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

[Report includes 35 plates]

By

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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 Three Bar Ranch quadrangle, Powder River County, Montana, and Campbell County, Wyoming, (35 plates; U.S. Geological Survey Open-File Report 79-791). 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 Three Bar Ranch 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 northern Campbell County, Wyoming. The quadrangle is about 25 miles (40.2 km) southwest of Broadus, Montana, and about 50 miles (80 km) north-northwest of Gillette, Wyoming.

Accessibility

The Three Bar Ranch quadrangle is accessible from Broadus, Montana, by going southeastward on U.S. Highway 212 for a distance of about 3 miles (4.8 km), then continuing southward on paved State Highway 59 for a distance of about 27 miles (43 km), and then proceeding westward on a local road about 14 miles (22.5 km) to the eastern border of the quadrangle. The quadrangle is also accessible from Gillette, Wyoming, by going northward on paved State Highway 59 for a distance of about 60 miles (96.5 km), and then proceeding westward a distance of about 14

miles (22.5 km) on a local road to the eastern border of the quadrangle. The nearest railroad is the Burlington Northern Railroad which is about 28 miles (45 km) southwest of the quadrangle at Kendrick, Wyoming.

Physiography

The Three Bar Ranch quadrangle is within the Missouri Plateau Division of the Great Plains physiographic province. The quadrangle is in the drainage basin of the Powder River, about 4 miles (6.4 km) southeast of the river. The Powder River flows northeastward from the area of the Three Bar Ranch quadrangle to Broadus and then generally northward until it meets the Yellowstone River about 113 miles (182 km) north-northeast of the quadrangle. The Three Bar Ranch quadrangle is drained entirely by northwestward-flowing tributaries of the Powder River, and the major features of the landscape are a series of linear broad valleys and narrow ridges that are aligned parallel to the direction of drainage.

The most prominent stream in the quadrangle is Three Bar Creek, which extends from the southeast to the northwest corners of the quadrangle. Slightly more than two-thirds of the quadrangle drains into Three Bar Creek and its major upstream tributaries. The remainder of the quadrangle is about equally divided between parts of the drainage basins of Bay Horse Creek, which flows northwestward across the northeast corner of the quadrangle, and of Buffalo Creek, which flows northwestward across the southwest corner of the quadrangle. All of the major streams are intermittent.

The valleys of the three major streams in the quadrangle are similar. They are about 3.5 to 4.0 miles (5.6 to 6.4 km) wide with broad, relatively gentle lower slopes bounded by the short, steep upper slopes of the narrow dividing ridges. The lower slopes of the valleys typically rise 150 to 250 feet (46 to 76 m) over distances of 1.25 to 1.75 miles (2.0 to 2.8 km). The slopes of the ridges rise 350 to 450 feet (107 to 137 m) over distances of 0.25 to 0.5 mile

(0.4 to 0.8 km). The dividing uplands are deeply dissected and are capped by sharp peaks or short, narrow ridges. The highest point in the quadrangle, with an elevation of 4,247 feet (1,294 m), is an unnamed peak on the divide between Three Bar Creek and Bay Horse Creek. The lowest point in the quadrangle, with an elevation of about 3,340 feet (1,018 m), is along Three Bar Creek at the northwest corner of the quadrangle. Topographic relief in the quadrangle is about 907 feet (276 m).

Climate

The climate of Powder River County, Montana, and Campbell County, Wyoming, 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 coal land ownership status within the Three Bar Ranch 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 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 in the southwestern part

of the Three Bar Ranch quadrangle. Bryson and Bass (1973, pl. 1) mapped all of the Three Bar Ranch 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 Three Bar Ranch quadrangle is shown on the Coal Data Sheet (pl. 3) of the CRO maps. The exposed bedrock units belong to the upper member of the Fort Union Formation (Paleocene), the Tongue River Member.

The upper part of the Tongue River Member has been removed by erosion, but the lower part remaining is about 1,500 feet (457 m) thick. It consists mainly of yellow sandstone, sandy shale, carbonaceous shale, and coal. The thicker coal beds have burned along the outcrops, baking the overlying sandstone and shale and forming thick, reddish-colored clinker beds.

