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

[Report includes 39 plates]

By

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This report has not been edited for conformity with U.S. Geological Survey editorial standards or stratigraphic nomenclature.

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ILLUSTRATIONS

[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 Bradshaw Creek quadrangle, Powder River County, Montana, and Campbell County, Wyoming, (39 plates; U.S. Geological Survey Open-File Report 79-785). 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 Bradshaw Creek 7 1/2-minute quadrangle is mainly in southwestern Powder River County, Montana. A narrow strip about 100 feet (30 m) wide along the eastern side of the southern border of the quadrangle, is in Campbell County, Wyoming. The quadrangle is about 34 miles (55 km) southwest of Broadus, a small town in the Powder River valley; about 50 miles (80 km) east-northeast of Sheridan, Wyoming; and 53 miles (85 km) northwest of Gillette, Wyoming. Broadus is on U.S. Highway 212. Sheridan and Gillette are on U.S. Interstate Highway 90 and the Burlington Northern Railroad.

Accessibility

The quadrangle is accessible from Broadus by going about 39 miles (63 km) southwestward on the graveled Powder River Road in the Powder River valley to the eastern border of the quadrangle. The quadrangle is also accessible from

Sheridan, Wyoming, by going about 52 miles (84 km) eastward on U.S. Highways 14 and 16 to the Powder River Road, then 20 miles (32 km) northward on the Powder River Road to the southern boundary of the quadrangle. The nearest railroad is a main line of the Burlington Northern Railroad up the Powder River valley near Kendrick, Wyoming, about 24 miles (39 km) south-southwest of the quadrangle.

Physiography

The Bradshaw Creek quadrangle is within the Missouri Plateau Division of the Great Plains physiographic province. More than 90 percent of the Bradshaw Creek quadrangle lies in the drainage basin of the Powder River, which flows northeastward across about 4.5 miles (7.2 km) of the quadrangle at its southeast corner. Most of the quadrangle lies northwest of the river and is drained by several more or less equally prominent southeastward-flowing intermittent streams, including Line Creek, Bradshaw Creek, Rough Creek, Trail Creek, and Thompson Creek. Only about 3 square miles (7.8 km^2) of the quadrangle lies southeast of the flood plain of the Powder River; the largest stream there is Bitter Creek. About 3.5 square miles (9.1 km^2) of the quadrangle in its northwest corner and a few very small areas along the west edge of the quadrangle drain westward to northward into Otter Creek, which begins its northward course in the Sayle Hall quadrangle, about 2 miles (3.2 km) west of the quadrangle.

The most prominent land form in the quadrangle is the flood plain of the Powder River. The narrow river meanders within the broadly sinuous pattern of the entrenched flood plain. The flood plain is typically 0.4 to 0.8 miles (0.64 to 1.3 km) wide and is surmounted by bluffs that rise 200 to 500 feet (61 to 152 m) over distances of 0.25 to 0.5 miles (0.40 to 0.80 km).

Most of the landscape in the Bradshaw Creek quadrangle comprises a series of fairly regular drainage basins of the southeastward-flowing tributaries of the Powder River. These streams are 1 to 2 miles (1.6 to 3.2 km) apart in narrow, entrenched, linear valleys with a pronounced northwest-southeast alignment. Most of the area of these drainages consists of moderately to very steep slopes formed by the incision of the streams and their tributaries. The streams are divided by narrow, irregularly linear, flat-topped or sharp ridges. These ridges rise typically 300 to 600 feet (91 to 183 m) over distances of 0.25 to 1.0 miles (0.40 to 1.6 km). In the northwest corner of the quadrangle, in the headwaters of Indian Creek, the streams have not entrenched, their valleys are broad, and slopes are relatively gradual. The highest point in the quadrangle, with an elevation of 4,361 feet (1,329 m), is on a mesa in the northwest corner of the quadrangle along the divide between Otter Creek and the Powder River. The lowest point in the quadrangle, with an elevation of about 3,350 feet (1,021 m), occurs along the Powder River at the east edge of the quadrangle. Topographic relief in the quadrangle is about 1,011 feet (308 m).

