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COAL RESOURCE OCCURRENCE AND COAL DEVELOPMENT POTENTIAL MAPS OF THE YAGER BUTTE QUADRANGLE, POWDER RIVER COUNTY, MONTANA

[Report includes 44 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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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 Yager Butte quadrangle, Powder River County, Montana, (44 plates; U.S. Geological Survey Open-File Report 79-102). 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 Yager Butte 7 1/2-minute quadrangle is in west-central Powder River County, Montana, about 9.5 miles (15.3 km) southeast of Ashland and about 29 miles (46.7 km) west of Broadus. Ashland and Broadus are 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 30 miles (48 km) northwest of the quadrangle, and at the Decker coal mine near the town of Decker, about 40 miles (64 km) southwest of the quadrangle.

Accessibility

The Yager Butte quadrangle is accessible from Ashland, Montana, by following U.S. Highway 212 southeastward from Ashland about 4 miles (6.4 km), and then taking the improved, graveled Otter Creek Road southward about 10 miles (16 km) to the local Tenmile Creek Road, or 13 miles (21 km) southward to the graveled Fifteenmile Creek Road, and then following these roads eastward about 1.5 or 2 miles (2.4 or 3.2 km) to the western border of the Yager Butte quadrangle. These roads continue eastward across the quadrangle to the small town of Sonnette, which is about 9 miles (14.5 km) east of the quadrangle. The Yager Butte quadrangle is also accessible from Broadus, Montana, by following U.S. Highway 212 westward about 22 miles (35 km) to the improved, graveled Pumpkin Creek Road, and then taking this road southward about 11 miles (17.7 km) to Sonnette, and then following the Tenmile Creek or Fifteenmile Creek roads 9 or 10 miles (14.5 or 16.1 km) westward to the eastern border of the quadrangle. There are only a few unimproved roads and trails in the quadrangle.

Physiography

The Yager Butte quadrangle is within the Missouri Plateau Division of the Great Plains physiographic province. The plateau is formed by nearly flat-lying sedimentary strata that vary in their resistance to erosion. The plateau has been deeply and intricately dissected by three westward- or northwestward-flowing perennial streams: Fifteenmile Creek in the southern part of the quadrangle, Tenmile Creek in the central part, and Threemile Creek just north of the quadrangle. These creeks are tributaries of Otter Creek which flows northward 1 to 3 miles (1.6 to 4.8 km) west of the quadrangle. Otter Creek flows into the northward-flowing Tongue River about 10 miles (16 km) northwest of the quadrangle near Ashland. Tenmile Creek and Fifteenmile Creeks have flood plains about 0.25 mile (0.4 km) wide. From the flood plains, the hills rise steeply about 400 or 500 feet (122 or 152 m), generally in a series of sloping steps, to the narrow flat tops of the interstream highlands. The flat tops of the highlands are grass covered, but the steep slopes are forested. All of the quadrangle except the western tier of sections is within the Custer National Forest.

The highest elevation, 4,023 feet (1,226 m), is on Yager Butte in the northeastern quarter of the quadrangle. The lowest elevation, about 3,130 feet (954 m), is on Tenmile Creek at the western border of the quadrangle. Topographic relief within the quadrangle is about 893 feet (272 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 Yager Butte quadrangle. All of the quadrangle is within the Northern Powder River Basin Known Recoverable Coal Resource Area (KRCRA). The Federal government owns most of the coal rights. In 1977 there were no Federal coal leases, prospecting permits, or leases.

GENERAL GEOLOGY

Previous work

Warren (1959, pl. 19) mapped the Yager Butte quadrangle as part of the Birney-Broadus coal field. Matson, Dahl, Jr., and Blumer (1968, p. 24-33) mapped the strippable coal deposits on State land along the western border of the quadrangle. Matson and Blumer (1973, pls. 12, 23A, and 23B) mapped the Knobloch, Elk, Dunning, and Cook coal beds in the quadrangle as part of the Otter Creek and Yager Butte coal deposits. In 1977 the U.S. Bureau of Land Management and the U.S. Bureau of Reclamation issued a Energy Mineral Rehabilitation Inventory and Analysis (EMRIA) report on resource evaluation of the Dam Creek study site, a small area in sec. 12, T. 5 S., R. 45 E., which extends into the quadrangle from the west.

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 Yager Butte quadrangle is shown on the Coal Data Sheet (pl. 3) of the CRO maps. The exposed bedrock units belong to the Tongue River Member, the uppermost member of the Fort Union Formation of Paleocene age.

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 by erosion from the quadrangle, but about 1,400 to 1,500 feet (427 to 457 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 Yager Butte quadrangle is in the north-central part of the Powder River structural basin. Regionally, the strata dip southward to southwestward at an angle of less than 1 degree, but in the Yager Butte quadrangle this dip is considerably modified by low-relief folding. Some of the nonuniformity in structure may be caused by differential compaction of the sediments 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 Yager Butte 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 in this quadrangle below the Tongue River Member.

