UNITED STATES DEPARTMENT OF THE INTERIOR

GEOLOGICAL SURVEY

Text to accompany:

Open-File Report 78-837

1978

COAL RESOURCE OCCURRENCE AND COAL DEVELOPMENT POTENTIAL MAPS OF THE CAREY-MALONE SCHOOL QUADRANGLE, CUSTER COUNTY, MONTANA

[Report includes 11 plates]

By

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

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ILLUSTRATIONS

[Plates are in pocket]

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Conversion table

To convert	Multiply by	To obtain
feet	0.3048	meters (m)
miles	1.609	kilometers (km)
acres	0.40469	hectares (ha)
tons (short)	0.907	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 Carey-Malone School quadrangle, Custer County, Montana, (11 plates; U.S. Geological Survey Open-File Report 78-837). 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 1975, 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 only those beds 5 feet (1.5 m) or more thick and under less than 3,000 feet (914 m) of overburden.

Location

The Carey-Malone School 7 1/2-minute quadrangle is in southwestern Custer County, Montana, about 28 miles (44.8 km) due south of Miles City, Montana. Miles City is on U.S. Interstate Highway 94 and the main lines of the Burlington Northern Railroad and the Chicago, Milwaukee, St. Paul, and Pacific Railroad.

Accessibility

The quadrangle is accessible from Miles City, Montana, by going south on U.S. Highway 312 a distance of 37 miles (59.2 km) to the improved Ash Creek Road and thence west 6 miles (9.6 km) to the east border of the quadrangle. The southern part of the quadrangle is also accessible by the

improved Basin Creek Road which intersects U. S. Highway 312 about 5.5 miles (8.8 km) farther to the south. A number of unimproved roads provide access to the rest of the quadrangle.

Physiography

The Carey-Malone School quadrangle is within the Missouri Plateau division of the Great Plains physiographic province. The upland plateau surface, however, has been almost completely dissected by tributaries of the northeasterly flowing Tongue River, which is about 6 miles (9.6 km) west of the quadrangle. A drainage divide oriented north-south remains as a remnant of the plateau surface in the center of the quadrangle. Foster, Haddow, and Ash Creeks are minor tributaries which drain northwestward to the Tongue River. Basin and Cottonwood Creeks drain eastward into Pumpkin Creek, the principal tributary of the Tongue River. The highest elevation, 3,392 feet (1,034 m), is at Holt triangulation station on the crest of the divide just east of the center of the quadrangle. The lowest elevation, just under 2,780 feet (847 m), is on the North Fork of Foster Creek at the west border of the quadrangle. Topographic relief is about 612 feet (189 m).

Climate

The climate of Custer 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 the quadrangle except much of the northwest quarter (the valley bottoms of Haddow Creek and North Fork Foster Creek), and part of the west half of the southwest quarter (the valley bottom of Foster Creek). 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 as of 1977.

GENERAL GEOLOGY

Previous work

Bass (1932) mapped the south two-thirds of the Carey-Malone School quadrangle as part of the Ashland coal field, Rosebud, Powder River, and Custer Counties, Montana. Pierce (1936) mapped the north third of the quadrangle as part of the Rosebud coal field, Rosebud and Custer Counties, Montana. Brown and others (1954) mapped the quadrangle as part of their Foster Creek Deposit, in a description of strippable coal in Custer and Powder River Counties, Montana. Gilmour and Williams (1969) mapped the quadrangle as part of the Foster Creek coal deposit. Matson and Blumer (1973) included a revision of the Gilmour and Williams work in their summary of strippable coal, southeastern Montana.

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 Fort Union Formation (Paleocene). The Fort Union Formation is composed of three members: the upper Tongue River Member, the middle Lebo Shale Member, and the lower Tullock Member. Pierce (1936) considered the Tullock to be a member of the Lance Formation, but since 1949 the U.S. Geological Survey has considered the Tullock to be the lowest member of the Fort Union Formation in Montana.

The Lebo Shale Member composes the lowest outcrops in the quadrangle, occurring as the lowermost beds exposed in the valleys of Haddow, North Fork Foster, and Foster Creeks. The Lebo Shale Member is 150 to 160 feet (45.7 to 48.8 m) thick and consists of shale and a few thin, lenticular sandstones, but no mappable coal beds.

The Tongue River Member caps the upland plateaus and ridges in the south two-thirds of the quadrangle and contains the only coal beds of economic interest. This unit is made up mainly of yellow sandstone, sandy shale, carbonaceous shale, and coal. Much coal has burned along outcrops, fracturing and baking the overlying sandstone and shale, forming thick clinker beds. Originally as much as 1,150 to 1,600 feet (350 to 488 m) thick in this vicinity (Bass, 1932, p. 34), most of the Tongue River Member has been removed by erosion so that only about the lower 400 feet (122 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 above sea level in a vast area of shifting flood plains, sloughs, swamps, and lakes that occupied the Northern Great Plains in 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 trace element content by the U.S. Geological Survey and the results 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 Carey-Malone School quadrangle is in the northeastern part of the Powder River structural basin. The strata dip about 20 feet per mile (3.8 m per km) to the southwest as indicated by the structure contours on the Terret coal bed (pl. 8). The regional dip is interrupted by several shallow, irregular folds that do not show any strong directional alignments.