Climate

The climate of Powder River County is characterized by pronounced variations in seasonal precipitation and temperature. Annual precipitation in the region varies from less than 12 inches (30 cm) to about 16 inches (41 cm). The heaviest precipitation is from April to August. The largest average monthly precipitation is during June. Temperatures in eastern Montana range from as low as -50°F (-46°C) to as high as 110°F (43°C). The highest temperatures occur in July and the lowest in January; the mean annual temperature is about 45°F (7°C) (Matson and Blumer, 1973, p. 6)

Land status

The Boundary and Coal Data Map (pl. 2) shows the land ownership status within the Bradshaw Creek quadrangle. All of the quadrangle except the small area in Wyoming lies within the Northern Powder River Known Recoverable Coal Resource

Area (KRCRA). There are no National Forest lands within the quadrangle. There were no outstanding Federal coal leases or prospecting permits as of 1977.

GENERAL GEOLOGY

Previous work

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

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

The exposed bedrock units in the quadrangle belong to the Tongue River Member, the uppermost member of the Fort Union Formation (Paleocene).

The Tongue River Member is made up mainly of yellow to gray sandstone, sandy shale, carbonaceous shale, and coal. Much of the coal has burned, baking the overlying sandstone and shale and forming thick, reddish-colored clinker beds. The upper part of the Tongue River Member has been removed by erosion, leaving as much as 2,000 feet (610 m) of the middle and lower parts of the member remaining in the quadrangle (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 Bradshaw Creek quadrangle is in the east-central part of the Powder River structural basin. Regionally the strata dip southwestward at an angle of less than 1 degree. In places, the regional dip is modified by local folding (pls. 4, 7, 11, 14, 17, 20, 23, 27, 30, 33, and 36). Some irregularities in dip may be caused by depositional variations as well as differential compaction, common in continental strata.

COAL GEOLOGY

The coal beds in the Bradshaw Creek 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 middle and lower 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 Contact coal bed which occurs about 190 feet (58 m) above the base of the Tongue River Member. The Contact coal bed is overlain successively by a noncoal interval of about 60 feet (18 m), the Broadus coal bed, a noncoal interval of about 150 feet (46 m), the Flowers-Goodale coal bed, a mostly noncoal interval of about 195 feet (59 m) containing two local coal beds, the Knobloch coal bed, a noncoal interval of about 65 to 90 feet (20 to 27 m), the King coal bed, a mostly noncoal interval of about 240 to 260 feet (73 to 79 m) containing four local coal beds, the Cache coal bed, a mostly noncoal interval of about 95 feet (29 m) containing two local coal beds, the Pawnee coal bed, a mostly noncoal interval of about 250 to 390 feet (76 to 119 m) containing two local coal beds, the Number 5 coal bed, a noncoal interval of 35 feet (11 m), the Number 4b coal bed, a noncoal interval of 35 feet (11 m), the lower split of the Cook coal bed, a noncoal interval of about 40 to 85 feet (12 to 26 m), the upper split of the Cook coal bed, a mostly noncoal interval of 90 to 205 feet (27 to 62 m) containing a local coal bed, the Canyon coal bed, a noncoal interval of about 90 to 115 feet (27 to 35 m), the Dietz coal bed, a noncoal interval of 35 to 105 feet (11 to 32 m), the Anderson coal bed, and a mostly noncoal interval of as much as 450 feet (137 m) containing several local coal beds.

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.

The trace-element content of coals in this quadrangle has not been determined; however, coals in the Northern Great Plains, including those in the Fort Union Formation in Montana, have been found to contain, in general, appreciably lesser amounts of most elements of environmental concern than coals in other areas of the United States (Hatch and Swanson, 1977, p. 147).

