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

[Report includes 11 plates]

By

Colorado School of Mines Research Institute

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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)	0.907	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 Olive quadrangle, Powder River County, Montana, (11 plates; U.S. Geological Survey Open-File Report 79-095). This set of maps was compiled to support the land planning work of the Bureau of Land Management in response to the Federal Coal Leasing Amendments Act of 1976, and to provide a systematic coal resource inventory of Federal coal lands in Known Recoverable Coal Resource Areas (KRCRAs) in the western United States. Coal beds considered in the resource inventory are 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, or are 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 Olive 7 1/2-minute quadrangle is in north-central Powder River County, Montana, about 55 miles (88 km) south-southeast of Miles City, a town in the Yellowstone River valley of eastern Montana, and 6 miles (9.6 km) northwest of Broadus, Montana, a small town in the Powder River valley. Miles City is on U.S. Interstate Highway 94 and the main east-west routes of the Burlington Northern Railroad and the Chicago, Milwaukee, St. Paul, and Pacific Railroad. Broadus is on U.S. Highway 212.

Accessibility

The quadrangle is accessible from Miles City, Montana, by going south on U.S. Highway 312 a distance of about 63 miles (101 km) to the northern border of the quadrangle. U.S. Highway 312 passes southward through the eastern part of the Olive quadrangle and is intersected by a number of graded and ungraded roads and trails which provide access to the remainder of the quadrangle. The

quadrangle is also accessible from Broadus, Montana, by going northwestward on U.S. Highway 212 and then on U.S. Highway 312 a total of 6 miles (9.6 km) to the southern border of the quadrangle.

Physiography

The Olive quadrangle is within the Missouri Plateau division of the Great Plains physiographic province. In this quadrangle the plateau has been dissected by northeastward-flowing Mizpah Creek and its tributaries. Mizpah Creek is a tributary of the Powder River which flows northward and joins the Yellowstone River about 30 miles (48 km) northeast of Miles City. Mizpah Creek and its principal tributaries have flood plains about 0.5 mile (0.8 km) wide at elevations of 3,200 to 3,300 feet (975 to 1,006 m). Above the flood plains the valley sides rise gently about 100 feet (30 m) to the base of a steep slope. This steep slope, which generally is about 100 feet (30 m) high, is capped by reddish-colored clinker formed by the burning of a coal bed. Above the steep slopes the rounded hills rise another 20 to 60 feet (6.1 to 18.3 m). The highest elevation 3,622 feet (1,104 m) is near the northwest corner of the quadrangle. The lowest elevation, 3,180 feet (969 m), is on Ash Creek and on Mizpah Creek at the eastern border of the quadrangle. Local relief between the valley bottoms and the upland surface ranges from about 150 to 200 feet (45.7 to 61 m). Topographic relief for the whole quadrangle is 442 feet (134.7 m).

Climate

The climate of Powder River County is characterized by pronounced variations in seasonal precipitation and temperature. Annual precipitation in the region varies from less than 12 inches (30 cm) to 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 Northern Powder River Basin Known Recoverable Coal Resource Area (KRCRA) covers most of the western half of the Olive quadrangle. The Boundary and Coal Data Map (pl. 2) shows the location of the KRCRA tracts and the land ownership status. There were no outstanding Federal coal leases or prospecting permits recorded as of 1977.

GENERAL GEOLOGY

Previous work

Bryson (1952) mapped the northern two-thirds of the Olive quadrangle as part of the Coalwood coal field, Powder River County, Montana. Warren (1959) mapped the southern third of the quadrangle as part of the Birney-Broadus coal field, Rosebud and Powder River Counties, Montana. Matson and Blumer (1973) mapped the eastern part of the Olive quadrangle as part of the Broadus coal field. V. W. Carmichael in Matson and Blumer (1973) mapped the northeastern part of the quadrangle as part of the Pumpkin Creek coal deposit.

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 two members of the Paleocene Fort Union Formation, the uppermost Tongue River Member and the underlying Lebo Shale Member.

The Tongue River Member is made up mainly of light-brown to gray sandstone, sandy shale, carbonaceous shale, and coal. Much of the coal has burned, baking the overlying sandstone and shale and forming thick reddish-colored clinker

beds. The upper part of the Tongue River Member has been removed by erosion, so only the basal 500 to 600 feet (152 to 183 m) remains.

