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COAL RESOURCE OCCURRENCE AND COAL DEVELOPMENT POTENTIAL MAPS OF THE BAY HORSE QUADRANGLE, POWDER RIVER COUNTY, MONTANA, AND CAMPBELL COUNTY, WYOMING

[Report includes 27 plates]

By

Colorado School of Mines Research Institute

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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 Bay Horse quadrangle, Powder River County, Montana, and Campbell County, Wyoming, (27 plates; U.S. Geological Survey Open-File Report 79-782). 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 Bay Horse 7 1/2-minute quadrangle is in south-central Powder River County, Montana, and north-central Campbell County, Wyoming, about 90 miles (145 km) south-southeast of Miles City, Montana, a town in the Yellowstone River valley of eastern Montana, and about 23 miles (37 km) south-southwest of Broadus, Montana, a small town in the Powder River valley. Miles City is on U.S. Interstate Highway 94 and the east-west routes of the Burlington Northern Railroad and the Chicago, Milwaukee, St. Paul and Pacific Railroad. Broadus is on east-west U.S. Highway 212. The quadrangle is about 50 miles (81 km) north of Gillette, Wyoming. Gillette is on U.S. Interstate Highway 90 and the Burlington Northern Railroad.

Accessibility

The quadrangle is accessible from Miles City, Montana, by going south on U.S. Highway 312 to Broadus and then on U.S. Highway 212 for a total of about 82

miles (132 km) to its intersection with State Highway 59 about 4 miles (6.4 km) southeast of Broadus. From this intersection the quadrangle can be reached by following State Highway 59 south about 27 miles (43 km), and then proceeding westward on an improved road for about 7 miles (11.3 km) to the east border of the quadrangle. The quadrangle is also accessible from Broadus by going about 23 miles (37 km) southwestward on an improved road on the south side of the Powder River, then going southeastward about 8 miles (13 km) on an unimproved road along Bay Horse Creek to the west boundary of the quadrangle. The quadrangle is accessible from Gillette, Wyoming, by traveling northward about 62 miles (100 km) on State Highway 59 and then westward about 7 miles (11.3 km) on an improved road to the east border of the quadrangle.

Physiography

The Bay Horse quadrangle is within the Missouri Plateau division of the Great Plains physiographic province. Bay Horse Creek, a tributary of the Powder River, flows northwestward across the quadrangle and is the dominant drainage feature. The valley of Bay Horse Creek is a broad expanse of rolling grassland from 1 to 2 miles (1.6 to 3.2 km) wide. Intricately dissected ridges capped by clinker border the valley. The northeastern part of the quadrangle is less rugged with broad rolling valleys. Butte Creek, which flows northward into the Powder River, drains this portion of the quadrangle. The Powder River flows northeastward about 8 miles (13 km) northwest of the quadrangle. Bowers Creek, in the southeastern part of the quadrangle, drains eastward into the Little Powder River, which is about 7 to 9 miles (11.3 to 14.5 km) east of the quadrangle. The Little Powder River flows northward and joins the Powder River near the town of Broadus. The highest point in the quadrangle, with an elevation of 4,288 feet (1,306 m), is at Bayhorse triangulation station on a hill in the central part of the quadrangle. The lowest point, with an elevation of about 3,580 feet (1,091

m) is in the valley of Bowers Creek in the southeastern corner of the quadrangle. Bay Horse Creek leaves the northwest corner of the quadrangle at only about a 20-foot (6.1-m) higher elevation. Topographic relief in the quadrangle is about 708 feet (216 m).

Climate

The climate of Powder River and Campbell 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 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 Northern Powder River Basin Known Recoverable Coal Resource Area (KRCRA) covers all of the quadrangle except a relatively narrow strip of land along the eastern margin of the quadrangle. The Boundary and Coal Data Map (pl. 2) shows the location of the KRCRA lands and the land ownership status. There are no National Forest lands within the quadrangle. There were no outstanding coal leases or prospecting permits recorded as of 1977.

