by the isopach map, plate 32. The bed dips southward at an angle of less than 1 degree (pl. 32). Overburden on the Terret coal bed ranges in thickness from zero at the outcrop to about 300 feet (91 m).

There are no publicly available chemical analyses for the Terret coal bed in the Cook Creek Reservoir quarangle. An analysis of the Terret coal from the Holt Mine in the Ashland quadrangle (sec. 10, T. 3 S., R. 44 E.), about 4 miles (6.4 km) southwest of the Cook Creek Reservoir quadrangle, shows ash 3.9 percent, sulfur 0.4 percent, and a heating value of 8,020 Btu per pound (20,980 kJ/kg) on an as-received basis (Gilmour and Dahl, 1967, p. 18). This heating value converts to about 9,390 Btu per pound (21,840 kJ/kg) on a moist, mineral-matter-free basis, indicating that the Terret coal at this location is subbituminous C in rank. Because of the proximity of this location to the Cook Creek Reservoir quadrangle, it is assumed that the Terret coal in the Cook Creek Reservoir quadrangle is similar in rank and is subbituminous C.

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, just north of the Cook Creek Reservoir quadrangle. The coal bed crops out near the north and west borders of the quadrangle. It decreases in thickness from about 11 feet (3.4 m) near the north border of the quadrangle to less than 5 feet (1.5 m) in the east-central and west-central parts of the quadrangle. The structure contour map of the Flowers-Goodale coal bed, plate 29, shows broad open folds, not over 100 feet (31 m) in relief. Overburden on the Flowers-Goodale coal bed ranges from zero at the outcrop to slightly over 1,200 feet (366 m) in thickness (pl. 30).

A chemical analysis of the Flowers-Goodale coal from a depth of 53 to 62 feet (16 to 19 m) in drill hole SH-7076, sec, 14, T. 1 S., R. 45 E. in the Cook Creek Reservoir quadrangle shows ash 8.144 percent, sulfur 0.496 percent, and heating value 8,417 Btu per pound (19,578 kJ/kg) on an as-received basis (Matson and Blumer, 1973, p. 121). This heating value converts to about 9,163 Btu per pound (21,313 kJ/kg) on a moist, mineral-matter-free basis, indicating that the

Flowers-Goodale coal in the Cook Creek Reservoir quadrangle is subbituminous C in rank.

Knobloch coal bed

The Knobloch coal bed was described by Bass (1924). The coal bed was named from the Knobloch Ranch and coal mine located in the Birney Day School quadrangle about 20 miles (32 km) southwest of the Cook Creek Reservoir quadrangle.

The Knobloch coal bed is about 20 to 90 feet (6 to 27 m) above the Flowers-Goodale coal bed. The Knobloch coal bed crops out in the western and northern parts of the quadrangle. The coal has been extensively burned along the outcrop, forming a clinker bed which is of considerable extent and thickness in the western part of the quadrangle. The thickness of the Knobloch coal bed increases from 10 to 20 feet (3 to 6 m) in the northern part of the quadrangle to 52 feet (16 m) in the southern part of the quadrangle, as shown by the isopach and structure map (pl. 25). Regionally the bed dips southward at an angle of less than 1 degree, but is slightly warped. Overburden on the Knobloch coal bed ranges from zero at the outcrops to about 1,260 feet (384 m) in thickness (pl. 26).

A chemical analysis of the Knobloch coal from depths of 100 to 106 feet (30 to 32 m) in drill hole SH-7048, sec. 20, T. 1 S., R. 45 E., in the Cook Creek Reservoir quadrangle shows ash 7.154 percent, sulfur 0.016 percent, and heating value 8,417 Btu per pound (19,578 kJ/kg) on an as-received basis (Matson and Blumer, 1973, p. 121). This heating value converts to about 9,065 Btu per pound on a moist, mineral-matter-free basis, indicating that the Knobloch coal in the Cook Creek Reservoir quadrangle 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 25 miles (40 km) west of the Cook Creek