Contact coal bed

The Contact coal bed, the lowermost recognized coal bed of the Tongue River Member of the Fort Union Formation in the quadrangle, was first described by Bass (1932, p. 53) from exposures in the Kirkpatrick Hill quadrangle about 55 miles (88 km) north-northeast of the Bradshaw Creek quadrangle. The Contact coal bed does not crop out in the Bradshaw Creek quadrangle but occurs about 190 feet (58 m) above the base of the Tongue River Member. Because this coal bed is less than 5 feet (1.5 m) in thickness, economic resources have not been assigned to it.

Broadus coal bed

The Broadus coal bed was first described by Warren (1959, p. 570) and derives its name from outcrops of the coal bed near the town of Broadus in the Epsie NE quadrangle about 30 miles (48 km) northeast of the Bradshaw Creek quadrangle. The Broadus coal bed does not crop out in the Bradshaw Creek quadrangle and occurs about 250 feet (76 m) above the base of the Tongue River Member of the Fort Union Formation. The Broadus coal bed is 64 to 67 feet (19.5 to 20.4 m) above the Contact coal bed in the two oil-and-gas test holes in which both beds are identified. The isopach and structure contour map (pl. 36) shows that the Broadus coal bed ranges from about 3 to 12 feet (0.9 to 3.7 m) in thickness and dips eastward at an angle of less than half a degree. Overburden on the Broadus coal bed (pl. 37) ranges from about 1,100 to 1,700 feet (335 to 518 m) in thickness.

There is no known, publicly available chemical analysis of the Broadus coal in the Bradshaw Creek quadrangle. However, Gilmour and Dahl (1967, p. 16) report that a chemical analysis of the Broadus coal from the Superior mine, sec. 14,

T. 5 S., R. 50 E., in the Epsie NE quadrangle about 26 miles (42 km) northeast of the Bradshaw Creek 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 at that location is lignite A in rank. However, because the Bradshaw Creek quadrangle lies deeper in the Powder River structural basin it is assumed that the coals are more compacted and that the Broadus coal in this quadrangle is subbituminous C in rank.

Flowers-Goodale coal bed

The Flowers-Goodale coal bed was named by Bass (1932, p. 53-54) for exposures at mines in the Ashland coal field in the Brandenberg quadrangle about 50 miles (30 km) north-northwest of the Bradshaw Creek quadrangle. The Flowers-Goodale coal bed does not crop out in the Bradshaw Creek quadrangle and occurs about 150 feet (46 m) above the Broadus coal bed. The isopach and structure contour map of the Flowers-Goodale coal bed (pl. 33) shows that the bed ranges from about 3 to 10 feet (0.9 to 3 m) in thickness and has a general southwestward dip of less than half a degree. Overburden on the Flowers-Goodale coal bed (pl. 34) ranges from about 1,000 to 1,600 feet (305 to 488 m) in thickness.

There is no known, publicly available chemical analysis of the Flowers-Goodale coal in the Bradshaw Creek quadrangle. Because other coals in this area are subbituminous C in rank, the Flowers-Goodale coal has also been assigned a rank of subbituminous C.

Knobloch coal bed

The Knobloch coal bed was named by Bass (1924) from a small mine on the Knobloch Ranch in the Tongue River valley in the Birney Day School quadrangle about 30 miles (48 km) northwest of the Bradshaw Creek quadrangle. In this quadrangle, the Knobloch occurs about 195 feet (59 m) above the Flowers-Goodale coal bed. The Knobloch does not crop out in the quadrangle. The isopach and structure contour map of the Knobloch coal bed (pl. 30) shows that the bed ranges from 2 to 7 feet (0.6 to 2.1 m) in thickness and has a general southwestward dip of less than 1 degree. Overburden on the Knobloch coal bed (pl. 31) ranges from about 800 to 1,400 feet (244 to 427 m) in thickness.