GENERAL GEOLOGY

Previous work

Bryson and Bass (1973) mapped the quadrangle as part of the Moorhead coal field. Matson and Blumer (1973, pl. 18) mapped the strippable coal beds in the quadrangle as part of the East Moorhead coal deposit.

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

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) and to the underlying Lebo Shale Member of the Fort Union Formation. The Tongue River Member is about 400 to 1,200 feet (122 to 366 m) thick in this quadrangle (Lewis and Roberts, 1978) and consists mainly of yellow sandstone, sandy shale, carbonaceous shale and coal. Coal has burned along outcrops, baking the overlying sandstone and shale and forming thick, reddish-colored clinker beds. The base of the Contact coal bed marks the base of the Tongue River Member.

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.

The Lebo Shale Member consists of dark-gray and brown shale, some beds of siltstone, and some thin, local coal beds. This member is about 250 feet (76 m) thick in this eastern part of the Powder River Basin.

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 Bay Horse quadrangle is on the eastern flank of the Powder River structural basin. The strata, in general, dip westward to southwestward at an angle of about 1 degree or less. In places, this dip is modified by minor folds and faults as shown by the structure contour maps (pls. 5, 8, 12, 15, 18, 21, and 24). Some of the nonconformity in structure may be due to the differential compaction and to irregularities in deposition of the coals and other beds as a result of their continental origin.

COAL GEOLOGY

The coal beds in the Bay Horse 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 mapped coal beds occur in the Tongue River Member of the Fort Union Formation (Paleocene). No commercial coals are known to exist below the Tongue River Member.

The lowermost coal beds in the Bay Horse quadrangle are thin local coal beds which occur in the Lebo Shale Member of the Fort Union Formation. The lowermost named coal bed is the Contact coal bed whose base marks the base of the overlying Tongue River Member. The Contact coal bed is overlain successively by a noncoal interval of 30 to 100 feet (9.1 to 30.5 m), the Broadus coal bed, a noncoal interval of about 15 to 40 feet (4.6 to 12.2 m), the Number 11 coal bed, a mainly noncoal interval of 140 to 300 feet (43 to 91 m) containing local coal beds, the Cache coal bed, a predominantly noncoal interval of about 50 to 200 feet (15 to 61 m) containing several local coal beds, the Pawnee coal bed, a noncoal interval of about 30 feet (9.1 m), the Number 5a coal bed, a noncoal interval of about 40 feet (12 m), the Number 5 coal bed, a noncoal interval of about 80 to 180 feet (24 to 55 m), the upper split of the Cook coal bed, a noncoal interval of about 60 to 120 feet (18 to 36.6 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).

Contact coal bed

The Contact coal bed whose base marks the base of the Tongue River Member crops out in the eastern part of the Bay Horse quadrangle. Because this coal bed is less than 5 feet thick, it has not been assigned economic coal resources.

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 Epsie NE quadrangle about 23 miles (37 km) north-northeast of the Bay Horse quadrangle. In the Bay Horse quadrangle, the Broadus coal bed occurs about 30 to 100 feet (9 to 30 m) above the base of the Tongue River Member. The Broadus coal bed does not crop out in the quadrangle, but was penetrated by a drill hole in the north-central part of the quadrangle. The isopach and structure map of the Broadus coal bed (pl. 24) was constructed by using data from this drill hole and data from adjacent quadrangles. This map shows that the Broadus coal bed ranges from about 5 to 10 feet (1.5 to 3 m) in thickness and, in general, dips westward at an angle of about 1 degree. Overburden on the Broadus coal bed (pl. 25) ranges from about 100 to about 900 feet (30 to 274 m) in thickness.