Reservoir quadrangle. In the latter quadrangle, the Sawyer coal bed is 200 to 250 feet (61 to 76 m) above the Knobloch coal bed. In the southern part of the Cook Creek Reservoir quadrangle, the Sawyer coal bed ranges from about 8 to 16 feet (2.4 to 4.9 m) in thickness, as shown by the isopach map, plate 19. In the central part of the quadrangle the Sawyer coal bed splits into two coal beds along a line estimated to occur as shown on plate 19. The lower split of the Sawyer coal bed was mapped by Bass (1932, pl. 3) as his A coal bed. The separation of the two beds increases northeastward to about 60 feet (18 m). The upper split of the Sawyer coal bed ranges from about 10 to 14 feet (3 to 4.3 m) in thickness. The lower split ranges from about 1.2 to 6 feet (0.37 to 1.8 m) in thickness. The coal beds dip southward or southwestward at an angle of less than 1 degree (pl. 20). Overburden on the Sawyer coal bed or its splits ranges from zero at the outcrop to about 960 feet (293 m) in thickness (pls. 21 and 23).

A chemical analysis of the Sawyer coal from a depth of 152 to 162 feet (46 to 49 m) in drill hole SH-7070, sec. 21, T. 2 S., R. 45 E., in the Cook Creek Reservoir quadrangle shows ash 4.914 percent, sulfur 0.008 percent, and heating value 7,814 Btu per pound (18,175 kJ/kg) on an as-received basis (Matson and Blumer, 1973, p. 73). This heating value converts to about 8,218 Btu per pound (19,115 kJ/kg) on a moist, mineral-matter-free basis, indicating that the Sawyer coal, according to this analysis, is slightly below subbituminous C in heating value and is lignite A in rank. However, a chemical analysis of the Sawyer coal from drill hole SH-7066, sec. 36, T. 2 S., R. 45 E., about 1 mile (1.6 km) southeast of the Cook Creek Reservoir quadrangle, in the Coleman Draw quadrangle (Matson and Blumer, 1973, p. 73) shows ash 4.672 percent, sulfur 0.297 percent, and heating value 8,015 Btu per pound (18,643 kJ/kg). This heating value converts to about 8,408 Btu per pound (19,557 kJ/kg) on a moist, mineral-matter-free basis, indicating that the coal at this location is subbituminous C in rank. The heating value of the Sawyer coal in the Cook Creek Reservoir quadrangle is evidently close to 8,300 Btu per pound (19,305 kJ/kg), the dividing value between lignite A and subbituminous C coals. To provide uniformity the Sawyer coal in the Cook Creek Reservoir quadrangle has been assigned a rank of subbituminous C for purposes of calculating resources.

C and D coal beds

The C and D coal beds were first described by Bass (1932, p. 55) from exposures in the Ashland coal field, possibly from the Cook Creek Reservoir or Beaver Creek School quadrangles, although a type locality was not given. In most places the two closely spaced beds have been represented on Bass's map (1932, pl. 3) as a single line. The D coal bed makes up the bulk of the coal mapped as the combined C and D coal beds, as it is the thicker and more widespread of the two. According to Bass (1932, p. 55), the underlying C coal bed is of little economic importance because it contains an abundance of silicified, partly carbonized tree stumps and fragments of logs which destroy the value of the bed. In the Cook Creek Reservoir quadrangle, the bed(s) crop out in the central and southeastern parts of the quadrangle but were not mapped continuously by Bass. As shown by the isopach and structure map (pl. 16), the C and D coal beds range in thickness from about 3 to 6 feet (0.9 to 1.8 m) and dip southward or southeastward at an angle of less than 1 degree. Overburden on the C and D beds ranges from zero at the outcrops to about 800 feet (244 m) in thickness (pl. 17).

There are no known publicly available chemical analyses of the C and D coal beds. For purposes of calculating reserves, the C and D beds have been assigned a rank of subbituminous C in accordance with the rank of closely associated coal beds in this quadrangle.

