UNITED STATES DEPARTMENT OF THE INTERIOR

GEOLOGICAL SURVEY

Text to accompany:

Open-File Report 79-089

1979

COAL RESOURCE OCCURRENCE AND COAL DEVELOPMENT POTENTIAL MAPS OF THE GREEN CREEK QUADRANGLE, ROSEBUD COUNTY, MONTANA

[Report includes 42 plates]

By

Colorado School of Mines Research Institute

CONTENTS

ILLUSTRATIONS

[Plates are in pocket]

Plates 1-39. Coal resource occurrence maps:

1A. Coal data map -- surface data.

1B. Coal data map -- subsurface data.

2. Boundary and coal data map.

3A. Coal data sheet.

3B. Coal data sheet.

4. Isopach and structure contour map of the Canyon coal bed.

5. Overburden isopach and mining-ratio map of the Canyon coal bed.

6. Areal distribution and tonnage map of identified resources of the Canyon coal bed.

7. Isopach and structure contour map of the lower split of the Cook coal bed.

8. Overburden isopach and mining-ratio map of the lower split of the Cook coal bed.

9. Areal distribution and tonnage map of identified resources of the lower split of the Cook coal bed.

10. Isopach and structure contour map of the Otter coal bed.

11. Overburden isopach and mining-ratio map of the Otter coal bed.

12. Areal distribution and tonnage map of identified resources of the Otter coal bed.

13. Isopach and structure contour map of the Wall coal bed.

14. Overburden isopach and mining-ratio map of the Wall coal bed.

15. Areal distribution and tonnage map of identified resources of the Wall coal bed.

Illustrations--Continued

Page

TABLES

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 Green Creek quadrangle, Rosebud County, Montana, (42 plates; U.S. Geological Survey Open-File Report 79-089). 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 Green Creek quadrangle is in southeastern Rosebud County, Montana, about 6 miles (9.7 km) south of Ashland, Montana, and 33.5 miles (53.9 km) northeast of Decker, Montana. Ashland is on east-west U.S. Highway 212. The nearest railroads are spur lines of the Burlington Northern Railroad at the Big Sky coal mine in the Colstrip SE quadrangle, about 25 miles (40 km) north-northwest of the quadrangle, and at the Decker coal mine in the Decker quadrangle, about 31 miles (50 km) southwest of the quadrangle.

Accessibility

The Green Creek quadrangle is accessible from Ashland, Montana, by going south on an improved, graveled road along the southeastern side of the Tongue River about 7 miles (11.3 km) to the northern border of the quadrangle. This road parallels the Tongue River through the northwestern part of the quadrangle and is intersected by a local road which parallels O'Dell Creek southeastward

through the quadrangle. Because of the rugged terrain there are few other local roads or trails in the quadrangle. The quadrangle is also accessible from Decker, Montana, by following State Highway 314 northward about 12 miles (19 km) to the Tongue River Road and then northeastward on this road about 36 miles (58 km) to the western border of the quadrangle.

Physiography

The Green Creek quadrangle is within the Missouri Plateau division of the Great Plains physiographic province. The plateau, which is formed by nearly flat-lying sedimentary rock of unequal resistance to erosion, has been deeply and intricately dissected by the Tongue River and its tributaries. All of the quadrangle is within the Tongue River drainage basin. The river flows northeastward through the northwestern part of the quadrangle in a flood plain about 0.5 mile (0.8 km) wide. The principal tributary stream is O'Dell Creek, which flows northwestward diagonally across the quadrangle. Other tributaries of the Tongue River are Dry Creek, Cedar Creek, and King Creek; they drain the northeastern part of the quadrangle. Gate Creek and Poker Teechee Creek drain the southwestern part. Tributaries of O'Dell Creek, including Green Creek, drain the rest of the quadrangle. All except the northwestern corner of the quadrangle is extremely rugged and is within the Custer National Forest.

The highest elevations, about 4,180 feet (1,274 m), are near O'Dell triangulation point near the southern border of the quadrangle and on a mesa in the east-central part of the quadrangle. The lowest elevation, about 2,975 feet (907 m), is on the Tongue River at the northern border of the quadrangle. Topographic relief in the quadrangle is about 1,205 feet (367 m).

Climate

The climate of Rosebud County is characterized by pronounced variations in seasonal precipitation and temperature. Annual precipitation in the region

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

Land status

The Boundary and Coal Data Map (pl. 2) shows the land ownership status within the Green Creek quadrangle. The lands northwest of the Tongue River are within the Northern Cheyenne Indian Reservation and are not Federal coal lands. Most of the lands southeast of the Tongue River are within the Northern Powder River Basin Known Recoverable Coal Resource Area (KRCRA). The Federal government owns most of the coal rights in the KRCRA. The non-Federal coal lands are in the northwestern part of the quadrangle.

In 1977, the quadrangle did not contain outstanding Federal coal leases, prospecting permits, or leases.

GENERAL GEOLOGY

Previous work

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

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

Stratigraphy

A generalized columnar section of the coal-bearing rocks of the Green Creek quadrangle is shown on the Coal Data Sheet (pl. 3A) of the CRO maps. The exposed bedrock units belong to the Tongue River Member, the uppermost member of the Fort Union Formation (Paleocene).