There is no known, publicly available chemical analysis of the Broadus coal in the Bay Horse quadrangle. However, a chemical analysis of this coal from the Black Diamond mine, sec. 11, T. 5 S., R. 50 E., in the Epsie NE quadrangle about 20 miles (32 km) north of the Bay Horse quadrangle (Bryson and Bass, 1973, p. 33), shows ash 6.5 percent, sulfur 0.3 percent, and heating value 7,380 Btu per pound (17,165 kJ/kg) on an as-received basis. This heating value converts to about 7,893 Btu per pound (18,359 kJ/kg) on a moist, mineral-matter-free basis, indicating that the coal at that location is lignite A in rank. Because of the structural relation of that location to the Bay Horse quadrangle, it is assumed that the Broadus coal in this quadrangle is similar and is also lignite A in rank.

Number 11 coal bed

The Number 11 coal bed was first described by Bryson and Bass (1973, p. 100) from exposures in the Moorhead coal field which includes the Bay Horse quadrangle. The Number 11 coal bed occurs about 15 to 40 feet (4.6 to 12.2 m) above the Broadus coal bed. The Number 11 coal bed does not crop out in the quadrangle nor was it penetrated by drill holes. The isopach and structure contour map (pl. 21) is based entirely on information projected from the Three Bar Ranch quadrangle to the west. This map shows that the Number 11 coal bed ranges in thickness from about 5 to 7 feet (1.5 to 2.1 m) and has a general northwestward dip of less than 0.5 degree. Overburden on the Number 11 coal bed (pl. 22) ranges from about 400 to about 800 feet (122 to 244 m) in thickness.

There is no known, publicly available chemical analysis of the Number 11 coal in the Bay Horse quadrangle. Because other, lower coals in this area are lignite A in rank, the Number 11 coal bed has also been assigned a rank of lignite A.

Cache coal bed

The Cache coal bed was first described by Warren (1959, p. 572) and was named for exposures along Cache Creek in the Lonesome Peak and Yarger Butte quadrangles about 16 miles (26 km) north of the Bay Horse quadrangle. In the Bay Horse quadrangle, the Cache coal bed occurs about 140 to 300 feet (43 to 91 m) above the Broadus coal bed. The Cache coal bed crops out in the eastern part of the quadrangle. The position of the Cache coal bed near the surface is generally marked by a clinker bed formed by the burning of the coal. The isopach and structure contour map (pl. 18) shows that the Cache coal bed ranges from 5 to 20 feet (1.5 to 6.1 m) in thickness and, in general, dips westward at less than 0.5 degree. Overburden on the Cache coal bed (pl. 19) ranges from 0 feet at the outcrops to about 400 feet (0-122 m) in thickness.

The T bed of Matson and Blumer (1973, p. 92) is equivalent to the Cache coal bed as defined in this report. A chemical analysis of the T coal (Matson and Blumer, 1973, p. 93) from a depth of 21 to 30 feet (6.4 to 9.1 m) in coal test hole SH-714, sec. 30, T. 8 S., R. 51 E., in the northeastern part of the Bay Horse quadrangle, shows ash 4.671 percent, sulfur 0.476 percent, and heating value 6,943 Btu per pound (16,149 kJ/kg) on an as-received basis. This heating value converts to about 7,283 Btu per pound (16,941 kJ/kg) on a moist, mineral-matter-free basis, indicating that the Cache coal in the Bay Horse quadrangle is lignite A in rank.

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 lies about 15 miles (24 km) northwest of the Bay Horse quadrangle. The Pawnee coal bed crops out in the northwestern part of the quadrangle and occurs about 50 to 200 feet (15 to 61 m) above the Cache coal bed. The isopach and structure contour map (pl. 15) shows

that the Pawnee coal bed ranges from about 4 to 14 feet (1.2 to 4.3 m) in thickness and, in general, dips westward at an angle of less than 0.5 degree. Overburden on the Pawnee coal bed (pl. 16) ranges from 0 feet at the outcrops to about 300 feet (0-91 m) in thickness.

There is no known, publicly available chemical analysis of the Pawnee coal in or near the Bay Horse quadrangle. Because other coals in this area are lignite A in rank, the Pawnee coal bed has also been assigned the rank of lignite A.