COAL GEOLOGY

Five coal beds, all in the Tongue River Member of the Fort Union Formation, were mapped on the surface in this quadrangle (pl. 1) and are shown in section on plate 3. The lowest of these is the Foster coal bed, which lies about 70 feet (21 m) above the base of the Tongue River Member. The Foster coal bed is overlain by a noncoal interval of 40 feet (12 m); the

Terret coal bed, a noncoal interval of 70 feet (21 m); the Haddow coal bed, a noncoal interval of 40 feet (12 m); the Flowers-Goodale coal bed, a noncoal interval of 70 feet (21 m); and the Knobloch coal bed.

The Terret, Flowers-Goodale, and Knobloch coal beds contain Reserve Base coal. However, the area with Knobloch coal is located entirely on non-Federal lands. For this reason maps delimiting the Knobloch coal bed (structure, isopach, overburden isopach, identified resources, etc.) have not been made, nor have calculations of the Reserve Base coal or coal reserves been made.

The Foster and Haddow coal beds are thin -- less than 4.5 feet (1.37 m) in thickness -- and local in extent. They do not contain Reserve Base coal.

The trace element content of coals in the Carey-Malone School 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).

Terret coal bed

The Terret coal bed was described by Bass (1932, p. 51) from a small mine on the Terret Ranch (Cook Creek Reservoir quadrangle) in the Ashland coal field, about 20 miles (32 km) southwest of the Carey-Malone School quadrangle. The Terret coal underlies the divides which separate the larger drainage valleys of Foster Creek, North (or East) Fork Foster Creek, Haddow Creek, and Ash Creek, and crops out on the valley sides (pl. 1). The

thickness ranges from 4 to 11.6 feet (1.2 to 3.5 m); the greatest thicknesses are in two large lobes in the east half of the quadrangle (pl. 7). The bed dips regionally to the southwest at about 20 feet per mile (3.8 m per km), but this dip is interrupted by several broad, shallow folds that do not have strong directional alignments (pl. 8). The overburden on the Terret coal bed ranges from zero to over 200 feet (61 m) in thickness (pl. 9). Where thickest, the overburden includes the Flowers-Goodale coal bed and also two local areas of the Knobloch coal bed (pl. 1).

No coal analyses are available for the Terret coal bed in the Carey-Malone School quadrangle; however, the Montana Bureau of Mines and Geology drilled and cored the Terret coal in drill hole FC-16 (sec. 17, T. 1 N., R. 48 E.) about 4 miles (6.4 km) south of the Carey-Malone School quadrangle in the Foster Creek School quadrangle. At depths of 53 to 62 feet (16.1 to 18.9 m) an analysis shows a heating value of 7,820 Btu per pound, ash 5.14 percent, and sulfur 0.21 percent, as received (Matson and Blumer, 1973, p. 86). This analysis converts to a moist, mineral-matter-free heating value of about 8,070 Btu per pound and determines the coal rank to be lignite A.

Flowers-Goodale coal bed

The Flowers-Goodale coal bed was described by Bass (1932, p. 53) from two small mines located in the Brandenberg quadrangle, about 15 miles (24 km) west-southwest of the Carey-Malone School quadrangle. The coal bed lies in approximately the position of the Rosebud coal bed west of the Tongue River, and may represent that bed east of the river (Bass, 1932, p. 54).

The Flowers-Goodale coal bed underlies the crest of the drainage divide in the east half of the Carey-Malone School quadrangle. The coal bed thickness ranges from 4 to 7 feet (1.2 to 2.1 m), becoming thicker in a westward direction (pl. 4). There is a slight dip westward, less than 40 feet per mile (7.62 m per km), as is shown on plate 4. The overburden on the Flowers-Goodale coal bed ranges from zero to about 150 feet (46 m) in thickness (pl. 5). Where thickest (two local areas on the crest of the drainage divide, see plate 1), the overburden includes the Knobloch coal bed.

No coal analyses are available for the Flowers-Goodale coal bed in the Carey-Malone School quadrangle; however, the Montana Bureau of Mines and Geology drilled and cored the Flowers-Goodale coal bed in drill hole FC-29 (sec. 21, T. 1 N., R. 46 E.) about 5 miles (8 km) south of the Carey-Malone School quadrangle, in the Foster Creek School quadrangle. At depths of 83 to 95.5 feet (25.3 to 29.1 m), an analysis shows a heating value of 7,540 Btu per pound, ash 7.27 percent, and sulfur 0.36 percent, as received (Matson and Blumer, 1973, p. 86). This analysis converts to a moist, mineral-matter-free heating value of about 8,170 Btu per pound and determines the coal rank to be lignite A.