The Tongue River Member consists of interbedded lenticular beds of gray, fine- to very fine-grained sandstone, light- to dark-gray siltstone, gray shale and claystone, brown carbonaceous shale, and coal beds. The thicker coal beds have burned along the outcrops, baking the overlying sandstone and shale and forming thick, reddish-colored clinker beds. The upper part of the Tongue River Member has been removed from the quadrangle by erosion, but about 1,850 feet (564 m) of Tongue River strata remains in the southern part of the quadrangle.

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 Green Creek quadrangle is in the north-central part of the Powder River structural basin. The strata regionally dip southward at an angle of less than

1 degree, but in the Green Creek quadrangle this dip is considerably modified by low-relief folding. Some of the nonuniformity in structure may be caused by differential compaction and to irregularities in deposition of the coals and other lenticular beds as a result of their continental origin.

COAL GEOLOGY

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

The lowermost recognized coal bed is a local coal bed which occurs at the base of the Tongue River Member. This local coal bed is overlain successively by a noncoal interval of about 55 to 60 feet (16.8 to 18.3 m), the Terret coal bed, a noncoal interval of about 126 to 200 feet (38.4 to 61 m), the Flowers-Goodale coal bed, a noncoal interval of about 125 to 200 feet (38 to 61 m), the Nance coal bed, a noncoal interval of about 40 to 80 feet (12.2 to 24.4 m), the lower split of the Knobloch coal bed, a noncoal interval of 20 to 35 feet (6.1 to 10.7 m), the upper split of the Knobloch coal bed, a mainly noncoal interval of 40 to 140 feet (12 to 43 m) containing in places a local coal bed, the King coal bed, a mainly noncoal interval of about 65 to 155 feet (19 to 47 m) containing local coal beds, the Odell coal bed, a noncoal interval of 120 to 300 feet (36.6 to 91.4 m), the Pawnee coal bed, a mainly noncoal interval of about 50 to 200 feet (15 to 61 m) containing local coal beds, the Wall coal bed, a noncoal interval of about 70 feet (21.3 m), the Otter coal bed, a mainly noncoal interval of about 50 to 120 feet (15.2 to 16.6 m) containing in places a local coal bed, the lower split of the Cook coal bed, a mainly noncoal interval of about 70 to 180 feet (21.3 to 54.9 m) containing local coal beds, the Canyon coal bed, a noncoal

interval of about 50 to 90 feet (15 to 27 m), the Alderson coal bed, a noncoal interval of about 60 feet (18 m), and the Garfield clinker bed.

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

Local coal bed at the base of the Tongue River Member

The local coal bed which occurs at the base of the Tongue River Member is the lowest known coal bed in the Green Creek quadrangle. This local bed does not crop out in the quadrangle but has been penetrated by an oil-and-gas test hole in the northwestern part of the quadrangle (pl. 1B). This local coal bed may correlate with the Contact coal bed which is at this stratigraphic position on the eastern side of the Northern Powder River Basin. However, because this coal bed cannot be mapped continuously it is called a local coal bed in this report. Because this local coal bed is of limited known areal extent and is less than 5 feet (1.5 m) thick, it has not been assigned economic coal resources.

Other local coal beds

Other local coal beds in the Green Creek quadrangle (see composite section, pl. 3A) occur between the Upper Knobloch and King coal beds, between the King and Odell, between the Pawnee and Wall, between the Otter and Lower Cook, and between the Lower Cook and Canyon coal beds. These local coal beds are thin and of small areal extent and, therefore, have not been assigned economic coal resources.

Terret coal bed

The Terret coal bed was first described by Bass (1932, p. 51) from a small coal mine in sec. 16, T. 1 S., R. 45 E. on the Terret Ranch located about 17 miles (27.4 km) north-northeast of the Green Creek quadrangle in the Cook Creek

Reservoir quadrangle. The Terret coal bed does not crop out in the Green Creek quadrangle but has been penetrated by two oil-and-gas test holes in the western part of the quadrangle (pls. 1B and 3B). The Terret coal bed occurs about 55 to 60 feet (16.8 to 18.3 m) above the local coal bed at the base of the Tongue River Member. The isopach and structure contour map (pl. 37) shows that the Terret coal bed ranges from about 3 to 11 feet (0.9 to 3.4 m) in thickness and, in general, dips southwestward at an angle of less than half a degree, although this dip is modified by low-relief folding. Overburden on the Terret coal bed (pl. 38), where the bed is more than 5 feet (1.5 m) thick, ranges from about 520 to 1,600 feet (158.5 to 487.7 m) in thickness.

There is no known, publicly available chemical analysis of the Terret coal in the Green Creek quadrangle. A chemical analysis of the Terret coal from the Holt mine (sec. 20, T. 3 S., R. 44 E.) about 4 miles (6.4 km) north of the Green Creek quadrangle in the Ashland quadrangle (Gilmour and Dahl, 1967, p. 18) shows ash 3.9 percent, sulfur 0.4 percent, and a heating value of 9,020 Btu per pound (20,980 kJ/kg) on an as-received basis. This heating value converts to about 9,386 Btu per pound (21,832 kJ/kg) on a moist, mineral-matter-free basis, indicating that the Terret coal at that location is subbituminous C in rank. Because of the proximity of that location to the Green Creek quadrangle, it is assumed that the Terret coal in this quadrangle is similar and is also subbituminous C in rank.