Number 5a coal bed

Bryson and Bass (1973, pl. 1) mapped the Number 5a coal bed in the northwestern part of the Bay Horse quadrangle. This bed occurs about 30 feet (9.1 m) above the Pawnee coal bed. Because the Number 5a coal bed is less than 5 feet thick, it has not been assigned economic coal resources.

Number 5 coal bed

The Number 5 coal bed was first described by Bryson and Bass (1973, p. 91) from exposures in the Moorhead coal field which includes the Bay Horse quadrangle. In the Bay Horse quadrangle, the Number 5 coal bed occurs about 40 feet (12.2 m) above the Number 5a coal bed. The position of the Number 5 coal bed near the surface is generally marked by a clinker bed formed by the burning of the coal. The isopach and structure maps of the Number 5 coal bed (pls. 11 and 12) show that the coal bed ranges from about 3 to 17 feet (0.9 to 5.2 m) in thickness and, in general, dips westward and southward at an angle of less than 1 degree. In places, the general dip is modified by low-relief folds. Overburden on the Number 5 coal bed (pl. 13) ranges from 0 feet at the outcrops to about 300 feet (0-91 m) in thickness.

There is no known, publicly available chemical analysis of the Number 5 coal in the Bay Horse quadrangle. Because other, lower coals in this area are lignite A in rank, the Number 5 coal has also been assigned a rank of lignite A.

Upper split of the Cook coal bed

The Cook coal bed was named by Bass (1932, p. 59) for outcrops on Cook Mountain in the Cook Creek Reservoir quadrangle in the Ashland coal field which lie about 45 miles (72 km) northwest of the Bay Horse quadrangle. Warren (1959, p. 573) recognized an upper bench of the Cook coal bed in the Birney-Broadus coal field a few miles (a few km) northwest of this quadrangle. Matson and Blumer (1973, p. 100, pl. 21) recognized two benches of the Cook coal bed in the Fire Gulch coal deposit about 12 miles (19.3 km) northwest of the Bay Horse quadrangle in the Yarger Butte quadrangle. Bryson and Bass (1973, pl. 1) mapped the Cook (Number 4) coal bed in the Moorhead coal field which includes the Bay Horse quadrangle. A preliminary regional isopach map of the Cook coal bed shows that the Cook (Number 4) coal bed of Bryson and Bass (1973) is the upper split of the Cook coal bed.

In the Bay Horse quadrangle, the upper split of the Cook coal bed occurs about 80 to 180 feet (24 to 55 m) above the Number 5 coal bed. The upper split of the Cook coal bed crops out in the northern part of the quadrangle. The position of the upper split of the Cook bed near the surface is generally marked by a clinker bed formed by the burning of the coal. The isopach and structure contour map (pl. 8) shows that this coal bed ranges from about 10 to 22 feet (3.0 to 6.7 m) in thickness and, in general, dips westward or northwestward at an angle of less than 1 degree. Overburden on the upper split of the Cook coal bed (pl. 9) ranges from 0 feet at the outcrops to about 200 feet (0-61 m) in thickness.

A chemical analysis of coal of the upper split of the Cook coal bed (Matson and Blumer, 1973, p. 99) from a depth of 115 to 125 feet (35 to 38 m) in coal test hole SH-7135, sec. 29, T. 6 S., R. 48 E., in the Hodsdon Flats quadrangle, about 16 miles (26 km) northwest of the Bay Horse quadrangle shows ash 4.738 percent, sulfur 0.258 percent, and heating value 7,350 Btu per pound (17,096 kJ/kg)

on an as-received basis. This heating value converts to about 7,716 Btu per pound (17,946 kJ/kg) on a moist, mineral-matter-free basis, indicating that coal of the upper split of the Cook bed at that location is lignite A in rank. Because of the proximity of that location to the Bay Horse quadrangle, it is assumed that the coal of the upper split of the Cook bed in this quadrangle is similar and is also lignite A in rank.

