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COAL RESOURCE OCCURRENCE AND COAL DEVELOPMENT POTENTIAL MAPS OF THE KIRKPATRICK HILL QUADRANGLE, CUSTER COUNTY, MONTANA

[Report includes 10 plates]

By

Colorado School of Mines Research Institute

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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 Kirkpatrick Hill quadrangle, Custer County, Montana, (10 plates; U.S. Geological Survey Open-File Report 78-838). 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 Kirkpatrick Hill 7 1/2-minute quadrangle is in southern Custer County, Montana, about 32 miles (51.2 km) south-southeast of Miles City, Montana. Miles City is located on U.S. Interstate Highway 94, and the main east-west lines of the Burlington Northern and the Chicago, Milwaukee, St. Paul, and Pacific railroads.

Accessibility

The Kirkpatrick Hill quadrangle is accessible from Miles City, Montana, by traveling south on U.S. Highway 312, a distance of 36 miles (58 km), to the east border of the quadrangle. U.S. Highway 312 continues through the eastern part of the quadrangle, where it is intersected by the improved Ash Creek Road which provides access to the north half of

the quadrangle, and by the improved Basin Creek Road which traverses the southern part of the quadrangle. The rest of the quadrangle may be reached from these by a number of unimproved roads.

Physiography

The Kirkpatrick Hill 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 Tongue River and Pumpkin Creek. The largest of these are Ash Creek in the north half of the quadrangle, and Betz, Cottonwood, and Basin Creeks in the south half. The divides between these creeks are resistant ridges and knobs, capped with clinker which has resulted from the burning of coal beds. The ridges may range to 3,290 feet (1,003 m) in elevation and are the highest points in the quadrangle. The lowest elevation, about 2,810 feet (856 m), is where Pumpkin Creek leaves the quadrangle near the center of the east border. Topographic relief is about 480 feet (146 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) extends into the west half of the 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 as of 1977.

GENERAL GEOLOGY

Previous work

Bass (1932) mapped the southwestern part of the Kirkpatrick Hill quadrange 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. Parker and Andrews (1939) mapped the southeastern part of the quadrangle as part of the Mizpah coal field, Custer County, Montana. Gilmour and Williams (1969) mapped most of the quadrangle as part of their Foster Creek coal deposit, eastern Montana. 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 lowermost member of the Fort Union Formation in Montana.

The Tullock Member composes the lowest outcrops in the quadrangle, occurring as the lowermost beds exposed in Pumpkin Creek valley in the northeast quarter of the quadrangle. The Tullock Member is approximately 300 feet (91 m) thick and is made up of alternating beds of sandstone and shale and contains unimportant local coal beds (Pierce, 1936). Only about the uppermost 30 feet (9 m) are exposed in Pumpkin Creek bottom where the creek leaves the quadrangle (Pierce, 1936, pl. 11).

The overlying Lebo Shale Member is 160 to 200 feet (49 to 61 m) thick and consists of shale and a few thin, lenticular sandstones, but no mappable coal beds. The Lebo Shale occupies most of the broad valley of Pumpkin Creek and its tributaries in the east half of the quadrangle.

The Tongue River Member caps the ridges between the valleys in the western half 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, and forming thick clinker beds. Originally more than 1,000 feet (305 m) thick in this vicinity, most of the Tongue River Member has been removed by erosion so that only about the lower 300 feet (91 m) remains (Pierce, 1936, p. 61).

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 flood plains, sloughs, swamps, and lakes that occupied 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 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 Kirkpatrick Hill quadrangle is in the northeastern part of the Powder River structural basin. Except where interrupted by gentle folds, the strata dip westward about 40 feet per mile (7.6 m per km). An anticlinal nose with up to 40 feet (12 m) of structural relief is mapped on the Terret coal bed in the northwest quarter of the quadrangle (pl. 7).

COAL GEOLOGY

Three 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 Contact coal bed which lies just above the base of the Tongue River Member. As it is thin (less than 5 feet or 1.5 m), shaley, and discontinuous throughout most of its extent, no economic resources have been attributed to it. It is overlain

successively by a 30 to 60 foot (9 to 18 m) thick noncoal interval, the Terret coal bed, another 75 foot (23 m) thick noncoal interval, and the Flowers-Goodale coal bed. The Flowers-Goodale coal is burned to clinker over most of its areal distribution. However, in places only the upper part of the coal bed has been burned (composite section 9, pl. 1).

The trace element content of coals in the Kirkpatrick Hill 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).

Contact coal bed

The Contact coal bed was named by Bass (1932) for exposures in the Kirkpatrick Hill quadrangle in the northeastern part of the Ashland coal field.

