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COAL RESOURCE OCCURRENCE AND COAL DEVELOPMENT POTENTIAL MAPS OF THE EPSIE QUADRANGLE, POWDER RIVER COUNTY, MONTANA

[Report includes 25 plates]

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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)	0.9072	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 Epsie quadrangle, Powder River County, Montana, (25 plates; U.S. Geological Survey Open-File Report 79-086). This set of maps was compiled to support the land-use planning work of the Bureau of Land Management in response to the Federal Coal Leasing Amendments Act of 1976 and to provide a systematic inventory of coal resources on Federal coal lands in Known Recoverable Coal Resource Areas (KRCRAs) in the western United States. The inventory includes only those beds of subbituminous coal that are 5 feet (1.5 m) or more thick and under less than 3,000 feet (914 m) of overburden and those beds of lignite that are 5 feet (1.5 m) or more thick and under less than 1,000 feet (305 m) of overburden.

Location

The Epsie 7 1/2-minute quadrangle is near the center of Powder River County, Montana, about 63 miles (101 km) south of Miles City, a town in the Yellowstone River valley of eastern Montana. Miles City is on U.S. Interstate Highway 94 and the main east-west routes of the Burlington Northern and the Chicago, Milwaukee, St. Paul and Pacific Railroad. The quadrangle is 10 miles (16 km) west of Broadus, Montana, a small town in the Powder River valley.

Accessibility

The quadrangle is accessible from Miles City, Montana, by going south on U.S. Highway 312 for a distance of 62 miles (100 km) to its intersection with east-west paved U.S. Highway 212 about 3 miles (4.8 km) northwest of Broadus and then following U.S. Highway 212 westward for a distance of 8 miles (12.9 km) to the eastern boundary of the quadrangle. U.S. Highway 212 proceeds westward across the quadrangle, through Ashland, and connects with U.S. Interstate Highway

90 at Crow Agency, about 15 miles (24 km) south of Hardin, Montana. An improved road connects with U.S. Highway 212 near the northeast corner of the quadrangle and parallels Mizpah Creek southward to its headwaters in the southeast corner of the quadrangle. Unimproved roads and trails provide access to the remainder of the quadrangle.

Physiography

The Epsie quadrangle is within the Missouri Plateau division of the Great Plains physiographic province. The central and northern parts of the quadrangle are drained and dissected by northward-flowing Mizpah Creek and its tributaries. Mizpah Creek flows through the northeastern corner of the quadrangle and joins the Powder River about 55 miles (88 km) north-northeast of the quadrangle. The remainder of the quadrangle is drained by southeastward-flowing tributaries of Cache Creek which joins the Powder River about 5 miles (8 km) southeast of the quadrangle. The Powder River flows northeastward and northward to join the Yellowstone River about 87 miles (140 km) north-northeast of the quadrangle.

In the central and eastern parts of the quadrangle, the relief is moderate; the rounded hills rise about 100 to 300 feet (30 to 91 m) above the valleys. In the western part of the quadrangle, the topography is quite rugged. The narrow, sharp ridges rise 300 to 500 feet (91 to 152 m) and more above the steep-sided valleys.

The lowest point in the quadrangle, with an elevation of 3,300 feet (1,006 m), is along Mizpah Creek at the northeastern corner of the quadrangle. The highest point in the quadrangle is an unnamed hill with an elevation of about 4,140 feet (1,262 m) at the western edge of the quadrangle. Topographic relief in the quadrangle is 840 feet (256 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 about 16 inches (41 cm). The heaviest precipitation is from April to August. The largest average monthly precipitation is during June. Temperatures in eastern Montana range from as low as -50°F (-46°C) to as high as 110°F (43°C). The highest temperatures occur in July and the lowest in January; the mean annual temperature is about 45°F (7°C) (Matson and Blumer, 1973, p. 6).

Land status

The entire Epsie quadrangle lies within the Northern Powder River Basin Known Recoverable Coal Resource Area (KRCRA). There are no National Forest lands within the quadrangle. The Boundary and Coal Data Map (pl. 2) shows the land ownership status. There were no outstanding Federal coal leases or prospecting permits recorded as of 1977.

