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COAL RESOURCE OCCURRENCE AND COAL DEVELOPMENT POTENTIAL MAPS OF THE SPRING GULCH QUADRANGLE ROSEBUD AND BIG HORN COUNTIES, MONTANA

[Report includes 32 plates]

By

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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 Spring Gulch quadrangle, Rosebud and Big Horn Counties, Montana, (32 plates; U.S. Geological Survey Open-File Report 79-778). 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 Spring Gulch quadrangle is in southwestern Rosebud County and southeastern Big Horn County, Montana. It is about 52 miles (84 km) southeast of Hardin, Montana, a town in the valley of the Bighorn River and the Little Bighorn River. Hardin is on U.S. Interstate Highway 90 and the Burlington Northern Railroad. The quadrangle is about 24 miles (39 km) north-northeast of Sheridan, Wyoming. Sheridan is also on U.S. Interstate Highway 90 and the Burlington Northern Railroad. A branch of this railroad runs from Sheridan about 19 miles (30.6 km) north-northeastward and terminates at the Decker coal mine, which is about 5 miles (8 km) southwest of the Spring Gulch quadrangle.

Accessibility

The Spring Gulch quadrangle is accessible from U.S. Highway 212 at Ashland, Montana, by taking an improved graveled road that leads southwestward up the

Tongue River about 35 miles (56 km) to the north boundary of the quadrangle. This road continues on westward and then southward about 15 miles (24 km) to the Decker coal mine.

Physiography

The Spring Gulch quadrangle lies within the Missouri Plateau Division of the Great Plains physiographic province. The flood plain of the northeastward-flowing Tongue River extends from the southwest corner to the northeast corner of the quadrangle. Steep slopes along the flood plain of the river rise to a high, dissected plateau. The quadrangle is drained by eastward- and northwestward-flowing tributary streams of the Tongue River which in turn flows northeastward and empties into the Yellowstone River at Miles City about 90 miles (145 km) northeast of the Spring Gulch quadrangle. The highest elevation in the quadrangle, about 4,160 feet (1,268 m), is on a ridge near the southeast corner of the quadrangle. The lowest elevation, about 3,220 feet (981 m), is along the Tongue River near the northeastern corner of the quadrangle. Relief is about 940 feet (287 m) .

Climate

The climate of Rosebud and Big Horn Counties 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 Spring Gulch quadrangle. Most of the quadrangle is Federal coal land. All of the quadrangle is within the Northern Powder River Basin Known Recoverable Coal Resource Area. There were no outstanding Federal coal leases or prospecting permits as of 1977.

GENERAL GEOLOGY

Previous work

Baker (1929, pls. 28 and 29) mapped the Spring Gulch quadrangle as part of the northward extension of the Sheridan coal field. Matson and Blumer (1973, pls. 6 and 7) remapped the principal coal beds in the same area.

The traces of coal outcrops shown by previous workers on primarily 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 is shown on the Coal Data Sheet (pl. 3) of the CRO maps. The exposed bedrock units belong to the Wasatch Formation (Eocene) and to the underlying upper part of the Tongue River Member, the uppermost member of the Fort Union Formation (Paleocene). The Wasatch Formation generally consists of brownish-gray to light-gray, fine- to coarse-grained lenticular beds of sandstone and interbedded gray shale and some coal. It contains a molluscan-bearing coquinoid zone as much as 30 feet (9.1 m) thick. In the Spring Gulch quadrangle, the Wasatch ranges in thickness from about 50 to 100 feet (15 to 30 m) and does not contain mapped coal beds. The base of the Wasatch Formation is at the top of the thick and persistent Roland coal bed as defined by Baker (1929).

The Tongue River Member of the Fort Union Formation is made up mainly of yellow sandstone, sandy shale, carbonaceous shale, and coal. Coal has burned along the outcrops, baking the overlying sandstone and shale and forming thick, reddish-colored clinker beds. The Tongue River Member is as much as 2,400 feet (732 m) thick in this quadrangle (Lewis and Roberts, 1978). All of the coal beds described in this report are found within the Tongue River Member of the Fort Union Formation (Paleocene).

Within the Northern Powder River Basin the Lebo Shale Member of the Fort Union Formation, which underlies the Tongue River Member, contains a few thin, local coal beds, but their existence in this quadrangle is uncertain.