There is no known, publicly available chemical analysis of the Knobloch coal in the Bradshaw Creek quadrangle. However, Matson and Blumer (1973, p. 68) report that a chemical analysis of the Knobloch coal at a depth of 106 to 116 feet (32 to 35 m) in drill hole SH-7052, sec. 27, T. 5 S., R. 45 E., in the Fort Howes quadrangle about 20 miles (32 km) northwest of the Bradshaw Creek quadrangle, shows ash 4.277 percent, sulfur 0.277 percent, and heating value 8,258 Btu per pound (19,208 kJ/kg) on an as-received basis. This heating value converts to about 8,627 Btu per pound (20,066 kJ/kg) on a moist, mineral-matter-free basis, indicating that the Knobloch coal at that location is subbituminous C in rank. Because of the proximity of that location to the Bradshaw Creek quadrangle, it is assumed that the coals are similar and that the Knobloch coal in this quadrangle is also subbituminous C in rank.

King coal bed

The King coal bed was first described by Warren (1959, p. 57), probably from exposures of the coal along King Creek in the Ashland and Green Creek quadrangles about 29 miles (46 km) northwest of the Bradshaw Creek quadrangle. The King coal bed occurs about 65 to 90 feet (20 to 27 m) above the Knobloch coal bed in the Bradshaw Creek quadrangle. Because this coal bed is less than 5 feet (1.5 m) thick, economic resources have not been assigned to it.

Cache coal bed

The Cache coal bed was first described by Warren (1959, p. 572) from exposures along Cache Creek in the Lonesome Peak and Yarger Butte quadrangles about

23 miles (37 km) northeast of the Bradshaw Creek quadrangle. The Cache coal bed occurs about 240 to 260 feet (73 to 79 m) above the King coal bed in the Bradshaw Creek quadrangle but does not crop out in this quadrangle. The isopach and structure contour maps (pls. 26 and 27) show that the Cache coal bed ranges from about 5 to 20 feet (1.5 to 6.1 m) in thickness and has a general southward dip of less than 1 degree. The general dip is modified by a low-relief, southward-plunging anticline and syncline. Overburden on the Cache coal bed (pl. 28) ranges from about 200 to 1,000 feet (61 to 305 m) in thickness.

There is no known, publicly available chemical analysis of the Cache coal from the Bradshaw Creek quadrangle. However, Matson and Blumer (1973, p. 93) report that a chemical analysis of the Cache coal 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 16 miles (26 km) east of the Bradshaw Creek quadrangle, showed 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 bed at that location is lignite A in rank. However, this heating value is very close to subbituminous C in rank. The Cache coal in the Bradshaw Creek quadrangle, which is closer to the center of the basin, is likely to have a higher heating value and is probably subbituminous C in rank.

Pawnee (Dunning) coal bed

The Pawnee coal bed was first described by Warren (1959, p. 572) from exposures in the Birney-Broadus coal field which lies about 9 miles (14 km) north of the Bradshaw Creek quadrangle. The Pawnee coal bed occurs about 95 feet (29 m) above the Cache coal bed in the Bradshaw Creek quadrangle. The Pawnee coal bed does not crop out in the quadrangle nor was it penetrated in drill holes. The isopach and structure contour map of the Pawnee coal bed (pl. 24) is based on projections from information in adjacent quadrangles. The map shows that the Pawnee coal bed ranges from about 4 to 8 feet (1.2 to 2.4 m) in thickness and has a general southwestward dip of less than half a degree. Overburden on the Pawnee coal bed (pl. 24) ranges from about 200 to 800 feet (61 to 244 m) in thickness.

There is no known, publicly available chemical analysis of the Pawnee coal in the Bradshaw Creek quadrangle. However, Matson and Blumer (1973, p. 110) report that a chemical analysis of the Pawnee coal at a depth of 30 to 37 feet (9 to 11 m) in drill hole SH-7116, sec. 29, T. 4 S., R. 48 E., in the Sonnette quadrangle about 25 miles (40 km) north-northeast of the Bradshaw Creek quadrangle shows ash 6.925 percent, sulfur 1.400 percent, and heating value 7,902 Btu per pound (18,380 kJ/kg) on an as-received basis. This heating value converts to about 8,490 Btu per pound (19,748 kJ/kg) on a moist, mineral-matter-free basis, indicating that the Pawnee coal at that location is subbituminous C in rank. Because of the proximity of that location to the Bradshaw Creek quadrangle, it is assumed that the coals are similar and that the Pawnee coal in this quadrangle is also subbituminous C in rank.