GENERAL GEOLOGY

Previous work

Warren (1959) mapped all of the Epsie quadrangle as part of the Birney-Broadus coal field. Matson, Dahl, and Blumer (1968) mapped the strippable coal deposits on State land in Powder River County. V. W. Carmichael in Matson and Blumer (1973) mapped the northern part of the quadrangle as part of the Pumpkin Creek coal deposit. Matson and Blumer (1973) mapped the northeastern part of the quadrangle as part of the Broadus coal deposit, and mapped the western part of the quadrangle as part of the Sonnette coal deposit.

Traces of coal bed outcrops shown by previous workers on planimetric maps which lack topographic control have been modified to fit the modern topographic map of the quadrangle.

Stratigraphy

The exposed bedrock units belong to the Tongue River Member, the uppermost member of the Fort Union Formation (Paleocene). The Tongue River Member is made up mainly of yellow to gray sandstone, sandy shale, carbonaceous shale, and coal. Much of the coal has burned, baking the overlying sandstone and shale and forming thick, reddish-colored clinker beds. The upper part of the Tongue River Member has been removed by erosion, leaving about the lower 900 feet (274 m) of the member in the quadrangle.

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 rivers, flood plains, sloughs, swamps, and lakes that occupied the area of 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 content of trace elements by the U.S. Geological Survey, and the results have been 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 rocks found throughout other parts of the western United States.

Structure

The Epsie quadrangle is on the northeastern flank of the Powder River structural basin. Regionally the strata dip westward or southwestward at an angle of less than 1 degree. The regional dip is modified in places by minor local folding (pls. 4, 7, 10, 14, 19, and 22).

COAL GEOLOGY

The coal beds in the Epsie 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 are in the Tongue River Member of the Fort Union Formation. The lowermost, important coal is the Broadus coal bed, which occurs about 120 to 180 feet (37 to 55 m) above the base of the Tongue River Member. The Broadus coal bed is overlain successively by a noncoal interval of about 60 to 160 feet (18 to 49 m), the Knobloch coal bed, a noncoal interval of about 200 to 240 feet (61 to 73 m), the lower split of the Sawyer coal bed, a noncoal interval of about 40 to 60 feet (12 to 18 m), the upper split of the Sawyer coal bed, an essentially noncoal interval of about 110 feet (34 m) containing a thin local coal bed, the Cache coal bed, an essentially noncoal interval of about 110 feet (34 m) containing two thin local coal beds, the Pawnee coal bed, an essentially noncoal interval of about 120 to 160 feet (37 to 49 m) containing a thin local coal bed, the lower split of the Cook coal bed, a noncoal interval of about 40 to 60 feet (12 to 18 m), the upper split of the Cook coal bed, a noncoal interval of about 40 feet (12 m), and the Canyon coal bed.

The coal found along the eastern flank of the Powder River Basin in Montana increases in rank from lignite in the east to subbituminous in the deeper parts of the basin to the west. All available chemical analyses of coal from this and adjacent quadrangles were considered in our decision to assign a rank of lignite A to the coal in this quadrangle.

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).

Broadus coal bed

The Broadus coal bed, first described by Warren (1959, p. 570), derives its name from exposures near the town of Broadus in the Broadus quadrangle about 10 miles (16 km) east of the Epsie quadrangle. The Broadus coal bed occurs about 120 to 180 feet (37 to 55 m) above the base of the Tongue River Member. The Broadus coal bed does not crop out in the Epsie quadrangle, but was penetrated by several drill holes (pls. 1 and 3). The isopach and structure contour map of the Broadus coal bed (pl. 22) shows that the Broadus coal ranges from about 5 to 25 feet (1.5 to 7.6 m) in thickness and dips to the west at an angle of less than 1 degree, although the dip is modified in places by minor, low-relief local folds. Overburden on the Broadus coal bed (pl. 23) ranges from about 140 to 960 feet (43 to 293 m) in thickness.