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 Spring Gulch quadrangle is in the west-central part of the Powder River structural basin. The coal beds and other strata dip regionally southeastward at an angle of about 1 degree. However, this dip is modified by two faults and minor low-relief folds as shown by structure contour maps (pls. 4, 7, 10, 14, 17, 20, 23, 26, and 29). Some of the nonconformity in structure may be due to differential compaction and to irregularities in deposition of the coals and other beds as a result of their continental origin.

COAL GEOLOGY

The coal beds in the Spring Gulch 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 belong to the upper part of the Tongue River Member of the Fort Union Formation.

The lowermost, recognized coal bed in the Spring Gulch quadrangle is a local coal bed which occurs about 100 feet (30 m) above the base of the Tongue River Member. This local coal bed is overlain successively by a noncoal interval of about 20 feet (6.1 m), the Flowers-Goodale coal bed, a noncoal interval of about 360 feet (110 m), a local coal bed, a noncoal interval of about 37 feet (11.3 m), a local coal bed, a noncoal interval of about 200 feet (61 m), the Brewster-Arnold coal bed, a noncoal interval of about 110 feet (33 m), a local coal bed, a noncoal interval of about 100 feet (30 m), the Wall coal-and-clinker bed, a noncoal interval of about 75 feet (22.9 m), a local coal bed, a noncoal interval of about 250 feet (76 m), the Cook coal bed, a noncoal interval of 20 to 110 feet (6.1 to 33.5 m), the Canyon coal-and-clinker bed, a noncoal interval of about 10 feet (3 m), a local coal bed, a noncoal interval of about 60 feet (18 m), the Dietz 3 coal bed, a noncoal interval of about 50 feet (15 m), a local coal bed, a noncoal interval of about 30 to 80 feet (9.1 to 24.3 m), the Dietz 2 coal bed, a noncoal interval of 50 to 110 feet (15 to 33 m), the Anderson (Dietz 1) coal-and-clinker bed, a noncoal interval of about 50 to 120 feet (15.2 to 36.6 m), the Smith coal-and-clinker bed, a noncoal interval of about 100 feet (30 m), and the Roland of Baker (1929) coal bed.

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

Local coal bed below the Flowers-Goodale coal bed

A local coal bed about 5 feet (1.5 m) in thickness which occurs about 20 feet (6.1 m) below the Flowers-Goodale coal bed was penetrated by an oil well in the southeastern part of the quadrangle (pls. 1 and 3). Because this coal bed is thin and is not known to occur in other places within the quadrangle, economic coal resources have not been assigned to it.

Flowers-Goodale coal bed

The Flowers-Goodale coal bed was named by Bass (1932, p. 53-54) for exposures at mines in the Ashland coal field about 47 miles (76 km) northeast of the Spring Gulch quadrangle in the Brandenberg quadrangle. In the Spring Gulch quadrangle, the Flowers-Goodale coal bed occurs about 120 feet (36.6 m) above the base of the Tongue River Member. This coal does not crop out in the Spring Gulch quadrangle, but it was penetrated by oil-and-gas test holes in the northern and southeastern parts of the quadrangle (pls. 1 and 3). Based on measurements at these locations and measurements in adjacent quadrangles, the isopach and structure contour map (pl. 29) shows that the Flowers-Goodale coal ranges from about 5 to 16 feet (1.5 to 4.9 m) in thickness and in general dips southerly at an angle of less than 1 degree. Overburden on the Flowers-Goodale coal bed (pl. 30) ranges from about 800 to 1,900 feet (244 to 579 m) in thickness.

There is no known publicly available chemical analysis of the Flowers-Goodale coal in the Spring Gulch quadrangle, but Matson and Blumer (1973, p. 121) report that a chemical analysis of the Flowers-Goodale coal from a depth of 53 to

61 feet (16 to 19 m) in coal test hole SH-7076, sec. 14, T. 1 S., R. 45 E., in the Cook Creek Reservoir quadrangle, about 41 miles (66 km) northeast of the Spring Gulch quadrangle 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 bed at that location is subbituminous C in rank. It is assumed that the Flowers-Goodale coal in the Spring Gulch quadrangle is similar and is also subbituminous C in rank.

Nance, Knobloch, and King coal beds

The Nance, Knobloch, and King coal beds, which have been recognized in the Birney quadrangle just northeast of the Spring Gulch quadrangle, have not been recognized in this quadrangle because they are either thin or absent. Therefore, economic coal resources have not been assigned to them in this quadrangle.

