UNITED STATES DEPARTMENT OF THE INTERIOR

GEOLOGICAL SURVEY

Text to accompany:

Open-File Report 79-787

1979

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

[Report includes 30 plates]

By

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[Plates are in pocket]

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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 Moorhead quadrangle, Powder River County, Montana, and Campbell County, Wyoming, (30 plates; U.S. Geological Survey Open-File Report 79-787). 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 Moorhead 7 1/2-minute quadrangle is mainly in south-central Powder River County, Montana. A narrow strip about 150 feet (46 m) wide along the southern border of the quadrangle is in Campbell County, Wyoming. The quadrangle is 30 miles (48 km) southwest of Broadus, Montana; about 50 miles (80 km) north-northwest of Gillette, Wyoming; and 55 miles (88 km) east-northeast of Sheridan, Wyoming. The nearest railroad is the Burlington Northern Railroad, about 24 miles (38.6 km) southwest of the quadrangle near Kendrick, Wyoming.

Accessibility

The Moorhead quadrangle is accessible from Broadus, Montana, by going southwestward about 32 miles (51 km) on the graveled Powder River Road in the Powder River valley to the northern border of the quadrangle. The quadrangle is accessible from Sheridan, Wyoming, by traveling generally eastward on U.S. Highways 14 and 16 about 52 miles (84 km) to the graveled Powder River Road and then northward on this road 23 miles (37 km) to the western border of the quadrangle. The quadrangle is accessible from Gillette, Wyoming, by traveling generally northward on U.S. Highways 14 and 16 about 31 miles (50 km) to the Recluse-Bitter Creek Road and then northward and northwestward on this road about 24 miles (38.6 km) to the southern border of the quadrangle.

Physiography

The Moorhead quadrangle is within the Missouri Plateau Division of the Great Plains physiographic province. The plateau, formed by nearly horizontal sedimentary strata differing in their resistance to erosion, has been deeply and intricately dissected by the Powder River and its tributaries. The Powder River flows northeastward in a meandering course across the northwestern part of the quadrangle in a deep, mainly steep-sided valley. The flood plain ranges from 0.5 to 0.75 mile (0.8 to 1.2 km) in width. The intermittent tributaries: Bitter, Dry, Jenkins, Bootjack, and Buffalo Creeks, flow toward the Powder River from the southeast. Bitter and Buffalo Creeks have wide grass-covered valleys flanked by high rugged hills and ridges; the other tributaries are in narrow steep-sided valleys. Much of the land surface is steep-sided bare ridges and hills capped by reddish-colored clinker beds formed by burning of coal beds. Pine trees grow on the clinker outcrops and along the margins of the high flat-topped mesas. The highest elevation in the quadrangle, about 4,160 feet (1,268 m), is on an unnamed ridge near the southeastern corner of the quadrangle. The lowest elevation, about 3,300 feet (1,006 m), is along the Powder River at the northern edge of the quadrangle. Topographic relief in the quadrangle is about 860 feet (262 m).

Climate

The climate of Powder River County, Montana, 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 Boundary and Coal Data Map (pl. 2) shows the land ownership status within the Moorhead quadrangle. All of the quadrangle is within the Northern Powder River Basin Known Coal Resource Area (KRCRA). The Federal government owns most of the coal rights. There are no National Forest lands within the quadrangle. There were no outstanding Federal coal leases or prospecting permits recorded as of 1977.

GENERAL GEOLOGY

Previous work

Olive (1957, pl. 1) mapped the Spotted Horse coal field, Sheridan and Campbell Counties, Wyoming, which includes a very small area of the southern part of the Moorhead quadrangle. Bryson and Bass (1973, pl. 1) mapped all of the Moorhead quadrangle as part of the Moorhead coal field.

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 in the Moorhead quadrangle is shown on the Coal Data Sheet (pl. 3) of the CRO maps. The exposed bedrock units belong to the upper and middle parts of 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 near the surface of the land, 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, but the remaining lower part is as much as 1,400 feet (427 m) thick (Lewis and Roberts, 1978).

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 Moorhead quadrangle is in the east-central part of the Powder River structural basin. The strata, in general, dip southwestward at an angle of less than 1 degree. In places the regional structure is modified by low-relief folds, as shown by the structure contour maps on top of the coal beds (pls. 4, 7, 10, 13, 17, 20, 23, and 27). Some of the nonuniformity in stucture may be due to 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 Moorhead 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 upper and middle parts of the Tongue River Member of the Fort Union Formation (Paleocene). No commercial coals are known to exist below the Tongue River Member.