There is no known, publicly available chemical analysis of the Broadus coal in the Epsie quadrangle. However, a chemical analysis of the Broadus coal from the Peerless mine, sec. 23, T. 4 S., R. 50 E., about 4.5 miles (7.2 km) east of the Epsie quadrangle in the Epsie NE quadrangle, shows ash 6.4 percent, sulfur 0.2 percent, and heating value 7,240 Btu per pound (16,840 kJ/kg) on an as-received basis (Gilmour and Dahl, 1967, p. 16). This heating value converts to about 7,735 Btu per pound (17,992 kJ/kg) on a moist, mineral-matter-free basis, indicating that the Broadus coal at that locality is lignite A in rank. Because of the proximity of that location to the Epsie quadrangle, it is assumed that the coals are similar and the Broadus coal in this quadrangle is also lignite A in rank.

Knobloch coal bed

The Knobloch coal bed was named by Bass (1924) from a small mine on the Knobloch Ranch in the Tongue River valley in the Birney Day School quadrangle, about 34 miles (55 km) west of the Epsie quadrangle. The Knobloch coal bed

occurs about 60 to 160 feet (18 to 49 m) above the Broadus coal bed. The Knoloch coal bed does not crop out in the Epsie quadrangle, but was penetrated by two drill holes (pls. 1 and 3). The isopach and structure contour map of the Knobloch coal bed (pl. 19) shows that the Knobloch coal bed ranges from less than 5 to 10 feet (1.5 to 3 m) in thickness and dips to the west at an angle of less than 1 degree. This dip is modified in places by minor, low-relief folds. Overburden on the Knobloch coal bed (pl. 20) ranges from about 40 to 700 feet (12 to 213 m) in thickness.

There is no known, publicly available chemical analysis of the Knobloch coal in the Epsie quadrangle. A chemical analysis of the Knobloch coal from drill hole FC-6, sec. 29, T. 1 S., R. 48 E., about 15 miles (24 km) north-northwest of the Epsie quadrangle in the Elk Ridge quadrangle, shows ash 6.66 percent, sulfur 0.37 percent, and heating value 7,380 Btu per pound (17,166 kJ/kg) on an as-received basis (Matson and Blumer, 1973, p. 87). This heating value converts to about 7,906 Btu per pound (18,389 kJ/kg) on a moist, mineral-matter-free basis, indicating that the Knobloch coal at that location is lignite A in rank. Because of the proximity of that location to the Epsie quadrangle, it is assumed that the Knobloch coal in the Epsie quadrangle is similar and is lignite A in rank.

Upper and lower splits of the Sawyer coal bed

The Sawyer coal bed was first described by Dobbin (1930, p. 28) from exposures in the Forsyth coal field, possibly in the Rough Draw or Black Spring quadrangles where the Sawyer is well exposed in the Little Wolf Mountains. These quadrangles are about 52 miles (84 km) west-northwest of the Epsie quadrangle.

In the Epsie quadrangle, the lower split of the Sawyer coal bed (the A coal bed of Bass) is about 200 to 240 feet (61 to 73 m) above the Knobloch coal bed and crops out in the northeastern part of the quadrangle (pls. 1 and 3). The isopach map of the lower split of the Sawyer coal bed (pl. 13) shows that the

coal ranges from about 5 to 10 feet (1.5 to 3 m) in thickness. The structure contour map (pl. 14) indicates that the bed dips westward at an angle of less than 1 degree. Overburden on the lower split of the Sawyer coal bed (pl. 17) ranges from 0 feet at the outcrops to about 420 feet (0-128 m) in thickness.

The separation between the lower and upper splits of the Sawyer coal bed ranges from 40 to 60 feet (12 to 18 m). The isopach map (pl. 13) shows that the upper split of the Sawyer coal bed ranges from about 5 to 16 feet (1.5 to 4.9 m) in thickness. The structure contour map (pl. 14) indicates that the coal bed dips westward at an angle of less than 1 degree. Overburden on the upper split of the Sawyer coal bed (pl. 15) ranges from 0 feet at the outcrops to about 480 feet (0-146 m) in thickness.