The lowermost recognized coal bed is the Broadus coal bed, which occurs about 160 to 170 feet (49 to 52 m) above the base of the Tongue River Member. The Broadus coal bed is overlain successively by a noncoal interval of about 176 to 195 feet (53.6 to 59.4 m), the Flowers-Goodale coal bed, a noncoal interval of about 50 to 230 feet (15 to 70 m), the Nance coal bed, a noncoal interval of about 50 to 77 feet (15 to 23.5 m), the lower split of the Knobloch coal bed, a noncoal interval of about 22 to 37 feet (6.7 to 11.3 m), the upper split of the Knobloch coal bed, a noncoal interval of about 35 to 50 feet (10.7 to 15.2 m), the local coal bed above the Knobloch coal bed, a noncoal interval of about 135 feet (41 m), the lower split of the Sawyer coal bed, a noncoal interval of about 8 feet (2.4 m), the upper split of the Sawyer coal bed, a noncoal interval of about 125 to 135 feet (38 to 41 m), the Odell coal bed, a mainly noncoal interval of about 100 to 200 feet (30 to 61 m) containing local coal beds, the Dunning coal bed, a noncoal interval of about 20 to 75 feet (6.1 to 22.9 m), the Elk coal bed, a mainly noncoal interval of about 100 to 130 feet (30 to 40 m) containing a local coal bed, the lower split of the Cook coal bed, a noncoal interval of about 55 to 140 feet (16.8 to 42.7 m), the upper split of the Cook coal bed, a mainly noncoal interval of about 100 to 200 feet (30.5 to 61 m) containing a local coal bed, 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).

Broadus coal bed

The Broadus coal bed was first described by Warren (1959, p. 570) from exposures of coal near the town of Broadus about 27 miles (43.4 km) east of the Yager Butte quadrangle in the Birney-Broadus coal field. The Broadus coal bed does not crop out in the Yager Butte quadrangle but has been recognized in oil-and-gas test holes. In these test holes the Broadus coal bed occurs about 160 to 170 feet (49 to 52 m) above the base of the Tongue River Member. However, because of the sparse information, the correlation of this coal bed with the Broadus coal bed at its type locality is uncertain.

The isopach and structure contour map (pl. 40) shows that the Broadus coal bed in this quadrangle ranges from about 5 to 15 feet (1.5 to 4.5 m) in thickness and dips southwestward at an angle of less than 0.5 degree. Overburden on the Broadus coal bed (pl. 41) ranges from about 460 to 1,200 feet (140 to 366 m) in thickness.

There is no known, publicly available chemical analysis of the Broadus coal in, or close, to the Yager Butte quadrangle. It is assumed that the Broadus coal is similar in rank to other closely associated coals in the Yager Butte quadrangle and is 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 in the Brandenberg quadrangle, about 23 miles (37 km) north-northwest of the Yager Butte quadrangle. The Flowers-Goodale coal bed does not crop out in the Yager Butte quadrangle, but it has been penetrated by oil-and-gas test holes (pls. 1A and 3). In these holes the Flowers-Goodale coal bed occurs about 176 to 195 feet (53.6-59.4 m) above the Broadus coal bed. The isopach and structure contour map (pl. 37) shows that the Flowers-Goodale coal bed ranges from about 3 to 10 feet (0.9 to 3.0 m) in thickness and, in general, dips westward or southward at an angle of less than 1 degree, although this dip is somewhat modified by low-relief folding. Overburden on the Flowers-Goodale coal bed where it is more than 5 feet (1.5 m) thick ranges from about 300 to 1,000 feet (91 to 305 m) in thickness.

There is no known, publicly available chemical analysis of the Flowers-Goodale coal from the Yager Butte 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., about 16.5 miles (26.5 km) north-northwest of the Yager Butte quadrangle in the Cook Creek Reservoir quadrangle (Matson and Blumer, 1973, p. 121) shows ash 8.144 percent, sulfur 0.961 percent, and heating value 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 Yager Butte quadrangle is deeper in the basin, the Flowers-Goodale coal bed in this quadrangle should be more compacted and, therefore, higher in heating value. It should be either subbituminous C or subbituminous B in rank.

Knobloch coal bed and its splits, including the Nance coal bed

The Knobloch coal bed was first described by Bass (1932, p. 52) from exposures of coal along the Tongue River in the Birney Day School quadrangle on the Knobloch Ranch in secs. 17 and 18, T. 5 S., R. 43 E., about 15 miles (24 km) west of the Yager Butte quadrangle. In the Yager Butte quadrangle, the Knobloch coal bed splits into four coal beds, as shown by the composite columnar section on plate 3.

The lowermost split of the Knobloch coal bed is the Nance coal bed which splits from the Knobloch coal bed in the northern part of the Yager Butte quadrangle, as shown on the isopach and structure contour map of the Nance coal bed (pl. 34). The next higher coal bed is the lower split of the Knobloch coal bed, which splits from the Knobloch in the north-central part of the quadrangle (pl. 31). South of this split line the upper split of the Knobloch coal bed is also present as a separate coal bed (pl. 28). A thin local coal bed splits from the top of the Knobloch coal bed in the northwestern part of the quadrangle (pl. 28). Only in the northernmost part of the quadrangle is the Knobloch coal a single, thick, unsplit coal bed (pl. 28).

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 17.5 miles (28.2 km) west-southwest of the Yager Butte quadrangle in the Browns Mountain quadrangle (Mapel and Martin, 1978, p. 21).