The lowermost recognized coal bed is the Cache coal bed which occurs about 750 feet (229 m) above the base of the Tongue River Member. The Cache coal bed is overlain successively by a predominantly noncoal interval of about 55 to 70 feet (17 to 21 m) containing a local coal bed, the Number 8 coal bed, a noncoal interval of about 30 feet (9 m), the Number 7 coal bed, a predominantly noncoal interval of about 40 to 60 feet (12 to 18 m) containing a local coal bed, the Pawnee coal bed, a predominantly noncoal interval of about 30 to 90 feet (9 to 27 m) containing a local coal bed, the Number 5a coal bed, a predominantly noncoal interval of about 20 to 150 feet (6 to 46 m) containing a local coal bed, the Number 5 coal bed, a predominantly noncoal interval of about 35 feet (11 m) containing a local coal bed, the Number 4b coal bed, a predominantly noncoal interval of about 20 to 160 feet (6 to 49 m) containing a local coal bed, the lower split of the Cook coal bed, a predominantly noncoal interval of about 30 to 120 feet (9 to 37 m) containing a local coal bed, the upper split of the Cook coal bed, a predominantly noncoal interval of about 70 to 200 feet (21 to 61 m) containing a local coal bed, the Canyon coal bed, a predominantly noncoal interval of about 40 to 120 feet (12 to 37 m) containing a local coal bed, the Dietz coal bed, a noncoal interval of about 40 to 180 feet (12 to 55 m), and the Anderson 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. The rank of coal is controlled by the amount of compaction to which the coal is subjected. The compaction is a result of the original depth of burial of the coal (thickness of overlying overburden) and of the degree of tectonic (mountain-building) activity to which the coal has been subjected. The eastern flank of the Powder River Basin has not been subjected to very much squeezing of sediments produced by tectonic activity so that the rank of coal there is primarily related to the original depth of burial (thickness of overburden) to which the coal has been subjected. Lignite A is a coal that has a heating value of 6,300 to 8,300 Btu per pound (14,654 to 19,306 kJ/kg) on a moist, mineral-matter-free basis. Subbituminous C coal has a heating value of 8,300 to 9,500 Btu per pound (19,306 to 22,097 kJ/kg) on a moist, mineral-matter-free basis.

All available analyses of the Broadus coal bed, the stratigraphically lowermost coal bed of importance in this area, were considered in making our decision to assign a rank of subbituminous C to the Broadus coal near this quadrangle. Overlying coal beds in this quadrangle grade upward into increasingly lower ranks of coal (coal having lower Btu values per pound of coal on a moist, mineral-matter-free basis) as the coal is less and less compacted because of decreasing amounts of overburden. Several of the overlying coal beds in this quadrangle, which are stratigraphically higher than the Broadus coal bed, have been determined to be lignite in rank. However, early in this mapping project to expedite the calculation of resource tonnage and the evaluation of development potential for surface mining of the near-surface coal beds, it was arbitrarily decided by us to assign a rank of subbituminous C to all of the coal beds above the Broadus in this quadrangle. Consequently, we have used the 500-foot (152-m) stripping limit (which the USGS has arbitrarily assigned for multiple beds of subbituminous coal in this area of Montana) in this quadrangle for all of the coal beds above the Broadus even though our subsequent detailed work has indicated that the 200-foot (61-m) stripping limit assigned for lignite beds in this area should have been used for the upper coal beds.

It is recommended that the 200-foot (61-m) stripping limit and the lignite weight-conversion factor should be used in any future revisions of the maps and coal tonnage calculations in this quadrangle. The use of the 200-foot (61-m) stripping limit will produce a more conservative and realistic picture of the surface-mining potential of the various coal beds 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).

Cache coal bed

The Cache coal bed was first described by Warren (1959, p. 572) and named for exposures along Cache Creek in the Lonesome Peak and Yarger Butte quadrangles about 20 miles (32 km) northeast of the Moorhead quadrangle. The Cache coal bed does not crop out in the Moorhead quadrangle but has been penetrated by an oil-and-gas test hole. It occurs about 750 feet (229 m) above the base of the Tongue River Member of the Fort Union Formation. The isopach and structure contour maps (pls. 26 and 27) show that the Cache coal bed ranges from 4 to 15 feet (1.2 to 4.6 m) in thickness and has a general westward dip of less than half a degree that is modified by a broad, low-relief syncline near the center of the quadrangle. Overburden on the Cache coal bed (pl. 28) ranges from about 50 to 600 feet (15 to 183 m).