Number 5 coal bed

The Number 5 coal bed was first described by Bryson and Bass (1973, p. 91) from exposures in the Baldy Peak quadrangle about 17 miles (27 km) northeast of the Bradshaw Creek quadrangle. The Number 5 coal bed crops out on the eastern part of the quadrangle. The isopach and structure contour map (pl. 20) shows that the Number 5 coal bed ranges from about 3 to 10 feet (0.9 to 3.0 m) in thickness and has a general southwestward dip of less than half a degree. In places, the general dip is modified by local, low-relief folding. Overburden on the Number 5 coal bed (pl. 21) ranges from 0 feet at the outcrops to about 500 feet (0-152 m) in thickness.

There is no known, publicly available chemical analysis of the Number 5 coal in the Bradshaw Creek quadrangle. Because other coals in this area are subbituminous C in rank, the Number 5 coal has also been assigned a rank of subbutuminous C.

Number 4b coal bed

The Number 4b coal bed was first described by Bryson and Bass (1973, p. 77) from exposures in the Moorhead quadrangle immediately east of the Bradshaw Creek quadrangle. The Number 4b coal bed is less than 5 feet (1.5 m) thick in this quadrangle; therefore, economic resources have not been assigned to it.

Upper and lower splits of the Cook coal bed

The Cook coal bed was named by Bass (1932, p. 59) for exposures in the Cook Creek Reservoir quadrangle which is about 40 miles (64 km) north-northwest of the Bradshaw Creek quadrangle. Warren (1959, p. 573) recognized the upper split of the Cook coal bed in the Birney-Broadus coal field which is about 9 miles (14 km) north of the Bradshaw Creek quadrangle. Bryson and Bass (1973, pl. 1) mapped the Cook (Number 4) coal bed in the Moorhead coal field which includes the Bradshaw Creek 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 Bradshaw Creek quadrangle, the lower split of the Cook coal bed occurs about 25 to 75 feet (7.6 to 23 m) above the Number 5 coal bed. The isopach and structure contour map (pl. 17) shows that the lower split of the Cook coal bed ranges from about 4 to 10 feet (1.2 to 3.0 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 lower split of the Cook coal bed, where it is more than 5 feet (1.5 m) thick, ranges from about 200 to 500 feet (61 to 152 m) in thickness.

The upper split of the Cook coal bed crops out in the eastern part of the quadrangle. In the Bradshaw Creek quadrangle, the upper split of the Cook coal occurs about 40 to 85 feet (12 to 26 m) above the lower split of the Cook coal bed. The isopach and structure contour map (pl. 14) shows that the upper split of the Cook coal bed ranges from about 2 to 8 feet (0.6 to 2.4 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 split of the Cook coal bed ranges from 0 feet at the outcrops to about 600 feet (0-183 m) in thickness.