The Nance coal bed does not crop out in the Yager Butte quadrangle but has been penetrated by a few test holes (pl. 1B). In these holes, the Nance coal bed occurs about 50 to 230 feet (15 to 70 m) above the Flowers-Goodale coal bed. The isopach and structure contour map (pl. 34) shows that the Nance coal bed ranges from about 6 to 18 feet (1.8 to 5.5 m) in thickness and has been folded into a broad, low-relief anticline and syncline. Overburden on the Nance coal bed (pl. 35) ranges from about 50 to 950 feet (15 to 290 m) in thickness.

There is no known, publicly available chemical analysis of the Nance coal in the Yager Butte 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 4.5 miles (7.2 km) northwest of the Yager Butte 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 Yager Butte quadrangle, it is assumed that the Nance coal in the Yager Butte quadrangle is similar and is also subbituminous C in rank.

Lower split of the Knobloch coal bed

The lower split of the Knobloch coal bed splits from the Knobloch coal bed along a split line in the north-central part of the Yager Butte quadrangle (pl. 31). The lower split of the Knobloch coal bed does not crop out in the Yager Butte quadrangle, but it has been penetrated by a few test holes (pl. 1B). In these test holes the lower split of the Knobloch coal bed occurs about 50 to 77 feet (15 to 23 m) above the Nance coal bed. The isopach and structure contour map (pl. 31) shows that the lower split of the Knobloch coal bed ranges from about 2 to 20 feet (0.6 to 6.1 m) in thickness and that the coal bed has been folded into a broad low-relief anticline in the central part of the quadrangle. Overburden on the lower split of the Knobloch coal bed (pl. 32) ranges from almost 0 feet to about 800 feet (244 m) in thickness. The lower split of the Knobloch coal bed is assumed to be similar in rank to the closely associated, upper split of the Knobloch coal bed and to be subbituminous C in rank also.

Upper split of the Knobloch coal bed

The upper split of the Knobloch coal bed crops out in the southwestern part of the Yager Butte quadrangle (pl. 1) and has been penetrated by several test holes (pl. 3). In these holes the upper split of the Knobloch coal bed occurs 22 to 37 feet (6.7 to 11.3 m) above the lower split of the Knobloch coal bed (pl. 3). The isopach and structure contour map (pl. 28) shows that the upper split of the Knobloch coal bed ranges from about 18 to 24 feet (5.5 to 7.3 m) in thickness and has been folded into a broad, low-relief anticline in the central part of the quadrangle. Overburden on the upper split of the Knobloch coal bed (pl. 29) ranges from 0 at the outcrops to about 800 feet (0 to 244 m) in thickness.

A chemical analysis of the upper split of the Knobloch coal bed from a depth of 116 to 126 feet (35 to 38 m) in coal test hole SH-7051, sec. 33, T. 4 S., R. 46 E. in the central part of the Yager Butte quadrangle (Matson and Blumer, 1973, p. 68) shows ash 5.019 percent, sulfur 0.181 percent, and heating value 8,305 Btu per pound (19,324 kJ/kg) on an as-received basis. This heating value converts to about 8,744 Btu per pound (20,339 kJ/kg) on a moist, mineral-matter-free basis, indicating that the upper split of the Knobloch coal in the Yager Butte quadrangle is subbituminous C in rank.

Knobloch coal bed

The unsplit Knobloch coal bed does not crop out in the Yager Butte quadrangle. As shown by the isopach and structure contour map (pl. 28), the unsplit

Knobloch coal bed occurs only in the northernmost part of the quadrangle. Here the Knobloch coal bed ranges from about 42 to 64 feet (12.8 to 19.5 m) in thickness. It dips westward only about 100 feet (30 m) in 6 miles (9.6 km). Overburden on the unsplit Knobloch coal (pl. 29) ranges from about 100 to 500 feet (30 to 152 m) in thickness.

There is no known, publicly available chemical analysis of the unsplit Knobloch coal bed in the Yager Butte quadrangle. It is presumed to be similar to the upper split of the Knobloch in this quadrangle and to be subbituminous C in rank.

Local coal bed above the Knobloch coal bed

The local coal bed which splits from the upper part of the Knobloch coal bed in the northwestern part of the Yager Butte quadrangle crops out locally in the southwestern part of the quadrangle (pl. 1). However, because this local coal bed is less than 5 feet (1.5 m) thick, it has not been assigned economic coal resources.

Lower split of the Sawyer coal bed

The Sawyer coal bed was first described by Dobbin (1930, p. 28) from exposures of coal in the foothills of the Little Wolf Mountains in the Forsyth coal field (Rough Draw and Black Springs quadrangles) about 40 miles (64 km) northwest of the Yager Butte quadrangle. The lower split of the Sawyer coal bed crops out near the northwestern corner of the Yager Butte quadrangle (pl. 1) where it was mapped as the King coal bed by Warren (1959, pl. 19). Preliminary regional mapping indicates that the Sawyer and King coal beds are equivalent. The oil-and-gas test hole in the northwestern part of the Yager Butte quadrangle penetrated an upper and lower Sawyer coal bed separated by 8 feet (2.4 m) of shale (pl. 1B). In this test hole the lower split of the Sawyer coal bed is 134 feet (40.8 m) above the Knobloch coal bed. The isopach and structure contour map (pl. 23) shows that the lower split of the Sawyer coal bed ranges from about 5 to 10 feet (1.5 to 3.0 m) in thickness and dips westward at an angle of less than 0.5 degree. Overburden on the lower split of the Sawyer coal bed (pl. 26) ranges from about 100 to 600 feet (30.5 to 183 m) in thickness.

