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COAL RESOURCE OCCURRENCE AND COAL DEVELOPMENT POTENTIAL MAPS OF THE SAYLE HALL QUADRANGLE, POWDER RIVER COUNTY, MONTANA

[Report includes 46 plates]

By

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

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ILLUSTRATIONS

[Plates are in pocket]

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Conversion table

To convert	Multiply by	To obtain
feet	0.3048	meters (m)
miles	1.609	kilometers (km)
acres	0.40469	hectares (ha)
tons (short)	0.9072	metric tons (t)
short tons/acre-ft	7.36	metric tons/hectare-meter (t/ha-m)
Btu/lb	2.326	kilojoules/kilogram (kJ/kg)

INTRODUCTION

Purpose

This text is for use in conjunction with the Coal Resource Occurrence (CRO) and Coal Development Potential (CDP) maps of the Sayle Hall quadrangle, Powder River County, Montana, (46 plates; U.S. Geological Survey Open-File Report 79-790). 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 Sayle Hall quadrangle is in southwestern Powder River County, Montana, about 0.5 mile (0.8 km) north of the Montana-Wyoming State border; about 36 miles (58 km) southwest of Broadus, Montana; 36 miles (58 km) east of Decker, Montana; 43 miles (69 km) east-northeast of Sheridan, Wyoming; and 55 miles (88 km) northwest of Gillette, Wyoming. Broadus is on east-west U.S. Highway 212 near its interchanges with U.S. Highway 312 and State Highway 59. Sheridan and Gillette are on U.S. Interstate Highway 90 and a main line of the Burlington Northern Railroad.

Accessibility

The Sayle Hall quadrangle is accessible from Broadus by taking paved, east-west U.S. Highway 212 about 22 miles (35 km) west-northwestward to its intersection with the Pumpkin Creek road, then southward 27 miles (43 km) through Sonnette to the northern border of the quadrangle. The nearest railroad is a main line of the Burlington Northern Railroad about 21 miles (34 km) south of the quadrangle near Kendrick, Wyoming.

Physiography

The Sayle Hall quadrangle is within the Missouri Plateau Division of the Great Plains physiographic province. The plateau is formed by nearly flat-lying sedimentary strata differing in their resistance to erosion. The plateau has been maturally dissected so that flat land surfaces remain only at the higher elevations. The southeastern and southernmost parts of the quadrangle are drained by short, steep, intermittent tributaries of the Powder River which flows northeastward about 3 miles (4.8 km) southeast of the quadrangle. This part of the quadrangle consists of very rough terrain or back lands. The slopes generally rise 250 to 300 feet (76 to 91 m) over a distance of 0.25 mile (0.4 km). The remainder, and larger part, of the quadrangle is drained by northward-flowing Otter Creek and its tributaries. Otter Creek flows into the Tongue River near Ashland about 33 miles (53 km) north-northwest of the quadrangle. This larger part of the quadrangle is less rugged, although the higher slopes of the intertributary ridges are steep. Most of the quadrangle is grass covered. Narrow stands of trees exist only on steep slopes mainly in the easternmost and southernmost parts of the quadrangle. The divide between the Powder River and Tongue River drainage basins trends northeastward across the quadrangle from its southwestern corner at elevations of 4,200 to 4,300 feet (1,280 to 1,311 m). The highest elevations in the quadrangle, about 4,320 feet (1,317 m), are on this divide near the eastern border of the quadrangle. The lowest elevation, about 3,650 feet (1,112 m), is on Otter Creek near the northwestern corner of the quadrangle. Topographic relief within the quadrangle is about 670 feet (204 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 Sayle Hall quadrangle. Most 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. There are no National Forest lands within the quadrangle. As of 1977 there were no coal leases or prospecting permits on the Federal coal lands.

GENERAL GEOLOGY

Previous work

Bryson and Bass (1973, pl. 1) mapped the Sayle Hall quadrangle as part of the Moorhead coal field. Matson (1973, pls. 1, 2, and 3) and Matson and Blumer (1973, pls. 10A, 10B, and 10C) mapped the Anderson, Dietz, and Canyon coal beds in the quadrangle as part of the West Moorhead coal deposit.

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

Stratigraphy

A generalized columnar section of the coal-bearing rocks of the Sayle Hall 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 (Paleocene), and to the overlying Wasatch Formation (Eocene).

The Tongue River Member of the Fort Union Formation 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 Tongue River Member is about 2,200 feet (670 m) thick in the Sayle Hall quadrangle. The boundary between the Fort Union and Wasatch Formations in this area has been drawn at the top of the Roland coal bed of Baker (1929) by previous workers.