Local coal beds above the Flowers-Goodale coal bed

Two local coal beds 8 and 4 feet (2.4 and 1.2 m) in thickness occur about 360 and 400 feet (110 and 122 m) above the Flowers-Goodale coal bed. Because these beds do not crop out and because their areal extent is unknown, economic coal resources have not been assigned to these coal beds.

Brewster-Arnold coal bed

The Brewster-Arnold coal bed was named by Baker (1929, p. 37-38, pl. 29) from a small mine on the Brewster-Arnold ranch in sec. 23, T. 6 S., R. 42 E., about 5 miles (8.1 km) northeast of the Spring Gulch quadrangle in the Birney quadrangle. In the Spring Gulch quadrangle, the Brewster-Arnold coal bed occurs about 600 feet (183 m) above the Flowers-Goodale coal bed. The coal is not exposed at the surface in the Spring Gulch quadrangle, but it has been penetrated by an oil-and-gas test hole in the southeastern part of the quadrangle (pls. 1

and 3). Based on the measurements at this location and measurements in adjacent quadrangles, the isopach and structure contour map (pl. 26) shows that the Brewster-Arnold coal ranges from about 10 to 15 feet (3.5 to 4.6 m) in thickness and dips southward to southeastward at an angle of less than 1 degree. A small fault in the northern part of the quadrangle cuts obliquely across the strike of the beds. Overburden on the Brewster-Arnold coal bed (pl. 27) ranges from about 100 to 1,300 feet (30 to 396 m) in thickness.

There is no known chemical analysis of the Brewster-Arnold coal in the Spring Gulch quadrangle, but Matson and Blumer (1973, p. 40) report that a chemical analysis of the Brewster-Arnold coal from a depth of 102 to 110 feet (31 to 33 m) in the coal test hole SH-7057, sec. 28, T. 5 S., R. 42 E., in the Birney quadrangle about 10 miles (16 km) northeast of the Spring Gulch quadrangle shows ash 12.525 percent, sulfur 0.533 percent, and heating value 7,979 Btu per pound (18,559 kJ/kg) on an as-received basis. This heating value converts to about 9,121 Btu per pound (21,215 kJ/kg) on a moist, mineral-matter-free basis, indicating that the Brewster-Arnold coal at that location is subbituminous C in rank. Because of the proximity of this location to the Spring Gulch quadrangle, it is assumed that the Brewster-Arnold coal in this quadrangle is similar and is also subbituminous C in rank.

Local coal bed above the Brewster-Arnold coal bed

A local coal bed that is not exposed at the surface occurs about 110 feet (33 m) above the Brewster-Arnold coal bed. Because the local coal bed is only 5 feet (1.5 m) thick and its areal extent is unknown, economic coal resources have not been assigned to this local coal bed.

Wall coal bed

The Wall coal bed was named by Baker (1929, p. 37), probably from exposures along Wall Creek, a tributary of the Tongue River in southern Birney quadrangle about 1 mile (1.6 km) northeast of the Spring Gulch quadrangle. The Wall coal bed occurs about 210 feet (64 m) above the Brewster-Arnold coal bed and is present over most of the quadrangle (pls. 1 and 3). In most places, an extensive clinker bed marks the former position of the Wall coal bed at the surface. The isopach and structure map of the Wall coal bed (pl. 23) shows that the Wall coal bed ranges from 15 to 55 feet (4.6 to 17 m) in thickness and dips regionally southeastward at an angle of less than 1 degree. In the northern part of the quadrangle, this dip is modified by minor faults and low-relief folding. Overburden on the Wall coal bed (pl. 24) ranges from zero at the outcrops to about 1,000 feet (305 m) in thickness.

A chemical analysis of the Wall coal (Matson and Blumer, 1973, p. 40) from a depth of 84 to 94 feet (26 to 29 m) in coal test hole SH-7013, sec. 21, T. 7 S., R. 41 E., in the northwestern part of the Spring Gulch quadrangle shows ash 5.141 percent, sulfur 0.352 percent, and heating value 8,910 Btu per pound (20,725 kJ/kg) on an as-received basis. This heating value converts to about 9,393 Btu per pound (21,848 kJ/kg) on a moist, mineral-matter-free basis, indicating that the Wall coal in this quadrangle is subbituminous C in rank.

