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COAL RESOURCE OCCURRENCE AND COAL DEVELOPMENT POTENTIAL MAPS OF THE BIRNEY DAY SCHOOL QUADRANGLE, ROSEBUD COUNTY, MONTANA

[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 Birney Day School quadrangle, Rosebud County, Montana, (35 plates; U.S. Geological Survey Open-File Report 79-080). 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 Birney Day School quadrangle is in southern Rosebud County, Montana, about 8 miles (13 km) southwest of Ashland, Montana; 4 miles (6.4 km) north-northeast of Birney, Montana; and 31 miles (50 km) northeast of Decker, Montana. Ashland is on east-west U.S. Highway 212. The nearest railroads are spur lines of the Burlington Northern Railroad at the Big Sky coal mine in the Colstrip SE quadrangle, about 25 miles (40 km) north-northwest of the quadrangle, and at the Decker coal mine about 27 miles (43 km) up the Tongue River southwest of the quadrangle.

Accessibility

The Birney Day School quadrangle is accessible from Ashland, Montana, by going south-southwestward on the Tongue River Road, an improved graveled road along the southeast side of the Tongue River, about 12 miles (19.3 km) to the eastern border of the quadrangle. This road passes through the southeastern part

of the quadrangle and continues on to Birney, about 4 miles (6.4 km) southwest of the quadrangle. There is also an unimproved road from Ashland through the quadrangle along the northwestern side of the Tongue River. A few local roads and trails intersect these roads to provide access to the less rugged parts of the quadrangle.

Physiography

The Birney Day School quadrangle is within the Missouri Plateau division of the Great Plains physiographic province. The Tongue River enters the southwestern corner of the quadrangle and flows northeastward across the quadrangle. The land surface is maturely dissected by the Tongue River and its tributaries. The Tongue River has a flood plain 0.5 to 1.0 mile (0.8 to 1.6 km) in width at an elevation of about 3,000 to 3,100 feet (914 to 945 m). Its principal tributaries: Kelly Creek, Pawnee Creek, Tie Creek, Poker Jim Creek, and Poker Techee Creek, have narrower flood plains. Except for areas close to the Tongue River and its principal tributaries the land surface is extremely rugged, and the sides of the intertributary divides in most places have been carved into badlands. The larger of these divides are narrow, flat-topped ridges capped by erosion-resistant clinker beds formed by the burning of coal beds.

The highest elevation in the quadrangle, about 4,174 feet (1,272 m), is on a southeastward-trending ridge in the northwestern part of the quadrangle. The lowest elevation, about 3,000 feet (914 m), is along the Tongue River in the northeastern part of the quadrangle. Topographic relief in the quadrangle is about 1,174 feet (358 m).

Climate

The climate of Rosebud 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 Birney Day School quadrangle. The lands northwest of the Tongue River are within the Northern Cheyenne Indian Reservation and contain no Federal coal lands. Most of the lands southeast of the Tongue River are within the Northern Powder River Basin Known Recoverable Coal Resource Area (KRCRA). The Federal government owns most of the coal rights in the KRCRA. The Custer National Forest covers the southeastern corner of the quadrangle. There were no Federal coal leases or prospecting permits recorded as of 1977.

GENERAL GEOLOGY

Previous work

Warren (1959, pl. 19, west half) mapped the southeastern part of the quadrangle as part of the Birney-Broadus coal field. Matson and Blumer (1973, pl. 11A) mapped the Knobloch coal bed in that part of the quadrangle southeast of the Tongue River as part of the Poker Jim-O'Dell Creek coal deposit.

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

Stratigraphy

A generalized columnar section of the coal-bearing rocks of the Birney Day School quadrangle is shown on the Coal Data Sheet (pl. 3A) of the CRO maps. The

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

The Tongue River Member consists of interbedded lenticular beds of gray, fine- to very fine-grained sandstone, light- to dark-gray siltstone, gray shale and claystone, brown carbonaceous shale, and coal beds. The thicker coal beds have burned along the outcrops, baking the overlying sandstone and shale and forming thick, reddish-colored clinker beds. The upper part of the Tongue River Member has been removed from the quadrangle by erosion, but about 1,450 to 1,700 feet (442-518 m) of Tongue River strata remains.