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 Three Bar Ranch quadrangle is in the northeastern part of the Powder River structural basin. The strata in general dip westward or west-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 (pls. 4, 8, 11, 14, 17, 20, 23, 26, 29, and 32). Some of the nonuniformity in structure 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 Three Bar Ranch 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 Broadus coal bed which occurs about 100 feet (30 m) above the base of the Tongue River Member. The Broadus coal bed is overlain successively by a noncoal interval of about 70 to 100 feet (21 to 30 m), the Number 11 coal bed, a noncoal interval of about 190 to 300 feet (58 to 91 m), the Cache coal bed, a noncoal interval of 50 to 65 feet (15 to 20 m), the Number 8a coal bed, a noncoal interval of 20 to 50 feet (6 to 15 m), the Number 8 coal bed, a noncoal interval of 55 feet (17 m), the Number 7 coal bed, a noncoal interval of about 10 feet (3 m), the Pawnee coal beds, a mainly noncoal interval of about 15 to 35 feet (4.6 to 10.7 m) containing a local coal bed, the Number 5a coal bed, a mainly noncoal interval of about 55 feet (16.8 m) containing a local coal bed, the Number 5 coal bed, a noncoal interval of about 65 to 90 feet (20 to 27 m), the Number 4a coal bed, a noncoal interval of about 15 to 25 feet (4.6 to 7.6 m), the Upper Cook coal bed, a noncoal interval of about 90

to 100 feet (27 to 30 m), the Canyon coal bed, a noncoal interval of about 50 to 85 feet (15.2 to 25.9 m) containing a local clinker bed, the Dietz coal bed, a noncoal interval of about 90 feet (27 m), and the Anderson (Dietz 1) clinker 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 within 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 surfacing 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.

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).

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 25 miles (40 km) north-northeast of the Three Bar Ranch quadrangle. In the Three Bar Ranch quadrangle, the Broadus coal bed occurs about 100 feet (30 m) above the base of the Tongue River Formation (Bryson and Bass, 1973, p. 100). The Broadus coal bed does not crop out in this quadrangle, but it was penetrated by two oil-and-gas test holes in the northern part of the quadrangle. The isopach and structure contour map (pl. 32) shows that the Broadus coal bed ranges from about

4 to 10 feet (1.2 to 3 m) in thickness and has a westward dip of less than 1 degree. Overburden on the Broadus coal bed (pl. 33) ranges from about 500 to 1,100 feet (152 to 335 m) in thickness.

There is no known, publicly available chemical analysis of the Broadus coal in the Three Bar Ranch quadrangle, but a chemical analysis of this coal from the Superior mine (Gilmour and Dahl, 1967, p. 16), sec. 14, T. 5 S., R. 50 E., in the Epsie NE quadrangle about 18 miles (29 km) north-northeast of the Three Bar Ranch quadrangle shows ash 6.0 percent, sulfur 0.4 percent, and heating value 7,290 Btu per pound (16,957 kJ/kg) on an as-received basis. This heating value converts to about 7,755 Btu per pound (18,038 kJ/kg) on a moist, mineral-matter-free basis, indicating that the Broadus coal in that locality is lignite A in rank. However, because the Three Bar Ranch quadrangle lies deeper in the Powder River structural basin, is assumed that the Broadus coal in this quadrangle is more compacted and is subbituminous C 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 Three Bar Ranch quadrangle. In this quadrangle the Number 11 coal bed occurs about 70 to 100 feet (21 to 30 m) above the Broadus coal bed. The Number 11 coal bed does not crop out in this quadrangle but was penetrated by three oil-and-gas test holes in the northeastern part of the quadrangle. The isopach and structure contour map (pl. 29) shows that the Number 11 coal bed ranges from about 5 to 7 feet (1.5 to 2.1 m) in thickness and dips to the northwest at an angle of less than 1 degree. Overburden in the Number 11 coal bed (pl. 30) ranges from 400 to 1,000 feet (122 to 305 m) in thickness.

There is no known, publicly available chemical analysis of the Number 11 coal in the Three Bar Ranch quadrangle. Because the deeper coals in this area

are subbituminous C in rank, the Number 11 coal bed has also been assigned a rank of subbituminous C.