Coal and other rocks comprising the Tongue River Member were deposited in a continental environment at elevations of perhaps a few tens of feet (a few meters) above sea level in a vast area of shifting rivers, sloughs, swamps, and lakes that occupied the Northern Great Plains in Paleocene (early Tertiary) time.

The Lebo Shale is predominantly dark-gray and light-gray claystone and brown to black carbonaceous shale containing some beds of siltstone. This member crops out only in the valleys of Mizpah Creek and its tributaries near the eastern border of the quadrangle.

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 the trace element content 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 rock types found throughout other parts of the western United States.

Structure

The Olive quadrangle is in the northeastern part of the Powder River structural basin. Regionally the strata dip southwestward at an angle of less than 1 degree. The regional dip is modified in places by minor local folding and faulting (pls. 4 and 8).

COAL GEOLOGY

The coal beds in the Olive 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 coal beds are in the Tongue River Member of the Fort Union Formation. The lowest of the

coals is the Broadus coal bed, which occurs about 150 feet (46 m) above the base of the Tongue River Member. The Broadus coal bed is overlain successively by a noncoal interval of 85 to 125 feet (25.9 to 38.1 m), a local coal bed, a noncoal interval of 6 to 16 feet (1.8 to 4.9 m), the Knobloch coal bed, a noncoal interval of 80 to 140 feet (24.4 to 42.7 m), the Sawyer coal bed, a noncoal interval of about 80 feet (24.4 m), and the Mackin-Walker coal bed.

The coal found along the eastern flank of the Powder River Basin in Montana increases in rank from lignite in the east to subbituminous in the deeper parts of the basin to the west. All available chemical analyses of coal from this and adjacent quadrangles were considered in our decision to assign a rank of lignite A to the coal in this quadrangle. Analyses of coal are given in the description of the various coal beds.

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

Broadus coal bed

The Broadus coal bed, first described by Warren (1959, p. 570), derives its name from the town of Broadus in the Broadus quadrangle about 5 miles (8 km) southeast of the Olive quadrangle. The Broadus coal has been almost entirely burned near the surface in the eastern part of the Olive quadrangle, where the reddish-brown, erosion-resistant Broadus clinker bed caps the hills. The Broadus coal bed crops out in only a few places in the western part of the quadrangle, but it has been penetrated by drill holes throughout the area. The isopach map (pl. 7) shows that the Broadus coal is generally from about 15 to 30 feet (4.6 to 9.1 m) thick. The structure contour map (pl. 8) shows that the Broadus coal bed

has a westward dip of less than 1 degree that is interrupted locally by minor folding and faulting.

A chemical analysis of the Broadus coal from a depth of 92 to 117 feet (28 to 35.7 m) in drill hole BR-6C, sec. 7, T. 3 S., R. 50 E., in the Olive quadrangle, shows ash 6.90 percent, sulfur 0.24 percent, and heating value 7,550 Btu per pound (17,561 kJ/kg) on an as-received basis (Matson and Blumer, 1973, p. 91). This heating value converts to about 8,110 Btu per pound (18,864 kJ/kg) on a moist, mineral-matter-free basis, indicating that the Broadus coal in the Olive quadrangle is lignite A in rank.

Local coal bed

The local coal bed which occurs about 6 to 16 feet (1.8 to 4.9 m) below the Knobloch coal bed ranges from only 1 to 3 feet (0.3 to 0.9 m) in thickness (pls. 1 and 3). Consequently, the local coal is not considered an economic coal resource.

Knobloch coal bed

The Knobloch coal bed was named by Bass (1924) from a small coal mine on the Knobloch Ranch in the Tongue River valley in the Birney Day School quadrangle, about 37 miles (59 km) west-southwest of the Olive quadrangle. The Knobloch coal bed crops out extensively in the northwestern part of the Olive quadrangle and occurs beneath the surface in the southwestern part of the quadrangle. As shown by the isopach and structure contour map (pl. 4), the Knobloch coal bed ranges from 3 to 8 feet (0.9 to 2.4 m) in thickness, and generally dips westward at an angle of less than 1 degree. Overburden on the Knobloch coal where the bed is more than 5 feet thick (pl. 5) ranges from zero at the outcrops to about 280 feet (85 m) in thickness (pl. 5).