There is no known, publicly available chemical analysis of coal from either the upper or lower splits of the Sawyer bed in the Epsie quadrangle. However, chemical analyses from drill hole PC-15 from depths of 52 to 64 feet (16 to 19.5 m) and from 112 to 124 feet (34 to 38 m) for the coal of the upper and lower splits, respectively, show ash 6.54 percent, sulfur 0.31 percent, and heating value 7,510 Btu per pound (17,468 kJ/kg) for the upper split, and ash 9.99 percent, sulfur 0.35 percent, and heating value 7,140 Btu per pound (16,607 kJ/kg) for the lower split on an as-received basis (Matson and Blumer, 1973, p. 83). These heating values convert to 8,035 and 7,932 Btu per pound (18,689 and 18,450 kJ/kg), respectively, on a moist, mineral-matter-free basis, indicating that coal from both splits of the Sawyer bed at that locality are lignite A in rank. That drill hole is located in sec. 32, T. 3 S., R. 49 E., about 2 miles (3.2 km) north of the Epsie quadrangle in the Leslie Creek quadrangle. Because of the proximity of that location to the Epsie quadrangle, it is assumed that the coals are similar and that coal of the upper and lower splits of the Sawyer bed in this quadrangle is also lignite A in rank.

Cache coal bed

The Cache coal bed was first described by Warren (1959, p. 572) and named for exposures along Cache Creek in the Yarger Butte and Lonesome Peak quadrangles just south and southeast of the Epsie quadrangle. The Cache coal bed crops out in the southeastern part of the Epsie quadrangle where it occurs about 110 feet (34 m) above the upper split of the Sawyer coal bed. Because the Cache coal bed is less than 5 feet (1.5 m) thick in the Epsie quadrangle, economic resources have not been assigned to it.

Pawnee coal bed

The Pawnee coal bed was first described by Warren (1959, p. 572) from exposures in the Birney-Broadus coal field, Montana, which includes the Epsie quadrangle. The Pawnee coal bed crops out in the western part of the Epsie quadrangle, where it is marked in places by an extensive clinker bed, formed by the burning of the coal. The Pawnee coal bed occurs about 110 feet (34 m) above the Cache coal bed and about 600 to 700 feet (183 to 213 m) above the Broadus coal bed. The isopach and structure contour map (pl. 10) shows that the Pawnee coal bed ranges from 6 to 20 feet (1.8 to 6.1 m) in thickness and dips westward at an angle of less than 1 degree, although this dip is modified in places by minor folding. Overburden on the Pawnee coal bed (pl. 11) ranges from 0 feet at the outcrops to about 440 feet (0-134 m) in thickness.

There is no known, publicly available chemical analysis of the Pawnee coal in the Epsie quadrangle. However, a chemical analysis of the Pawnee coal from a depth of 40 to 56 feet (12 to 17 m) in drill hole SH-7115, sec. 34, T. 4 S., R. 48 E. in the Sonnette quadrangle, about 2 miles (3.2 km) west of the Epsie quadrangle, shows ash 3.877 percent, sulfur 0.191 percent, and heating value 7,228 Btu per pound (16,812 kJ/kg) on an as-received basis (Matson and Blumer, 1973, p. 110). This heating value converts to 7,520 Btu per pound (17,492 kJ/kg) on a

moist, mineral-matter-free basis, indicating that the Pawnee coal at that location is lignite A in rank. Because of the proximity of that location to the Epsie quadrangle, it is assumed that the coals are similar and that the Pawnee coal in this quadrangle is lignite A in rank.

Upper and lower splits of the Cook coal bed

The Cook coal bed was named by Bass (1932, p. 59) for outcrops on the Cook Mountain in the Cook Creek Reservoir quadrangle in the Ashland coal field, which lie about 22 miles (35.4 km) west-northwest of the Epsie quadrangle. Warren (1959, p. 573) recognized an upper bench of the Cook coal bed in the Birney-Broadus coal field which includes the Epsie quadrangle. Matson and Blumer (1972, p. 107 and pl. 25B) recognized two benches in the Cook coal bed in the Sonnette coal deposit which includes the Epsie quadrangle.