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 17 miles (27 km) north of the Three Bar Ranch quadrangle. The Cache coal bed is not exposed at the surface in this quadrangle but was penetrated by four test holes in the northern half of the quadrangle. In the Three Bar Ranch quadrangle, the Cache coal bed occurs about 190 to 300 feet (58 to 91 m) above the Number 11 coal bed. The isopach and structure contour map (pl. 26) shows that the Cache coal bed has a general westward dip of less than 0.5 degree and ranges from about 4 to 12 feet (1.2 to 3.7 m) in thickness. Overburden on the Cache coal bed (pl. 27) ranges from about 200 to 700 feet (61 to 213 m) in thickness.

Matson and Blumer (1973, p. 92) correlated the Cache coal bed with the T coal bed. A chemical analysis of the T coal (Matson and Blumer, 1973, p. 93) from a depth of 50 to 60 feet (15 to 18 m) in drill hole SH-716, sec. 36, T. 8 S., R. 50 E., in the Bay Horse quadrangle about 5 miles (8 km) east of the Three Bar Ranch 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 8,010 Btu per pound (18,631 kJ/kg) on a moist, mineral-matter-free basis, indicating that the Cache coal at that location is lignite A in rank. Because of the proximity of that location to the Three Bar Ranch quadrangle, it is assumed that the Cache coal in this quadrangle is similar and is also lignite A in rank. However, because the Three Bar Ranch quadrangle lies deeper in the Powder River structural basin, the Cache coal here is more compacted and may reach subbituminous C in rank.

Number 8a, Number 8, and Number 7 coal beds

These coal beds occur in the interval between the Cache and the Lower Pawnee coal beds. Because these coal beds are less than 5 feet (1.5 m) in thickness, economic coal resources have not been assigned to them.

Lower Pawnee coal bed

The Pawnee coal bed was first described by Warren (1959, p. 572) from exposures in the Birney-Broadus coal field, Montana, possibly from the Epsie quadrangle about 17 miles (27 km) north of the Three Bar Ranch quadrangle. In the Three Bar Ranch quadrangle, the Pawnee coal bed splits into three coal beds which we have designated as the Lower, Middle, and Upper Pawnee coal beds. In the northern portion of the quadrangle, the Pawnee coal beds have been extensively burned forming a thick clinker bed which caps the hills.

In the Three Bar quadrangle, the Upper Pawnee occurs about 210 (64 m) above the Cache coal bed and the Lower Pawnee occurs about 25 feet (7.6 m) below the base of the Upper Pawnee coal bed. The isopach and structure contour map (pl. 23) shows that the Lower Pawnee coal bed ranges from 0 feet to about 12 feet (0-3.7 m) in thickness and has a general southward dip of less than 0.5 degree. Overburden on the Lower Pawnee coal bed (pl. 24) ranges from 0 feet at the outcrops to about 400 feet (0-122 m) in thickness.

A chemical analysis of the Pawnee coal (Matson, Dahl, and Blumer, 1968) from a core sample in sec. 36, T. 5 S., R. 48 E., about 17 miles (21 km) north-northwest of the Three Bar Ranch quadrangle in the Hodsdon Flats quadrangle shows ash 6 percent, sulfur 0.2 percent, and heating value of 7,650 Btu per pound (17,794 kJ/kg) on an as-received basis. This heating value converts to about 7,191 Btu per pound (16,726 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 Three Bar Ranch quadrangle and the close

stratigraphic relationship of the Pawnee and the Lower Pawnee coal beds, it is assumed that the Lower Pawnee coal in this quadrangle is similar and is also lignite A in rank.

Middle Pawnee coal bed

In the Three Bar Ranch quadrangle, the Middle Pawnee coal bed occurs about 5 to 8 feet (1.5 to 2.4 m) above the Lower Pawnee coal bed. The isopach and structure contour map (pl. 20) shows that the Middle Pawnee coal bed ranges from 0 feet to about 8 feet (0-2.4 m) in thickness and has a general southward dip of less than 1 degree. Overburden on the Middle Pawnee coal bed (pl. 21) ranges from 0 feet at the outcrops to about 300 feet (0-91 m) in thickness.

A publicly available chemical analysis is not available for the Middle Pawnee coal, but it is assumed that this coal is similar to the Pawnee coal and is also lignite A in rank.

Upper Pawnee coal bed

In the Three Bar Ranch quadrangle, the Upper Pawnee coal bed occurs about 5 to 8 feet (1.5 to 2.4 m) above the Middle Pawnee coal bed. The isopach and structure contour map (pl. 17) shows that the Upper Pawnee coal bed ranges in thickness from about 2 to 18 feet (0.6 to 5.5 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 Upper Pawnee coal bed (pl. 18) ranges from 0 feet at the outcrops to 500 feet (0-152 m) in thickness.