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 Birney Day School quadrangle is in the north-central part of the Powder River structural basin. The strata regionally dip southward at an angle of less than 1 degree, but in the Birney Day School quadrangle this dip is considerably modified by low-relief folding. Some of the nonuniformity in structure may be

caused by differential compaction and to irregularities in deposition of the coals and other lenticular beds as a result of their continental origin.

COAL GEOLOGY

The coal beds in the Birney Day School quadrangle are shown in outcrop on the Coal Data Map (pl. 1) and in section on the Coal Data Sheet (pls. 3A and 3B). All of the mapped coal beds occur in the Tongue River Member of the Fort Union Formation (Paleocene). No commercial coals are known to exist below the Tongue River Member.

The lowermost recognized coal bed is a local coal bed which occurs at the base of the Tongue River Member. This local coal bed is overlain successively by a noncoal interval of about 60 to 70 feet (18.3 to 21.3 m), the Terret coal bed, a noncoal interval of about 100 to 120 feet (30.5 to 37 m), the Flowers-Goodale coal bed, a noncoal interval of about 140 feet (42.7 m), the Nance coal bed, a noncoal interval of about 18 to 130 feet (5.5 to 39.6 m), the Knobloch coal bed, a noncoal interval of about 12 to 75 feet (3.7 to 22.9 m), the King coal bed, a mainly noncoal interval of about 100 to 120 feet (30.5 to 36.6 m) containing a local coal bed, the Cache (Odell) coal bed, a mainly noncoal interval of about 100 feet (30.5 m) containing two local coal beds, the Pawnee coal bed, a noncoal interval of about 140 to 180 feet (42.7 to 54.9 m), the Wall coal bed, a mainly noncoal interval of about 80 to 175 feet (24.4 to 53.3 m) containing a local coal bed, the Otter coal bed, a noncoal interval of about 35 to 40 feet (10.7 to 12.2 m), the lower split of the Cook coal bed, a mainly noncoal interval of about 70 to 160 feet (21.3 to 48.8 m) containing a local coal bed, the Canyon coal bed, a noncoal interval of about 80 feet (24.4 m), and the Alderson coal bed.

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).

Local coal bed at the base of the Tongue River Member

The local coal bed which occurs at the base of the Tongue River Member is the lowest known coal bed in the Birney Day School quadrangle. This local bed does not crop out in the quadrangle but has been penetrated by two oil-and-gas test holes in the southern part of the quadrangle (pls. 1 and 3B). Because this local coal has a limited, known areal extent and ranges from 3 to 5 feet (0.9 to 1.5 m) in thickness, it has not been assigned economic coal resources.

Other local coal beds

Other local coal beds occur in the Birney Day School quadrangle (composite section, pl. 3A) between the King and Cache (Odell) coal beds, between the Cache (Odell) and Pawnee coal beds, between the Wall and the Otter coal beds, between the lower split of the Cook and Canyon coal beds, and above the Alderson coal bed. These local coal beds are thin and of small areal extent and, therefore, have not been assigned economic coal resources.

Terret coal bed

The Terret coal bed was first described by Bass (1932, p. 51) from a small coal mine in sec. 16, T. 1 S., R. 45 E. on the Terret Ranch in the Cook Creek Reservoir quadrangle, about 20 miles (32 km) northeast of the Birney Day School quadrangle. The Terret coal bed does not crop out in the Birney Day School quadrangle but has been penetrated by two oil-and-gas test holes in the southern part of the quadrangle (pls 1 and 3B). In these test holes the Terret coal bed occurs about 60 to 70 feet (18.3 to 21.3 m) above the local coal bed at the base of the Tongue River Member. The isopach and structure contour map (pl. 31) shows that the Terret coal bed ranges from about 5 to 10 feet (1.5 to 3.0 m) in

thickness and, in general, dips eastward at an angle of less than half a degree, although this dip is modified slightly by low-relief folding. Overburden on the Terret coal bed (pl. 32) ranges from about 420 to 1,400 feet (128 to 427 m) in thickness.

