UNITED STATES DEPARTMENT OF THE INTERIOR

GEOLOGICAL SURVEY

Text to accompany:

Open-File Report 79-105

1979

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

(Report includes 59 plates)

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COAL RESOURCE OCCURRENCE

Introduction

Purpose

This text is for use in conjunction with the Coal Resource Occurrence (CRO) and Coal Development Potential (CDP) maps of the Otter quadrangle, Powder River County, Montana (59 plates; U.S. Geological Survey Open-File Report 79-015). The maps are intended to support land use planning and coal leasing activities of the Bureau of Land Management in response to the Federal Coal Leasing Amendments Act of 1976, and to provide information leading to a systematic coal resource inventory of Federal coal lands in Known Recoverable Coal Resource Areas (KRCRA's) in the western United States. The only coal beds considered are those 5 feet (1.5 m) or more thick, and under less than 1,000 feet (305 m) of overburden (Reserve Base for subbituminous coals); thinner or deeper beds that are present are not shown on the maps (CRO plates 1-58) or included in the resources estimates.

Location

The Otter 7½-minute quadrangle is within the drainage of Bear Creek and Otter Creek, the latter a major north-flowing tributary of Tongue River. The Otter Post Office is along Otter Creek in the north-central part of the quadrangle. The nearest town is Ashland, about 35 miles (56 km) to the north.

Accessibility

All-weather roads in the valleys of Otter and Bear Creeks are the principal routes of travel in the quadrangle. Secondary ranch and Forest Service roads branch from these roads, providing good access to most parts of the quadrangle. A paved east-west highway, U.S. Highway 212, passes through Ashland to the north.

Physiography

The quadrangle is dissected by Bear and Otter Creeks and their tributaries. Relief within a half mile is commonly 300 to 500 feet (91-152 m) in the northern part of the quadrangle, decreasing southward. Elevations range from 3,370 to 4,005 feet (1,027-1,221 m).

Climate

The quadrangle has an average annual rainfall of about 14 inches (36 cm). Water is available for livestock from springs both along the major creeks and on the valley sides. Annual range in temperature is about 100°F to -30°F (38°C to -34°C).

Land Status

The quadrangle is in the central part of the Northern Powder River Basin KRCRA, Montana. The northern half of the quadrangle (T. 7 S., Rs. 45-46 E.) is in the Custer National Forest. Except for three small tracts totaling about 1 square mile (2.6 km^2) in area, all coal in the quadrangle is federally owned.

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

General Geology

Sources of Information

Warren (1959) mapped the area about 1 mile (1.6 km) north of the quadrangle at a scale of 1:63,360 as part of the Birney-Broadus coal field, Montana. Bryson and Bass (1973) mapped the area of the Otter quadrangle, also at a scale of 1:63,360, as part of the Moorhead coal field. McKay (unpublished) mapped the Otter quadrangle in 1976 on a scale of 1:24,000. McKay's map, which incorporates the earlier work, is the principal source for coal-bed outcrops, and the boundaries showing the extent of burning of near-surface coals (CRO pl. 1).

Subsurface information on the coal is provided by 14 coal exploratory holes, and 3 oil-and-gas exploratory holes that have been drilled in the quadrangle. Areas suitable for strip mining of the Anderson, Dietz, and Canyon coal beds were outlined by Matson and others (1973, pls. 10a, b, c), according to criteria developed by them.

Coal bed names are from Baker (1929), Bass (1924, 1932), Warren (1959), Bryson and Bass (1973), and Culbertson and Klett (1976). Much of the stratigraphic control for coal beds in the subsurface are from Mapel, Martin, and Butler (1978a) in the adjacent Hamilton Draw quadrangle to the west.

Stratigraphy

All the coal-bearing rocks exposed in the quadrangle, and those present to depths of several hundred feet, belong to the Tongue River Member of the Fort Union Formation of Paleocene age.

The Tongue River Member is about 2,000 feet (610 m) thick in the quadrangle and consists of interbedded lenticular beds of yellowish-gray to light-gray fine- to very fine-grained mostly friable sandstone, light- to dark-gray siltstone and clayey siltstone, gray shale and claystone, brown and black carbonaceous shale, and persistent coal beds. The continental environment of deposition of rocks comprising the Tongue River was one of shifting streams, flood plains, and swamps in a region of low-relief draining toward a sea in northeastern Montana and North Dakota.

Representative samples of the sedimentary rocks adjacent to 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 Department of Agriculture and others (1974) and by Swanson (in Mapel and others, 1977, pt. A, p. 42-44). These results show that the rocks contain no greater amounts of trace elements of environmental concern than do similar types of rocks found throughout other parts of the United States.

Structure

The quadrangle is on the east side of the Powder River structural basin. Regional dip is south-southwestward at less than 90 feet per mile (44 m per km). Structural relief within the quadrangle, exemplified by the Canyon bed, is about 240 feet (73 m), as shown on CRO plate 15.