Flowers-Goodale coal bed

The Flowers-Goodale coal bed was first described by Bass (1932, p. 53) from two small mines about 24 miles (38.6 km) north-northeast of the Green Creek quadrangle in the Brandenberg quadrangle. The Flowers-Goodale coal bed does not crop out in the Green Creek quadrangle but has been penetrated by the two oil-and-gas test holes in the western part of the quadrangle (pls. 1B and 3B). In

these test holes, the Flowers-Goodale coal bed occurs about 126 to 200 feet (38.4 to 61 m) above the Terret coal bed. The isopach and structure contour map (pl. 34) shows that the Flowers-Goodale coal bed ranges from about 4 to 20 feet (1.2 to 6.1 m) in thickness and, in general, dips southward or westward at an angle of less than half a degree, but this dip is somewhat modified by low-relief folding. Overburden on the Flowers-Goodale coal bed (pl. 35) ranges from about 180 to 1,380 feet (55 to 421 m) in thickness.

There is no known, publicly available chemical analysis of the Flowers-Goodale coal from the Green Creek quadrangle. However, a chemical analysis of this coal from a depth of 53 to 62 feet (16 to 19 m) in coal test hole SH-7076, sec. 14, T. 1 S., R. 45 E., in the Cook Creek Reservoir quadrangle about 17.5 miles (28 km) north-northeast of Green Creek quadrangle (Matson and Blumer, 1973, p. 121) shows ash 8.144 percent, sulfur 0.961 percent, and a heating value of 8,102 Btu per pound (18,845 kJ/kg) on an as-received basis. This heating value converts to about 8,820 Btu per pound (20,515 kJ/kg) on a moist, mineral-matter-free basis, indicating that the Flowers-Goodale coal at that location is subbituminous C in rank. Because the Green Creek quadrangle is deeper in the basin, the Flowers-Goodale coal in this quadrangle would be more compressed and higher in heating value and would be either subbituminous C or possibly subbituminous B in rank.

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

The Knobloch coal bed was first described by Bass (1924) from exposures along the Tongue River on the Knobloch Ranch in secs. 17 and 18, T. 5 S., R. 43 E. in the Birney Day School quadrangle, about 4 miles (6.4 km) west of the Green Creek quadrangle. In the Green Creek quadrangle, the Knobloch coal bed splits into four coal beds, as shown by the composite columnar section on plate 3A.

The lowermost split of the Knobloch is the Nance coal bed which splits from the Knobloch coal bed in the northern part of the Green Creek quadrangle, as shown in the isopach and structure contour map of the Nance coal bed (pl. 31). The next higher coal bed is the lower split of the Knobloch coal bed which splits from the Knobloch farther south than the Nance in the central part of the Green Creek quadrangle (pl. 28). South of this split line, the upper split of the Knobloch is also present as a separate coal bed (pl. 25). A local coal bed splits from the top of the Knobloch coal bed in the northernmost part of the quadrangle about 2 miles (3.2 km) south of the Nance split line (pl. 25). As the name implies, this local coal bed is present only locally south of its split line. Only in the northern part of the quadrangle is the Knobloch coal a single, thick, unsplit coal bed (pl. 25).

Nance coal bed

The Nance coal bed is named for its occurrence at a depth of 242 feet (73.8 m) in the Nance and Hayes M11-2 drill hole, SE¼ SE¼, sec. 25, T. 5 S., R. 42 E., about 5.3 miles (8.5 km) west-southwest of the Green Creek quadrangle in the Brown's Mountain quadrangle (Mapel and Martin, 1978, p. 21).

The Nance coal bed does not crop out in the Green Creek quadrangle but is penetrated by an oil-and-gas test hole in the southwestern part of the quadrangle (pl. 1B). The Nance coal bed occurs 125 to 200 feet (38 to 61 m) above the Flowers-Goodale coal bed. The isopach and structure contour map (pl. 31), based mainly on data in adjoining quadrangles, shows that the Nance coal bed ranges from about 4 to 10 feet (1.2 to 3.0 m) in thickness and, in general, dips southwestward at an angle of less than 1 degree. Overburden on the Nance coal bed (pl. 32) ranges from about 320 to 1,280 feet (97.5 to 390 m) in thickness.

There is no known, publicly available chemical analysis of the Nance coal in the Green Creek quadrangle. However, an analysis of the upper, middle, and

lower (Nance) benches of the Knobloch coal from a depth of 216 to 218 feet (65.8 to 66.4 m) in coal test hole SH-7055, sec. 6, T. 4 S., R. 45 E., about 1.7 miles (2.7 km) northeast of the Green Creek quadrangle in the Willow Crossing quadrangle (Matson and Blumer, 1973, p. 64) shows ash 6.381 percent, sulfur 0.154 percent, and heating value 8,558 Btu per pound (19,906 kJ/kg) on an as-received basis. This heating value converts to about 9,141 Btu per pound on a moist, mineral-matter-free basis, indicating that the Nance coal at that location is subbituminous C in rank. Because of the proximity of that location to the Green Creek quadrangle, it is assumed that the Nance coal in the Green Creek quadrangle is similar and is also subbituminous C in rank.