About 100 feet (30.5 m) of the basal part of the Wasatch Formation overlies the Roland coal bed of Baker (1929) in the southwestern part of the Sayle Hall quadrangle. The formation here consists of grayish-brown and gray shale, some carbonaceous shale, thin beds of brown calcareous sandstone containing abundant clam and snail shells, and the Arvada coal bed.

Coal and other rocks comprising the lower part of the Wasatch Formation and the Tongue River Member of the Fort Union Formation 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 and early Eocene (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 Sayle Hall quadrangle is in the northeastern part of the Powder River structural basin. The strata dip regionally southwestward at an angle of less than 1 degree, but this dip is modified locally by low-relief folding. Some of the nonuniformity in structure may be caused by differential compaction and by irregularities in deposition of the coals and other beds as a result of their continental origin.

COAL GEOLOGY

The coal beds in the Sayle Hall 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 lower part of the Wasatch Formation (Eocene) and the underlying 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 about 130 feet (39.6 m) above the base of the Tongue River Member. This local coal bed is overlain successively by a noncoal interval of about 75 to 80 feet (22.9 to 24.4 m), the Broadus coal bed, a mainly noncoal interval of about 240 to 340 feet (73 to 104 m) containing a local coal bed, the Flowers-Goodale coal bed, a noncoal interval of about 160 to 220 feet (49 to 67 m), the Knobloch coal bed, a noncoal interval of about 62 to 78 feet (19 to 24 m), the King coal bed, a noncoal interval of about 290 feet (88.4 m), the Cache (Odell) coal bed, a noncoal interval of about 160 to 190 feet (49 to 58 m), the Pawnee (Dunning) coal bed, a mainly noncoal interval of about 160 to 200 feet (49 to 61 m) containing a local coal bed, the lower split of the Cook coal bed, a noncoal interval of about 60 to 90 feet (18.3 to 27.4 m), the upper split of the Cook coal bed, a noncoal interval of about 125 to 180 feet (38 to 55 m), the Canyon coal bed, a mainly noncoal interval of about 60 to 160 feet (18 to 49 m) containing local coal beds, the Dietz coal bed, a mainly noncoal interval of about 25 to 100 feet (7.6 to 30 m) containing local coal beds, the Anderson coal bed, a mainly noncoal interval of about 300 to 370 feet (91 to 113 m) containing local coal beds, the Roland coal bed of Baker (1929), a noncoal interval of about 50 feet (15.2 m), and the Arvada 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 in the Epsie NE quadrangle about 36 miles (58 km) northeast of the Sayle Hall quadrangle in the Birney-Broadus coal field. The Broadus coal bed does not crop out in the Sayle Hall quadrangle but has been recognized in two oil-and-gas test holes in the eastern part of the quadrangle. In these test holes, the Broadus coal bed occurs about 75 to 80 feet (22.9 to 24.4 m) above a local coal bed which occurs about 130 feet (39.6 m) above the base of the Tongue River Member. The isopach and structure contour map (pl. 43) shows that the Broadus coal bed ranges from about 5 to 13 feet (1.5 to 4.0 m) in thickness and dips southwestward at an angle of less than 1 degree. Overburden on the Broadus coal bed (pl. 44) ranges from about 1,400 to 2,000 feet (427 to 610 m) in thickness.

There is no known, publicly available chemical analysis of the Broadus coal in the Sayle Hall quadrangle. However, a chemical analysis of the Broadus coal from the Superior mine, sec. 14, T. 5 S., R. 50 E., about 30 miles (48 km) northeast of the Sayle Hall quadrangle, in the Epsie NE quadrangle (Gilmour and Dahl, 1967, p. 16), shows ash 6.0 percent, sulfur 0.4 percent, and heating value 7,290 Btu per pound (16,957 kJ/kg) on an as-received basis. This heating value converts to about 7,755 Btu per pound (18,038 kJ/kg) on a moist, mineral-matter-free basis, indicating that the Broadus coal at that location is lignite A in rank. However, because the Sayle Hall quadrangle lies deeper in the Powder River structural basin, it is assumed that the coals are more compacted and that the Broadus coal in this quadrangle is subbituminous C in rank.

Flowers-Goodale coal bed

The Flowers-Goodale coal bed was first described by Bass (1932, p. 53) from two small mines about 49 miles (79 km) north-northwest of the Sayle Hall quadrangle in the Brandenberg quadrangle. The Flowers-Goodale coal bed does not crop out in the Sayle Hall quadrangle, and it has not been recognized with certainty in test holes. However, it has been projected into the subsurface of the quadrangles from the quadrangles to the north, east, and west. It occurs about 240 to 340 feet (73 to 104 m) above the Broadus coal bed. The isopach and structure contour map (pl. 40) shows that the Flowers-Goodale coal bed ranges from about 5 to 10 feet (1.5 to 3.0 m) in thickness and dips southwestward or southward at an angle of less than 1 degree. Overburden on the Flowers-Goodale coal bed (pl. 41) ranges from about 1,100 to 1,700 feet (305 to 518 m) in thickness.