There is no known, publicly available chemical analysis of the upper and lower splits of the Cook coal in the Bradshaw Creek quadrangle. However, Matson and Blumer (1973, p. 99) report that a chemical analysis of the coal of the upper split of the Cook coal bed at a depth of 125 to 133 feet (38 to 40 m) in drill hole SH-7135, sec. 29, T. 6 S., R. 48 E., in the Hodsdon Flats quadrangle about 12 miles (19 km) north-northeast of the Bradshaw Creek quadrangle shows ash 3.458 percent, sulfur 0.384 percent, and heating value 8,189 Btu per pound (19,048 kJ/kg) on an as-received basis. This heating value converts to about 8,482 Btu per pound (19,730 kJ/kg) on a moist, mineral-matter-free basis, indicating that the Cook coal at that location is subbituminous C in rank. Because of the proximity of that location to the Bradshaw Creek quadrangle, it is assumed that the coals are similar and that the coal of the upper split of the Cook coal bed in this quadrangle is also subbituminous C in rank. Because of the close stratigraphic relationship of the upper and lower splits of the Cook coal bed, it is assumed that they are similar and that the coal of the lower split of the Cook coal bed is also subbituminous C 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, possibly along Canyon Creek in the northern part of Spring Gulch quadrangle about 36 miles (58 km) west-northwest of the Bradshaw Creek quadrangle. The Canyon coal bed occurs about 90 to 205 feet (27 to 62 m) above the upper split of the Cook coal bed in the Bradshaw Creek quadrangle. The Canyon coal bed crops out extensively in this quadrangle. The isopach and structure contour maps (pls. 10 and 11) show that the Canyon coal bed ranges from about 5 to 22 feet (1.5 to 6.7 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. 12) 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 Canyon coal in the Bradshaw Creek quadrangle. However, Matson and Blumer (1973, p. 96) report that a chemical analysis of the Canyon coal at a depth of 56 to 93 feet (17 to 28 m) in drill hole SH-7124, sec. 30, T. 6 S., R. 47 E., in the Goodspeed Butte quadrangle about 11 miles (18 km) north-northwest of the Bradshaw Creek quadrangle, shows ash 3.296 percent, sulfur 0.262 percent, and heating value 7,897 Btu per pound (18,368 kJ/kg) on an as-received basis. This heating value converts to about 8,165 Btu per pound (18,994 kJ/kg) on a moist, mineral-matter-free basis, indicating that the Canyon coal at that location is high lignite A in rank. Because the coals above the Canyon coal bed in the Bradshaw Creek quadrangle are subbituminous C in rank, it is assumed that the Canyon coal in this quadrangle is similar and is also subbituminous C in rank.

Dietz coal bed

The Dietz 1, 2, and 3 coal beds were first described by Taff (1909, p. 139-140) from exposures near the old mining town of Dietz in the Sheridan coal field, Wyoming, about 48 miles (77 km) west-southwest of the Bradshaw Creek quadrangle. Bryson and Bass (1973, p. 70) mapped the Dietz coal bed in the Bradshaw Creek quadrangle. The Dietz coal bed occurs about 90 to 115 feet (27 to 35 km) above the Canyon coal bed in the Bradshaw Creek quadrangle. The Dietz coal bed crops out in the western part of the quadrangle. The isopach and structure contour map (pl. 7) shows that the Dietz coal bed ranges from about 4 to 10 feet (1.2 to 3.0 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 Dietz coal bed (pl. 8) ranges from 0 feet at the outcrops to about 500 feet (0-152 m) in thickness.

There is no known, publicly available chemical analysis of the Dietz coal in the Bradshaw Creek quadrangle. However, Matson and Blumer (1973, p. 59) report that a chemical analysis of the Dietz coal at a depth of 43 to 52 feet (13 to 16 m) in drill hole SH-7043, sec. 24, T. 8 S., R. 45 E., in the Otter quadrangle about 7 miles (11 km) west of the Bradshaw Creek quadrangle, shows ash 3.800 percent, sulfur 0.660 percent, and heating value 8,080 Btu per pound (18,794 kJ/kg) on an as-received basis. This heating value converts to about 8,399 Btu per pound (19,536 kJ/kg) on a moist, mineral-matter-free basis, indicating that the Dietz coal at that location is subbituminous C in rank. Because of the proximity of that location to the Bradshaw Creek quadrangle, it is assumed that the coals are similar and that the Dietz coal in this quadrangle is also subbituminous C in rank.

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, possibly along Anderson Creek in the southern part of the Spring Gulch quadrangle, about 35 miles (56 km) west of the Bradshaw Creek quadrangle. The Anderson coal bed occurs about 35 to 105 feet (11 to 32 m) above the Dietz coal bed in the Bradshaw Creek quadrangle. The Anderson coal bed crops out in the western part of the quadrangle. The isopach and structure contour map (pl. 4) shows that the Anderson coal bed ranges from about 5 to 30 feet (1.5 to 9.1 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 Anderson coal bed (pl. 5) ranges from 0 feet to about 400 feet (0-122 m) in thickness.