There are no known, publicly available chemical analyses of the Cache coal in the Moorhead quadrangle. However, a chemical analysis of this coal from a depth of 50 to 60 feet (15 to 18 m) in drill hole SH-716 (Matson and Blumer, 1973, p. 93), sec. 36, T. 8 S., R. 50 E., in the Bay Horse quadrangle about 11 miles (18 km) east of the Moorhead quadrangle shows ash 5.213 percent, sulfur 0.360 percent, and heating value 7,592 Btu per pound (17,659 kJ/kg) on an as-received basis. This heating value converts to about 8,009 Btu per pound (18,630 kJ/kg) on a moist, mineral-matter-free basis, indicating that the Cache coal in the Bay Horse quadrangle is lignite A in rank. However, because the Moorhead quadrangle is closer to the deeper part of the basin, the coal in the Moorhead quadrangle is likely to be higher in rank and to be subbituminous C in rank.

Number 8 coal bed

The Number 8 coal bed was first described by Bryson and Bass (1973, p. 82) from exposures in the Bloom Creek quadrangle about 9 miles (14 km) north of the Moorhead quadrangle. The Number 8 coal bed occurs about 55 to 70 feet (17 to 21 m) above the Cache coal bed in the Moorhead quadrangle. Because this coal bed is less than 5 feet (1.5 m) in thickness, economic resources have not been assigned to it.

Number 7 coal bed

The Number 7 coal bed was first described by Bryson and Bass (1973, p. 82) from exposures on the divide between the Powder River and Bay Horse Creek in the Huckins School quadrangle about 5 miles (8 km) northeast of the Moorhead quadrangle. The Number 7 coal bed occurs about 30 feet (9 m) above the Number 8 coal bed in the Moorhead quadrangle. Because this coal bed is less than 5 feet (1.5 m) in thickness, 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 in Montana, possibly from the Epsie quadrangle about 20 miles (32 km) north-northeast of the Moorhead quadrangle, or possibly from exposures along Pawnee Creek in the Birney Day School quadrangle about 35 miles (56.3 Km) northwest of the Moorhead quadrangle.

The Pawnee coal bed occurs about 40 to 60 feet (12 to 18 m) above the Number 7 coal bed. The isopach and structure contour map (pl. 23) shows that the Pawnee coal bed ranges from about 4 to 13 feet (1.2 to 4 m) in thickness and has a general southward dip of less than half a degree. In places the general dip is modified by low-relief folding. Overburden on the Pawnee coal bed ranges from 0 feet at the outcrops to about 650 feet (0-198 m) in thickness.

There are no known, publicly available chemical analyses of the Pawnee coal in the Moorhead quadrangle. However, a chemical analysis of the Pawnee coal (Matson, Dahl, Jr., and Blumer, 1968, p. 19) from a core sample in sec. 36, T. 5 S., R. 48 E., in the Yarger Butte quadrangle about 16 miles (26 km) north of the Moorhead quadrangle, shows ash 6 percent, sulfur 0.2 percent, and heating value 7,650 Btu per pound (17,794 kJ/kg) on an as-received basis. This heating value converts to about 8,138 Btu per pound (18,930 kJ/kg) on a moist, mineral-matter-free basis, indicating that the Pawnee coal in the Yarger Butte quadrangle is high lignite A in rank. Because of the proximity of that location to the Moorhead quadrangle, it is assumed that the Pawnee coal in the Moorhead quadrangle is similar and is also lignite A or possibly subbituminous C in rank.

Number 5a coal bed

The Number 5a coal bed was first described by Bryson and Bass (1973, p. 103) from exposures of coal in the Bear Skull Mountain quadrangle about 15 miles (24 km) northeast of the Moorhead quadrangle. The Number 5a coal bed occurs about 30 to 90 feet (9 to 27 m) above the Pawnee coal bed in the Moorhead quadrangle. The isopach and structure contour map (pl. 20) shows that the Number 5a coal bed ranges from about 3 to 5 feet (0.9 to 1.2 m) in thickness and has a general northwestward dip of less than half a degree. Overburden on the Number 5a coal bed (pl. 21) ranges from 0 feet at the outcrops to about 560 feet (0-171 m) in thickness.