A publicly available chemical analysis of the Upper Pawnee coal is not available but it is assumed that the composition of this coal is similar to other analyses of the Pawnee coal in the area and is lignite A in rank.

Number 5a coal bed

The Number 5a coal bed was first described by Bryson and Bass (1973) from exposures in the Moorhead coal field which includes the Three Bar Ranch

quadrangle. In this quadrangle, the Number 5a coal bed is about 30 feet (9.1 m) above the Pawnee coal bed. Because the Number 5a coal bed is only 4.2 feet (1.3 m) in thickness and has a limited areal extent, economic resources have not been assigned to this coal bed.

Number 5 coal bed

The Number 5 coal bed was first described by Bryson and Bass (1973) from exposures in the Moorhead coal field which includes the Three Bar Ranch quadrangle. In the Three Bar Ranch quadrangle, the Number 5 coal bed occurs about 40 to 110 feet (12 to 33 m) above the Pawnee coal bed. The isopach and structure contour map (pl. 14) shows that the Number 5 coal bed ranges from about 5 to 13 feet (1.5 to 3.9 m) in thickness and has a general westward dip of less than 1 degree. In places, the general dip is modified by low-relief folding. Overburden on the Number 5 coal bed (pl. 14) ranges from 0 feet at the outcrops to about 400 feet (0-122 m) in thickness.

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

Number 4a coal bed

Bryson and Bass (1973, p. 77) recognized a few thin, lenticular coal beds below the Cook coal bed in the Sayle quadrangle about 7 miles (11 km) west-northwest of the Three Bar Ranch quadrangle. They named the uppermost lenticular coal bed the Number 4a coal bed. This coal bed crops out in the southwestern part of the Three Bar Ranch quadrangle. Because the Number 4a coal bed is thin and of limited areal extent, economic coal resources have not been assigned to it.

Upper Cook coal bed

The Cook coal bed was first described by Bass (1932, p. 59) from exposures in the Cook Creek Reservoir quadrangle about 41 miles (66 km) northwest of the

Three Bar Ranch quadrangle. Warren (1959, p. 573) recognized the upper split of the Cook coal bed in the Birney-Broadus coal field about 20 miles (32 km) northeast of this quadrangle. Bryson and Bass (1973, pl. 1) mapped the Cook (Number 4) coal bed in the Moorhead coal field, which includes the Three Bar Ranch 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 Cook coal bed.

In the Three Bar Ranch quadrangle, the Upper Cook coal bed occurs about 15 to 25 feet (4.6 to 35 m) above the Number 4a coal bed. The isopach and structure contour map (pl. 11) shows that the Upper Cook coal bed ranges in thickness from about 2 to 10 feet (0.6 to 3.0 m) and, in general, dips northeastward at an angle of less than 1 degree, although this dip is modified by low-relief folding. Overburden on the Upper Cook coal bed (pl. 12) ranges from 0 feet at the outcrops to 200 feet (0-61 m) in thickness.

A chemical analysis of Upper Cook coal (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., about 13 miles (21 km) northwest of the Three Bar Ranch quadrangle in the Hodsdon Flats 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 7,905 Btu per pound (18,387 kJ/kg) on a moist, mineral-matter-free basis, indicating that the Upper Cook coal at that locality is lignite A in rank. Because of the proximity of that location to the Three Bar Ranch quadrangle, it is assumed that the Upper Cook coal 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 46 miles (74 km) west of the Three Bar Ranch quadrangle. In the Three Bar Ranch quadrangle, the Canyon coal bed occurs about 90 to 100 feet (27 to 30 m) above the Upper Cook coal bed. Its position near the surface is generally marked by a clinker bed formed by burning of the coal. The isopach and structure contour maps (pls. 7 and 8) show that the Canyon coal bed ranges from 5 to 20 feet (1.5 to 6.1 m) in thickness and in general dips westward and southwestward at an angle of less than 1 degree. The general dip is modified by several low-relief folds. Overburden on the Canyon coal bed (pl. 9) ranges from 0 feet at the outcrops to about 200 feet (0-61 m) in thickness.