A chemical analysis of the Sawyer coal from a depth of 90 to 97 feet (27.4 to 29.6 m) in coal test hole SH-7064, sec. 8, T. 3 S., R. 46 E., about 6 miles (9.7 km) north of the Yager Butte quadrangle in the Coleman Draw quadrangle (Matson and Blumer, 1973, p. 73) shows ash 4.026 percent, sulfur 0.352 percent, and heating value 7,965 Btu per pound (18,527 kJ/kg) on an as-received basis. This heating value converts to about 8,299 Btu per pound (18,557 kJ/kg) on a moist, mineral-matter-free basis, indicating that the Sawyer coal at that location is very close to the border between lignite A and subbituminous C in rank. Because the Yager Butte quadrangle is deeper in the basin, it is assumed that the Sawyer coal in this quadrangle would have been compacted more and, therefore, have a greater heating value and would be subbituminous C in rank.

Upper split of the Sawyer coal bed

The upper split of the Sawyer coal bed does not crop out in the Yager Butte quadrangle but has been penetrated by an oil-and-gas test hole in the northwestern part of the quadrangle (pl. 1B). In this test hole, it occurs 8 feet (2.4 m) above the lower split of the Sawyer coal bed and is 5 feet (1.5 m) thick, as shown on the isopach and structure contour map (pl. 23). Overburden on the upper split of the Sawyer coal bed (pl. 24) ranges from about 200 to 400 feet (61 to 122 m) in thickness. A chemical analysis of the Sawyer coal is given in the discussion of the lower split of this coal bed. The upper split should be subbituminous C in rank.

Odell (Cache) coal bed

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, about 9 miles (14.5 km) west of the Yager Butte quadrangle. Warren (1959, pl. 19) mapped the Cache coal bed at the same stratigraphic position in the King Mountain quadrangle just west of Yager Butte quadrangle and just east of the Green Creek quadrangle. The Cache coal bed was named by Warren (1959, p. 572) for exposures along Cache Creek about 18 miles (29 km) east-southeast of the Yager Butte quadrangle in the Yarger Butte and Lonesome Peak quadrangles. Our preliminary regional mapping indicates that the Cache and Odell coal beds are equivalent and probably are the same coal bed.

The Odell (Cache) coal bed and its clinker bed formed by burning of the Odell coal, crop out extensively in the Yager Butte quadrangle. It occurs about 125 to 135 feet (38 to 41 m) above the Upper Sawyer coal bed. The isopach and structure contour map (pl. 20) shows that the Odell (Cache) coal bed ranges from about 2 to 9.5 feet (0.6 to 2.9 m) in thickness and regionally dips southwestward at an angle of less than 0.5 degree, although this dip is modified by low-relief folding. Overburden on the Odell (Cache) coal bed ranges from 0 feet at the outcrops to about 500 feet (0 to 152 m) in thickness.

There is no known, publicly available chemical analysis of the Odell (Cache) coal in, or close, to the Yager Butte quadrangle. It is assumed that the Odell coal is similar to other closely associated coals in the Yager Butte quadrangle and is subbituminous C in rank.

Dunning (Pawnee) coal bed

The Dunning coal bed was first described by Warren (1959, p. 572) from exposures of coal in the Birney-Broadus coal field which includes the Yager Butte quadrangle. Warren (1959, pl. 19) and Matson and Blumer (1973, pl. 23A) mapped the Dunning coal bed in the quadrangle. The Dunning coal bed and its clinker bed, which was formed by burning of the Dunning coal, crop out extensively (pl. 1). It occurs about 100 to 200 feet (30 to 61 m) above the Odell (Cache) coal bed. The isopach and structure contour map (pl. 17) shows that the Dunning coal bed ranges from about 1.8 to 18 feet (0.5 to 5.5 m) in thickness and regionally is quite flat, but has been affected by broad low-relief folding. Overburden on the Dunning coal bed (pl. 18) ranges from 0 feet at the outcrops to about 500 feet (0 to 152 m) in thickness.

We have used the name Dunning for this coal bed in the Yager Butte, Three-mile Buttes, Goodspeed Butte, and Reanus Cone quadrangles based upon usage in early day geological reports on those areas by previous authors (Warren 1959; and others). However, in twenty-one adjacent quadrangles surrounding these four quadrangles we have mapped a coal bed at this same stratigraphic horizon which we, and others, have called the Pawnee coal bed. The Pawnee coal bed was first described by Warren (1959, p. 572) from exposures in the Birney-Broadus coal field, Montana, which includes the Yager Butte quadrangle. Based upon our present-day coal isopachs and structure contours, the Dunning and Pawnee appear to be the same coal bed.

A chemical analysis of the Dunning (Pawnee) coal from a depth of 106 to 110 feet (32 to 33.5 m) in drill hole SH-7146, sec. 20, T. 4 S., R. 46 E. in the Yager Butte quadrangle (Matson and Blumer, 1973, p. 105) shows ash 4.356 percent, sulfur 0.210 percent, and heating value 7,991 Btu per pound (18,587 kJ/kg) on an as-received basis. This heating value converts to about 8,355 Btu per pound (19,434 kJ/kg) on a moist, mineral-matter-free basis, indicating that the Dunning (Pawnee) coal in the Yager Butte quadrangle is subbituminous C in rank.