Canyon coal bed

The Canyon coal bed was first described by Baker (1929, p. 36) from exposures in the northward extension of the Sheridan coal field. Although a type locality was not given, it may be along Canyon Creek in the northern part of the Spring Gulch quadrangle, about 53 miles (85 km) west of the Bay Horse quadrangle. Data on the stratigraphic position of the Canyon coal bed in the Bay Horse quadrangle is very limited, but this bed appears to be about 60 to 120 feet (18 to 37 m) above the upper split of the Cook coal bed. Outcrops of the Canyon coal are limited to a few small isolated tracts in the western part of the quadrangle. The isopach and structure contour maps (pls. 4 and 5), which are based on very limited data, indicate that the Canyon coal bed ranges from 2.3 to 20 feet (0.7 to 6.1 m) in thickness and has a general westward dip of less than 1 degree. In the southwestern part of the quadrangle, the general dip has been modified by low-relief folding. Overburden on the Canyon coal bed (pl. 6) ranges from 0 feet at the outcrops to about 50 feet (0-15 m) in thickness.

There is no known, publicly available chemical analysis of the Canyon coal in the Bay Horse quadrangle. However, a chemical analysis of the Canyon coal (Matson and Blumer, 1973, p. 97) from a depth of 54 to 64 feet (16 to 19 m) in coal test hole SH-7134, sec. 29, T. 6 S., R. 48 E., in the Hodsdon Flats quadrangle, about 16 miles (26 km) northwest of the Bay Horse quadrangle shows ash 5.157 percent, sulfur 0.523 percent, and heating value 7,296 Btu per pound

(16,970 kJ/kg) on an as-received basis. This heating value converts to about 7,693 Btu per pound (17,893 kJ/kg) on a moist, mineral-matter-free basis, indicating that the Canyon coal at that location is lignite A in rank. Because of the proximity of that location to the Bay Horse quadrangle, it is assumed that the coal in this quadrangle is similar and is also lignite A in rank.

Local coal beds

Local coal beds occur at several places in the Bay Horse quadrangle. Because these local beds are thin and of limited areal extent, 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.

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. The coal beds in this part of Montana which borders Wyoming are relatively thin -- ranging from 2 feet (0.6 m) to as much as 30 feet (9.1 m) in thickness. Of the 17 coal beds in this area, most of them average 5 to 16 feet (1.5-4.9 m) in thickness, while only two of them average 21 to 30 feet (6.4 and 9.1 m) in thickness, respectively. Because of the relative thinness of the coal beds in this area, only 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. The 85 percent recovery factor for this area contrasts with the 90 to 95 percent recovery factor prevalent for surface mining found 30 miles (48 km) to the south in Wyoming where the coal beds are 100 to 125 feet (30-38 m) thick. The thicker the coal beds -- the higher the recovery factor can be for surface mining.

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 485.56 million short tons (440.50 million t). As shown by table 2, the total federally owned, underground-minable Reserve Base coal is estimated to be 499.69 million short tons (453.32 million t). The total federally owned, underground-minable Hypothetical coal is estimated to be 17.11 million short tons (15.52 million t). The total tonnage of surface- and underground-minable Reserve Base coal is 985.25 million short tons (893.82 million t), and the total of surface- and underground-minable Hypothetical coal is 17.11 million short tons (15.52 million t).

About 9 percent of the surface-minable Reserve Base tonnage is classed as Measured, 46 percent as Indicated, and 45 percent as Inferred. About 1 percent of the underground-minable Reserve Base tonnage is Measured, 12 percent is Indicated, and 87 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 that the Federal coal lands have for surface-mining methods is shown on the Coal Development Potential map (pl. 27). Most of the Federal coal lands in the quadrangle have a high development potential for surface mining.

The potential surface-mining area for the Broadus coal bed (pl. 25) is confined to the northern part of the map. A very limited area of high and moderate development potential occurs in the northeast portion of the quadrangle. Low development potential is limited to a narrow band between the 15 mining-ratio contour

and the arbitrarily assigned stripping limit of 200 feet (61 m). Most of the Broadus coal bed has no development potential for surface mining.