There is no known, publicly available chemical analysis of the Terret coal in the Birney Day School quadrangle. A chemical analysis of the Terret coal from the Holt mine (sec. 20, T. 3 S., R. 44 E.) in the Ashland quadrangle (Gilmour and Dahl, 1967, p. 18), about 5 miles (8.0 km) northeast in the Birney Day School quadrangle, shows ash 3.9 percent, sulfur 0.4 percent, and a heating value of 9,020 Btu per pound (20,980 kJ/kg) on an as-received basis. This heating value converts to about 9,386 Btu per pound (21,832 kJ/kg) on a moist, mineral-matter-free basis, indicating that the Terret coal at that location is subbituminous C in rank. Because of the proximity of that location to the Birney Day School quadrangle, it is assumed that the Terret coal in this quadrangle is similar and is also subbituminous C in rank.

Flowers-Goodale coal bed

The Flowers-Goodale coal bed was first described by Bass (1932, p. 53) from two small mines about 26 miles (42 km) northeast of the Birney Day School quadrangle in the Brandenberg quadrangle. The Flowers-Goodale coal bed does not crop out in the Birney Day School quadrangle but has been penetrated by two oil-and-gas test holes in the southern part of the quadrangle (pls. 1 and 3B). In these test holes the Flowers-Goodale coal bed occurs about 100 to 120 feet (30.5 to 37 m) above the Terret coal bed. The isopach and structure contour map (pl. 28) shows that the Flowers-Goodale coal bed ranges from about 6 to 24 feet (1.8 to 7.3 m) in thickness and, in general, dips southward or eastward at an angle of less than half a degree, but this dip is somewhat modified by low-relief

folding. Overburden on the Flowers-Goodale coal bed (pl. 29) ranges from about 180 to 1,200 feet (55 to 366 m) in thickness.

There is no known, publicly available chemical analysis of the Flowers-Goodale coal in the Birney Day School quadrangle. However, a chemical analysis of this coal from a depth of 53 to 62 feet (16 to 19 m) in coal test hole SH-7076, sec. 14, T. 1 S., R. 45 E., in the Cook Creek Reservoir quadrangle, about 20 miles (32 km) northeast of Birney Day School quadrangle (Matson and Blumer, 1973, p. 121), shows ash 8.144 percent, sulfur 0.961 percent, and heating value of 8,102 Btu per pound (18,845 kJ/kg) on an as-received basis. This heating value converts to about 8,820 Btu per pound (20,515 kJ/kg) on a moist, mineral-matter-free basis, indicating that the Flowers-Goodale coal at that location is subbituminous C in rank. Because the Birney Day School quadrangle is deeper in the basin, the Flowers-Goodale coal in this quadrangle would be higher in heating value and would be subbituminous C or possibly subbituminous B in rank.

Nance coal bed

The Nance coal bed is named for its occurrence at a depth of 242 feet (73.8 m) in the Nance and Hayes M11-2 drill hole, SE¼ SE¼ sec. 25, T. 5 S., R. 42 E., about 0.4 mile (0.6 km) south of the Birney Day School quadrangle in the Browns Mountain quadrangle (Mapel and Martin, 1978, p. 21). A coal at about the same stratigraphic horizon in holes drilled in the valley of the Tongue River in the Birney Day School and adjacent quadrangles was regarded by Matson and Blumer (1973, pl. 33) as a lower bench of the Knobloch coal bed. This coal bed is referred to as the Lower Knobloch by Culbertson and Klett (1976) following a modification of the usage of Matson and Blumer (1973).

The Nance coal bed does not crop out in the Birney Day School quadrangle but is penetrated by two drill holes in the southern part of the quadrangle (pls. 1 and 3B). In these holes the Nance coal bed occurs about 140 feet (42.7 m)

above the Flowers-Goodale coal bed. The isopach and structure contour map (pl. 25) shows that the Nance coal bed ranges from about 4 to 10 feet (1.2 to 3.0 m) in thickness and, in general, dips southward or eastward at an angle of less than 1 degree, although this dip is modified by low-relief folding. Overburden on the Nance coal bed (pl. 26) ranges from about 100 to 1,100 feet (30.5 to 335.3 m) in thickness.