Elk coal bed

The Elk coal bed was first described by Warren (1959, p. 572) from exposures of coal along Elk Creek in the northern part of the Goodspeed Butte quadrangle, which is just south of the Yager Butte quadrangle. Warren (1959, pl. 19) and Matson and Blumer (1973, pl. 23A) mapped the Elk coal bed in the Yager Butte quadrangle. This coal bed crops out extensively in the quadrangle, although it has been burned in many places near the land surface (pl. 1). It occurs about 20 to 75 feet (6.1 to 22.9 m) above the Dunning (Pawnee) coal bed. The isopach and structure contour map (pl. 14) shows that the Elk coal bed ranges from about 12 to 19 feet (3.7 to 5.8 m) in thickness and is almost flat-lying, although it has been affected a little by broad, low-relief folding. Overburden on the Elk coal bed (pl. 15) ranges from 0 feet to about 400 feet (0 to 122 m) in thickness. A chemical analysis of the Elk coal at a depth of 35 to 40 feet (10.7 to 12.2 m) in coal test hole SH-7146, sec. 20, T. 4 S., R. 46 E. in the Yager Butte quadrangle (Matson and Blumer, 1973, p. 105) shows ash 4.471 percent, sulfur 0.222 percent, and heating value 7,943 Btu per pound (18,475 kJ/kg) on an as-received basis. This heating value converts to about 8,315 Btu per pound (19,341 kJ/kg) on a moist, mineral-matter-free basis, indicating that the Elk coal in the Yager Butte quadrangle 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 10 miles (16 km) north-northwest of the Yager Butte quadrangle. Our preliminary regional mapping indicates that the Cook coal bed in places splits into two coal beds, and that both the upper and lower splits of the Cook coal bed are present in the Yager Butte quadrangle. Matson and Blumer (1973, pl. 23B) mapped the Upper and Lower Cook coal beds in this quadrangle. Warren (1959, pl. 19) mapped the lower split of the Cook coal bed as the Wall coal bed in the Birney-Broadus coal field, which includes the Yager Butte quadrangle.

The lower split of the Cook coal bed occurs about 100 to 130 feet (30 to 40 m) above the Elk coal bed and crops out high on the hill slopes in the Yager Butte quadrangle. The isopach map (pl. 10) shows that the lower split of the Cook coal bed ranges from about 1.5 to 8 feet (0.5 to 2.4 m) in thickness. The structure contour map (pl. 11) shows that this coal bed is quite flat, although it is affected somewhat by low-relief folding. Overburden on the lower split of the Cook coal bed (pl. 12) ranges from 0 feet at the outcrop to about 100 feet (0 to 30.5 m) in thickness.

A chemical analysis of the coal of the lower split of the Cook coal bed from a depth of 72 to 76 feet (22 to 23 m) in coal test hole SH-7048, sec. 25, T. 5 S., R. 46 E., Goodspeed Butte quadrangle, about 0.5 mile (0.8 km) south of the Yager Butte quadrangle (Matson and Blumer, 1973, p. 104), shows ash 3.724 percent, sulfur 0.465 percent, and heating value 7,541 Btu per pound (17,540 kJ/kg) on an as-received basis. This heating value converts to about 7,833 Btu per pound (18,217 kJ/kg) on a moist, mineral-matter-free basis, indicating that the lower split of the Cook coal bed at that location is lignite A in rank. Because of the proximity of that location to the Yager Butte quadrangle, it is assumed that the lower split of the Cook coal bed in this quadrangle is similar and is also lignite A in rank.

Upper split of the Cook coal bed

The upper split of the Cook coal bed (pl. 1) crops out near the crests of the hills in the eastern part of the Yager Butte quadrangle. It occurs about 55 to 140 feet (16.8 to 42.7 m) above the lower split of the Cook coal bed. The isopach and structure contour map (pl. 7) shows that the upper split of the Cook coal bed ranges from about 2.4 to 12 feet (0.7 to 3.7 m) in thickness, and that it is quite flat-lying, although it is affected by low-relief folding. Overburden on the upper split of the Cook coal bed (pl. 8) ranges from 0 feet at the outcrop to about 100 feet (0 to 30.5 m) in thickness.

A chemical analysis of the coal of the upper split of the Cook coal bed from a depth of 62 to 72 feet (19 to 22 m) in coal test hole SH-7048, sec. 25, T. 5 S., R. 46 E., about 0.5 mile (0.4 km) south of the Yager Butte quadrangle in the Goodspeed Butte quadrangle (Matson and Blumer, 1973, p. 104) shows ash 6.638 percent, sulfur 0.672 percent, and heating value 7,496 Btu per pound (17,436 kJ/kg) on an as-received basis. This heating value converts to about 8,029 Btu per pound (18,675 kJ/kg) on a moist, mineral-matter-free basis, indicating that the upper split of the Cook coal bed at that location is lignite A in rank. Because of the proximity of that location to the Yager Butte quadrangle, it is assumed that the upper split of the Cook coal bed in this quadrangle is similar and is also lignite A in rank.