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

Number 5 coal bed

The Number 5 coal bed was first described by Bryson and Bass (1973, p. 71) from exposures of coal in the Moorhead coal field which includes the Moorhead quadrangle. The Number 5 coal bed crops out in the western and northwestern parts of the quadrangle and occurs about 20 to 150 feet (6 to 46 m) above the Number 5a coal bed in the Moorhead quadrangle. The isopach and structure contour maps (pls. 16 and 17) show that the Number 5 coal bed ranges from about 2 to 12 feet (0.6 to 3.7 m) in thickness and has a general northwestward dip of less than half a degree. In places the general dip is modified by low-relief folding. Overburden on the Number 5 coal bed (pl. 18) ranges from 0 feet at the outcrops to about 550 feet (0-168 m) in thickness.

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

Number 4b coal bed

The Number 4b coal bed was first described by Bryson and Bass (1973, p. 77) from exposures of coal in the Moorhead coal field which includes the Moorhead quadrangle. In this quadrangle the Number 4b coal bed occurs about 35 feet (11 m) above the Number 5 coal bed. Because this coal bed is less than 5 feet (1.5 m) in thickness, economic resources have not been assigned to it.

Upper and lower splits of the Cook coal bed

The Cook coal bed was first described by Bass (1932, p. 59) from exposures in the Cook Creek Reservoir quadrangle about 40 miles (64 km) north-northwest of the Moorhead quadrangle. Warren (1959, p. 573) recognized the upper split of the

Cook coal bed in the Birney-Broadus coal field about 10 miles (16 km) north of the Moorhead quadrangle. Bryson and Bass (1973, pl. 1) mapped the Cook (Number 4) coal bed in the Moorhead coal field, which includes the Moorhead 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 Moorhead quadrangle, the lower split of the Cook coal bed (Number 4a of Bryson and Bass, 1973) occurs about 30 to 80 feet (9 to 24 m) above the Number 4b coal bed. The isopach and structure contour map (pl. 13) shows that the lower split of the Cook coal bed ranges from about 2 to 11 feet (0.6 to 3.3 m) in thickness and has a general southwestward dip of less than 1 degree. Overburden on the lower split of the Cook coal bed ranges from 0 feet at the outcrops to about 440 feet (0-134 m) in thickness.

In the Moorhead quadrangle, the upper split of the Cook coal bed occurs about 30 to 120 feet (9 to 37 m) above the lower split of the Cook coal bed. The isopach and structure contour map (pl. 10) shows that the upper split of the Cook coal bed ranges from about 3 to 12 feet (0.9 to 3.7 m) in thickness and has a general southwestward dip of less than half a degree. In places the general dip is modified by low-relief folding. Overburden on the upper split of the Cook coal bed ranges from 0 feet at the outcrops to about 360 feet (0-110 m) in thickness.

There is no known, publicly available chemical analysis of the Cook coal from the Moorhead quadrangle. However, a chemical analysis of the Cook coal (Matson and Blummer, 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 11 miles (18 km) north of the Moorhead quadrangle shows ash 4.738 percent, sulfur 0.258 percent, and heating value 7,530 Btu per pound (17,515 kJ/kg) on an as-received basis. This heating value converts to about 7,904 Btu per pound (18,386 kJ/kg) on a moist, mineral-matter-free basis, indicating that the Cook coal in the Hodsdon Flats quadrangle is lignite A in rank. Because of the proximity of that location to the Moorhead quadrangle and the close stratigraphic relationship of the upper and lower splits of the Cook coal bed, it is assumed that the coals are similar and that the splits of the Cook coal bed in the Moorhead quadrngle are 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 42 miles (68 km) west of the Moorhead quadrangle. The Canyon coal bed occurs about 70 to 200 feet (21 to 61 m) above the upper split of the Cook coal bed in the Moorhead quadrangle. The isopach and structure contour map (pl. 7) shows that the Canyon coal bed ranges from about 5 to 19 feet (1.5 to 5.8 m) in thickness and has a general southwestward dip of less than 1 degree. In places the general dip is modified by low-relief folding. Overburden on the Canyon coal bed (pl. 8) ranges from 0 feet at the outcrops to about 250 feet (0-76 m) in thickness.

There are no known, publicly available chemical analyses of the Canyon coal in the Moorhead quadrangle. However, a chemical analysis of the Canyon coal (Matson and Blumer, 1973, p. 96) 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 11 miles (18 km) north of the Moorhead 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 in the Hodsdon Flats quadrangle is lignite A in rank. Because of the proximity of that location to the Moorhead quadrangle, it is assumed that the Canyon coal bed in the quadrangle is similar and is also lignite A in rank.