Lower split of the Knobloch coal bed

The lower split of the Knobloch coal bed splits from the Knobloch coal bed along a line in the central part of the Green Creek quadrangle, as shown on the isopach and structure contour map (pl. 28), and is present in the southern part of the quadrangle where it has been penetrated by two test holes. This lower split occurs about 4 to 80 feet (12.2 to 24.4 m) above the Nance coal bed, and is 5 feet (1.5 m) thick in the two test holes which penetrate it (pl. 28). Overburden on the lower split of the Knobloch coal bed (pl. 29) ranges from about 175 to 1,100 feet (53.3 to 304.8 m) in thickness where the bed is 5 feet (1.5 m) or more in thickness. The lower split of the Knobloch coal is assumed to be similar in rank to the Knobloch coal in the Ashland quadrangle and to be subbituminous C in rank.

Upper split of the Knobloch coal bed

The upper split of the Knobloch coal bed (pl. 29) occurs in the southern and central parts of the Green Creek quadrangle where it has been penetrated by three test holes. Here it occurs from about 20 to 35 feet (6.1 to 10.7 m) above the lower split of the Knobloch. The isopach and structure contour map (pl. 25)

shows that the upper split ranges from about 14 to 30 feet (4.3 to 9.1 m) in thickness and, in general, dips westward or southwestward at an angle of half a degree or less, although this dip is modified locally by low-relief folding. Overburden on the upper split of the Knobloch coal bed (pl. 26) ranges from 0 feet at the outcrops to about 1,050 feet (0-320 m) in thickness. The upper split of the Knobloch coal is believed to be subbituminous C in rank, in accordance with the rank of the Knobloch coal in the Ashland quadrangle.

Knobloch coal bed

A thick clinker bed formed by the burning of the Knobloch coal bed crops out in the northwestern part of the Green Creek quadrangle. The Knobloch coal bed is thickest in the northeasternmost part of the quadrangle (pl. 25) where the Nance coal bed and other coal beds are not split from it. Here the Knobloch coal bed occurs about 130 feet (39.6 m) above the Flowers-Goodale coal bed, and ranges from about 30 to 50 feet (9.1 to 15.2 m) in thickness. South of the line where the Nance splits from the Knobloch (pl. 25) the Knobloch coal bed ranges from about 32 to 38 feet (9.7 to 11.6 m) in thickness. South of the line where the local bed above the Knobloch splits from the Knobloch (pl. 25), the Knobloch coal bed ranges from 28 to 34 feet (8.5 to 10.4 m) in thickness. Structure contours (pl. 25) indicate that the Knobloch coal bed dips eastward or northeastward, at an angle of less than half a degree, although this dip is modified by low-relief folding. Overburden on the Knobloch coal bed (pl. 26) ranges from about 50 to 1,100 feet (15 to 335 m) in thickness.

A chemical analysis of the Knobloch coal from drill hole SH-7059 in sec. 34, T. 3 S., R. 44 E. (Matson and Blumer, 1973, p. 64) in the Ashland quadrangle, about 2.1 miles (3.41 km) north of the Green Creek quadrangle, shows ash 3.669 percent, sulfur 0.095 percent, and heating value 9,005 Btu per pound (20,945 kJ/kg) on an as-received basis. This heating value converts to about 9,350 Btu

per pound (21,748 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 Green Creek quadrangle, it is assumed that the Knobloch coal in this quadrangle is similar and is also subbituminous C in rank.

Local coal bed above the Knobloch coal bed

The local coal bed which splits from the upper part of the Knobloch coal bed is penetrated by a coal test hole in the southern part of the Green Creek quadrangle. This bed is less than 5 feet (1.5 m) thick in this quadrangle and has not been assigned economic coal resources.

King coal bed

The King coal bed was named by Warren (1959, p. 571), presumably for outcrops of the bed near King Creek, a tributary of the Tongue River, in the northern part of the Green Creek quadrangle and the southern part of the Ashland quadrangle just to the north. The same coal bed was called the upper bench of the Knobloch coal bed by Matson and Blumer (1973, pls. 11A and 33) along the Tongue River in, and near, the Green Creek quadrangle. This bed was called the Upper Knobloch coal bed by Culbertson and Klett (1976) in the northern part of the Browns Mountain quadrangle just southwest of the Green Creek quadrangle.

The King coal bed crops out in places in the northern and northwestern parts of the Green Creek quadrangle and has been penetrated by drill holes (pl. B). It occurs about 40 to 140 feet (12 to 43 m) above the Knobloch coal bed (pls. 1, 3A, and 3B). The isopach and structure contour map (pl. 22) shows that the King coal bed ranges from about 2.7 to 7 feet (0.8 to 2.1 m) in thickness and, in general, dips southwestward at an angle of less than 1 degree, although this dip is modified by low-relief folding. Overburden on the King coal bed (pl. 23), where it

is more than 5 feet (1.5 m) thick, ranges from about 180 to 1,060 feet (55 to 323 m) in thickness.