Alderson coal bed

The Alderson coal bed was first described by Warren (1973, p. 574) from exposures of coal in the Birney-Broadus coal field which includes the Yager Butte quadrangle. This coal bed crops out near the crests of hills in the northeastern part of the quadrangle where it occurs about 100 to 200 feet (30.5 to 61 m) above the upper split of the Cook coal bed. The isopach and structure contour map (pl. 4) shows that the Alderson coal bed ranges from about 5 to 6.1 feet (1.5 to 1.9 m) in thickness and dips westward at an angle of about 1 degree or less. Overburden on the Alderson coal bed (pl. 5) ranges from 0 feet at the outcrop to about 50 feet (0 to 50 m) in thickness.

There is no known, publicly available chemical analysis of the Alderson coal in, or close, to the Yager Butte quadrangle. It is assumed that the Alderson coal is similar to the Cook coal beds below it and is lignite A in rank.

Local coal beds

Local coal beds occur in the Yager Butte quadrangle between the Odell (Cache) and Dunning (Pawnee) coal beds, between the Elk and Lower Cook coal beds, and between the Upper Cook and Alderson coal beds. Because these local coal beds are thin and of limited areal extent, they have not been assigned economic coal resources.

COAL RESOURCES

Data from all publicly available drill holes and from surface mapping by others (see list of references) were used to construct outcrop, isopach, and structure contour maps of the coal beds in this quadrangle.

A coal resource classification system has been established by the U.S. Bureau of Mines and the U.S. Geological Survey and published in U.S. Geological Survey Bulletin 1450-B (1976). Coal resource is the estimated gross quantity of coal in the ground that is now economically extractable or that may become so. Resources are classified as either Identified or Undiscovered. Identified Resources are specific bodies of coal whose location, rank, quality, and quantity are known from geologic evidence supported by specific measurements. Undiscovered Resources are bodies of coal which are surmised to exist on the basis of broad geologic knowledge and theory.

Identified Resources are further subdivided into three categories of reliability of occurrence: namely Measured, Indicated, and Inferred, according to their distance from a known point of coal-bed measurement. Measured coal is coal located within 0.25 mile (0.4 km) of a measurement point, Indicated coal extends 0.5 mile (0.8 km) beyond Measured coal to a distance of 0.75 mile (1.2 km) from the measurement point, and Inferred coal extends 2.25 miles (3.6 km) beyond Indicated coal to a distance of 3 miles (4.8 km) from the measurement point.

Undiscovered Resources are classified as either Hypothetical or Speculative. Hypothetical Resources are those undiscovered coal resources in beds that may reasonably be expected to exist in known coal fields under known geologic conditions. In general, Hypothetical Resources are located in broad areas of coal fields where the coal bed has not been observed and the evidence of coal's existence is from distant outcrops, drill holes, or wells that are more than 3 miles (4.8 km) away. Hypothetical Resources are located beyond the outer boundary of the Inferred part of Identified Resources in areas where the assumption of continuity of the coal bed is supported only by extrapolation of geologic evidence. Speculative Resources are undiscovered resources that may occur in favorable areas where no discoveries have been made. Speculative Resources have not been estimated in this report.

For purposes of this report, Hypothetical Resources of subbituminous coal are in coal beds which are 5 feet (1.5 m) or more thick, under less than 3,000 feet (914 m) of overburden, but occur 3 miles (4.8 km) or more from a coal-bed measurement. Hypothetical Resources of lignite are in lignite beds which are 5 feet (1.5 m) or more thick, under less than 1,000 feet (305 m) of overburden, but occur 3 miles (4.8 km) or more from a coal-bed measurement.

Reserve Base coal is that economically minable part of Identified Resources from which Reserves are calculated. In this report, Reserve Base coal is the gross amount of Identified Resources that occurs in beds 5 feet (1.5 m) or more thick and under less than 3,000 feet (914 m) of overburden for subbituminous coal or under less than 1,000 feet (305 m) of overburden for lignite.

Reserve Base coal may be either surface-minable coal or underground-minable coal. In this report, surface-minable Reserve Base coal is subbituminous coal that is under less than 500 feet (152 m) of overburden or lignite that is under less than 200 feet (61 m) of overburden. In this report, underground-minable

Reserve Base coal is subbituminous coal that is under more than 500 feet (152 m), but less than 3,000 feet (914 m) of overburden, or lignite that is under more than 200 feet (61 m), but less than 1,000 feet (305 m) of overburden.

Reserves are the recoverable part of Reserve Base coal. 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) or a conversion factor of 1,750 short tons of lignite per acre-foot (12,870 metric tons per hectare-meter). Tonnages of coal in Reserve Base, Reserves, and Hypothetical categories, rounded to the nearest one-hundredth of a million short tons, for each coal bed are shown on the Areal Distribution and Tonnage maps (see list of illustrations).

As shown by table 1, the total tonnage of federally owned, surface-minable Reserve Base coal in this quadrangle is estimated to be 2,357.90 million short tons (2,139.09 million t). The total tonnage of federally owned, surface-minable Hypothetical coal is estimated to be 31.36 million short tons (28.45 million t). As shown by table 2, the total federally owned, underground-minable Reserve Base coal is estimated to be 989.12 million short tons (897.38 million t). The total federally owned, underground-minable Hypothetical coal is estimated to be 54.25

million short tons (49.21 million t). The total tonnage of surface- and underground-minable Reserve Base coal is 3,347.07 million short tons (3,036.46 million t), and the total of surface- and underground-minable Hypothetical coal is 85.61 million short tons (77.67 million t).