Dietz coal bed

The Dietz coal bed was first described by Taff (1909, p. 129-140) from exposures in abandoned coal mines at and near Dietz, Wyoming, in the Sheridan quadrangle about 53 miles (85 km) west-southwest of the Moorhead quadrangle. In the Moorhead quadrangle, the Dietz coal bed occurs about 40 to 120 feet (12 to 37 m) above the Canyon coal bed. In most places the Dietz coal bed has burned, forming a clinker bed that caps the hills. The isopach and structure contour map (pl. 4) shows that the Dietz coal bed ranges from about 18 to 23 feet (5.5 to 7 m) in thickness. The structural information shown on the map is very limited, but a regional structure map shows that the coal strata have a general southwestward dip of less than 1 degree. Overburden on the Dietz coal bed ranges from about 0 feet at the outcrops to about 150 feet (0-46 m) in thickness.

There is no known, publicly available chemical analysis of the Dietz coal in the Moorhead quadrangle. Because other coals in the area are lignite A in rank, the Dietz coal has also been assigned a rank of lignite A.

Anderson coal bed

The Anderson coal bed was first described by Baker (1929, p. 35) from exposures in the northward extension of the Sheridan coal field, probably along Anderson Creek in the southern part of the Spring Gulch quadrangle, about 42 miles (68 km) west of the Moorhead quadrangle.

In the Moorhead quadrangle, the Anderson coal bed is represented by a clinker bed which occurs about 40 to 180 feet (12 to 55 m) above the Dietz coal bed. The Anderson coal bed has been entirely burned in the Moorhead quadrangle.

Local coal beds

Local coal beds occur at several places in the Moorhead quadrangle (pls. 1 and 3). Because these coal beds are thin and of limited 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.

For purposes of this report, Hypothetical Resources of subbituminous coal are in coal beds which are 5 feet (1.5 m) or more thick, under less than 3,000 feet (914 m) of overburden, but occur 3 miles (4.8 km) or more from a coal-bed measurement. 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 3,000 feet (914 m) of overburden for subbituminous coal or 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 subbituminous coal that is under less than 500 feet (152 m) of overburden or lignite that is under less than 200 feet (61 m) of overburden. In this report, underground-minable Reserve Base coal is subbituminous coal that is under more than 500 feet (152 m), but less than 3,000 feet (914 m) of overburden, or 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 to 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 1,770 short tons of subbituminous coal per acre-foot (13,018 metric tons per hectare-meter) or 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 506.52 million short tons (459.51 million t). The total tonnage of federally owned, surface-minable Hypothetical coal is estimated to be 7.83 million short tons (7.10 million t). As shown by table 2, the total federally owned, underground-minable Reserve Base coal is estimated to be 52.05 million short tons (47.22 million t). The total federally owned, underground-minable Hypothetical coal is estimated to be 2.66 million short tons (2.41 million t). The total tonnage of surface- and underground-minable Reserve Base coal is 558.57 million short tons (506.73 million t), and the total of surface- and underground-minable Hypothetical coal is 10.49 million short tons (9.52 million t).

About 7 percent of the surface-minable Reserve Base tonnage is classed as Measured, 33 percent as Indicated, and 60 percent as Inferred. About 0 percent of the underground-minable Reserve Base tonnage is Measured, 5 percent is Indicated, and 95 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 thickness of overburden is the assigned stripping limit for surface mining of multiple beds of subbituminous coal 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 coal is:

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

where MR = mining ratio
t_o = thickness of overburden, in feet
t_c = thickness of coal, in feet
rf = recovery factor = 0.85 in this area
cf = conversion factor = 0.911 cu. yds./short ton for subbituminous coal or 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 or 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. 30).

The Cache coal bed (pl. 28) has development potential for surface mining in the southwestern part of the quadrangle. Small areas of high development potential occur along the Powder River and its tributaries and extend up the slopes to the 10 mining-ratio contour. Limited areas of moderate development potential occur as narrow bands between the 10 and 15 mining-ratio contours. Large areas of low development potential extend from the 15 mining-ratio up the slopes to the 500-foot (152-m) overburden contour, the stripping limit. Large areas of no development potential for surface mining extend from the 500-foot (152-m) overburden isopach to the crests of the highest hills.

The Number 8 and Number 7 coal beds (pls. 1 and 3) have no development potential for surface mining because the coal beds are less than 5 feet (1.5 m) in thickness.