E coal bed

The E coal bed, or more properly group of beds, was first described by Bass (1932, p. 55) after exposures in the Ashland coal field, possibly from the Cook Creek Reservoir or Beaver Creek School quadrangle, although a type locality was not given. The E bed occurs in the central and southeastern parts of the Cook Creek Reservoir quadrangle (pl. 1) about 50 to 90 feet (15 to 27 m) above the D coal bed. At some places in the quadrangle, only one E bed has been mapped, at other places there are two E beds with 5 to 10 feet (1.5 to 3 m) of separation. The upper E bed ranges from 2.5 to 16 feet (0.76 to 4.9 m) in thickness (pl. 10), and the lower E bed ranges from 2.5 to 8 feet (0.76 to 2.4 m) in thickness (pl. 13). The beds are almost flat but may be slightly warped (pls. 10 and 13). Overburden on the E beds ranges from zero at the outcrops to slightly more than 600 feet (183 m) in thickness (pls. 11 and 14).

There is no known publicly available chemical analysis of the E coal beds. It is assumed that the E beds are similar in rank to the other closely associated coal beds in the Cook Creek Reservoir quadrangle and are 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 in the Ashland coal field. About 10 miles (16 km) to the southeast there is an Upper and Lower Cook coal bed, but in the Cook Creek Reservoir quadrangle, only the Lower Cook coal bed is present. The Lower Cook coal bed crops out about 120 to 190 feet (37 to 58 m) above the E coal beds in the high country around Cook Mountain in the southeast quarter of the quadrangle (pl. 1). This coal bed ranges from about 5 to 12 feet (1.5 to 3.7 m) in thickness and dips southward at an angle of less than 1 degree (pl. 7). Overburden on the Lower Cook coal bed ranges from zero at the outcrop to about 560 feet (171 m) in thickness (pl. 8).

There is no known publicly available chemical analysis of the Cook coal in or reasonably close to the Cook Creek Reservoir quadrangle. For purposes of calculation of reserves, the Cook coal has been assigned a rank of subbituminous C in accordance with the rank of other closely associated coals in this quadrangle.

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 about 10-20 miles (16-32 km) southeast of the Cook Creek Reservoir quadrangle. A type locality was not given. We are here applying the name Ferry to the coal bed which Bass (1932) called the F coal bed in his report on the Ashland coal field, which includes this quadrangle. We feel that Ferry is a better name for this coal bed of regional extent. In the Cook Creek Reservoir quadrangle, the Ferry coal bed crops out about 100 feet (30 m) above the Cook coal bed in the high country around Cook Mountain in the southeast quarter of the quadrangle. Here the Ferry coal bed ranges from about 3 to 7.6 feet (0.9 to 2.3 m) in thickness and dips westward at an angle of less than 1 degree (pl. 4). Overburden on the Ferry coal bed ranges from zero to about 480 feet (146 m) in thickness (pl. 5).

There is no known publicly available chemical analysis of the Ferry coal bed. For purposes of calculation of coal resources, the Ferry coal has been assigned a rank of subbituminous C in accordance with the rank of other closely associated coals in this quadrangle.