A chemical analysis of the Canyon coal (Matson and Blumer, 1973, p. 96) from a depth of 54 to 64 feet (16.5 to 19.5 m) in coal test hole SH-7134, sec. 29, T. 6 S., R. 48 E., about 13 miles (21 km) northwest of the Three Bar Ranch quadrangle in the Hodsdon Flats 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 (17,894 kJ/kg) on a moist, mineral-matter-free basis, indicating that the Canyon coal at that locality is lignite A in rank. Because of the proximity of that location to the Three Bar Ranch quadrangle, it is assumed that the Canyon coal bed in this quadrangle is similar and is also lignite A in rank.

Dietz coal bed

The Dietz 1, 2, and 3 coal beds were first described by Taff (1909, p. 129-140) from exposures in abandoned coal mines at and near Dietz, Wyoming, in the Sheridan quadrangle about 60 miles (96 km) west-southwest of the Three Bar Ranch quadrangle. The Dietz 1 coal bed is equivalent to the Anderson coal bed as mapped by Baker (1929, pl. 28) in the northward extension of the Sheridan coal field about 46 miles (74 km) west of the Three Bar Ranch quadrangle. The Dietz 2 and 3 coal beds of Matson and Blumer (1973, p. 33) combine into a single coal bed

called the Dietz in the Three Bar Ranch quadrangle. In most places the Dietz coal bed has burned forming a clinker bed that caps the higher hills. Unburned Dietz coal is present only in a few very limited areas in the north-central part of the quadrangle. The isopach and structure contour map of the Dietz coal bed (pl. 4) is based on very limited data. This map shows that the Dietz coal bed ranges from 4.5 to 5.7 feet (1.4 to 1.7 m) in thickness and dips northwestward at less than 1 degree. Overburden on the Dietz coal bed (pl. 5) ranges from 0 feet at the outcrops to 100 feet (0-30 m) in thickness.

There is no known, publicly available chemical analysis of the Dietz coal in or near the Three Bar Ranch quadrangle. However, it is assumed that the Dietz coal is similar to other coals in the area and is lignite A in rank.

Anderson (Dietz 1) coal bed

The Anderson (Dietz 1) 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 48 miles (77 km) west of the Three Bar Ranch quadrangle. The Dietz 1 coal bed was named by Taff (1909, p. 129-140) for exposures at the abandoned No. 1 mine at the old mining town of Dietz in the Sheridan coal field, Wyoming. The Dietz 1 coal bed is equivalent to the Anderson coal bed as mapped by Baker (1929, pl. 28).

In the Three Bar Ranch quadrangle, the Anderson (Dietz 1) coal bed is represented by a clinker bed which occurs about 90 feet (27 m) above the Dietz coal bed. The Anderson (Dietz 1) coal bed has been entirely burned in this quadrangle.

Local coal beds

Local coal beds occur at several places in the Three Bar Ranch quadrangle (pls. 1 and 3). Because these local beds are thin and are 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.

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 and 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 1,770 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 570.72 million short tons (517.76 million t). The total tonnage of federally owned, surface-minable Hypothetical coal is estimated to be 4.61 million short tons (4.18 million t). As shown by table 2, the total federally owned, underground-minable Reserve Base coal is estimated to be 108.29 million short tons (98.24 million t). The total federally owned, underground-minable Hypothetical coal is estimated to be 0.87 million short tons (0.79 million t). The total tonnage of surface- and underground-minable Reserve Base coal is 679.01 million short tons (616.00 million t), and the total of surface- and underground-minable Hypothetical coal is 5.48 million short tons (4.97 million t).

About 11 percent of the surface-minable Reserve Base tonnage is classed as Measured, 36 percent as Indicated, and 53 percent as Inferred. About 2 percent of the underground-minable Reserve Base tonnage is Measured, 23 percent is Indicated, and 75 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 first 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 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. 35).

The Broadus coal bed (pl. 33) has some low development potential for surface mining in the valley of Bay Horse Creek extending up to the 500-foot (152-m) overburden isopach. The remainder of the Broadus coal bed has no development potential.

The Number 11 coal bed (pl. 30) has relatively large areas of low development potential along the valleys of Bay Horse Creek and its tributaries in the northeastern part of the quadrangle. The remainder of the Number 11 coal bed has no development potential for surface mining.