There is no known publicly available chemical analysis of the Knobloch coal in the Olive quadrangle. A chemical analysis of the Knobloch coal from drill

hole FC-6, sec. 29, T. 1 S., R. 48 E., about 13 miles (20.9 km) northwest of the Olive quadrangle, in the Elk Ridge quadrangle, shows ash 6.66 percent, sulfur 0.37 percent, and heating value 7,380 Btu per pound (17,166 kJ/kg) on an as-received basis (Matson and Blumer, 1973, p. 87). This heating value converts to about 7,906 Btu per pound (18,389 kJ/kg) on a moist, mineral-matter-free basis, indicating that the Knobloch coal at this location is lignite A in rank. Because this location is close to the Olive quadrangle, it is assumed that the Knobloch coal in the Olive quadrangle is similar and is lignite A in rank.

Sawyer coal bed

The Sawyer coal bed was first described by Dobbin (1930, p. 28) after exposures in the foothills of the Little Wolf Mountains in the Forsyth coal field, Rough Draw and Black Spring quadrangles, about 55 miles (88 km) west-northwest of the Olive quadrangle.

The Sawyer coal bed occurs in the western part of the Olive quadrangle about 80 to 140 feet (24.4 to 42.7 m) above the Knobloch coal bed (pls. 1 and 3). However, the Sawyer coal has been almost entirely burned, forming a thick clinker bed. In the west-central part of the quadrangle, the Sawyer coal is locally split into two beds. The two small areas of unburned Sawyer coal, near the western border of the quadrangle, are on non-Federal coal land, and therefore coal resources for them have not been calculated.

Mackin-Walker coal bed

The Mackin-Walker coal bed was first described by Bryson (1952, p. 76) from the Mackin-Walker coal mine in the Coalwood coal field in the Box Elder Creek quadrangle just northwest of the Olive quadrangle. The Mackin-Walker coal bed, which occurs about 80 feet (24.4 m) above the Sawyer coal bed, is present only in one small area on the crest of a hill near the western border of the quadrangle.

The coal here is only 3.9 feet (1.2 m) thick, and therefore coal resources have not been calculated for the Mackin-Walker coal bed.

COAL RESOURCES

Data from all publicly available drill holes and from surface mapping by others (see list of references) were used to construct the coal data, isopach, and structure contour maps of the coal beds in this quadrangle. These maps were used to construct derivative maps showing overburden isopachs, mining-ratio contours, and the areal distribution and tonnages of coal resources.

Coal resource tonnages shown in this report are the Reserve Base (RB) part of the Identified Resources as discussed in U.S. Geological Survey Bulletin 1450-B.

The Reserve Base for lignite is lignite that is 5 feet (1.5 m) or more thick, under 1,000 feet (305 m) or less of overburden, and located within 3 miles (4.8 km) of a point of coal-bed measurement. Reserve Base is subdivided into reliability categories according to distance from a point of measurement of the coal bed. Measured coal is 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.

Hypothetical Resources are undiscovered coal resources in beds that may reasonably be expected to exist in known mining districts under known geologic conditions. In general, Hypothetical Resources are located in broad areas of coal fields where no points of observation are present, and the evidence of the 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. There are no Hypothetical coal resources in this quadrangle.

Reserves are the recoverable part of the Reserve Base coal. For surface-minable coal in this quadrangle the coal reserves are considered to be 85 percent (the recovery factor for this area) of that part of the Reserve Base that is beneath 200 feet (61 m) or less of overburden (the stripping limit for beds of lignite in this area).

Estimated coal resources in this quadrangle were calculated using data obtained from the coal isopach maps (pls. 4 and 7). The coal-bed acreage (measured by planimeter) multiplied by the average isopached thickness of the coal bed times a conversion factor of 1,750 short tons of lignite per acre-foot (12,880 metric tons per hectare-meter) yields the coal resources in short tons for each coal bed with economic resources. The tonnages of Reserve Base for the Knobloch and Broadus coal beds are shown on plates 6 and 10, respectively, and are rounded to the nearest one-hundredth of a million short tons.

The total Reserve Base tonnage of federally owned, surface-minable lignite in this quadrangle is estimated to be 267.04 million short tons (242.20 million t). The total Reserve Base tonnage of underground-minable coal in this quadrangle is estimated to be 81.29 million short tons (73.73 million t). The Reserve Base tonnage totals per section are shown in the northwest corner of the Federal coal lands in each section on plate 2. Reserve Base tonnages by development-potential category for the entire quadrangle are shown in tables 1 and 2. All numbers are rounded to the nearest one-hundredth of a million short tons. About 6 percent of the Reserve Base tonnage of surface-minable coal is classed as Measured, 40 percent as Indicated, and 54 percent as Inferred. About 15 percent of the Reserve Base tonnage of underground-minable coal is classed as Indicated and 85 percent as Inferred.