A chemical analysis of the King coal (upper bench of Knobloch by Matson and Blumer, 1973, p. 64) from a depth of 60 to 66 feet (18.3 to 20.1 m) in coal test hole SH-117, sec. 30, T. 5 S., R. 43 E., about 5 miles (8 km) west of the Green Creek quadrangle in the Birney Day School quadrangle, shows ash 4.776 percent, sulfur 0.594 percent, and heating value 9,135 Btu per pound (21,248 kJ/kg) on an as-received basis. This heating value converts to about 9,593 Btu per pound (22,313 kJ/kg) on a moist, mineral-matter-free basis, indicating that the King coal at that location is subbituminous B in rank. Because of the proximity of that location to the Green Creek quadrangle, it is assumed that the King coal in this quadrangle is similar and is also subbituminous B in rank.

Odell coal bed

The Odell coal bed was first described by Warren (1959, p. 572) from exposures of coal in the Birney-Broadus coal field, presumably near O'Dell Creek in the Green Creek quadrangle. This coal outcrops locally in the northern and northwestern parts of the quadrangle, although in most places it is burned near the land surface. It occurs about 65 to 155 feet (19 to 47 m) above the King coal bed. The isopach and structure contour map (pl. 19) shows that the Odell coal bed ranges from about 2.1 to 8.1 feet (0.6 to 2.5 m) in thickness and is nearly flat lying. Overburden on the Odell coal bed (pl. 20), where it is more than 5 feet (1.5 m) thick, ranges from 0 feet at the outcrops to about 600 feet (0-183 m) in thickness.

There is no known, publicly available chemical analysis of the Odell coal in, or close, to the Green Creek quadrangle. It is assumed that the Odell coal bed is similar to other closely associated coal beds in this quadrangle and that it is subbituminous B in rank.

Pawnee coal bed

The Pawnee coal bed was first described by Warren (1959, p. 572) from outcrops in the Birney-Broadus coal field which includes the Green Creek quadrangle. This coal bed crops out extensively in the quadrangle and occurs about 120 to 300 feet (36.6 to 91.4 m) above the Odell coal bed. The isopach and structure contour map (pl. 16) shows that the Pawnee coal bed ranges from about 3.3 to 10 feet (1.0 to 3.0 m) in thickness and dips westward at an angle of 1 degree or less. Overburden on the Pawnee coal bed (pl. 17) ranges from 0 feet at the outcrops to about 800 feet (0-244 m) in thickness.

There is no known, publicly available chemical analysis of the Pawnee coal in, or close, to the Green Creek quadrangle. It is assumed that the Pawnee coal is similar to other closely associated coals in the Green Creek quadrangle and is subbituminous B in rank.

Wall coal bed

The Wall coal bed was first described by Baker (1929, p. 37) probably from exposures along Wall Creek about 15 miles (24 km) southwest of the Green Creek quadrangle in the southwestern part of the Birney quadrangle. The Wall coal bed was mapped by Warren (1959, pl. 19) in the eastern and southern parts of the Green Creek quadrangle. This coal bed occurs about 50 to 200 feet (15 to 61 m) above the Pawnee coal bed. The isopach and structure contour map (pl. 13) shows that the Wall coal bed ranges from 1.9 to 14 feet (0.6 to 4.3 m) in thickness and, in general, dips westward or southward at an angle of 1 degree or less, although this dip has been considerably modified by low-relief folding. Overburden on the Wall coal bed (pl. 14) ranges from 0 feet at the outcrops to about 600 feet (0-183 m) in thickness.

There is no known, publicly available chemical analysis of the Wall coal in the Green Creek quadrangle. A chemical analysis of the Wall coal (Matson and

Blumer, 1973, p. 39) from a depth of 150 to 159 feet (45.7 to 48.5 m) in coal test hole SH-110, sec. 33, T. 5 S., R. 41 E., about 15 miles (24 km) west-southwest of the Green Creek quadrangle in the Birney SW quadrangle shows ash 5.790 percent, sulfur 0.380 percent, and heating value 8,972 Btu per pound (20,869 kJ/kg) on an as-received basis. This heating value converts to about 9,523 Btu per pound (22,150 kJ/kg) on a moist, mineral-matter-free basis, indicating that the Wall coal at that location is low subbituminous B in rank, but close to subbituminous C in rank. Because of the proximity of that location to the Green Creek quadrangle, it is assumed that the Wall coal in this quadrangle is similar and is subbituminous B or C in rank.

Otter coal bed

The Otter coal bed is a name first used by Bryson and Bass (1973, p. 56) for a coal bed exposed in the valleys of Otter Creek and its tributaries in the vicinity of Otter Post Office (T. 7 S., R. 45 E.) about 12 miles (19.3 km) south-southeast of the Green Creek quadrangle in the Otter quadrangle. Warren (1959, pl. 19) did not map the Otter coal bed in the Green Creek quadrangle, presumably because it does not crop out. However, Culbertson and Klett (1976) used the names Upper and Lower Otter beds for a pair of coal beds 5 to 30 feet (1.5 to 9 m) apart in outcrops in the Browns Mountain quadrangle directly southwest of the Green Creek quadrangle. The Otter coal bed crops out in the northern part of the Poker Jim Butte quadrangle just south of the Green Creek quadrangle and has been recognized in three oil-and-gas test holes there (Mapel, Martin, and Butler, 1978, p. 12). The Otter coal bed has also been penetrated by a test hole in the southwestern part of the Green Creek quadrangle. Here the Otter coal bed occurs about 70 feet (21.3 m) above the Wall coal bed.