Local coal beds

There are a number of thin, local coal beds shown on plates 1 and 3. These local beds are less than 5 feet (1.5 m) thick and consequently 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 Cook Creek Reservoir quadrangle were calculated using data obtained from the coal isopach maps (pls. 4, 7, 10, 13, 16, 19, 25, 28, and 32). 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, Lower Cook, Upper E, Lower E, C and D, Upper Sawyer, Lower Sawyer, Knobloch, Flowers-Goodale, and Terret coal beds are shown on plates 6, 9, 12, 15, 18, 22, 24, 27, 31, and 34, 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 Cook Creek Reservoir quadrangle is calculated to be 1,024.86 million short tons (929.55 million t), and the total Hypothetical tonnage of surface-minable coal is calculated to be 20.87 million short tons (18.93 million t), as shown in table 1. The underground-minable Reserve Base tonnage is 386.84 million short tons (350.86 million t), and the Hypothetical underground-minable tonnage is 248.91 million short tons (225.76 million t), as shown in table 2. All of the 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, 34 percent as Indicated, and 59 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 zero 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, 17, 21, 23, 26, 30, and 33 for the Ferry, Lower Cook, Upper E, Lower E, 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 (less than 500 feet or 152 m of overburden) is shown on the CDP map (pl. 35). Most of the Federal coal land in the Cook Creek Reservoir quadrangle has a high development potential for surface mining. A minor amount of the land in the southern half of the quadrangle has a low or moderate development potential.

The Terret coal bed (pl. 33) has limited areas of high development potential (mining-ratio values 0-10) above the outcrops in valleys in the western and northern parts of the quadrangle. Upslope from these areas are narrow bands of moderate development potential (mining-ratio values 10-15). Still farther upslope is a wide area of low development potential (mining-ratio values greater than 15) extending to the boundary (B) formed by the 5-foot isopach for this coal bed.

The Flowers-Goodale (pl. 30) has rather limited areas of high development potential for surface mining in the northern half of the quadrangle in the valleys extending from the outcrops to the 10 mining-ratio contour. Upslope from these areas are narrow bands of moderate development potential (mining-ratio values 10-15). Still further upslope above these narrow bands is an extensive area of low development potential (mining-ratio values greater than 15) extending to the arbitrarily assigned stripping limit at the 500-foot (152-m) overburden isopach or to the boundary (B) formed by the 5-foot (1.5 m) isopach for the coal bed.

The Knobloch coal bed (pl. 26) has a high development potential (mining-ratio values 0-10) in extensive areas in stream valleys in the northern, western, and southeastern parts of the quadrangle. Upslope from these areas are narrow bands where the coal has a moderate development potential (mining-ratio values 10-15). Still higher are extensive areas of low development potential (mining-ratio values greater than 15).

The Lower Sawyer coal bed (pl. 23) has a development potential for surface mining in only a small area in the east-central part of the quadrangle. In only two very small areas along the eastern quadrangle boundary are there areas of high development potential (mining-ratio values of 0-10) which are bordered by narrow bands of moderate development potential (mining-ratio values of 10-15). Elsewhere in the small eastern area between the 15 mining-ratio contour and the boundary (B) formed by the 5-foot coal isopach the Lower Sawyer coal bed has a low development potential.

The Sawyer coal bed and the upper split of the Sawyer coal bed (pl. 21) have a development potential for surface mining in the south-central, central, and east-central parts, and the southeastern corner of the quadrangle. The western and northern parts of the quadrangle have no development potential because these beds have been removed by erosion there. In most of the southeastern quarter of the quadrangle, except for the southeastern corner, these beds have more than 500 feet (152 m) of overburden and consequently are considered as having no potential for surface mining. The Sawyer coal bed has a wide area of high development potential in the south-central part of the quadrangle between the outcrops and the 10 mining-ratio contour. Elsewhere in the quadrangle the beds have only narrow areas of high development potential on Federal coal land. Wide areas of low development potential extend from the 15 mining-ratio contour to the arbitrarily assigned stripping limit at the 500-foot (152-m) overburden isopach.

The combined C and D coal beds (pl. 17) have two areas with coal development potential for surface mining in the southeast part of the quadrangle between the outcrops and the boundary formed by the 5-foot (1.5-m) coal isopach. Only very narrow areas have high and moderate development potential.

The Lower E coal bed (pl. 14) has a potential for development within five small areas in the central part of the quadrangle. The coal under only small parts of these areas has a high development potential. The Upper E coal bed (pl. 11) in the southeastern quarter of the quadrangle has narrow bands of high development potential between the outcrops and the 10 mining-ratio contour in the high valleys. These bands are succeeded at slightly higher elevations by narrow bands of moderate development potential (mining-ratio values 10-15). These in turn are succeeded by more extensive areas having mining-ratio values greater than 15 and extending to the stripping limit at the 500-foot (152-m) overburden isopach.