There is no known, publicly available chemical analysis of the Nance coal in the Birney Day School quadrangle. However, an analysis of the upper, middle, and lower (Nance) benches of the Knobloch coal from a depth of 216 to 218 feet (65.8 to 66.4 m) in coal test hole SH-7055, sec. 6, T. 4 S., R. 45 E., about 7.5 miles (12 km) northeast of the Birney Day School quadrangle in the Willow Crossing quadrangle (Matson and Blumer, 1973, p. 64), shows ash 6.381 percent, sulfur 0.154 percent, and heating value 8,558 Btu per pound (19,906 kJ/kg) on an as-received basis. This heating value converts to about 9,141 Btu per pound on a moist, mineral-matter-free basis, indicating that the Nance coal at that location is subbituminous C in rank. Because of the proximity of that location to the Birney Day School quadrangle, it is assumed that the Nance coal in the Birney Day School quadrangle is similar and is also subbituminous C in rank.

Knobloch coal bed

The Knobloch coal bed (misspelled Knoblock in early reports) was first described by Bass (1924) from exposures along the Tongue River on the Knobloch Ranch in secs. 17 and 18, T. 5 S., R. 43 E. in the Birney Day School quadrangle. The coal bed identified in this report as the Knobloch was called the middle bench of the Knobloch by Matson and Blumer (1973, pls. 11A and 33), and the Middle Knobloch by Culbertson and Klett (1976) in their report on the Browns Mountain quadrangle located just south of the Birney Day School quadrangle.

In the Birney Day School quadrangle, the Knobloch crops out along the Tongue River (pl. 1) and occurs about 18 to 130 feet (5.5 to 39.6 m) above the Nance coal bed (pl. 3B). The isopach and structure contour map (pl. 22) shows that the Knobloch coal bed ranges from about 10 to 24 feet (3.0 to 7.3 m) in thickness and, in general, dips southward or eastward at an angle of less than 1 degree. Overburden on the Knobloch coal bed (pl. 23) ranges from 0 feet at the outcrops to about 1,000 feet (0-305 m) in thickness.

There is no known, publicly available chemical analysis of the Knobloch coal from the Birney Day School quadrangle. However, a chemical analysis of the Knobloch coal (Matson and Blumer, 1973, p. 64) from a depth of 105 to 112 feet (32.0 to 34.1 m) in coal test hole SH-103, sec. 7, T. 6 S., R. 43 E., about 3 miles (4.8 km) south-southwest of the Birney Day School quadrangle in the Birney quadrangle, shows ash 5.903 percent, sulfur 0.163 percent, and heating value 8,963 Btu per pound (20,848 kJ/kg) on an as-received basis. This heating value converts to about 9,525 Btu per pound (22,155 kJ/kg) on a moist, mineral-matter-free basis, indicating that the Knobloch coal at that location is subbituminous B in rank. Because of the proximity of that location to the Birney Day School quadrangle, it is assumed that the Knobloch coal in this quadrangle is similar and is also subbituminous B in rank.

King coal bed

The King coal bed was named by Warren (1959, p. 571), presumably for outcrops of the bed near King Creek, a tributary of the Tongue River, located about 3 miles (4.8 km) east of the Birney Day School quadrangle in the Green Creek and Ashland quadrangles. The same coal bed was called the upper bench of the Knobloch coal bed by Matson and Blumer (1973, pls. 11A and 33) along the Tongue River in and near the Birney Day School quadrangle. This bed was called the Upper Knobloch coal bed by Culbertson and Klett (1976) in the northern part

of the Browns Mountain quadrangle just south of the Birney Day School quadrangle.

The King coal bed crops out locally in the southwestern and south-central parts of the Birney Day School quadrangle and has been penetrated by drill holes (pl. 1). It occurs about 12 to 75 feet (3.7 to 22.9 m) above the Knobloch coal bed (pls. 1, 3A, and 3B). The isopach and structure contour map (pl. 19) shows that the King coal bed ranges from about 2.3 to 9 feet (0.7 to 2.7 m) in thickness and, in general, dips southward or southeastward at an angle of less than 1 degree, although this dip is somewhat modified by low-relief folding. Overburden on the King coal bed (pl. 20) ranges from 0 feet at the outcrops to about 1,000 feet (0-304.8 m) in thickness.