In the Epsie quadrangle the lower split of the Cook coal bed occurs about 120 to 160 feet (37 to 49 m) above the Pawnee coal bed. The lower split of the Cook coal bed crops out along the western edge of the quadrangle and is marked by a clinker bed formed by the burning of the coal. The isopach and structure contour map (pl. 7) shows that the lower split of the Cook coal bed ranges from about 1.9 to 6 feet (0.6 to 1.8 m) in thickness and dips eastward at an angle of less than 1 degree. Overburden on the lower split of the Cook coal bed (pl. 8) ranges from 0 feet at the outcrops to about 230 feet (0-70 m) in thickness.

The separation between the lower and upper splits of the Cook coal bed ranges from 40 to 60 feet (12 to 18 m). The upper split of the Cook coal bed crops out along the western edge of the quadrangle and is marked by an extensive clinker bed. The isopach and structure contour map (pl. 4) shows that the upper split of the Cook coal bed ranges from about 3.5 to 16 feet (1 to 4.9 m) in thickness and generally dips to the west, although this dip is modified in places

by local folding. Overburden on the upper split of the Cook coal bed (pl. 5) ranges from 0 feet at the outcrops to about 185 feet (0-56 m) in thickness.

There are no known, publicly available chemical analyses of coal from either the upper or lower split of the Cook bed in the Epsie quadrangle. However, chemical analyses from drill hole SH-7117 from depths of 72 to 82 feet (22 to 25 m) and from 114 to 119 feet (35 to 36 m) for coal of the upper and lower splits of the Cook bed, respectively, show ash 6.500 percent, sulfur 0.736 percent, and heating value 7,186 Btu per pound (16,715 kJ/kg) for the upper split, and ash 8.967 percent, sulfur 1.655 percent, and heating value 7,000 Btu per pound (16,282 kJ/kg) for the lower split, on an as-received basis (Matson and Blumer, 1973, p. 110). These heating values convert to 7,686 and 7,690 Btu per pound (17,878 and 17,887 kJ/kg), respectively, on a moist, mineral-matter-free basis, indicating that coal from the upper and lower splits of the Cook bed is lignite A in rank. This drill hole is located in sec. 7, T. 5 S., R. 48 E., about 4 miles (6.4 km) west of the Epsie quadrangle in the Sonnette quadrangle. Because of the proximity of that location to the Epsie quadrangle, it is assumed that the coals are similar, and that the coal from both splits of the Cook bed in this quadrangle is also lignite A in rank.

Canyon coal bed

The Canyon coal bed is not shown in outcrop on plate 1. However, a preliminary isopach and structure contour map projected into the Epsie quadrangle from the Sonnette quadrangle to the west, showed that the coal was less than 5 feet (1.5 m) thick and was at an elevation of about 4,000 feet (1,219 m), about 40 feet above the upper split of the Cook coal bed. Because the Canyon coal bed is less than 5 feet (1.5 m) thick, it has not been assigned economic coal resources.

Local coal beds

The local coal beds shown on plates 1 and 3 are thin and of very limited extent, 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.

A coal resource classification system has been established by the U.S. Bureau of Mines and the U.S. Geological Survey and published in U.S. Geological Survey Bulletin 1450-B (1976). Coal resource is the estimated gross quantity of coal in the ground that is now economically extractable or that may become so. Resources are classified as either Identified or Undiscovered. Identified Resources are specific bodies of coal whose location, rank, quality, and quantity are known from geologic evidence supported by specific measurements. Undiscovered Resources are bodies of coal which are surmised to exist on the basis of broad geologic knowledge and theory.

Identified Resources are further subdivided into three categories of reliability of occurrence: namely Measured, Indicated, and Inferred, according to their distance from a known point of coal-bed measurement. Measured coal is coal located within 0.25 mile (0.4 km) of a measurement point, 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.