The Lower Cook coal bed (pl. 8) and the Ferry coal bed (pl. 5) each have areas of coal development potential for surface mining in the high country in the southeast quarter of the quadrangle. Each of these coal beds has narrow bands of high development potential (mining-ratio values 0-10) and narrow bands of moderate development potential (mining-ratio values 10-15) and more extensive areas of low development potential between the 15 mining-ratio contour and the stripping limit at the 500-foot (152-m) overburden isopach.

About 91 percent of the Federal coal lands in the Cook Creek Reservoir quadrangle has a high development potential for surface mining, 3 percent has a moderate development potential, and 6 percent has a low development potential, as shown on plate 35.

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 (in short tons) by development-potential category for Federal coal lands in the Cook Creek Reservoir quadrangle, Powder River and Rosebud Counties, Montana

[Development potentials are based on mining ratios (cubic yards of overburden/short ton of recoverable coal). To convert short tons to metric tons, multiply by 0.9072]

Coal bed	High development potential (0-10 mining ratio)	Moderate development potential (10-15 mining ratio)	Low development potential (>15 mining ratio)	Total
Reserve Base tonnage				
Ferry	750,000	1,010,000	8,530,000	10,290,000
Cook	2,600,000	2,140,000	8,720,000	13,460,000
E and Upper E	24,050,000	12,390,000	64,320,000	100,760,000
Lower E	720,000	860,000	3,020,000	4,600,000
C and D	3,160,000	2,440,000	13,710,000	19,310,000
Sawyer and Upper Sawyer	16,810,000	11,020,000	40,360,000	68,190,000
Lower Sawyer	0	0	2,690,000	2,690,000
Knobloch	521,180,000	103,490,000	36,190,000	660,860,000
Flowers-Goodale	12,700,000	10,150,000	68,160,000	91,010,000
Terret	7,050,000	4,630,000	42,010,000	53,690,000
Total	589,020,000	148,130,000	287,710,000	1,024,860,000
Hypothetical Resource tonnage				
Knobloch	0	310,000	0	310,000
Flowers-Goodale	0	0	20,560,000	20,560,000
Total	0	310,000	20,560,000	20,870,000
Grand Total	589,020,000	148,440,000	308,270,000	1,045,730,000

Table 2.--Underground-minable coal resource tonnage (in short tons) by development-potential category for Federal lands in the Cook Creek Reservoir quadrangle, Powder River and Rosebud Counties, Montana

[To convert short tons to metric tons, multiply by 0.9072]

Coal bed	High Development potential	Moderate development potential	Low development potential	Total
Reserve Base tonnage				
Cook	0	0	380,000	380,000
E and Upper E	0	0	13,670,000	13,670,000
Lower E	0	0	60,000	60,000
C and D	0	0	2,030,000	2,030,000
Sawyer and Upper Sawyer	0	0	24,030,000	24,030,000
Lower Sawyer	0	0	20,000	20,000
Knobloch	0	0	321,880,000	321,880,000
Flowers-Goodale	0	0	24,770,000	24,770,000
Total	0	0	386,840,000	386,840,000
Hypothetical Resource tonnage				
Knobloch	0	0	193,360,000	193,360,000
Flowers-Goodale	0	0	55,550,000	55,550,000
Total	0	0	248,910,000	248,910,000
Grand Total	0	0	635,750,000	635,750,000

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.

Gilmour, E. H., and Dahl, G. G., Jr., 1967, Montana coal analysis: Montana Bureau of Mines and Geology Special Publication 43, 21 p.

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 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.

Wegemann, C. H., 1910, Notes on the coals of the Custer National Forest, Montana: U.S. Geological Survey Bulletin 381-A, p. 108-114.

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.