Matson and Blumer (1973, p. 60) report that a chemical analysis of the Anderson coal at a depth of 86 to 115 feet (26 to 35 m) in drill hole SM-4, sec. 27, T. 8 S., R. 47 E., in the northern part of the Bradshaw Creek quadrangle, shows ash 5.1 percent, sulfur 0.4 percent, and heating value 8,150 Btu per pound (18,957 kJ/kg) on an as-received basis. This heating value converts to about 8,588 Btu per pound (19,976 kJ/kg) on a moist, mineral-matter-free basis, indicating that the Anderson coal at this location in the Bradshaw Creek quadrangle is subbituminous C in rank.

Local coal beds

Local coal beds occur at several places in the Bradshaw Creek 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.

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.

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. 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.

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

For economic reasons coal is not presently being mined by underground methods in the Northern Powder River Basin. Therefore, the underground-mining recovery factor is unknown and Reserves have not been calculated for the underground-minable Reserve Base coal.

Tonnages of coal resources were estimated using coal-bed thicknesses obtained from the coal isopach map for each coal bed (see list of illustrations). The coal resources, in short tons, for each isopached coal bed are the product of the acreage of coal (measured by planimeter), the average thickness in feet of the coal bed, and a conversion factor of 1,770 short tons of subbituminous coal per acre-foot (13,018 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 1,313.88 million short tons (1,191.95 million t). The total tonnage of federally owned, surface-minable Hypothetical coal is estimated to be 17.04 million short tons (15.46 million t). As shown by table 2, the total federally owned, underground-minable Reserve Base coal is estimated to be 689.03 million short tons (625.08 million t). The total federally owned, underground-minable Hypothetical coal is estimated to be 39.58 million short tons (35.91 million t). The total tonnage of surface- and underground-minable Reserve Base coal is 2,002.91 million short tons (1,817.04 million t), and the total of surface- and underground-minable Hypothetical coal is 56.62 million short tons (51.37 million t).

About 5 percent of the surface-minable Reserve Base tonnage is classed as Measured, 28 percent as Indicated, and 67 percent as Inferred. About 2 percent of the underground-minable Reserve Base tonnage is Measured, 12 percent is Indicated, and 86 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). The 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 subbituminous 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 lignite, in feet

rf = recovery factor = 0.85 in this area

cf = conversion factor = 0.911 cu. yds./short ton for subbituminous coal

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 for surface-mining methods on Federal coal lands is shown on the Coal Development Potential map (pl. 39). Most of the coal lands in the quadrangle have a high development potential for surface mining.

The Broadus, Flowers-Goodale, and Knobloch coal beds have no development potential for surface mining because overburden on all of these coal beds is greater than 500 feet (152 m), the arbitrarily assigned stripping limit.

The Cache coal bed (pl. 28) has development potential for surface mining along the eastern side of the quadrangle. A small area of high development potential extends from the eastern border up the slopes to the 10 mining-ratio contour. Small areas of moderate development occur as narrow to wide bands between the 10 and 15 mining-ratio contours. Relatively large areas of low development potential extend from the 15 mining-ratio contour up the slopes to the 500-foot (152-m) overburden contour. The remainder of the quadrangle has no development potential because the overburden is greater than 500 feet (152 m) in thickness.

The Pawnee coal bed (pl. 24) has development potential for surface mining in the northern portion of the quadrangle. Small areas of low development potential extend from the coal boundary up the slopes to the 500-foot (152-m) overburden contour.

The Number 5 coal bed (pl. 21) has development potential for surface mining in two isolated areas, one in the northeastern part of the quadrangle and the other in the southwestern part of the quadrangle. Very small areas of high development potntial extend from the coal boundary up the valleys to the 10 mining-ratio contour. Extremely small areas of moderate development potential occur as narrow bands between the 10 and 15 mining-ratio contours. The remainder of the surface mining area has low development potential.