Undiscovered Resources are classified as either Hypothetical or Speculative. Hypothetical Resources are those undiscovered coal resources in beds that may reasonably be expected to exist in known coal fields under known geologic conditions. In general, Hypothetical Resources are located in broad areas of coal

fields where the coal bed has not been observed and the evidence of 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. Speculative Resources are undiscovered resources that may occur in favorable areas where no discoveries have been made. Speculative Resources have not been estimated in this report.

Hypothetical Resources of lignite are in lignite beds which are 5 feet (1.5 m) or more thick, under less than 1,000 feet (305 m) of overburden, but occur 3 miles (4.8 km) or more from a coal-bed measurement.

Reserve Base coal is that economically minable part of Identified Resources from which Reserves are calculated. In this report, Reserve Base coal is the gross amount of Identified Resources that occurs in beds 5 feet (1.5 m) or more thick and under less than 1,000 feet (305 m) of overburden for lignite.

Reserve Base coal may be either surface-minable coal or underground-minable coal. In this report, surface-minable Reserve Base coal is lignite that is under less than 200 feet (61 m) of overburden. In this report, underground-minable Reserve Base coal is lignite that is under more than 200 feet (61 m), but less than 1,000 feet (305 m) of overburden.

Reserves are the recoverable part of Reserve Base coal. In this area, 85 percent of the surface-minable Reserve Base coal is considered to be recoverable (a recovery factor of 85 percent). Thus, these Reserves amount to 85 percent of the surface-minable Reserve Base coal. For economic reasons coal is not presently being mined by underground methods in the Northern Powder River Basin. Therefore, the underground-mining recovery factor is unknown and Reserves have not been calculated for the underground-minable Reserve Base coal.

Tonnages of coal resources were estimated using coal-bed thicknesses obtained from the coal isopach map for each coal bed (see list of illustrations). The coal resources, in short tons, for each isopached coal bed are the product of the acreage of coal (measured by planimeter), the average thickness in feet of the coal bed, and a conversion factor of 1,750 short tons of lignite per acre-foot (12,870 metric tons per hectare-meter). Tonnages of coal in Reserve Base, Reserves, and Hypothetical categories, rounded to the nearest one-hundredth of a million short tons, for each coal bed are shown on the Areal Distribution and Tonnage maps (see list of illustrations).

As shown by table 1, the total tonnage of federally owned, surface-minable Reserve Base coal in this quadrangle is estimated to be 195.28 million short tons (177.15 million t). There is no federally owned, surface-minable Hypothetical coal in the quadrangle. As shown by table 2, the total federally owned, underground-minable Reserve Base coal is estimated to be 781.53 million short tons (709.00 million t). The total federally owned, underground-minable Hypothetical coal is estimated to be 86.43 million short tons (78.41 million t). The total tonnage of surface- and underground-minable Reserve Base coal is 976.81 million short tons (886.16 million t), and the total of surface- and underground-minable Hypothetical coal is 86.43 million short tons (78.41 million t).

About 15 percent of the surface-minable Reserve Base tonnage is classed as Measured, 57 percent as Indicated, and 28 percent as Inferred. About 2 percent of the underground-minable Reserve Base tonnage is Measured, 20 percent is Indicated, and 78 percent is Inferred.

The total tonnages per section for both Reserve Base and Hypothetical coal, including both surface- and underground-minable coal are shown in the northwest corner of the Federal coal lands in each section on plate 2. All numbers on plate 2 are rounded to the nearest one-hundredth of a million short tons.

COAL DEVELOPMENT POTENTIAL

There is a potential for surface-mining in the Northern Powder River Basin in areas where subbituminous coal beds 5 feet (1.5 m) or more thick are overlain by less than 500 feet (152 m) of overburden (the stripping limit), or where lignite beds of the same thickness are overlain by 200 feet (61 m) or less of overburden (the stripping limit). This last thickness of overburden is the assigned stripping limit for surface mining of lignite in this area. Areas having a potential for surface mining were assigned a high, moderate, or low development potential based on their mining-ratio values (cubic yards of overburden per short ton of recoverable coal).