The Pawnee coal bed (pl. 24) has potential for surface mining in the northeastern and northwestern parts of the quadrangle. Small areas of high development potential extend from the outcrops up the slopes to the 10 mining-ratio contour. Very small areas of moderate development potential occur as narrow bands between the 10 and 15 mining-ratio contours. Small areas of low development potential for surface mining extend from the 15 mining-ratio contour up the slopes to the 500-foot (152-m) overburden isopach, the stripping limit.

The Number 5a coal bed (pl. 21) has development potential for surface mining in a small area in the southwestern part of the quadrangle. Very small areas of high development potential extend from the outcrops up the slopes to the 10 mining-ratio contour. Very small areas of moderate development potential occur as very narrow bands between the 10 and 15 mining-ratio contours. Larger areas of low development potential for surface mining extend from the 15 mining-ratio contour to the 500-foot (152-m) overburden isopach, the stripping limit.

The Number 5 coal bed (pl. 18) has development potential for surface mining in the eastern and northwestern parts of the quadrangle. Relatively large areas of high development potential extend from the coal boundary up the stream valleys to the 10 mining-ratio contour. Relatively large areas of moderate development potential occur as narrow bands between the 10 and 15 mining-ratio contours. Very large areas of low development potential extend from the 15 mining-ratio contour and the coal boundary under the crests of the highest hills.

The lower split of the Cook coal bed (pl. 14) has development potential for surface mining in the southern part of the quadrangle. Small areas of high development potential extend from the outcrops up the stream valleys to the 10 mining-ratio contour. Very small areas of moderate development potential occur as very narrow bands between the 10 and 15 mining-ratio contours. Relatively large areas of low development potential extend from the 15 mining-ratio contour under the crests of the highest hills.

The upper split of the Cook coal bed (pl. 11) has development potential for surface mining in several areas scattered throughout the quadrangle. Small areas of high development potential extend from the outcrops up the stream valleys to the 10 mining-ratio contour. Small areas of moderate development potential occur as very narrow bands between the 10 and 15 mining-ratio contours. Large areas of low development potential extend from the 15 mining-ratio contour up the slopes under the crests of the highest hills.

The Canyon coal bed (pl. 8) has development potential for surface mining over about one-half of the quadrangle. Large areas of high development potential extend from the outcrop up the stream valleys to the 10 mining-ratio contour. Relatively large areas of moderate development potential occur as bands between the 10 and 15 mining-ratio contours. Small areas of low development potential extend from the 15 mining-ratio contour under the crests of the highest hills.

The Dietz coal bed (pl. 5) has development potential for surface mining in a small area in the southern part of the quadrangle. All of the Dietz coal has high development potential.

About 69 percent of the Federal coal land in the quadrangle has a high development potential for surface mining, 3 percent has a moderate development potential, 11 percent has a low development potential, and 17 percent has no development potential.

Development potential for underground mining and in-situ gasification

Subbituminous 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 and lignite beds of the same 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 Moorhead 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				
Dietz	17,920,000	0	0	17,920,000
Canyon	76,690,000	28,180,000	14,820,000	119,690,000
Upper Cook	8,070,000	5,420,000	29,340,000	42,830,000
Lower Cook	6,670,000	3,130,000	16,510,000	26,310,000
Number 5	20,320,000	12,490,000	107,190,000	140,000,000
Number 5a	1,300,000	720,000	3,400,000	5,420,000
Pawnee	10,770,000	2,720,000	20,080,000	33,570,000
Cache	17,550,000	11,110,000	92,120,000	120,780,000
Total	159,290,000	63,770,000	283,460,000	506,520,000
Hypothetical Resource tonnage				
Cache	260,000	510,000	7,060,000	7,830,000
Total	260,000	510,000	7,060,000	7,830,000
Grand Total	159,550,000	64,280,000	290,520,000	514,350,000

Table 2.--Underground-minable coal resource tonnage (in short tons) by development-potential category for Federal lands in the Moorhead quadrangle, Powder River County, Montana, and Campbell 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				
Number 5	0	0	650,000	650,000
Pawnee	0	0	4,380,000	4,380,000
Cache	0	0	47,020,000	47,020,000
Total	0	0	52,050,000	52,050,000
Hypothetical Resource tonnage				
Cache	0	0	2,660,000	2,660,000
Total	0	0	2,660,000	2,660,000
Grand Total	0	0	54,710,000	54,710,000

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