A chemical analysis of the King coal (upper bench of the Knobloch coal of Matson and Blumer, 1973, p. 64) from a depth of 60 to 66 feet (18.3 to 20.1 m) in coal test hole SH-117, sec. 30, T. 5 S., R. 43 E., in the southwestern part of the Birney Day School quadrangle shows ash 4.776 percent, sulfur 0.594 percent, and heating value 9,135 Btu per pound (21,248 kJ/kg) on an as-received basis. This heating value converts to about 9,593 Btu per pound (22,313 kJ/kg) on a moist, mineral-matter-free basis, indicating that the King coal in the Birney Day School quadrangle is subbituminous B in rank.

Cache (Odell) coal bed

The Cache coal bed was named by Warren (1959, p. 572) for exposures along Cache Creek about 37 miles (59.5 km) east-southeast of the Birney Day School quadrangle in the Yarger Butte and Lonesome Peak quadrangles. The Odell coal bed was first described by Warren (1959, p. 572) presumably from exposures of coal along O'Dell Creek in the Green Creek quadrangle just east of the Birney Day School quadrangle. Warren (1959, pl. 19) also mapped the Odell coal bed in the Birney Day School quadrangle. Preliminary regional mapping indicates

that the Cache and Odell coal beds are equivalent. The name Cache coal bed is used in this report because this name has been used over a wider area and appears to be a better regional name for the coal bed.

The Cache (Odell) coal bed crops out in the southern part of the Birney Day School quadrangle (pl. 1). It occurs about 100 to 120 feet (30.5 to 36.6 m) above the King coal bed. Because the Cache (Odell) coal bed is less than 5 feet (1.5 m) thick, it has not been assigned economic coal resources.

Pawnee coal bed

The Pawnee coal bed was first described by Warren (1959, p. 572) from outcrops in the Birney-Broadus coal field which includes the Birney Day School quadrangle. This coal bed crops out in the southern part of the quadrangle and occurs about 100 feet (30.5 m) above the Cache (Odell) coal bed. The isopach and structure contour map (pl. 16) shows that the Pawnee coal bed ranges from about 4 to 10 feet (1.2 to 3.0 m) in thickness. The bed is quite flat but has been folded into a low-relief syncline. Overburden on the Pawnee coal bed (pl. 17) 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 Pawnee coal in or close to the Birney Day School quadrangle. It is assumed that the Pawnee coal is similar to other closely associated coals in the Birney Day School quadrangle and is subbituminous C in rank.

Wall coal bed

The Wall coal bed was first described by Baker (1929, p. 37), probably from exposures along Wall Creek about 10 miles (16 km) southwest of the Birney Day School quadrangle in the southwestern part of the Birney quadrangle. The Wall coal bed was mapped by Warren (1959, pl. 19) in the southeastern part of the Birney Day School quadrangle. This coal bed occurs about 140 to 180 feet (42.7 to 54.9 m) above the Pawnee coal bed. The isopach and structure contour map

(pl. 13) shows that the Wall coal bed ranges from 3.3 to 6.4 feet (1.0 to 2.0 m) in thickness and is quite flat, although it has been folded into a low-relief syncline. Overburden on the Wall coal bed (pl. 14) 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 Wall coal in the Birney Day School quadrangle. A chemical analysis of the Wall coal (Matson and Blumer, 1973, p. 39) from a depth of 150 to 159 feet (45.7 to 48.5 m) in coal test hole SH-110, sec. 33, T. 5 S., R. 41 E., about 9 miles (14.5 km) west-southwest of the Birney Day School quadrangle in the Birney SW quadrangle, shows ash 5.790 percent, sulfur 0.380 percent, and heating value 8,972 Btu per pound (20,869 kJ/kg) on an as-received basis. This heating value converts to about 9,523 Btu per pound (22,150 kJ/kg) on a moist, mineral-matter-free basis, indicating that the Wall coal at that location is subbituminous B in rank but close to subbituminous C in rank. Because of the proximity of that location to the Birney Day School quadrangle, it is assumed that the Wall coal in this quadrangle is similar and is subbituminous B or C in rank.