The formula used to calculate mining-ratio values for lignite is:

$$MR = \frac{t_o\,(cf)}{t_c(rf)}$$

where MR = mining ratio
t_o = thickness of overburden, in feet
t_c = thickness of lignite, in feet
rf = recovery factor = 0.85 in this area
cf = conversion factor = 0.922 cu. yds./ short ton for lignite

The mining-ratio values are used to rate the degree of potential that areas within the stripping limit have for surface-mining development. Areas having mining-ratio values of 0 to 10, 10 to 15, and greater than 15 are considered to have high, moderate, and low development potential, respectively. This grouping of mining-ratio values was provided by the U.S. Geological Survey and is based on economic and technological criteria. Mining-ratio contours and the stripping-limit overburden isopach, which serve as boundaries for the development-potential areas, are shown on the overburden isopach and mining-ratio contour plates. Estimated tonnages of surface-minable Reserve Base and Hypothetical coal

resources in each development-potential category (high, moderate, and low) are shown in table 1.

Estimated tonnages of underground-minable coal resources are shown in table 2. Because coal is not presently being mined by underground mining in the Northern Powder River Basin for economic reasons, for purposes of this report all of the underground-minable coal resources are considered to have low development potential.

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). For example, 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. Alternatively, if such a 40-acre (16.2-ha) tract of land contains areas of moderate, low, and no development potential, the entire tract is assigned to the moderate development-potential category for CDP mapping purposes. For practical reasons, the development-potential categories of areas of coal smaller than 1 acre (0.4 ha) have been disregarded in assigning a development potential to the entire 40-acre (16.2-ha) tract.

In areas of moderate to high topographic relief, the area of moderate development potential for surface mining of a coal bed (area having mining-ratio values of 10 to 15) is often restricted to a narrow band between the high and low development-potential areas. In fact, because of the 40-acre (16.2-ha) minimum size of coal development-potential tracts, the narrow band of moderate development-potential area often does not appear on the CDP map because it falls within the 40-acre (16.2-ha) tracts that also include areas of high development

potential. The Coal Development Potential (CDP) map then shows areas of high development potential abutting against areas of low development potential.

The coal development potential for surface-mining methods on Federal coal lands is shown on the Coal Development Potential map (pl. 25). Most of the Federal coal lands in the western part of the quadrangle have a high development potential for surface mining.

The surface-mining potential of the Broadus coal bed (pl. 23) is limited to the extreme northeastern part of the quadrangle. There is an area of high development potential extending from the northeast corner of the quadrangle to the 10 mining-ratio contour or to the 200-foot overburden isopach, the arbitrarily assigned stripping limit in this quadrangle. A wide area of moderate development potential extends from the 10 mining-ratio contour to the 15 mining-ratio contour or to the stripping limit. A wide area of low development potential extends from the 15 mining-ratio contour to the stripping limit. The majority of the Broadus coal in the Epsie quadrangle has no development potential for surface-mining methods, because it is under more than 200 feet (61 m) of overburden.

The Knobloch coal (pl. 20) has a rather limited area of high development potential extending from the northern edge of the quadrangle in the northeast corner to the 10 mining-ratio contour. There is a fairly wide area of moderate development potential between the 10 and 15 mining-ratio contours. A wide area of low development potential extends from the 15 mining-ratio contour to the stripping limit. Most of the Knobloch coal in the Epsie quadrangle is under more than 200 feet (61 m) of overburden and therefore has no development potential for surface-mining methods.

The lower split of the Sawyer coal (pl. 17) has a fairly wide area of high development potential extending from the outcrops to the 10 mining-ratio contour. An equally wide area of moderate development potential extends from the 10

mining-ratio contour to the 15 mining-ratio contour. A very large area of low development potential is found between the 15 mining-ratio contour and the 200-foot overburden isopach. The lower split of the Sawyer coal bed is under more than 200 feet (61 m) of overburden in the northwest corner of the quadrangle, and therefore has no development potential for surface mining in that area.