The Cache coal bed (pl. 27) has a very limited area of moderate development potential along the valley of Bay Horse Creek in the northeastern part of the quadrangle. Large areas of low development potential lie between the 15 mining-ratio contour or the coal boundary and the arbitrarily assigned stripping limit of 500 feet (152 m). There are relatively large areas of no development potential for surface mining under the crests of the hills above the 500-foot (152-m) overburden isopach.

Potential surface mining of the Lower Pawnee coal bed (pl. 24) is limited to a small area in the north-central part of the quadrangle. About one-half of this area has a high development potential. A narrow band of moderate development potential lies between the 10 and 15 mining-ratio contours. The remainder of the area has a low development potential.

Potential surface mining of the Middle Pawnee coal bed (pl. 21) is limited to a small area in the north-central part of the quadrangle. About one-half of this area has a high development potential. A minor amount of moderate development potential lies between the 10 and 15 mining-ratio contours. The remainder of the area has low development potential for surface mining.

The Upper Pawnee coal bed (pl. 18) has extensive areas of high development potential for surface mining extending from the coal boundary to the 10 mining-ratio contour. There are relatively narrow bands of moderate development potential on the hill slopes extending from the 10 mining-ratio contour to the 15 mining-ratio contour. The remainder of the coal has a low development potential.

The Number 5 coal bed (pl. 15) has extensive areas of high development potential extending from the coal boundary to the 10 mining-ratio contour. Very narrow bands of moderate development coal are found on the hill slopes extending from the 10 mining-ratio to the 15 mining-ratio contour. The remainder of the coal has low development potential.

The Upper Cook coal bed (pl. 12) has surface mining potential in four very small areas in the northern portion of the quadrangle. These small tracts contain high, moderate, and low development potential coal.

The Canyon coal bed (pl. 9) has small tracts of surface mining potential scattered throughout the quadrangle. Rather extensive areas of high development potential extend from the coal boundary to the 10 mining-ratio contour. Very narrow bands of moderate development potential extend up the hill slopes from the 10 mining-ratio contour to the 15 mining-ratio contour. A small amount of low development potential extends from the 15 mining-ratio contour under the crests of the hills.

Potential surface mining of Dietz coal bed (pl. 5) is restricted to a very small area of high and moderate development potential in the northern part of the quadrangle.

About 70 percent of the Federal coal lands in the quadrangle has a high development potential for surface mining, 5 percent has a moderate development potential, 13 percent has a low development potential, and 12 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 Three Bar Ranch 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	100,000	90,000	0	190,000
Canyon	21,490,000	4,020,000	1,730,000	27,240,000
Upper Cook	920,000	80,000	250,000	1,250,000
Number 5	112,210,000	38,360,000	48,750,000	199,320,000
Upper Pawnee	53,310,000	8,590,000	9,060,000	70,960,000
Middle Pawnee	960,000	820,000	550,000	2,330,000
Lower Pawnee	2,390,000	1,550,000	1,340,000	5,280,000
Cache	0	9,460,000	217,970,000	227,430,000
Number 11	0	0	26,760,000	26,760,000
Broadus	0	0	9,960,000	9,960,000
Total	191,380,000	62,970,000	316,370,000	570,720,000
Hypothetical Resource tonnage				
Cache	0	0	4,470,000	4,470,000
Broadus	0	0	140,000	140,000
Total	0	0	4,610,000	4,610,000
Grand Total	191,380,000	62,970,000	320,980,000	575,330,000

Table 2.--Underground-minable coal resource tonnage (in short tons) by development-potential category for Federal lands in the Three Bar Ranch 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 Pawnee	0	0	200,000	200,000
Cache	0	0	17,650,000	17,650,000
Number 11	0	0	42,930,000	42,930,000
Broadus	0	0	47,510,000	47,510,000
Total	0	0	108,290,000	108,290,000
Hypothetical Resource tonnage				
Cache	0	0	350,000	350,000
Broadus	0	0	520,000	520,000
Total	0	0	870,000	870,000
Grand Total	0	0	109,160,000	109,160,000

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.

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

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.

Olive, W. W., 1957, The Spotted Horse coal field, Sheridan and Campbell Counties, Wyoming: U.S. Geological Survey Bulletin 1050, 83 p.

Taff, J. A., 1909, The Sheridan coal field, Wyoming: U.S. Geological Survey Bulletin 341-B, p. 123-150.

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.