The Number 11 coal bed (pl. 21) has no potential for surface mining because all of the coal is below the arbitrarily assigned stripping limit of 200 feet 61 m).

The Cache coal bed (pl. 19) has rather extensive areas of high development potential extending from the outcrops to the 10 mining-ratio contour. A narrow band of moderate development potential extends from the 10 mining-ratio contour. A narrow band of low development potential extends from the 15 mining-ratio contour to the arbitrarily assigned stripping limit of 200 feet (61 m). Most of the coal in the quadrangle has no development potential for surface mining.

Potential surface mining of the Pawnee coal bed (pl. 16) is limited to a small area in the northwestern part of the quadrangle. About one-half of this small area has a high development potential. A narrow bed of moderate development potential lies between the 10 and 15 mining-ratio contours. The remainder of the area has a low mining potential except in a few localities where the overburden is greater than 200 feet (61 m) and the coal has no development potential.

The Number 5 coal bed (pl. 13) has extensive areas of high development potential for surface mining extending from the outcrops to the 10 mining-ratio contour. Narrow bands of moderate development potential parallel the high development potential and lie between the 10 and 15 mining-ratio contours. Most of the remainder of the coal has a low development potential. A few tiny areas of no development potential occur beneath the crests of the highest hills.

The surface-mining potential of the upper split of the Cook coal bed (pl. 9) is limited to a small area in the northwestern part of the quadrangle and a few isolated tracts. Most of the upper split of the Cook coal bed has a high development potential. A few tiny areas have a moderate development potential.

The Canyon coal bed surface-mining potential (pl. 6) consists of a few small isolated tracts of high development potential.

About 71 percent of the Federal coal lands in the quadrangle has a high development potential for surface mining, 14 percent has a moderate development potential, 5 percent has a low development potential, and 10 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 Bay Horse quadrangle, Powder River County, Montana, and Campbell County, Wyoming

[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				
Canyon	2,700,000	0	0	2,700,000
Upper Cook	22,600,000	5,620,000	670,000	28,890,000
Number 5	93,350,000	28,720,000	13,030,000	135,100,000
Pawnee	11,920,000	4,340,000	5,990,000	22,250,000
Cache	143,210,000	98,950,000	39,830,000	281,990,000
Broadus	1,690,000	6,030,000	6,910,000	14,630,000
Total	275,470,000	143,660,000	66,430,000	485,560,000

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

[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				
Upper Cook	0	0	80,000	80,000
Number 5	0	0	6,050,000	6,050,000
Pawnee	0	0	8,420,000	8,420,000
Cache	0	0	337,250,000	337,250,000
Number 11	0	0	52,070,000	52,070,000
Broadus	0	0	95,820,000	95,820,000
Total	0	0	499,690,000	499,690,000
Hypothetical Resource tonnage				
Broadus	0	0	17,110,000	17,110,000
Total	0	0	17,110,000	17,110,000
Grand Total	0	0	516,800,000	516,800,000

REFERENCES

Baker, A. A., 1929, The northward extension of the Sheridan coal field, Big Horn and Rosebud Counties, Montana: U.S. Geological Survey Bulletin 806-B, p. 15-67.

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

Bryson, R. P., 1952, The Coalwood coal field, Powder River County, Montana: U.S. Geological Survey Bulletin 973-B, p. 23-106.

Bryson, R. P., and Bass, N. W., 1973, Geology of the Moorhead coal field, Powder River, Big Horn, and Rosebud Counties, Montana: U.S. Geological Survey Bulletin 1338, 116 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.

Lewis, B. D., and Roberts, R. S., 1978, Geology and water-yielding characteristics of rocks of the northern Powder River Basin, southeastern Montana: U.S. Geological Survey Miscellaneous Geologic Investigations Map 1-847-D.

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.

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.