The lower split of the Cook coal bed (pl. 18) has development potential for surface mining in the southeastern, southwestern, and northwestern portions of the quadrangle. Very small areas of high development potential extend from the coal boundary up the valleys to the 10 mining-ratio contour. Extremely small areas of moderate development occur as narrow bands between the 10 and 15 mining-ratio contours. The remainder of the surface-minable coal has low development potential.

The upper split of the Cook coal bed (pl. 15) has areas of development potential for surface mining scattered over most 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 very narrow bands between the 10 and 15 mining-ratio contours. Large areas of low development potential extend up the slopes from the 15 mining-ratio contour or the coal boundary to the 500-foot (152-m) overburden contour under the crests of the highest hills.

The Canyon coal bed (pl. 12) has development potential for surface mining over most of the quadrangle. Very large areas of high development potential extend up the slopes and the stream valleys from the coal boundary or outcrop to the 10 mining-ratio contour. Small 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 contour under the crests of the highest hills.

The Dietz coal bed (pl. 8) has development potential for surface mining in the western part of the quadrangle. Relatively large areas of high development potential extend from the outcrop up the slopes and stream valleys to the 10 mining-ratio contour. Small areas of moderate development potential occur as 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 Anderson coal bed (pl. 5) has development potential for surface mining along the western portion of the quadrangle. Small areas of high development potential extend from the outcrops or coal boundaries up the slopes and stream valleys 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 extend from the 15 mining-ratio contour and the coal boundary under the crests of the highest hills.

About 89 percent of the Federal coal land in the quadrangle has a high development potential for surface mining, 5 percent has a moderate development potential, 6 percent has a low development potential, and less than 1 percent has no development potential for surface mining.

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 Bradshaw Creek 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				
Anderson	137,160,000	49,710,000	24,190,000	211,060,000
Dietz	44,890,000	23,420,000	63,310,000	131,620,000
Canyon	275,600,000	136,520,000	132,190,000	544,310,000
Upper Cook	9,870,000	6,750,000	80,430,000	97,050,000
Lower Cook	1,280,000	1,850,000	63,240,000	66,370,000
Number 5	3,150,000	2,120,000	23,710,000	28,980,000
Pawnee	0	0	16,020,000	16,020,000
Cache	38,760,000	33,310,000	146,400,000	218,470,000
Total	510,710,000	253,680,000	549,490,000	1,313,880,000
Hypothetical Resource tonnage				
Upper Cook	0	0	12,400,000	12,400,000
Pawnee	0	0	4,640,000	4,640,000
Total	0	0	17,040,000	17,040,000
Grand Total	510,710,000	253,680,000	566,530,000	1,330,920,000

Table 2.--Underground-minable coal resource tonnage (in short tons) by development-potential category for Federal lands in the Bradshaw Creek 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				
Dietz	0	0	1,880,000	1,880,000
Canyon	0	0	13,710,000	13,710,000
Upper Cook	0	0	6,920,000	6,920,000
Lower Cook	0	0	12,760,000	12,760,000
Number 5	0	0	170,000	170,000
Pawnee	0	0	70,620,000	70,620,000
Cache	0	0	332,200,000	332,200,000
Knobloch	0	0	32,450,000	32,450,000
Flowers-Goodale	0	0	146,060,000	146,060,000
Broadus	0	0	72,260,000	72,260,000
Total	0	0	689,030,000	689,030,000
Hypothetical Resource tonnage				
Upper Cook	0	0	1,020,000	1,020,000
Pawnee	0	0	19,530,000	19,530,000
Cache	0	0	80,000	80,000
Knobloch	0	0	9,580,000	9,580,000
Flowers-Goodale	0	0	5,140,000	5,140,000
Broadus	0	0	4,230,000	4,230,000
Total	0	0	39,580,000	39,580,000
Grand Total	0	0	728,610,000	728,610,000

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