Local coal bed above the Wall coal bed

A local coal bed occurs in an oil-and-gas test hole about 75 feet (22.9 m) above the Wall coal bed. The local coal bed is about 10 feet (3 m) thick. Because of its limited known areal extent, it has not been assigned economic coal resources.

Cook coal bed

The Cook coal bed was named by Bass (1932, p. 79) for outcrops in the Ashland coal field about 35 miles (56 km) northeast of the Spring Gulch quadrangle in the Cook Creek Reservoir quadrangle. In the Spring Gulch quadrangle, the Cook coal bed occurs about 330 feet (101 m) above the Wall coal bed. The isopach and structure contour map (pl. 20) shows that the Cook coal bed ranges from about 2 to 11 feet (0.6 to 3.4 m) in thickness and, in general, dips southward at an angle of less than 1 degree. A southeastward-plunging anticline is superimposed on the regional dip. Overburden on the Cook coal bed (pl. 21) ranges from zero at the outcrops to a maximum of 800 feet (244 m) in thickness near the southeastern corner of the quadrangle.

A chemical analysis of the Cook coal (Matson and Blumer, 1973, p. 59) 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 27 miles (43 km) east of the Spring Gulch quadrangle in the Reanus Cone quadrangle shows ash 3.130 percent, sulfur 0.151 percent, and heating value of 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 (19,084 kJ/kg) on a moist, mineral-matter-free basis, indicating that the Cook coal at that location is lignite A in rank. Because the Cook coal in the Spring Gulch quadrangle is under considerably more overburden, it is assumed that the Cook coal in this quadrangle is higher in rank and is subbituminous C in accordance with other closely associated coals in the quadrangle.

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, probably along Canyon Creek in northern Spring Gulch quadrangle or southern Birney SW quadrangle to the north. In the Spring Gulch quadrangle, the Canyon coal bed occurs about 20 to 110 feet (6.1 to 33 m) above the Cook coal bed. Its stratigraphic position at the surface is generally marked by a clinker bed formed by burning of the coal. The isopach and structure contour map (pl. 17) shows that the Canyon coal bed ranges from 4 to about 20 feet (1.2 to 6.1 m) in thickness and, in general, dips southeastward at an angle of 1 degree or less. This dip is modified by low-relief folding and faulting. Overburden on the Canyon coal bed (pl. 18) ranges from zero at the outcrops to about 700 feet (213 m) in thickness near the southeastern corner of the quadrangle.

A chemical analysis of the Canyon coal (Matson and Blumer, p. 40) from a depth of 48 to 58 feet (14.6 to 17.7 m) in coal test hole SH-48, sec. 16, T. 6 S., R. 40 E., about 6 miles (10 km) northwest of the Spring Gulch quadrangle in the Taintor Desert quadrangle, shows ash 6.090 percent, sulfur 0.188 percent, and heating value 8,914 Btu per pound (20,734 kJ/kg) on an as-received basis. This heating value converts to about 9,565 Btu per pound (22,249 kJ/kg) on a moist, mineral-matter-free basis, indicating that the Canyon coal at that location is subbituminous B in rank. Because of the proximity of that location to the Spring Gulch quadrangle, it is assumed that the Canyon coal in this quadrangle is similar and is also subbituminous B in rank.

Local coal beds above the Canyon coal bed

A local coal bed occurs about 10 feet (3 m) above the Canyon coal bed. This local coal bed is only 2 feet (0.6 m) in thickness and is discontinuous. Another local coal bed occurs about 100 to 160 feet (30 to 49 m) above the Canyon coal bed and ranges from 3 to 8 feet (0.9 to 2.4 m) in thickness. Because of their thinness and limited known areal extent, these local coal beds have not been assigned economic coal resources.

Dietz 3 coal bed and local coal bed

A local coal bed is shown on the composite columnar section (pl. 3) about 50 feet (15 m) above the Dietz 3 coal bed. The Dietz 3 coal bed is entirely burned in the Spring Gulch quadrangle. The local coal bed shown in drill hole data in the eastern half of the quadrangle is in about the same stratigraphic position as the Dietz coal bed; however, the correlation of these two coal beds is uncertain because of the distance between measurement points and the discontinuous nature of continental strata.