There is no known, publicly available chemical analysis of the Flowers-Goodale coal in or close to the Sayle Hall quadrangle. It is assumed that the

Flowers-Goodale coal is similar to other closely associated coals in this quadrangle and is subbituminous C in rank.

Knobloch coal bed

The Knobloch coal bed was first described by Bass (1932, p. 52) from exposures of coal along the Tongue River on the Knobloch Ranch in secs. 17 and 18, T. 5 S., R. 43 E. about 26 miles (42 km) northwest of the Sayle Hall quadrangle in the Birney Day School quadrangle. The Knobloch coal bed does not crop out in the Sayle Hall quadrangle, but it is penetrated by three oil-and-gas test holes in the quadrangle (pls. 1 and 3). The Knobloch coal bed occurs about 160 to 220 feet (49 to 67 m) above the Flowers-Goodale coal bed. The isopach and structure contour map (pl. 37) shows that the Knobloch coal bed ranges from about 5 to 7 feet (1.5 to 2.1 m) in thickness southward or southwestward at an angle of less than 1 degree. Overburden on the Knobloch coal bed (pl. 38) ranges from about 800 to 1,600 feet (244 to 488 m) in thickness.

There is no known, publicly available chemical analysis of the Knobloch coal in the Sayle Hall quadrangle. However, a chemical analysis of the Knobloch coal from a depth of 178 to 187 feet (54 to 57 m) in coal test hole SH-7044, sec. 30, T. 5 S., R. 46 E., about 16.5 miles (26.5 km) north of the Sayle Hall quadrangle in the Goodspeed Butte quadrangle (Matson and Blumer, 1973, p. 68), shows ash 5.423 percent, sulfur 0.157 percent, and heating value 8,515 Btu per pound (19,806 kJ/kg) on an as-received basis. This heating value converts to about 9,003 Btu per pound (20,942 kJ/kg) on a moist, mineral-matter-free basis, indicating that the Knobloch coal at that location is subbituminous C in rank. Because of the proximity of that location to the Sayle Hall quadrangle, it is assumed that the Knobloch coal in this quadrangle is similar and is also subbituminous C in rank.

King coal bed

The King coal bed was first described by Warren (1959, p. 571) probably for exposures of coal along King Creek in the Ashland and Green Creek quadrangles, about 28 miles (45 km) northwest of the Sayle Hall quadrangle. The King coal bed does not crop out in the Sayle Hall quadrangle but has been penetrated in three oil-and-gas test holes (pls. 1 and 3). In these test holes, the King coal bed occurs 62 to 78 feet (19 to 24 m) above the Knobloch coal bed. The isopach and structure contour map (pl. 34) shows that the King coal bed ranges from about 5 to 6 feet (1.5 to 1.8 m) in thickness and dips southwestward at an angle of less than 1 degree. Overburden on the King coal bed (pl. 35) ranges from about 1,000 to 1,500 feet (305 to 457 m) in thickness.

There is no known, publicly available chemical analysis of the King coal in or close to the Sayle Hall quadrangle. It is assumed that the King coal is similar to other closely associated coals in the Sayle Hall quadrangle and is subbituminous C in rank.

Cache (Odell) coal bed

The Cache coal bed was named by Warren (1959, p. 572) for exposures of coal along Cache Creek about 25 miles (40 km) northeast of the Sayle Hall quadrangle in the Yarger Butte and Lonesome Peak quadrangles. Bryson and Bass (1973, pl. 1) mapped the Cache (No. 8-9 and 9) coal bed in the Moorhead coal field which includes the Sayle Hall quadrangle. The Odell coal bed was named by Warren (1959, p. 572) for exposures of coal along O'Dell Creek about 22 miles (35 km) north-northwest of the Sayle Hall quadrangle in the Green Creek quadrangle. The Brewster-Arnold coal bed was named by Bass (1924) for a coal exposure at the Brewster-Arnold coal mine on the Tongue River about 24 miles (38.6 km) northwest of the Sayle Hall quadrangle in the Birney quadrangle. McKay, Butler, and Robinson (1979) mapped the Brewster-Arnold coal bed in the subsurface of the Bear

Creek School quadrangle just west of the Sayle Hall quadrangle. Preliminary regional mapping indicates that the Cache, Odell, and Brewster-Arnold coal beds are equivalent.