About 4 percent of the surface-minable Reserve Base tonnage is classed as Measured, 26 percent as Indicated, and 70 percent as Inferred. About 3 percent of the underground-minable Reserve Base tonnage is Measured, 13 percent is Indicated, and 84 percent is Inferred.

The total tonnages per section for both Reserve Base and Hypothetical coal, including both surface- and underground-minable coal are shown in the northwest corner of the Federal coal lands in each section on plate 2. All numbers on plate 2 are rounded to the nearest one-hundredth of a million short tons.

COAL DEVELOPMENT POTENTIAL

There is a potential for surface-mining in the Northern Powder River Basin in areas where subbituminous coal beds 5 feet (1.5 m) or more thick are overlain by less than 500 feet (152 m) of overburden (the stripping limit), or where lignite beds of the same thickness are overlain by 200 feet (61 m) or less of overburden (the stripping limit). This thickness of overburden is the assigned stripping limit for surface mining of multiple beds of subbituminous coal in this area. Areas having a potential for surface mining were assigned a high, moderate, or low development potential based on their mining ratios (cubic yards of overburden per short ton of recoverable coal).

The formula used to calculate mining-ratio values for coal is:

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

where MR = mining ratio

t_o = thickness of overburden, in feet

t_c = thickness of coal, in feet

rf = recovery factor = 0.85 in this area

cf = conversion factor = 0.911 cu. yds./short ton for subbituminous coal or 0.922 cu. yds./short ton for lignite

The mining-ratio values are used to rate the degree of potential that areas within the stripping limit have for surface-mining development. Areas having mining-ratio values of 0 to 10, 10 to 15, and greater than 15 are considered to have high, moderate, and low development potential, respectively. This grouping of mining-ratio values was provided by the U.S. Geological Survey and is based on economic and technological criteria. Mining-ratio contours and the stripping-limit overburden isopach, which serve as boundaries for the development-potential areas, are shown on the overburden isopach and mining-ratio contour plates. Estimated tonnages of surface-minable Reserve Base and Hypothetical coal resources in each development-potential category (high, moderate, and low) are shown in table 1.

Estimated tonnages of underground-minable coal resources are shown in table 2. Because coal is not presently being mined by underground mining in the Northern Powder River Basin for economic reasons, for purposes of this report all of the underground-minable coal resources are considered to have low development potential.

Development potential for surface-mining methods

The Coal Development Potential (CDP) map included in this series of maps pertains only to surface mining. It depicts the highest coal development-potential category which occurs within each smallest legal subdivision of land (normally about 40 acres or 16.2 ha). For example, if such a 40-acre (16.2-ha) tract of land contains areas of high, moderate, and low development potential, the entire tract is assigned to the high development-potential category for CDP mapping purposes. Alternatively, if such a 40-acre (16.2-ha) tract of land contains areas of moderate, low, and no development potential, the entire tract is assigned to the moderate development-potential category for CDP mapping purposes. For practical reasons, the development-potential categories of areas of coal smaller than 1 acre (0.4 ha) have been disregarded in assigning a development potential to the entire 40-acre (16.2-ha) tract.

In areas of moderate or high topographic relief, the area of moderate development potential for surface mining of a coal bed (area having mining-ratio values of 10 to 15) is often restricted to a narrow band between the high and low development-potential areas. In fact, because of the 40-acre (16.2-ha) minimum size of coal development-potential tracts, the narrow band of moderate development-potential area often does not appear on the CDP map because it falls within the 40-acre (16.2-ha) tracts that also include areas of high development potential. The Coal Development Potential (CDP) map then shows areas of high development potential abutting against areas of low development potential.

The coal development potential for surface-mining methods in the Federal coal lands is shown on the Coal Development Potential Map (pl. 42). Most of the Federal lands have a high development potential for surface mining.

The Alderson coal bed (pl. 5) in the northeastern part of the quadrangle has two very small areas of high development potential for surface mining (mining-ratio values less than 10) near the crests of hills.

The upper split of the Cook coal bed (pl. 8) has a few very small areas of high, moderate, and low development potential for surface mining near the crests of hills in the southeastern part of the quadrangle.

The lower split of the Cook coal bed (pl. 12) has small areas of high, moderate, and low development potential for surface mining in the eastern part of the quadrangle.

The Elk coal bed (pl. 15) and the Dunning (Pawnee) coal bed (pl. 18) have quite wide areas of high development potential for surface mining (mining-ratio values less than 10) on hill slopes in the wastern and central parts of the quadrangle. There are narrow bands of moderate development potential (mining-ratio values

10-15) higher on the hill slopes. Wider areas of low development potential extend from the 15 mining-ratio contour to the crests of the hills or to the 500-foot (152 m) overburden isopach (the stripping limit for subbituminous coal).

The Odell (Cache) coal bed (pl. 21) has an extensive area of development potential for surface mining in this quadrangle. However, there are only narrow bands of high development potential (mining-ratio values less than 10) and very narrow bands of moderate development potential (mining-ratio values 10-15) on the hill slopes. Most of the Odell (Cache) coal is in areas of low development potential extending from the 15 mining-ratio contour to the crests of the hills or to the 500-foot (152 m) overburden isopach (the stripping limit). There are a few small areas of no development potential for surface mining above the 500-foot (152 m) overburden isopach.