COAL DEVELOPMENT POTENTIAL

Areas where lignite beds are 5 feet (1.5 m) or more thick and are overlain by 200 feet (61 m) or less of overburden are considered to have potential for surface mining and were assigned a high, moderate, or low development potential based on the mining ratio (cubic yards of overburden per ton of recoverable coal). The formula used to calculate mining-ratio values for lignite is:

$$MR = \frac{t_o\ (0.922)}{t_c\ (rf)}$$

where MR = mining ratio
t_o = thickness of overburden
t_c = thickness of lignite
rf = recovery factor = 0.85
0.922 = conversion factor (cu. yds./ton)

Areas of high, moderate, and low development potential for surface mining of coal are here defined as areas underlain by coal beds having less than 200 feet (61 m) of overburden and having respective mining-ratio values of zero to 10, 10 to 15, and greater than 15, as shown on CRO maps, plates 5 and 9, for the Knobloch and Broadus coal beds, respectively. These mining-ratio values for each development-potential category are based on economic and technological criteria that were provided by the U.S. Geological Survey. Estimated tonnages of surface-minable Reserve Base coal in each development-potential category (high, moderate, and low), are shown in table 1. Estimated tonnages of underground-minable Reserve Base coal are shown in a like manner in table 2.

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.

In areas of moderate to high topographic relief, the area of moderate-development potential for surface mining (area having mining-ratio values of 10 to 15) is often restricted to a narrow band between the areas of high and low development potential. In fact, because of the 40-acre (16.2-ha) minimum size of coal development-potential tracts, the narrow areas of moderate development potential often are not apparent on the CDP map because they occur in 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 for surface-mining on federally owned coal land where there is 5 feet (1.5 m) or more of lignite under 200 feet (61 m) or less of overburden is shown on the CDP map (pl. 11). Most of the Federal coal lands in the western half of the Olive quadrangle have a high potential for surface mining primarily because of the Broadus coal bed and secondarily because of the Knobloch coal bed. Most of the Federal coal lands in the eastern half of the quadrangle have no potential for surface mining because the Knobloch coal bed is absent and the Broadus coal bed has been almost entirely burned.

The Broadus coal bed (pl. 9) has wide areas of high development potential extending from the border of the Reserve Base coal to the 10 mining-ratio contour or to the stripping limit at the 200-foot overburden isopach if the mining ratio is less than 10. A minor amount of Broadus coal in the west-central part of the quadrangle between the 10 mining-ratio contour and the 200-foot (61 m) overburden isopach has a moderate development potential.

The Knobloch coal bed (pl. 5) has small areas of high and moderate development potential and larger areas of low development potential in the north-west and southwest quarters of the quadrangle.

About 35.7 percent of the Federal coal land in the Olive quadrangle has a high development potential for surface mining, 0.6 percent has a moderate development potential, 1.7 percent has a low development potential, and 62.0 percent has no development potential.

Development potential for underground mining and in-situ gasification

Lignite beds 5 feet (1.5 m) or more in thickness lying more than 200 feet (61 m) but less than 1,000 feet (305 m) below the surface of this quadrangle are considered to have development potential for underground mining. Estimates of the tonnage of underground-minable lignite 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 these methods are not profitable at this time. Therefore, the coal development potential for underground mining of these resources 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.

Table 1.--Surface-minable coal resource tonnage (in short tons) by development-potential category for Federal coal lands in the Olive quadrangle, Powder River County, Montana

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

Coal bed	High development potential (0-10 mining ratio)	Moderate development potential (10-15 mining ratio)	Low development potential (>15 mining ratio)	Total
Reserve Base tonnage				
Knobloch	1,070,000	330,000	3,760,000	5,160,000
Broadus	261,210,000	670,000	0	261,880,000
Total	262,280,000	1,000,000	3,760,000	267,040,000

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

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

Coal bed	High Development potential	Moderate development potential	Low development potential	Total
Reserve Base tonnage				
Knobloch	0	0	130,000	130,000
Broadus	0	0	81,160,000	81,160,000
Total	0	0	81,290,000	81,290,000

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