The Cache coal bed does not crop out in the Sayle Hall quadrangle but has been penetrated by the three oil-and-gas test holes (pls. 1 and 3). In these test holes, the Cache coal bed is 290 to 294 feet (88.4 to 89.6 m) above the King coal bed. The isopach map (pl. 30) shows that the Cache coal bed ranges from about 7 to 13 feet (2.1 to 4.0 m) in thickness. The structure contour map (pl. 31) shows that the Cache coal bed generally dips southwestward at an angle of less than 1 degree but has been affected in places by minor low-relief folding. Overburden on the Cache coal bed ranges from about 460 to 1,240 feet (140 to 378 m) in thickness.

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

Pawnee (Dunning) coal bed

The Pawnee coal bed and the Dunning coal bed were first described by Warren (1959, p. 572) for exposures of coal in the Birney-Broadus coal field, the southern border of which is about 9.75 miles (15.7 km) north of the Sayle Hall quadrangle. Bryson and Bass (1973, pl. 1) mapped the Pawnee and Dunning coal beds in different parts of the Moorhead coal field which includes the Sayle Hall quadrangle. Warren (1959, p. 572) believed that the Dunning coal bed is the same as the upper bench of the Pawnee coal bed. Preliminary regional mapping indicates that in the vicinity of the Sayle Hall quadrangle the Pawnee and Dunning coal beds are equivalent.

The Pawnee (Dunning) coal bed does not crop out in the Sayle Hall quadrangle but has been projected into the subsurface of the quadrangle from the Reanus Cone quadrangle to the north where it has been mapped by us as the Dunning coal bed. The Pawnee coal bed occurs about 160 to 190 feet (49 to 58 m) above the Cache coal bed. The isopach and structure contour map (pl. 27) shows that the Pawnee coal bed ranges from about 6 to 8 feet (1.8 to 2.4 m) in thickness and dips westward at an angle of less than half a degree. Overburden on the Pawnee coal bed (pl. 28) ranges from about 320 to 900 feet (97.5 to 274 m) in thickness.

There is no known, publicly available chemical analysis of the Pawnee coal in or close to the Sayle Hall quadrangle. It is assumed that the Pawnee coal is similar to other closely associated coals in the Sayle Hall 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 38 miles (61 km) north-northwest of the Sayle Hall quadrangle. 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 beds are present in the Sayle Hall quadrangle.

The lower split of the Cook coal bed does not crop out in the Sayle Hall quadrangle but has been penetrated by the three oil-and-gas test holes (pls. 1 and 3). In these holes the lower split of the Cook coal bed occurs about 312 to 369 feet (95 to 112 m) above the Cache coal bed. In the northernmost part of the quadrangle where the Pawnee (Dunning) coal bed is present, the Lower Cook occurs about 160 to 200 feet (49 to 61 m) above the Pawnee coal bed. The isopach and structure contour map (pl. 24) shows that the lower split of the Cook coal bed ranges from about 4 to 14 feet (1.2 to 4.3 m) in thickness and generally dips southward or southwestward at an angle of half a degree or less, although this dip is slightly modified by minor low-relief folding. Overburden on the lower split of the Cook coal bed (pl. 25) ranges from about 80 to 850 feet (24 to 259 m) in thickness.

There is no known, publicly available chemical analysis of the lower split of the Cook coal in or close to the Sayle Hall quadrangle. However, it is assumed that this coal is similar to the upper split of the Cook coal bed in this quadrangle and is subbituminous C in rank.

Upper split of the Cook coal bed

The upper split of the Cook coal bed does not crop out in the Sayle Hall quadrangle but has been penetrated by the three oil-and-gas test holes (pls. 1 and 3). In these test holes, the upper split of the Cook coal bed is about 60 to 90 feet (18.3 to 27.4 m) above the lower split of the Cook coal bed. The isopach and structure contour map (pl. 21) shows that the upper split of the Cook coal bed ranges from about 4 to 8 feet (1.2 to 2.4 m) in thickness and dips southward or southwestward at an angle of half a degree or less, although this dip is modified slightly by minor low-relief folding. Overburden on the upper split of the Cook coal bed (pl. 22) ranges in thickness from about 70 to 800 feet (21 to 244 m).