Otter coal bed

The Otter coal bed is a name first used by Bryson and Bass (1973, p. 56) for a coal bed exposed in the valley of Otter Creek and its tributaries in the vicinity of Otter Post Office (T. 7 S., R. 45 E.) about 15 miles (24.1 km) southeast of the Birney Day School quadrangle in the Otter quadrangle. Warren (1959, pl. 19) did not map the Otter coal bed in the Birney Day School quadrangle, presumably because it does not crop out. However, Culbertson and Klett (1976) used the names Upper and Lower Otter beds for a pair of coal beds 5 to 30 feet (1.5 to 9 m) apart in outcrops in the Browns Mountain quadrangle directly south of the Birney Day School quadrangle. The Otter coal bed crops out in the northern part of the Poker Jim Butte quadrangle just southeast of Birney

Day School quadrangle and has been recognized in three oil-and-gas test holes there (Mapel, Martin, and Butler, 1978, p. 12). The Otter coal bed has also been recognized in a test hole in the Green Creek quadrangle (Colorado School of Mines Research Institute, 1979, pls. 1 and 3) just east of the Birney Day School quadrangle.

The Otter coal bed has been projected into the subsurface of the southeastern part of the Birney Day School quadrangle from the quadrangles to the south and east. The isopach and structure contour map (pl. 10), based on measurements in adjacent quadrangles, shows that the Otter coal bed in the Birney Day School quadrangle ranges from about 5 to 9 feet (1.5 to 2.7 m) in thickness and is almost flat. Overburden on the Otter coal bed (pl. 11) ranges from 0 feet to about 400 feet (0-122 m).

There is no known, publicly available chemical analysis of unweathered Otter coal in or near the Birney Day School quadrangle. It is assumed that the Otter coal is similar to other closely associated coals in the Birney Day School quadrangle and is subbituminous C in rank.

Lower split of the Cook coal bed

The Cook coal bed was first described by Bass (1932, p. 59-60) from exposures of coal in the Cook Creek Reservoir quadrangle about 15 miles (24 km) northeast of the Birney Day School quadrangle. Preliminary regional mapping indicates that the Cook coal bed in places splits into two coal beds and that this bed in the Birney Day School quadrangle correlates with the lower split of the Cook coal bed. This coal bed outcrops in the southeastern part of the Birney Day School quadrangle (pl. 1). It occurs about 35 to 40 feet (10.7 to 12.2 m) above the Otter coal bed. The isopach and structure contour map (pl. 7) shows that the lower split of the Cook coal bed ranges from about 5 to 9 feet (1.5 to 2.7 m) in thickness and is folded into a low-relief syncline. Overburden on

this coal bed (pl. 8) ranges from 0 feet at the outcrops to about 380 feet (0-115.8 m) in thickness.

There is no known, publicly available chemical analysis of coal of the lower Cook split in, or close to, the Birney Day School quadrangle. It is assumed that the lower split of the Cook coal is similar to other closely associated coals in this quadrangle and is 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. Although a type locality was not given, it may be along Canyon Creek in the northern part of the Spring Gulch quadrangle, about 13 miles (21 km) southwest of the Birney Day School quadrangle. Warren (1959, pl. 19) mapped the Canyon coal bed in the southeastern part of the Birney Day School quadrangle. The Canyon coal bed occurs about 70 to 160 feet (21.3 to 48.8 m) above the lower split of the Cook coal bed. The isopach and structure contour map (pl. 4) shows that the Canyon coal bed ranges from about 3.9 to 10.6 feet (1.2 to 3.2 m) in thickness and dips to the west at an angle of less than half a degree. Overburden on the Canyon coal bed (pl. 5) ranges from 0 feet at the outcrops to about 200 feet (0-61 m) in thickness.

There is no known, publicly available chemical analysis of the Canyon coal in the Birney Day School quadrangle. A chemical analysis of the Canyon coal (Matson and Blumer, 1973, p. 47) from a depth of 43 to 53 feet (13.1 to 16.2 m) in coal test hole SH-7038, sec. 9, T. 7 S., R. 44 E., about 9 miles (14.5 km) south-southeast of the Birney Day School quadrangle, in the Hamilton Draw quadrangle, shows ash 3.761 percent, sulfur 0.165 percent, and heating value 8,801 Btu per pound (20,471 kJ/kg) on an as-received basis. This heating value converts to about 9,145 Btu per pound (21,271 kJ/kg) on a moist,

mineral-matter-free basis, indicating that the Canyon coal at that location is subbituminous C in rank. Because of the proximity of that location to the Birney Day School quadrangle, it is assumed that the Canyon coal in this quadrangle is similar and is also subbituminous C in rank.