Knobloch coal bed

The Knobloch coal bed was described by Bass (1932) from the Knobloch Ranch and coal mine in the Birney Day School quadrangle located about 40 miles (64 km) southwest of the Carey-Malone School quadrangle.

The Knobloch coal bed is present in two local areas on the crest of the drainage divide in the east half of the Carey-Malone School quadrangle (pl. 1).

However, these coal areas are located entirely on non-Federal lands. For this reason no maps have been made outlining and describing the coal bed, nor have calculations been made of the Reserve Base coal or coal reserves.

COAL RESOURCES

Data from oil-and-gas and coal test holes, as well as from all publicly available 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.

Coal resource tonnages shown in this report are the Reserve Base part of the Identified Resources (as discussed in U.S. Geological Survey Bulletin 1450-B). The Reserve Base for lignitic coal is coal that is 5 feet (1.5 m) or more thick, under 3,000 feet (914 m) or less of overburden, and located within 3 miles (4.8 km) of a point of coal bed measurement. Reserve Base is further subdivided into reliability categories according to their nearness to a measurement of the coal bed. Measured coal is coal within 0.25 mile (0.4 km) of a measurement, 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.

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. This depth of overburden is 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 coal per acre-foot (12,880 metric tons per hectare-meter) for lignite yields the lignite resources in short tons for each isopached bed. Reserve Base and Reserve tonnage values for the Flowers-Goodale and Terret 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 coal (lignite) in this quadrangle is calculated to be 121.97 million short tons (110.85 million metric t). Of this total, 119.44 million short tons (108.36 million metric t) are comsidered to be surface minable (table 1), and 2.43 million short tons (2.20 million metric t) are considered to be underground minable (table 2). The Reserve Base tonnage totals per section are shown in the northwest corner of each section on CRO plate 2 and by development potential category in tables 1 and 2. All numbers are rounded to the nearest one-hundredth of a million short tons. About 13 percent of the surface-minable Reserve Base tonnage is classed as Measured, 50 percent as Indicated, and 37 percent as Inferred.

COAL DEVELOPMENT POTENTIAL

Areas where coal 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 ratios for lignite is as follows:

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

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 are here defined as areas underlain by coal beds having respective mining-ratio values of 0 to 10, 10 to 15, and greater than 15, as shown on CRO plates 5 and 9. These mining-ratio values for each development-potential category are based on current economic and technological criteria and were provided by the U.S. Geological Survey. Calculated tonnages in each development potential category (high, moderate, and low) for surface mining are shown in table 1.

Development potential for surface-mining methods

The Coal Development Potential (CDP) map, plate 11, in this series of maps depicts the highest coal development potential category which occurs within each smallest legal subdivision of land (normally about 40 acres or 16.2 ha). 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, etc.

The coal development potential for surface-mining methods (less than 200 feet or 61 m of overburden) is shown on the Coal Development Potential

map (pl. 11). Either the Terret or the Flowers-Goodale coal (or both) have a high development potential over 97 percent of their combined areas of occurrence in the quadrangle. (Most of the quarter-quarter sections are rated high development potential, although based upon mining-ratio contours, some of the coal may fall into the moderate development potential category in table 1.) The remaining 3 percent of their areas of occurrence has a moderate development potential. The rest of the quadrangle has no coal development potential for surface mining.

Development potential for underground mining and in situ gasification

For economic reasons, coal is not currently being mined by underground methods in the Northern Powder River Basin, Montana. Consequently, coal beds found beneath 200 feet (61 m) of overburden in this quadrangle are considered as having a low development potential for underground mining wherever such beds are present, and a Coal Development Potential map for underground mining was not made. The Terret coal bed is estimated to contain 2.43 million short tons (2.20 million t) of underground-minable lignite in this quadrangle, as shown in table 2.

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 stripping limit in this area is rated as low.

Table 1.--Surface-minable coal resource tonnage by development potential category for Federal coal lands (in short tons) in the Carey-Malone School quadrangle, Custer 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
Terret	71,030,000	20,280,000	13,850,000	105,160,000
Flowers-Goodale	11,830,000	2,040,000	410,000	14,280,000
Total	82,860,000	22,320,000	14,260,000	119,440,000

Table 2.--Underground-minable coal resource tonnage by development potential category for Federal coal lands (in short tons) in the Carey-Malone School quadrangle, Custer 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
Terret	0	0	2,430,000	2,430,000
Flowers-Goodale	0	0	0	0
Total	0	0	2,430,000	2,430,000

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