The isopach and structure contour map (pl. 10), based partly on measurements in adjacent quadrangles, shows that the Otter coal bed in the Green Creek

quadrangle ranges from about 5 to 10 feet (1.5 to 3.0 m) in thickness and is almost flat. Overburden on the Otter coal bed (pl. 11) ranges from almost 0 feet to about 580 feet (0-177 m) in thickness.

There is no known, publicly available chemical analysis of unweathered Otter coal in, or near, the Green Creek quadrangle. It is assumed that the Otter coal is similar to other closely associated coals in the Green Creek 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 10 miles (16 km) north-northeast of the Green Creek quadrangle. Preliminary regional mapping indicates that the Cook coal bed in places splits into two coal beds and that this bed in the Green Creek quadrangle correlates with the lower split of the Cook coal bed. This coal bed outcrops in the southern and eastern parts of the Green Creek quadrangle (pl. 1). It occurs about 50 to 120 feet (15.2 to 16.6 m) above the Otter coal bed. The isopach and structure contour map (pl. 7) shows that the lower split of the Cook coal bed ranges from about 5 to 12.2 feet (1.5 to 3.7 m) in thickness and, in general, dips southward or westward at an angle of 1 degree or less, although this dip is somewhat modified by low-relief folding. Overburden on this coal bed (pl. 8) ranges from 0 feet at the outcrops to about 480 feet (0-146.3 m) in thickness.

There is no known, publicly available chemical analysis of the Lower Cook coal in, or close to, the Green Creek quadrangle. It is assumed that the lower split of the Cook coal bed is similar to other closely associated coals in the Green Creek quadrangle and is subbituminous C in rank.

Canyon coal bed

The Canyon coal bed was first described by Baker (1929, p. 36) from exposures in the northward extension of the Sheridan coal field. Although a type locality was not given, it may be along Canyon Creek in the northern part of the Spring Gulch quadrangle, about 19 miles (30.6 km) southwest of the Green Creek quadrangle. Warren (1959, pl. 19) mapped the Canyon coal bed in the eastern and southern parts of the Green Creek quadrangle. The Canyon coal bed occurs about 70 to 180 feet (21.3 to 54.9 m) above the Lower Cook coal bed. The isopach and structure contour map (pl. 4) shows that the Canyon coal bed ranges from about 3.5 to 12.3 feet (1.1 to 3.7 m) in thickness and has been folded into a broad, low-relief anticline. Overburden on the Canyon coal bed (pl. 5) ranges from 0 feet at the outcrops to about 300 feet (0-91 m) in thickness.

There is no known, publicly available chemical analysis of the Canyon coal in the Green Creek quadrangle. A chemical analysis of the Canyon coal (Matson and Blumer, 1973, p. 47) from a depth of 43 to 53 feet (13.1 to 16.2 m) in coal test hole SH-7038, sec. 9, T. 7 S., R. 44 E., about 9 miles (14.5 km) south of the Green Creek quadrangle in the Hamilton Draw quadrangle, shows ash 3.761 percent, sulfur 0.165 percent, and heating value 8,801 Btu per pound (20,471 kJ/kg) on an as-received basis. This heating value converts to about 9,145 Btu per pound (21,271 kJ/kg) on a moist, mineral-matter-free basis, indicating that the Canyon coal at that location is subbituminous C in rank. Because of the proximity of that location to the Green Creek quadrangle, it is assumed that the Canyon coal in this quadrangle is similar and is also subbituminous C in rank.

Alderson coal bed

Warren (1959, p. 574 and pl. 19) described and mapped the Alderson coal bed near the tops of divides in the eastern and southern parts of the Green Creek quadrangle, where it occurs about 50 to 90 feet (15 to 27 m) above the Canyon

coal bed. Warren states that this coal bed consists of thin lenses of small areal extent and is nowhere more than 5 feet (1.5 m) thick. The Alderson coal bed has not been assigned economic coal resources in this quadrangle.

Garfield clinker bed

A thick clinker bed, formed by burning of the Garfield coal bed, caps the highest hills in the eastern and southern parts of the Green Creek quadrangle. In this quadrangle, the Garfield coal apparently has been entirely burned.

COAL RESOURCES

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

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

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

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

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

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

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

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

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

As shown by table 1, the total tonnage of federally owned, surface-minable Reserve Base coal in this quadrangle is estimated to be 1,220.35 million short tons (1,107.10 million t). The total tonnage of federally owned, surface-minable Hypothetical coal is estimated to be 15.90 million short tons (14.42 million t). As shown by table 2, the total federally owned, underground-minable Reserve Base coal is estimated to be 1,407.06 million short tons (1,276.49 million t). The total federally owned, underground-minable Hypothetical coal is estimated to be 205.79 million short tons (186.86 million t). The total tonnage of surface- and underground-minable Reserve Base coal is 2,627.31 million short tons (2,383.50 million t), and the total of surface- and underground-minable Hypothetical coal is 221.87 million short tons (201.28 million t).