A chemical analysis of the upper split of the Cook coal from a depth of 48 to 50 feet (14.6 to 15.2 m) in coal test hole SH-64, sec. 10, T. 7 S., R. 46 E., about 8 miles (12.9 km) north of the Sayle Hall quadrangle in the Reanus Cone quadrangle (Matson and Blumer, 1973, p. 59), shows ash 3.130 percent, sulfur 0.151 percent, and heating value 7,948 Btu per pound (18,487 kJ/kg) on an as-received basis. This heating value converts to about 8,205 Btu per pound (19,085 kJ/kg) on a moist, mineral-matter-free basis, indicating that the upper split of the Cook coal at that location is lignite A in rank but close to subbituminous C in rank. Because the Sayle Hall quadrangle is deeper in the basin, it is believed that this coal in the Sayle Hall quadrangle would have a higher heating value and would be 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, Montana, probably from exposures along Canyon Creek in the northern part of the Spring Gulch quadrangle, about 30 miles (48 km) west of the Sayle Hall quadrangle. Bryson and Bass (1973, pl. 1) and Matson and Blumer (1973, pl. 10C) mapped the Canyon coal bed in the Sayle Hall quadrangle. A thick clinker bed, formed by the burning of the Canyon coal bed, crops out in the northwestern part of the quadrangle (pl. 1). The coal bed has been penetrated by several test holes (pls. 1 and 3). The Canyon coal bed occurs about 125 to 180 feet (38 to 55 m) above the upper split of the Cook coal bed. The isopach map (pl. 17) shows that the Canyon coal bed ranges from about 12 to 24 feet (3.7 to 7.3 m) in thickness. The structure contour map (pl. 18) shows that the Canyon coal bed generally dips southward or southwestward at an angle of half a degree or less, although this dip is considerably modified by low-relief folding. Overburden on the Canyon coal bed (pl. 19) ranges from 0 feet to about 600 feet (0-183 m) in thickness.

A chemical analysis of the Canyon coal from a depth of 84 to 103 feet (25.6 to 31.4 m) in coal test hole SM-13, sec. 16, T. 8 S., R. 46 E., about 0.5 mile (0.8 km) north of the Sayle Hall quadrangle in the Reanus Cone quadrangle (Matson and Blumer, 1973, p. 60), shows ash 3.9 percent, sulfur 0.2 percent, and heating value 8,920 Btu per pound (20,748 kJ/kg) on an as-received basis. This heating value converts to about 9,281 Btu per pound (21,588 kJ/kg) on a moist, mineral-matter-free basis, indicating that the Canyon coal at that location is subbituminous C in rank.

Dietz coal bed

The Dietz coal bed was named by Taff (1909, p. 139-140) from exposures of coal in the Sheridan quadrangle, Wyoming, about 43 miles (69 km) west-southwest of the Sayle Hall quadrangle near the old coal-mining town of Dietz in the Sheridan coal field, Wyoming. In the Sayle Hall quadrangle, the Dietz coal bed was mapped by Bryson and Bass (1973, pl. 1), Matson (1973, pl. 2), and Matson and Blumer (1973, pl. 10B). This coal bed crops out on hill slopes in the northwestern and southeastern parts of the quadrangle (pl. 1) and has been penetrated by several test holes (pls. 1 and 3). It occurs about 60 to 160 feet (18 to 49 m) above the Canyon coal bed. The isopach and structure contour map (pl. 14) shows that the Dietz coal bed ranges from about 5 to 14 feet (1.5 to 4.3 m) in thickness and generally dips southwestward at an angle of half a degree or less, although this dip is somewhat modified by low-relief folding. Overburden on the Dietz coal bed (pl. 15) ranges from 0 feet to about 540 feet (0-165 m) in thickness.

A chemical analysis of the Dietz coal from a depth of 43 to 52 feet (13 to 16 m) in coal test hole SH-7043, sec. 24, T. 8 S., R. 45 E., in the Otter quadrangle, about 1.5 miles (2.4 km) west-northwest of the Sayle Hall quadrangle (Matson and Blumer, 1973, p. 59), shows ash 3.800 percent, sulfur 0.660 percent, and heating value 8,080 Btu per pound (18,794 kJ/kg) on an as-received basis. This heating value converts to about 8,399 Btu per pound (19,536 kJ/kg) on a moist, mineral-matter-free basis, indicating that the Dietz coal at that location is subbituminous C in rank. Because of the proximity of that location to the Sayle Hall quadrangle, it is assumed that the Dietz coal in this quadrangle is similar and is subbituminous C in rank.