Alderson coal bed

Warren (1959, p. 574 and pl. 19) described and mapped the Alderson coal bed near the tops of divides in the southeastern part of the Birney Day School quadrangle where it occurs about 80 feet (24.4 m) above the Canyon coal bed. Warren states that this coal bed consists of thin lenses of coal of limited areal extent and is nowhere more than 5 feet (1.5 m) thick. The Alderson coal bed has not been assigned economic coal resources in this quadrangle.

Garfield clinker bed

A clinker bed, formed by the burning of the Garfield coal bed, caps the highest hills near the southeastern corner of the quadrangle. The Garfield coal has been entirely burned in this quadrangle.

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

Tonnages of coal resources were estimated using coal-bed thicknesses obtained from the coal isopach map for each coal bed (see list of illustrations). The coal resources, in short tons, for each isopached coal bed are the product of the acreage of coal (measured by planimeter), the average thickness in feet of the coal bed, and a conversion factor of 1,770 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 614.40 million short tons (557.38 million t). The total tonnage of federally owned, surface-minable Hypothetical coal is estimated to be 0.13 million short tons (0.12 million t). As shown by table 2, the total federally owned, underground-minable Reserve Base coal is estimated to be 362.51 million short tons (328.86 million t). There is no federally owned, underground-minable Hypothetical coal. The total tonnage of surface- and underground-minable Reserve Base coal is 976.91 million short tons (886.25 million t), and the total of surface- and underground-minable Hypothetical coal is 0.13 million short tons (0.12 million t).

About 8 percent of the surface-minable Reserve Base tonnage is classed as Measured, 28 percent as Indicated, and 64 percent as Inferred. About 3 percent of the underground-minable Reserve Base tonnage is Measured, 23 percent is Indicated, and 74 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). This thickness of overburden is the assigned stripping limit for surface mining of multiple beds of subbituminous coal in this area. Areas having a potential for surface mining were assigned a high, moderate, or low development potential based on their mining ratios (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 coal, 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 to high topographic relief, the area of moderate development potential for surface mining of a coal bed (area having mining-ratio values of 10 to 15) is often restricted to a narrow band between the high and low development-potential areas. In fact, because of the 40-acre (16.2-ha) minimum size of coal development-potential tracts, the narrow band of moderate development-potential area often does not appear on the CDP map because it falls within the 40-acre (16.2-ha) tracts that also include areas of high development potential. The Coal Development Potential (CDP) map then shows areas of high development potential abutting against areas of low development potential.

The coal development potential for surface-mining methods in the Federal coal lands is shown on the Coal Development Potential map (pl. 34). Most of the Federal lands have a high development potential for surface mining.

The Canyon coal bed (pl. 5) has narrow bands of high development potential for surface mining (mining-ratio values less than 10) and moderate development potential (mining-ratio values 10-15) near the tops of hills in the southeastern part of the quadrangle. There are small areas of low development potential extending from the 15 mining-ratio contour to the crests of the hills.

The lower split of the Cook coal bed (pl. 8) and the Otter coal bed (pl. 11) have narrow bands of high development potential for surface mining (mining-ratio values less than 10) and narrow bands of moderate development potential (mining-ratio values 10 to 15) on hill sides in the southeastern part of the quadrangle. There are wider areas of low development potential extending from the 15 mining-ratio contour to the crests of the hills.

The Wall coal bed (pl. 14) has narrow bands of high development potential for surface mining (mining-ratio values less than 10), and very narrow bands of moderate development potential (mining-ratio values 10 to 15) on hill sides in the southeastern part of the quadrangle. There are relatively wide areas of low development potential extending from the 15 mining-ratio contour to the crests of the hills or to the 500-foot (154.2-m) overburden isopach (the stripping limit).

The Pawnee coal bed (pl. 17) has quite wide bands of high development potential for surface mining on the lower hill slopes in the southern and southeastern parts of the quadrangle extending from the boundary of the coal to the 10 mining-ratio contour. There are narrow bands of moderate development potential higher on the slopes between the 10 and 15 mining-ratio contours. Wider areas of low development potential extend from the 15 mining-ratio contour to the crest of the hills or to the 500-foot (152.4-m) overburden isopach (the stripping limit).