About 4 percent of the surface-minable Reserve Base tonnage is classed as Measured, 27 percent as Indicated, and 69 percent as Inferred. About 1 percent of the underground-minable Reserve Base tonnage is Measured, 8 percent is Indicated, and 91 percent is Inferred.

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

COAL DEVELOPMENT POTENTIAL

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

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

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

where MR = mining ratio
t_o = thickness of overburden, in feet
t_c = thickness of coal, in feet
rf = recovery factor = 0.85 in this area
cf = conversion factor = 0.911 cu. yds./ short ton for subbituminous coal

The mining-ratio values are used to rate the degree of potential that areas within the stripping limit have for surface-mining development. Areas having mining-ratio values of 0 to 10, 10 to 15, and greater than 15 are considered to

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

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

Development potential for surface-mining methods

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

In areas of moderate 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 for surface-mining methods in the Federal coal lands is shown on the Coal Development Potential map (pl. 40). Most of the Federal lands do have a high development potential for surface mining .

The Canyon coal bed (pl. 5) has narrow bands of high development potential for surface mining (mining-ratio values less than 10) and narrow bands of moderate development potential (mining-ratio values 10-15) high on the hill slopes in the southern and east-central parts of the quadrangle. There are larger areas of low development potential extending from the 15 mining-ratio contour to the crests of the hills.

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

The Wall coal bed (pl. 14) has narrow bands of high development potential for surface mining (mining-ratio values less than 10), and equally narrow bands of moderate development potential (mining-ratio values 10-15) on hill sides in

the southern and eastern parts of the quadrangle. There are wide areas of low development potential extending from the 15 mining-ratio contour to the crests of the hills or to the 500-foot (152.4-m) overburden isopach (the stripping limit).

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

The Odell coal bed (pl. 20) where it is more than 5 feet (1.5 m) thick in the northern part of the quadrangle has narrow bands of high development potential for surface mining (mining-ratio values less than 10) on the hill slopes. There are even narrower bands of moderate development potential between the 10 and 15 mining-ratio contours. Quite wide areas of low development potential extend from the 15 mining-ratio contour to the crests of the hills.

The King coal bed (pl. 23) has no areas of high or moderate development potential for surface mining. In the southwestern part of the quadrangle where the King coal bed is more than 5 feet (1.5 m) thick, there are small areas of low development potential for surface mining extending from the boundary of the coal to the 500-foot (152-m) overburden isopach (the stripping limit). Most of the King coal has no development potential for surface mining, as it is beyond the stripping limit.

The Knobloch coal bed and the upper split of the Knobloch coal bed (pl. 26) has wide areas of high development potential for surface mining on the hill slopes southeast of the Tongue River and in the valley of O'Dell Creek extending

from the boundary of the coal to the 10 mining-ratio contour. There is a moderately wide band of moderate development potential higher on the slopes between the 10 and 15 mining-ratio contours. In the northern part of the quadrangle where the Knobloch coal bed is thick, the bands of moderate development potential extend from the 10 mining-ratio contour to the 500-foot (152-m) overburden isopach (the stripping limit). In the southern part of the quadrngle, there are quite narrow bands of low development potential for surface mining between the 15 mining-ratio contour and the 500-foot (152-m) overburden isopach (the stripping limit).

The lower split of the Knobloch coal bed (pl. 29) has a small area of development potential for surface mining in the central part of the Green Creek quadrangle. However, this is an area of low development potential (mining-ratio values greater than 15) extending from the boundary of the coal to the 500-foot (152-m) overburden isopach (the stripping limit). The small area in the southwestern part of the quadrangle where this coal bed is more than 5 feet (1.5 m) thick has no development potential for surface mining, as the overburden is more than 500 feet (152 m) thick.

The Nance coal bed (pl. 32) has no areas of high or moderate development potential for surface mining because the mining–ratio values are everywhere greater than 15. There are some small areas of low development potential extending from the boundary of the coal to the 500-foot (152-m) overburden isopach. Most of the Nance coal has no development potential for the surface mining, as it is beyond the stripping limit.

The Flowers-Goodale coal bed (pl. 35) likewise has no areas of high or moderate development potential for surface mining because the mining-ratio values for this coal are greater than 15. There is a wide area of low development potential, mainly the valley of O'Dell Creek, extending from the boundary of the

coal to the 500-foot (152-m) overburden isopach (the stripping limit). Most of the Flowers-Goodale coal has no development potential for surface mining, as it is beyond the stripping limit.

The Terret coal bed (pl. 38) has no development potential for surface mining in the Green Creek quadrangle because all of the coal more than 5 feet (1.5 m) thick in this coal bed is beyond the stripping limit.

About 84 percent of the Federal coal lands in the Green Creek quadrangle has a high development potential for surface mining, 6 percent has a moderate development potential, 7 percent has a low development potential, and 3 percent has no development potential for surface mining.