The upper split of the Sawyer coal bed (pl. 24) and the lower split of the Sawyer coal bed (pl. 26) have small areas of low development potential for surface mining (mining-ratio values greater than 15) on high hill slopes in the northwestern part of the quadrangle.

The unsplit Knobloch coal bed and the upper split of the Knobloch coal bed (pl. 32) have wide areas of high development potential for surface mining (mining-ratio values less than 10) under the flood plains and on the adjacent lower hill slopes. There are quite wide bands of moderate development potential (mining-ratio values 10-15) higher on the hill slopes. There are wide areas of low development potential for surface mining extending from the 15 mining-ratio contour to the 500-foot (152 m) overburden isopach (the stripping limit). There are also wide areas of no development potential for surface mining under the crests of the hills above the 500-foot overburden isopach (the stripping limit).

The lower split of the Knobloch coal bed (pl. 32) has an area of high development potential for surface mining (mining-ratio values less than 10) mainly under the flood plain of Tenmile Creek. There are bands of moderate development potential (mining-ratio value 10-15). Most of this coal is in areas of low development potential for surface mining extending from the 15 mining-ratio contour to the 500-foot (152 m) overburden isopach (the stripping limit). There are also wide areas of no development potential for surface mining under the crests of the hills above the 500-foot (152 m) overburden isopach (the stripping limit).

The Nance coal bed (pl. 35) has a small area of high development potential for surface mining (mining-ratio values less than 10) under the flood plain of South Fork of Threemile Creek. There is a quite wide area of moderate development potential (mining-ratio values 10-15) under the same flood plain and on the lower hill slopes. Most of the Nance coal is in areas of low development potential for surface mining extending from the 15 mining-ratio contour to the 500-foot (152 m) overburden isopach (the stripping limit) or in areas of no development potential for surface mining above the stripping limit.

The Flowers-Goodale coal bed (pl. 38) has no areas of high or moderate development potential for surface mining in this quadrangle because the mining-ratio values for this coal are greater than 15. There are wide areas of low development potential for surface mining (mining-ratio values greater than 15) extending from the boundary of the coal to the 500-foot (152 m) overburden isopach (the stripping limit). Most of the Flowers-Goodale coal in this quadrangle has no development potential for surface mining as the coal is beyond the stripping limit.

The Broadus coal bed (pl. 41) has no areas of high or moderate development potential for surface mining in the Yager Butte quadrangle because the mining-ratio values for this coal are greater than 15. There is a small area of low development potential for surface mining (mining-ratio values greater than 15) under the flood plain of Tenmile Creek in the west-central part of the quadrangle extending from the bottom of the valley to the 500-foot (152 m) overburden isopach (the stripping limit). Most of the Broadus coal in this quadrangle has no potential for surface mining because it is under more than 500 feet (152 m) of overburden and thus beyond the stripping limit.

About 91 percent of the Federal coal lands in the Yager Butte quadrangle has a high development potential for surface mining, 8 percent has a moderate development potential, and 1 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 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 Yager Butte quadrangle, Powder River 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				
Alderson	730,000	0	0	730,000
Upper Cook	1,640,000	300,000	430,000	2,370,000
Lower Cook	3,140,000	2,680,000	2,640,000	8,460,000
Elk	193,010,000	37,250,000	25,440,000	255,700,000
Dunning (Pawnee)	96,770,000	45,890,000	72,810,000	215,470,000
Odell (Cache)	28,790,000	18,770,000	142,040,000	189,600,000
Upper Sawyer	0	0	3,760,000	3,760,000
Lower Sawyer	0	0	30,840,000	30,840,000
Knobloch and Upper Knobloch	553,920,000	330,930,000	330,730,000	1,215,580,000
Lower Knobloch	6,650,000	5,230,000	77,230,000	89,110,000
Nance	1,990,000	14,970,000	274,250,000	291,210,000
Flowers-Goodale	0	0	49,810,000	49,810,000
Broadus	0	0	5,260,000	5,260,000
Total	886,640,000	456,020,000	1,015,240,000	2,357,900,000
Hypothetical Resource tonnage				
Odell	190,000	1,890,000	996,890,000	5,310,000
Lower Knobloch	0	20,000	9,540,000	9,540,000
Flowers-Goodale	0	0	16,490,000	16,490,000
Total	190,000	1,910,000	29,260,000	31,360,000
Grand Total	886,830,000	457,930,000	1,044,500,000	2,389,260,000

Table 2.--Underground-minable coal resource tonnage (in short tons) by development-potential category for Federal lands in the Yager Butte quadrangle, Powder River 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				
Dunning (Pawnee)	0	0	150,000	150,000
Odell (Cache)	0	0	1,570,000	1,570,000
Lower Sawyer	0	0	750,000	750,000
Knobloch and Upper Knobloch	0	0	326,390,000	326,390,000
Lower Knobloch	0	0	88,790,000	88,790,000
Nance	0	0	217,670,000	217,670,000
Flowers-Goodale	0	0	136,510,000	136,510,000
Broadus	0	0	217,340,000	217,340,000
Total	0	0	989,170,000	989,170,000
Hypothetical Resource tonnage				
Lower Knobloch	0	0	740,000	740,000
Flowers-Goodale	0	0	27,250,000	27,250,000
Broadus	0	0	26,260,000	26,260,000
Total	0	0	54,250,000	54,250,000
Grand Total	0	0	1,043,420,000	1,043,420,000

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