Anderson coal bed

The Anderson coal bed was first described by Baker (1929, p. 35) from exposures of coal in the northward extension of the Sheridan coal field, Montana, possibly along Anderson Creek in the southern part of the Spring Gulch quadrangle about 30 miles (48.3 km) west of the Sayle Hall quadrangle. In the Sayle Hall quadrangle, the Anderson coal bed was mapped by Bryson and Bass (1973, pl. 1), Matson (1973, pl. 3), and Matson and Blumer (1973, pl. 10A). The Anderson coal bed, or its clinker bed formed by the burning of the coal, crops out on the high hill slopes in the northern, central, and southeastern parts of the quadrangle (pl. 1) and has been penetrated by several test holes (pls. 1 and 3). It occurs about 25 to 100 feet (7.6 to 30.5 m) above the Dietz coal bed. The isopach map (pl. 10) shows that the Anderson coal bed ranges from about 5 to 30 feet (1.5 to 9.1 m) in thickness. The structure contour map (pl. 11) shows that the coal bed generally dips westward or southward at an angle of less than 1 degree but this dip is modified by low-relief folding. Overburden on the Anderson coal bed (pl. 12) ranges from 0 feet to about 460 feet (0-140 m) in thickness.

A chemical analysis of the Anderson coal from a depth of 64 to 78 feet (19.5 to 23.8 m) in coal test hole SM-15, sec. 16, T. 9 S., R. 46 E., in the Sayle Hall quadrangle (Matson and Blumer, 1973, p. 60), shows ash 6.7 percent, sulfur 0.400 percent, and heating value 7,950 Btu per pound (18,492 kJ/kg) on an as-received basis. This heating value converts to about 8,521 Btu per pound (19,820 kJ/kg) on a moist, mineral-matter-free basis, indicating that the Anderson coal in the Sayle Hall quadrangle is subbituminous C in rank.

Roland coal bed of Baker (1929)

The Roland coal bed was named by Taff (1909, p. 130 and 142) from exposures in the Sheridan coal field, Wyoming. A coal bed mistakenly assumed to be the same bed was called the Roland coal bed in the northward extension of the Sheridan coal field, Montana, by Baker (1929). Subsequent work in the Sheridan coal field has shown that the Roland coal bed of Baker (1929) lies about 125 feet (30 m) above the original Roland coal bed of Taff (1909). The top of the Roland coal bed of Baker (1929) is generally used in southern Montana as the contact between the Fort Union Formation (Paleocene) and the overlying Wasatch Formation (Eocene). Bryson and Bass (1973, pl. 1) mapped the Roland coal bed of Baker (1929) in the Sayle Hall quadrangle. The Roland coal bed of Baker (1929) crops out on the high hill slopes in the southwestern part of the quadrangle (pl. 1) where it occurs about 300 to 370 feet (91 to 113 m) above the Anderson coal bed. The isopach and structure contour map (pl. 7) shows that the Roland coal bed of Baker (1929) ranges from about 5 to 7 feet in thickness and dips westward and southward at an angle of less than half a degree. Overburden on the Roland coal bed of Baker (1929) (pl. 8) ranges from 0 feet to about 100 feet (0-30.5 m) in thickness.

A chemical analysis of the Roland coal from a depth of 68 to 76 feet (20.7 to 23.2 m) in coal test hole SH-7029, sec. 23, T. 9 S., R. 42 E., about 21 miles (33.8 km) west of the Sayle Hall quadrangle in the Pine Butte School quadrangle (Matson and Blumer, 1973, p. 27) shows ash 4.728 percent, sulfur 0.235 percent, and heating value 8,086 Btu per pound (18,808 kJ/kg) on an as-received basis. This heating value converts to about 8,487 Btu per pound (19,741 kJ/kg) on a moist, mineral-matter-free basis, indicating that the Roland coal at that location is subbituminous C in rank. Although that location is slightly deeper in the basin than the Sayle Hall quadrangle, it is believed that the Roland coal of Baker (1929) in the Sayle Hall quadrangle would be somewhat similar and would also be subbituminous C in rank.

Arvada coal bed

The Arvada coal bed was described by Olive (1957, p. 29) for exposures of coal near the town of Arvada (Arvada quadrangle, Wyoming) about 24 miles (38.6 km) south of the Sayle Hall quadrangle in the Spotted Horse coal field, Wyoming. The Arvada coal bed is the lowermost coal bed in the Wasatch Formation (Eocene), occurring about 50 feet (15.2 m) above the Roland coal bed of Baker (1929). This coal bed crops out near the crests of hills in the southwestern part of the Sayle Hall quadrangle. The isopach and structure contour map (pl. 4) shows that the Arvada coal bed ranges from about 4.8 to 7 feet (1.5 to 2.1 m) in thickness and is almost flat-lying. Overburden on the Arvada coal bed (pl. 5) ranges from 0 feet to about 50 feet (0-15.2 m) in thickness.