Dietz 2 coal bed

The Dietz 1, 2, and 3 coal beds were first described by Taff (1909, p. 139-140) from exposures in the Sheridan coal field, Wyoming. The Dietz 1 coal bed is equivalent to the Anderson coal bed as mapped by Baker (1929, pl. 28) in the northward extension of the Sheridan coal field. Baker did not map the Dietz 2 and 3 coal beds, but in places shows a local coal bed at about their stratigraphic position. Matson and Blumer (1973, pl. 5B) mapped the Dietz coal bed in the Taintor Desert quadrangle northwest of the Spring Gulch quadrangle. We have carried the Dietz 2 coal bed southeastward into the Spring Gulch quadrangle correlating it in places with a local coal bed mapped by Baker (1929, pl. 28).

The Dietz 2 coal bed occurs in the southern and eastern parts of the Spring Gulch quadrangle about 100 to 220 feet (30.5 to 67 m) above the Canyon coal bed. The isopach and structure contour maps (pls. 13 and 14) show that the Dietz 2 coal ranges from about 3 to 21 feet (0.9 to 6.4 m) in thickness and, in general, dips southerly at an angle of 1 degree or less. The regional dip is modified by low-relief folds. Overburden on the Dietz 2 coal bed (pl. 15) ranges from zero at the outcrops to a maximum of about 500 feet (152 m) in thickness near the southeastern corner of the quadrangle.

A chemical analysis of the Dietz 2 coal at a depth of 96 to 106 feet (29 to 32 m) in drill hole SH-31, sec. 8, T. 7 S., R. 40 E., (Matson and Blumer, 1973, p. 34) about 5 miles (8 km) west of the Spring Gulch quadrangle in the Tongue River Dam quadrangle, shows ash 4.914 percent, sulfur 0.288 percent, and heating value 8,275 Btu per pound (19,248 kJ/kg) on an as-received basis. This heating value converts to about 8,612 Btu per pound (20,032 kJ/kg) on a moist, mineral-matter-free basis, indicating that the Dietz 2 coal at that location is subbituminous C in rank. Because of the proximity of that location to the Spring Gulch quadrangle, it is assumed that the Dietz 2 coal in this quadrangle is similar and is also subbituminous C in rank.

Anderson (Dietz 1) coal bed

The Anderson coal bed was first described by Baker (1929, p. 35) from exposures in the northward extension of the Sheridan coal field which includes the Spring Gulch quadrangle. Baker did not give a specific type locality but it could have been along Anderson Creek in the Spring Gulch quadrangle. The Dietz 1 coal bed was named by Taff (1909, p. 139-140) for exposures at the abandoned No. 1 mine at the old mining town of Dietz in the Sheridan coal field, Wyoming, about 20 miles (32 km) southwest of the Spring Gulch quadrangle in the Acme quadrangle. The Dietz 1 coal bed is equivalent to the Anderson coal bed as mapped by Baker (1929, pl. 28). In the Spring Gulch quadrangle, the Anderson (Dietz 1) coal bed occurs 50 to 160 feet (15 to 49 m) above the Dietz 2 coal bed. A thick clinker bed formed by the burning of the Anderson (Dietz 1) coal bed caps the higher hills in the southern and eastern parts of the quadrangle. As shown by the isopach and structure contour map (pl. 10), the Anderson (Dietz 1) coal bed ranges from 5 to 25 feet (1.5 to 7.6 m) in thickness and in general dips southerly at an angle of less than 1 degree. Several small, low-relief folds interrupt the continuity of the dip. Overburden on the Anderson (Dietz 1) coal bed (pl. 11) ranges from zero at the outcrops to about 400 feet (122 m) in thickness.

A chemical analysis of the Anderson (Dietz 1) coal (Matson and Blumer, 1973, p. 35) from a depth of 35 to 43 feet (11 to 13 m) in coal test hole SH-107, sec. 30, T. 7 S., R. 40 E., about 5 miles (8 km) west of the Spring Gulch quadrangle in the Tongue River Dam quadrangle, shows ash 3.403 percent, sulfur 0.209 percent, and heating value 8,493 Btu per pound (18,608 kJ/kg) on an as-received basis. This heating value converts to about 8,792 Btu per pound (20,450 kJ/kg) on a moist, mineral-matter-free basis, indicating that the Anderson (Dietz 1) coal bed at that location is subbituminous C in rank. Because of the proximity of that location to the Spring Gulch quadrangle, it is assumed that the Anderson (Dietz 1) coal bed in this quadrangle is similar and is also subbituminous C in rank.