The King coal bed (pl. 20) has quite wide areas of high development potential for surface mining on the hill slopes southeast of the Tongue River in the southern part of the quadrangle extending from the boundary of the coal to the 10 mining-ratio contour. There are narrow areas of moderate development potential between the 10 and 15 mining-ratio contours. Wide areas of low development potential extend from the 15 mining-ratio contour to the crests of

the hills or to the 500-foot (152.4-m) overburden isopach (the stripping limit).

The Knobloch coal bed (pl. 23) has a wide area of high development potential for surface mining on the hill slopes southeast of the Tongue River extending from the boundary of the coal to the 10 mining-ratio contour. There is a moderately wide band of moderate development potential higher on the slopes between the 10 and 15 mining-ratio contours. A wider band of low development potential extends from the 15 mining-ratio contour to the 500-foot (152.4-m) overburden isopach (the stripping limit).

The Nance coal bed (pl. 26) has no areas of high development potential for surface mining. There is an area of moderate development under the flood plain of the Tongue River extending from the Northern Cheyenne Indian Reservation boundary to the 15 mining-ratio contour. There is an extensive area of low development potential on the hill slopes extending from the 15 mining-ratio contour to the 500-foot (152.4-m) overburden isopach (the stripping limit).

The Flowers-Goodale coal bed (pl. 29) has no areas of high or moderate development potential for surface mining because the mining-ratio values for this coal are greater than 15. The Flowers-Goodale coal bed has a wide area of low development potential for surface mining under the flood plain of the Tongue River and on the hill slopes to the southeast extending from the boundary of the Northern Cheyenne Indian Reservation to the 500-foot (152.4-m) overburden isopach (the stripping limit).

The Terret coal bed (pl. 32) has no areas of high or moderate development potential for surface mining because the mining-ratio values for this coal bed are greater than 15. There is a quite wide area of low development potential under the Tongue River flood plain and the bordering hill slopes extending from

the Northern Cheyenne Indian Reservation boundary or the boundary of the coal to the 500-foot (152.4-m) overburden isopach (the stripping limit).

About 83 percent of the Federal coal lands in the Birney Day School quadrangle has a high development potential for surface mining, 7 percent has a moderate development potential, and 10 percent has a low 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 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 Birney Day School quadrangle, Rosebud County, Montana

[Development potentials are based on mining ratios (cubic yards of overburden/short ton of recoverable coal). To convert short tons to metric tons, multiply by 0.9072]

Coal bed	High development potential (0-10 mining ratio)	Moderate development potential (10-15 mining ratio)	Low development potential (>15 mining ratio)	Total
Reserve Base tonnage				
Canyon	1,280,000	1,100,000	1,310,000	3,690,000
Lower Cook	450,000	990,000	4,510,000	5,950,000
Wall	900,000	620,000	5,260,000	6,780,000
Otter	6,100,000	490,000	2,450,000	9,040,000
Pawnee	14,450,000	10,100,000	24,330,000	48,880,000
King	9,760,000	4,650,000	67,950,000	82,360,000
Knobloch	82,940,000	59,350,000	93,610,000	235,900,000
Nance	0	5,800,000	96,760,000	102,560,000
Flowers-Goodale	0	0	109,130,000	109,130,000
Terret	0	0	10,110,000	10,110,000
Total	115,880,000	83,100,000	415,420,000	614,400,000
Hypothetical Resource tonnage				
Flowers-Goodale	0	0	130,000	130,000
Total	0	0	130,000	130,000
Grand Total	115,880,000	83,100,000	415,550,000	614,530,000

Table 2.--Underground-minable coal resource tonnage (in short tons) by development-potential category for Federal lands in the Birney Day School quadrangle, Rosebud County, Montana

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

Coal bed	High Development potential	Moderate development potential	Low development potential	Total
Reserve Base tonnage				
Wall	0	0	350,000	350,000
Pawnee	0	0	3,500,000	3,500,000
King	0	0	14,110,000	14,110,000
Knobloch	0	0	50,610,000	50,610,000
Nance	0	0	36,820,000	36,820,000
Flowers-Goodale	0	0	182,400,000	182,400,000
Terret	0	0	74,720,000	74,720,000
Total	0	0	362,510,000	362,510,000

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