A chemical analysis of the Arvada coal from the Sweat and Smith mine, sec. 13, T. 55 N., R. 78 W., Wyoming, about 18 miles (29 km) south-southwest of the Sayle Hall quadrangle in the Arvada quadrangle (Olive, 1957, p. 26), shows ash 6.4 percent, sulfur 1.2 percent, and heating value 9,207 Btu per pound (21,415 kJ/kg) on an as-received basis. This heating value converts to about 9,964 Btu on a moist, mineral-matter-free basis, indicating that the Arvada coal at that location is subbituminous B in rank. That location is somewhat deeper in the basin than the Sayle Hall quadrangle. Therefore, the Arvada coal in this quadrangle probably would be either subbituminous B or subbituminous C in rank.

Local coal beds

In the Sayle Hall quadrangle, thin local coal beds occur between the Pawnee and the lower split of the Cook coal beds, between the Canyon and the Dietz, between the Dietz and the Anderson, and between the Anderson and the Roland coal beds. Because these local coal beds are less than 5 feet (1.5 m) thick, they have not been assigned economic coal resources.

COAL RESOURCES

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

A coal resource classification system has been established by the U.S. Bureau of Mines and the U.S. Geological Survey and published in U.S. Geological

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

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

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

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

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

Reserve Base coal may be either surface-minable coal or underground-minable coal. In this report, surface-minable Reserve Base coal is subbituminous coal that is under less than 500 feet (152 m) of overburden. In this report, underground-minable Reserve Base coal is subbituminous coal that is under more than 500 feet (152 m), but less than 3,000 feet (914 m) of overburden.

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

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

Tonnages of coal resources were estimated using coal-bed thicknesses obtained from the coal isopach map for each coal bed (see list of illustrations). The coal resources, in short tons, for each isopached coal bed are the product of the acreage of coal (measured by planimeter), the average thickness in feet of the coal bed, and a conversion factor of 1,770 short tons of subbituminous coal per acre-foot (13,018 metric tons per hectare-meter) or a conversion factor of 1,750 short tons of lignite per acre-foot (12,870 metric tons per hectare-meter). Tonnages of coal in Reserve Base, Reserves, and Hypothetical categories, rounded to the nearest one-hundredth of a million short tons, for each coal bed are shown on the Areal Distribution and Tonnage maps (see list of illustrations).

As shown by table 1, the total tonnage of federally owned, surface-minable Reserve Base coal in this quadrangle is estimated to be 2,370.77 million short tons (2,150.76 million t). The total tonnage of federally owned, surface-minable Hypothetical coal is estimated to be 10.55 million short tons (9.57 million t). As shown by table 2, the total federally owned, underground-minable Reserve Base coal is estimated to be 1,978.84 million short tons (1,795.20 million t). The total federally owned, underground-minable Hypothetical coal is estimated to be 115.70 million short tons (104.95 million t). The total tonnage of surface- and underground-minable Reserve Base coal is 4,349.61 million short tons (3,945.97 million t), and the total of surface- and underground-minable Hypothetical coal is 126.25 million short tons (114.53 million t).

About 5 percent of the surface-minable Reserve Base tonnage is classed as Measured, 28 percent as Indicated, and 67 percent as Inferred. About 1 percent of the underground-minable Reserve Base tonnage is Measured, 11 percent is Indicated, and 88 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. This thickness of overburden is the assigned stripping limit for surface mining of multiple beds of subbituminous coal in this area. Areas having a potential for surface mining were assigned a high, moderate, or low development potential based on their mining-ratio values (cubic yards of overburden per short ton of recoverable coal).

The formula used to calculate mining-ratio values for 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 <u>high</u>, <u>moderate</u>, and <u>low development potential</u>, 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. 46). Most of the Federal lands have a high development potential for surface mining.

The deeper coal beds: the Broadus (pl. 44), Flowers-Goodale (pl. 41), Knobloch (pl. 38), and the King (pl. 35) coal beds have no potential for surface mining, as they have more than 500 feet (152 m) of overburden and are thus beyond the stripping limit for thin, multiple beds of subbituminous coal.

The Cache coal bed (pl. 32) has a small area of low development potential for surface mining (mining-ratio values greater than 15) under the Otter Creek flood plain in the northwestern part of the quadrangle extending from the bottom of the valley to the 500-foot (152-m) overburden isopach, the stripping limit. The Cache coal in the remainder of the quadrangle has no potential for surface mining, as it is beyond the stripping limit.

The Pawnee coal bed (pl. 28) has small areas of low development potential for surface mining (mining-ratio values greater than 15) in the northwestern part of the quadrangle below the 500-foot (152-m) overburden isopach, the stripping limit. Most of the Pawnee coal has no potential for surface mining, as it is beyond the stripping limit.