Smith coal bed

The Smith coal bed was named by Taff (1909, p. 130) from exposures in the Sheridan coal field, Wyoming, and was traced into the Spring Gulch quadrangle by Baker (1929, pl. 29). In this quadrangle, the Smith coal bed occurs about 50 to 120 feet (15.2 to 36.6 m) above the Anderson (Dietz 1) coal bed. The outcrop trace of the Smith coal bed is generally marked by a clinker bed formed by the burning of the coal. Occurrences of the Smith coal are limited to the southeastern part of the quadrangle. The isopach and structure contour map (pl. 7) shows that the Smith coal bed ranges in thickness from 10 to a little more than 20 feet (3 to 6 m) and, in general, dips southerly at an angle of less than 1 degree where the dip is not modified by low-relief folding. Overburden on the Smith coal bed (pl. 8) ranges from zero at the outcrops to about 200 feet (61 m) in thickness.

There is no known publicly available chemical analysis of the Smith coal in the Spring Gulch quadrangle, but Matson and Blumer (1973, p. 25) report that a chemical analysis of the Smith coal from a depth of 41 to 50 feet (12 to 15 m) in coal test hole SH-7022, sec. 10, T. 9 S., R. 41 E., in the Holmes Ranch quadrangle about 6 miles (10 km) south of the Spring Gulch quadrangle shows ash 6.849 percent, sulfur 0.591 percent, and heating value 8,272 Btu per pound (19,241 kJ/kg) on an as-received basis. This heating value converts to about 8,880 Btu per pound (20,655 kJ/kg) on a moist, mineral-matter-free basis, indicating that the Smith coal at that locality is subbituminous C in rank. Because of the proximity of the Spring Gulch quadrangle to that locality, it is assumed that the Smith coal in this quadrangle is similar and is also subbituminous C in rank.

Roland of Baker (1929) coal bed

The Roland coal bed was named by Taff (1909, p. 130 and 142) from exposures in the Sheridan coal field, Wyoming. A coal bed 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 of Baker (1929) coal bed lies about 125 feet (30 m) above the original coal bed of Taff (1909). The top of the Roland of Baker (1929) coal bed is generally used in southern Montana as the contact between the Fort Union Formation (Paleocene) and the overlying Wasatch Formation (Eocene). The Roland of Baker (1929) coal occurs in the southeastern part of the quadrangle about 45 to 100 feet (13.7 to 30.5 m) above the Smith coal bed. The isopach and structure contour map (pl. 4) shows that this coal bed ranges from about 2 to 7 feet (0.6 to 2.1 m) in thickness. The coal bed is folded into a shallow syncline. Overburden on the Roland of Baker (1929) coal bed (pl. 5) ranges from zero at the outcrops to about 50 feet (15 m) in thickness.

Chemical analyses of the Roland of Baker (1929) coal are not available from this quadrangle, but analyses of this coal at a depth of 53 to 63 feet (16 to 19 m) in drill hole SH-7024, sec. 25, T. 8 S., R. 41 E., (Matson and Blumer, 1973, p. 27) about 2 miles (3.2 km) south of the Spring Gulch quadrangle in the Holmes Ranch quadrangle shows ash 5.875 percent, sulfur 0.674 percent, and heating value 7,021 Btu per pound (16,330 kJ/kg) on an as-received basis. This value converts to about 7,459 Btu per pound (17,350 kJ/kg) on a moist, mineral-matter-free basis, indicating that the Roland of Baker (1929) coal at that location is lignite A in rank. Because of the nearness of that location to the Spring Gulch quadrangle, it is assumed that the Roland of Baker (1929) coal in this quadrangle is similar and is also lignite A in rank.

Early in this mapping project, to expedite the calculation of resource tonnage and the evaluation of development potential for surface mining of the near-surface coal beds, it was arbitrarily decided by us to assign a rank of subbituminous to all of the coal beds located in this quadrangle, where the vast majority of the coal beds are subbituminous in rank. Consequently, we have used the 500-foot stripping limit (which the USGS has arbitrarily assigned for multiple beds of subbituminous coal in the Northern Powder River Basin, Montana) for all of the coal beds in this quadrangle, even though our subsequent detailed work has indicated that the 200-foot stripping limit assigned for lignite beds in the Northern Powder River Basin should have been used for the upper coal bed, the Roland of Baker (1929) coal bed.

It is recommended that the 200-foot stripping limit and the lignite conversion factor should be used for the Roland of Baker (1929) coal bed in this quadrangle in any future revisions of its maps and coal tonnage calculations. The use of the 200-foot stripping limit for the Roland coal in this quadrangle will produce a more conservative and realistic picture of the surface-mining potential of this coal bed.