The upper split of the Sawyer coal bed (pl. 15) has a very wide area of high development potential extending from the outcrops to the 10 mining-ratio contour. A narrower band of moderate development potential extends from the 10 mining-ratio contour to the 15 mining-ratio contour or to the 200-foot (61-m) overburden isopach. In places, a fairly wide band of low development potential extends from the 15 mining-ratio contour to the 200-foot (61-m) overburden isopach. Along the western edge of the quadrangle there is a large area of no development potential for surface mining, because the upper split of the Sawyer coal bed in this area is under more than 200 feet (61 m) of overburden.

The Pawnee coal bed (pl. 11) has a fairly wide band of high development potential for surface mining extending from the outcrops to the 10 mining-ratio contour. A very narrow band of moderate development potential extends from the 10 mining-ratio to the 15 mining-ratio contour or to the 200-foot (61-m) overburden isopach. In places there are areas of low development potential between the 15 mining-ratio contour and the 200-foot (61-m) overburden isopach. A large area of no development potential for surface mining extends from the 200-foot (61-m) overburden isopach to the western edge of the quadrangle.

The lower split of the Cook coal bed (pl. 6) has small areas of high development potential for surface mining extending from the outcrops or the 5-foot coal isopach to the 10 mining-ratio contour. A wider band of moderate development potential is found between the 10 and 15 mining-ratio contours. A large area of low development potential lies beyond the 15 mining-ratio contour to the 200-foot (61-m) overburden

isopach. A small area of no development potential for surface mining is at the western edge of the quadrangle.

The upper split of the Cook coal bed (pl. 5) has wide areas of high development potential for surface mining extending from the outcrops to the 10 mining-ratio contour. A few narrow bands of moderate development potential lie between the 10 and 15 mining-ratio contours. There are two small areas of low development potential beyond the 15 mining-ratio contour.

About 20 percent of the Federal coal lands in the quadrangle has a high development potential for surface mining, 4 percent has a moderate development potential, 8 percent has a low development potential, and 68 percent has no development potential.

Development potential for underground mining and in-situ gasification

Lignite beds 5 feet (1.5 m) or more in thickness lying more than 200 feet (61 m) but less than 1,000 feet (305 m) below the surface 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 for purposes of this report 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, and a Coal Development Potential map for in-situ gasification of coal was not made.

Table 1.--Surface-minable coal resource tonnage (in short tons) by development-potential category for Federal coal lands in the Epsie 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				
Upper Cook	9,560,000	710,000	140,000	10,410,000
Lower Cook	1,240,000	890,000	1,130,000	3,260,000
Pawnee	54,230,000	11,410,000	3,380,000	69,020,000
Upper Sawyer	24,010,000	6,110,000	8,550,000	38,670,000
Lower Sawyer	2,650,000	1,600,000	11,700,000	15,950,000
Knobloch	190,000	4,170,000	10,070,000	14,430,000
Broadus	5,250,000	6,690,000	31,600,000	73,540,000
Total	97,130,000	31,580,000	66,570,000	195,280,000

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

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

Coal bed	High Development potential	Moderate development potential	Low development potential	Total
Reserve Base tonnage				
Pawnee	0	0	42,110,000	42,110,000
Upper Sawyer	0	0	13,210,000	13,210,000
Lower Sawyer	0	0	3,220,000	3,220,000
Knobloch	0	0	54,890,000	54,890,000
Broadus	0	0	668,100,000	668,100,000
Total	0	0	781,530,000	781,530,000
Hypothetical Resource tonnage				
Knobloch	0	0	1,440,000	1,440,000
Broadus	0	0	84,990,000	84,990,000
Total	0	0	86,430,000	86,430,000
Grand Total	0	0	867,960,000	867,960,000

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 analyses: 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.

Matson, R. E., Dahl, G. G., Jr., and Blumer, J. W., 1968, Strippable coal deposits on State land, Powder River County, Montana: Montana Bureau of Mines and Geology Bulletin 69, 81 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.

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.