Development potential for underground mining and in-situ gasification

Subbituminous coal beds 5 feet (1.5 m) or more in thickness lying more than 500 feet (152 m) but less than 3,000 feet (914 m) below the surface 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 Green Creek quadrangle, Rosebud County, Montana

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

Coal bed	High development potential (0-10 mining ratio)	Moderate development potential (10-15 mining ratio)	Low development potential (>15 mining ratio)	Total
Reserve Base tonnage				
Canyon	6,670,000	5,400,000	21,910,000	33,980,000
Lower Cook	10,090,000	9,030,000	70,270,000	89,390,000
Otter	4,940,000	4,050,000	38,290,000	47,280,000
Wall	7,370,000	8,540,000	78,550,000	94,460,000
Pawnee	25,440,000	12,650,000	119,920,000	158,010,000
Odell	3,370,000	3,050,000	13,400,000	19,820,000
King	0	0	6,810,000	6,810,000
Upper Knobloch	375,580,000	205,350,000	133,130,000	714,060,000
Lower Knobloch	0	0	4,020,000	4,020,000
Nance	0	0	15,470,000	15,470,000
Flowers-Goodale	0	0	37,770,000	37,770,000
Total	433,460,000	248,070,000	539,620,000	1,221,150,000
Hypothetical Resource tonnage				
Nance	0	0	7,470,000	7,470,000
Flowers-Goodale	0	0	8,430,000	8,430,000
Total	0	0	15,100,000	15,100,000
Grand Total	433,460,000	248,070,000	554,720,000	1,236,250,000

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

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

Coal bed	High Development potential	Moderate development potential	Low development potential	Total
Reserve Base tonnage				
Otter	0	0	1,640,000	1,640,000
Wall	0	0	5,720,000	5,720,000
Pawnee	0	0	39,580,000	39,580,000
Odell	0	0	80,000	80,000
King	0	0	41,870,000	41,870,000
Upper Knobloch	0	0	650,760,000	650,760,000
Lower Knobloch	0	0	8,440,000	8,440,000
Nance	0	0	121,840,000	121,840,000
Flowers-Goodale	0	0	342,220,000	342,220,000
Terret	0	0	194,910,000	194,910,000
Total	0	0	1,407,060,000	1,407,060,000
Hypothetical Resource tonnage				
Upper Knobloch	0	0	12,960,000	12,960,000
Nance	0	0	15,690,000	15,690,000
Flowers-Goodale	0	0	119,050,000	119,050,000
Terret	0	0	58,270,000	58,270,000
Total	0	0	205,970,000	205,970,000
Grand Total	0	0	1,613,030,000	1,613,030,000

REFERENCES

Baker, A. A., 1929, The northward extension of the Sheridan coal field, Big Horn and Rosebud Coiunties, Montana: U.S. Geological Survey Bulletin 806, Part II, p. 15-67.

Bass, N. W., 1924, Coal in Tongue River valley, Montana: U.S. Geological Survey Press Memoir 16748.

_____1932, The Ashland coal field, Rosebud, Powder River, and Custer Counties, Montana: U.S. Geological Survey Bulletin 831-B, p. 19-105.

Bryson, R. P., and Bass, N. W., 1973, Geology of Moorhead coal field, Powder River, Big Horn, and Rosebud Counties, Montana: U.S. Geological Survey Bulletin 1338, 116 p.

Culbertson, W. C., and Klett, M. C., 1976, Geologic map and coal sections of the Browns Mountain quadrangle, Rosebud County, Montana: U.S. Geological Survey Miscellaneous Field Studies Map MF-814.

Gilmour, E. H., and Dahl, G. G., Jr., 1967, Montana coal analyses: Montana Bureau of Mines and Geology Special Publication 43, 21 p.

Hatch, J. R., and Swanson, V. E., 1977, Trace elements in Rocky Mountain coals, in Proceedings of the 1976 symposium, Geology of Rocky Mountain coal, 1977: Colorado Geological Survey, Resource Series 1, p. 143-163.

Mapel, W. J, and Martin, B K., 1978, Coal resource occurrence and coal development potential maps of the Browns Mountain quadrangle, Rosebud County, Montana: U.S. Geological Survey Open-File Report 78-039.

Mapel, W. J., Martin, B. K., and Butler, B. A., 1978, Coal resource occurrence and coal development potential maps of the Poker Jim Butte quadrangle, Rosebud and Powder River Counties, Montana: U.S. Geological Survey Open-File Report 78-651.

Mapel, W. J., Swanson, V. E., Connor, J. J., Osterwald, F. W., and others, 1977, Summary of the geology, mineral resources, environmental geochemistry, and engineering geologic characteristics of the northern Powder River coal region, Montana: U.S. Geological Survey Open-File Report 77-292.

Matson, R. E., and Blumer, J. W., 1973, Quality and reserves of strippable coal, selected deposits, southeastern Montana: Montana Bureau of Mines and Geology Bulletin 91, 135 p.

U.S. Bureau of Mines and U.S. Geological Survey, 1976, Coal resource classification system of the U.S. Bureau of Mines and U.S. Geological Survey: U.S. Geological Survey Bulletin 1450-B, 7 p.

U.S. Department of Agriculture, Interstate Commerce Commission, and U.S. Department of the Interior, 1974, Final environmental impact statement on proposed development of coal resources in the eastern Powder River coal basin of Wyoming: v. 3, p. 39-61.

Warren, W. C., 1959, Reconnaissance geology of the Birney-Broadus coal field, Rosebud and Powder River Counties, Montana: U.S. Geological Survey Bulletin 1072-J, p. 561-585.