COAL RESOURCES

Data from all publicly available drill holes and from surface mapping by others in this and adjacent quadrangles (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 1,776.77 million short tons (1,611.89 million t). The total tonnage of federally owned, surface-minable Hypothetical coal is estimated to be 120.38 million short tons (109.21 million t). As shown by table 2, the total federally owned, underground-minable Reserve Base coal is estimated to be 1,387.74 million short tons (1,258.96 million t). The total federally owned, underground-minable Hypothetical coal is estimated to be 152.87 million short tons (138.68 million t). The total tonnage of surface- and underground-minable Reserve Base coal is 3,164.51 million short tons (2,870.84 million t), and the total of surface- and underground-minable Hypothetical coal is 273.25 million short tons (247.89 million t).

About 5 percent of the surface-minable Reserve Base tonnage is classed as Measured, 35 percent as Indicated, and 60 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, or where lignite beds of the same thickness are overlain by 200 feet (61 m) or less of overburden. Areas having a potential for surface mining were assigned a high, moderate, or low development potential based on their mining-ratios (cubic yards of overburden per short ton of recoverable coal).

The formula used to calculate mining-ratio values for subbituminous coal or lignite 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

cf = conversion factor = 0.922 cu. yds./ short ton for lignite

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

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

Development potential for surface-mining methods

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

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

The coal development potential that the Federal coal lands have for surface-mining methods is shown on the Coal Development Potential map (pl. 32). Most of the Federal coal lands in the quadrangle have a high development potential for surface mining. Scattered tracts have moderate or low coal development potential.

The Flowers-Goodale coal bed (pl. 30) has no potential for surface mining in this quadrangle as all of the coal in this bed is below the arbitrarily assigned stripping limit of 500 feet (152.4 m).

The Brewster-Arnold coal bed (pl. 27) has limited areas of high development potential adjacent to the flood plain of the Tongue River in the north-central part of the quadrangle. A narrow band of moderate development potential higher on the hills where the overburden is thicker parallels the high development potential. A narrow band of low development potential also parallels along the Tongue River, extending from the 15 mining-ratio contour to the arbitrarily assigned stripping limit at the 500-foot overburden isopach. Approximately one-half of the quadrangle has no development potential for surface mining of the Brewster-Arnold coal because the overburden is greater than 500 feet (152.4 m)

Most of the Wall coal on the west side of the Tongue River has high development potential. The remaining coal on the west side of the river is classified as having a moderate development potential. On the east side of the river, the area of high development potential coal extends from the boundary of the coal up the sides of the hills to the 10 mining-ratio contour. Moderate development potential coal forms a narrow band along the east side of the river and its tributaries; the band extends from the 10 mining-ratio contour to the 15 mining-ratio contour or the 500-foot overburden isopach. A small area of low development potential coal extends up the sides of the hills from the 15 mining-ratio contour to the 500-foot overburden isopach. Most of the southeast quarter and part of the southwest quarter of the quadrangle have no surface-mining potential because the overburden is greater than 500 feet.

The Cook coal bed (pl. 21) has limited areas of high development potential adjacent to the Tongue River and its tributaries in the northeastern corner and the southwestern part of the quadrangle. The area of moderate development potential is restricted to narrow bands between the 10 and 15 mining-ratio contours on the hills above the high development potential areas. Large areas of low development potential occur between the 15 mining-ratio contour and the 500-foot overburden isopach. Erosion has removed all of the Cook coal bed from most of the northern and central portions of the quadrangle.

The Canyon coal bed (pl. 18) has been burned or removed by erosion in a considerable part of the quadrangle. Rather extensive areas of high development potential occur in the southwest quarter of the quadrangle and in isolated tracts adjacent to the main streams. In the northern half of the quadrangle, there are relatively narrow bands of moderate development potential on the hill slopes extending from the 10 mining-ratio contour to the 15 mining-ratio contour. Narrow bands of moderate development potential also occur in the southwestern part of the quadrangle. The remainder of the quadrangle has low development potential or no development potential for surface mining.