The Contact coal bed lies at the base of the Tongue River Member in the south half of this quadrangle (pl. 1). Its thickness is generally less than 2 feet (0.6 m), although one measurement is 4.8 feet (1.5 m). Because of its thinness and lack of continuity no Reserve Base coal has been attributed to it.

Terret coal bed

The Terret coal bed was named by Bass (1932, p. 51) after a small mine on the Terret Ranch (Cook Creek Reservoir quadrangle) in the Ashland coal field about 25 miles (40 km) to the southwest of the Kirkpatrick Hill quadrangle. The Terret bed crops out on the sides of the stream valleys in

the west half of the quadrangle. The Terret coal bed ranges from 4.9 to over 8 feet (1.5 to over 2.4 m) in thickness (pl. 7). Regional dip on the bed is westward about 40 feet per mile (7.6 m per km).

Overburden on the Terret coal bed ranges from zero to 200 feet (61 m), as shown on plate 8. The Flowers-Goodale coal bed and/or its clinker lie within this interval, about 75 feet (22.9 m) above the Terret (pl. 1).

No coal analyses are available for the Terret coal bed in the Kirkpatrick Hill 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.) in the Foster Creek School quadrangle, about 3 miles (4.8 km) southwest of the Kirkpatrick Hill quadrangle. At depths of 53 to 62 feet (16.1 to 18.9 m), the 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 named by Bass (1932, p. 53) after two small mines located in the Brandenberg quadrangle, about 20 miles (32 km) west-southwest of the Kirkpatrick Hill quadrangle. The Flowers-Goodale coal bed is believed to be the eastward equivalent of the Rosebud coal bed which is present west of the Tongue River (Bass, 1932, p. 54).

The Flowers-Goodale coal is present only in small local areas in the southwest quarter of the quadrangle, but its clinker caps large areas of the east-west ridges in the west half of the quadrangle. At one point the clinker

has eroded away, exposing 7.7 feet (2.4 m) of coal. This thickness and coal bed thicknesses projected from adjacent quadrangles have been used to make the isopach map (pl. 4) and to calculate reserves. Overburden on the Flowers-Goodale coal bed in the Kirkpatrick Hill quadrangle is less than 100 feet or 30.5 m in thickness (pl. 5).

No coal analyses are available from the Flowers-Goodale coal bed in the Kirkpatrick Hill quadrangle; however, the Montana Bureau of Mines and Geology drilled and cored the Flowers-Goodale coal in drill hole FC-32 (sec. 25, T. 1 N., R. 47 E.) about 6 miles (9.6 km) southwest of the Kirkpatrick Hill 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.

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 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 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 (12,870 t/ha-m) for lignite yields the lignite resources in short tons of each isopached bed. Reserve Base and Reserve tonnage values for the Flowers-Goodale and Terret coal beds are shown on plates 6 and 9, respectively, and are rounded to the nearest one-hundredth of a million short tons.

The total Reserve Base tonnage of federally owned lignite in this quadrangle is calculated to be 21.54 million short tons (19.54 million t). 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 18 percent of the Reserve Base tonnage is classed as Measured, 59 percent as Indicated, and 23 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 (6.1 m) or less of overburden are considered to have potential for surface mining in this quadrangle 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 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 6 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 10 in this series of maps, depicts the highest coal development potential category which occurs within each smallest legal subdivision of Federal coal land (normally about 40 acres or 16.2 ha). If such a 40-acre (16-ha) tract of land contains areas of high, moderate, and low development potential, the entire tract is assigned to the high 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. 10). Either the Terret or the Flowers-Goodale coal (or both) has a high development potential over 97.5 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 2.5 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. Therefore, coal beds found beneath 200 feet (61 m) of overburden in the quadrangle are considered as having a low development potential for underground mining wherever such beds are present. Consequently, a Coal Development Potential map for underground mining was not made for this quadrangle. The

Terret coal bed is estimated to contain 0.20 million short tons (0.18 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 Kirkpatrick Hill 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
Flowers-Goodale	1,110,000	210,000	100,000	1,420,000
Terret	13,130,000	4,440,000	2,350,000	19,920,000
Total	14,240,000	4,650,000	2,450,000	21,340,000

Table 2.--Underground-minable coal resource tonnage by development potential category for Federal coal lands (in short tons) in the Kirkpatrick Hill 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	200,000	200,000

The total of 200,000 tons, above classed as underground-minable coal, lies beneath 200 feet or more of overburden and is adjacent to much larger quantities of surface-minable coal. This 200,000 tons would no doubt be mined by surface methods along with the adjacent coal, or it would be bypassed and not mined at all.

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