The lower split of the Cook coal bed (pl. 25) has a small area of moderate development potential for surface mining (mining-ratio values 10-15) under the northwestern corner of the quadrangle. There is a large area 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. Most of the lower split of the Cook coal in the southern part of the quadrangle has no development potential for surface mining, as it is beyond the stripping limit.

The upper split of the Cook coal bed (pl. 22) has a minute area of high development potential for surface mining (mining-ratio values less than 10) at the northern border of the quadrangle. There are only very small areas of moderate development potential (mining-ratio values 10-15) near the northern border of the quadrangle. Most of the upper split of the Cook 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. Some of the upper split of the Cook coal has no development potential for surface mining, as it is beyond the stripping limit.

The Canyon coal bed (pl. 19) has wide areas of high development potential for surface mining (mining-ratio values less than 10) mainly on the lower hill slopes in the northern and central parts of the quadrangle. There are also quite wide areas of moderate development potential (mining-ratio values 10-15) on the intermediate 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. Some of the Canyon coal has no potential for surface mining, as it is beyond the stripping limit.

The Dietz coal bed (pl. 15) has wide areas of high development potential for surface mining (mining-ratio values less than 10) in valleys and along the lower slopes. There are narrow to quite wide bands of moderate development potential (mining-ratio values 10-15) on the higher slopes. There is a wide area of low development potential for surface mining extending from the 15 mining-ratio contours to the crests of the hills or to the 500-foot (152-m) overburden isopach, the stripping limit.

The Anderson coal bed (pl. 12) has wide areas of high development potential for surface mining (mining-ratio values less than 10) in the valleys and on the lower slopes. There are locally narrow to generally wide areas of moderate development potential (mining-ratio values 10-15). There are small and large areas of low development potential for surface mining extending from the 15 mining-ratio contour to the crests of the hills.

The Roland coal bed (pl. 8) has a wide area of high development potential for surface mining (mining-ratio values less than 10) on high hill slopes in the southwestern part of the quadrangle. There are narrow bands of moderate development potential (mining-ratio values 10-15), and one minute area of low development potential (mining-ratio values greater than 15) on a hill top.

The Arvada coal bed (pl. 5) has a few small areas of high development potential for surface mining (mining-ratio values less than 10) at the crests of hills in the southwestern part of the quadrangle.

About 86 percent of the Federal coal lands in the Sayle Hall quadrangle have a high development potential for surface mining, 11 percent have a moderate development potential, and 3 percent have 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 Sayle Hall 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				
Arvada	2,430,000	0	0	2,430,000
Roland of Baker (1929)	15,480,000	2,790,000	110,000	18,380,000
Anderson	455,300,000	285,700,000	153,760,000	894,760,000
Dietz	87,320,000	39,590,000	204,620,000	331,530,000
Canyon	224,890,000	233,470,000	397,990,000	856,350,000
Upper Cook	30,000	460,000	115,750,000	116,240,000
Lower Cook	0	570,000	143,230,000	143,800,000
Pawnee	0	0	3,160,000	3,160,000
Cache	0	0	4,120,000	4,120,000
Total	785,450,000	562,580,000	1,022,740,000	2,370,770,000
Hypothetical Resource tonnage				
Upper Cook	0	0	1,580,000	1,580,000
Pawnee	0	0	8,970,000	8,970,000
Total	0	0	10,550,000	10,550,000
Grand Total	780,220,000	562,580,000	1,033,290,000	2,376,090,000

Table 2.--Underground-minable coal resource tonnage (in short tons) by development-potential category for Federal lands in the Sayle Hall 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				
Dietz	0	0	3,040,000	3,040,000
Canyon	0	0	193,990,000	193,990,000
Upper Cook	0	0	62,190,000	62,190,000
Lower Cook	0	0	271,620,000	271,620,000
Pawnee	0	0	31,840,000	31,840,000
Cache	0	0	583,090,000	583,090,000
King	0	0	62,060,000	62,060,000
Knobloch	0	0	165,120,000	165,120,000
Flowers-Goodale	0	0	119,920,000	119,920,000
Broadus	0	0	485,970,000	485,970,000
Total	0	0	1,978,840,000	1,978,840,000
Hypothetical Resource tonnage				
Upper Cook	0	0	1,470,000	1,470,000
Lower Cook	0	0	1,430,000	1,430,000
Pawnee	0	0	23,600,000	23,600,000
Cache	0	0	18,910,000	18,910,000
Knobloch	0	0	12,820,000	12,820,000
Flowers-Goodale	0	0	52,150,000	52,150,000
Broadus	0	0	5,320,000	5,320,000
Total	0	0	115,700,000	115,700,000
Grand Total	0	0	2,094,540,000	2,094,540,000

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