The Dietz 2 coal bed (pl. 15) has been burned or removed by erosion from more than one-half of the quadrangle. The Dietz 2 coal bed has rather extensive areas of high development potential extending from the stream valleys up the hill slopes to the 10 mining-ratio contour. Relatively narrow bands of moderate development potential extend up the hill slopes from the 10 mining-ratio contour to the 15 mining-ratio contour. Low development potential extends from the 15 mining-ratio contour to the crests of the hills or to the arbitrarily assigned stripping limit of the 500-foot overburden isopach in the southeast corner of the quadrangle.

Much of the Anderson (Dietz 1) coal bed (pl. 11) has been burned leaving only isolated areas of unburned coal in the eastern and southern parts of the quadrangle. Extensive areas of high development potential extend from the boundary of the coal to the 10 mining-ratio contour. Narrow bands of moderate development potential occur between the 10 and 15 mining-ratio contours and, in general, parallel the areas of high development potential. The area of low development potential coal is located under the crests of the hills which extend above the 15 mining-ratio contour in the southeast corner of the quadrangle.

All of the Smith coal bed (pl. 8) has been removed by erosion except for a small remnant in the southeastern quarter of the quadrangle. Most of this remnant has high development potential for surface mining, and only a limited amount has moderate development potential. Beneath the crest of the ridge north of Anderson Creek and above the 15 mining-ratio contour is a small area of low development potential for surface mining of the Smith coal bed.

The Roland of Baker (1929) coal bed (pl. 5) has small areas of high, moderate, and low development potential in a small tract on the ridge north of Anderson Creek in the southeastern part of the quadrangle.

About 88 percent of the Federal coal lands in the quadrangle has a high development potential for surface mining, 7 percent has a moderate development potential, and 5 percent has a low development potential.

Development potential for underground mining and in-situ gasification

Subbituminous coal beds 5 feet (1.5 m) or more in thickness lying more than 500 feet (152 m) but less than 3,000 feet (914 m) below the surface and lignite beds of the same thickness lying more than 200 feet (61 m) but less than 1,000 feet (305 m) below the surface are considered to have development potential for underground mining. Estimates of the tonnage of underground-minable coal are listed in table 2 by development-potential category for each coal bed. Coal is not currently being mined by underground methods in the Northern Powder River Basin because of poor economics. Therefore, the coal development potential for underground mining of these resources for purposes of this report is rated as low, and a Coal Development Potential map for underground mining was not made.

In-situ gasification of coal on a commercial scale has not been done in the United States. Therefore, the development potential for in-situ gasification of coal found below the surface-mining limit in this area is rated as low, and a Coal Development Potential map for in-situ gasification of coal was not made.

Table 1.--Surface-minable coal resource tonnage (in short tons) by development-potential category for Federal coal lands in the Spring Gulch quadrangle, Rosebud and Big Horn Counties, 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				
Roland of Baker (1929)	1,350,000	270,000	90,000	1,710,000
Smith	38,260,000	4,110,000	3,600,000	45,970,000
Anderson (Dietz 1)	60,620,000	22,520,000	23,210,000	106,350,000
Dietz 2	53,650,000	35,780,000	51,240,000	140,670,000
Canyon	70,670,000	52,860,000	184,950,000	308,480,000
Cook	4,210,000	4,360,000	147,420,000	155,990,000
Wall	715,850,000	148,180,000	74,680,000	938,710,000
Brewster-Arnold	1,430,000	2,580,000	74,880,000	78,890,000
Total	946,040,000	270,660,000	560,070,000	1,776,770,000
Hypothetical Resource tonnage				
Brewster-Arnold	1,900,000	7,670,000	110,810,000	120,380,000
Total	1,900,000	7,670,000	110,810,000	120,380,000
Grand Total	949,940,000	278,330,000	670,880,000	1,897,150,000

Table 2.--Underground-minable coal resource tonnage (in short tons) by development-potential category for Federal lands in the Spring Gulch quadrangle, Rosebud and Big Horn Counties, 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 2	0	0	90,000	90,000
Canyon	0	0	24,890,000	24,890,000
Cook	0	0	33,950,000	33,950,000
Wall	0	0	659,020,000	659,020,000
Brewster-Arnold	0	0	263,850,000	263,850,000
Flowers-Goodale	0	0	405,940,000	405,940,000
Total	0	0	1,387,740,000	1,387,740,000
Hypothetical Resource tonnage				
Brewster-Arnold	0	0	111,520,000	111,520,000
Flowers-Goodale	0	0	41,350,000	41,350,000
Total	0	0	152,870,000	152,870,000
Grand Total	0	0	1,540,610,000	1,540,610,000

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