Coal Geology

Fifteen coal beds ranging in thickness from 2 to 35 feet (0.6-11 m) were identified on the surface or in the subsurface in the Otter quadrangle (CRO pl. 1). The stratigraphically highest coal bed, the Smith bed, is less than 5 feet (1.5 m) thick and is not shown on plate 1. About 130 feet (40 m) below the Smith is the Anderson bed. The latter is underlain by a noncoal interval 60 feet (18 m) thick; the Dietz coal bed; an interval about 150 feet (45 m) thick containing a local coal bed near the middle; the Canyon coal bed; an interval about 180 feet (55 m) thick containing a local coal bed 50 to 80 feet (15-24 m) below the top; the Cook coal bed; a noncoal interval 20 to 70 feet (6-21 m) thick; the Otter coal bed; an interval 70 to 180 feet (21-55 m) thick containing local beds near the top and base; the Poker Jim coal bed; a noncoal interval 5 to 170 feet (1.5-52 m) thick; the Brewster-Arnold bed; a noncoal interval 160 feet (49 m) thick; the King bed; a noncoal interval about 100 feet (30 m) thick; the Knobloch bed; a noncoal interval 100 feet (30 m) thick; the Nance coal bed; noncoal interval 90 to 140 feet (27-43 m) thick; the Flowers-Goodale bed; a noncoal interval 90 to 300 feet (27-91 m) thick; and the lowest recognized coal bed, the Kendrick coal bed, at the base.

Coal bed thicknesses shown on the CRO maps are the bed thicknesses reported at outcrops or in drill holes rounded to the nearest foot, excluding partings. Partings generally are thin or absent.

In the past, many of the thicker coal beds have caught fire at the outcrop, and have burned underground for varying distances, some for 1 mile (1.6 km) or more. The heat from the burning coal has baked and fused the overlying rocks to form a resistant reddish-colored rock called clinker (also called scoria, red shale, and other names locally). In this quadrangle, clinker is as much as 100 feet (30 m) thick.

Analyses made of the Dietz and Canyon coal beds in holes drilled in the quadrangle by the Montana Bureau of Mines and Geology (pls. 2, 16, and 17), show the rank to vary from subbituminous C to lignite A (Matson and Blumer, 1973, p. 59). Trace element content of the coals in the Otter quadrangle has not been determined, but the same coals contain, in general, lesser amounts of most elements of environmental concern than coals in other areas of the United States (Hatch and Swanson, 1977, pl. 47).

Coal-bed nomenclature

The nomenclature used for coal beds in the Otter quadrangle in this report differs from that used in earlier reports, as summarized in a table below. The changes are the result of regional coal-bed correlations made possible by logs of drill holes not available to earlier workers. Drill holes that reach coals deeper than the Canyon coal bed are sparse, in and near the quadrangle, however, and coal-bed names for the deeper coals are subject to further changes as more information becomes available.

Coal bed names used by different writers in and near the Otter quadrangle

This report	Bryson and Bass (1973)	Warren (1959)
Anderson	Anderson	Garfield zone
Dietz	Dietz	Garfield zone
Canyon	Canyon	Canyon
Cook	Otter[1]	Wall
Otter	Elk	Elk

[1]Name appears to have been used for a stratigraphically lower coal bed by Bryson and Bass (1973) east of the Otter quadrangle in and near sec. 26, T. 7 N., R. 46 E.

Anderson coal bed

(CRO pls. 4-8)

The Anderson coal bed name used in the Otter quadrangle is the Anderson bed as mapped by Bryson and Bass (1973) and Matson and Blumer (1973).

The Anderson is burned everywhere in the quadrangle except for the southwestern corner where it ranges in thickness from 32 to 35 feet (10-11 m) (CRO pl. 4). The Anderson is under less than 200 feet (61 m) of overburden and has a high potential for surface mining in the small areas where present in the quadrangle as shown on CRO plate 6.

Coal in the Anderson bed has not been analyzed in the Otter quadrangle.

Dietz coal bed

(CRO pls. 9-13)

The usage of the name Dietz for a coal bed in the Otter quadrangle is the same as that of Bryson and Bass (1973) and Matson and Blumer (1973). The Dietz bed is present mostly in the western two-thirds of the quadrangle. Its thickness ranges between 5 and 12 feet (1.5-4 m) (CRO pl. 9). In most areas the bed is covered by 100 feet (30 m) or less of overburden (CRO pl. 11), but the bed is generally thin, and the potential for strip mining at most places is moderate or low.

Analyses of two samples of coal from the Dietz bed, reported by Matson and Blumer (1973, p. 59), show sulfur 0.31-0.66 percent; ash 3.4-3.8 percent; and heat value 7,966-8,080 Btu, on the as-received basis.

Canyon coal bed

(CRO pls. 14-18)

The Canyon coal bed is the coal referred to by that name by Bryson and Bass (1973) and Matson and Blumer (1973). It is correlated with the Upper Canyon bed of the Fort Howes and Poker Jim Butte quadrangles, to the north and northwest, respectively. The thickness of the Canyon bed is mostly between 18 and 19 feet (5-9 m) as shown by measurements in drill holes and at outcrops (CRO pl. 14).

Coal in the Canyon bed has good potential for surface mining as shown by mining-ratio values of less than 10 on CRO pl. 16.

Analyses of 4 samples of coal from the Canyon bed, reported by Matson and Blumer (1973, p. 59), show sulfur 0.14-1.2 percent; ash 3.2-9.5 percent, and heat value 7,419-8,241 Btu, on the as-received basis.

Local coal bed between Canyon and Cook coal beds

(CRO pls. 19-23)

A local coal bed between the Canyon and Cook beds is tentatively correlated with the Lower Canyon bed of the Fort Howes and Poker Jim Butte quadrangles to the north and northwest, respectively. It has been mapped on the east side of the Otter quadrangle and identified in a few drill holes. Its range in thickness is from 3 to 13 feet (1-4 m) (CRO pl. 19). Relatively broad areas of coal in the northeastern corner of the quadrangle are under less than 200 feet (61 m) of overburden, have mining-ratio values of less than 10, and offer a high potential for surface mining (CRO pl. 21).

Analyses have not been made of the local coal bed in this quadrangle.

Cook coal bed

(CRO pls. 24-28)

The Cook coal bed was named by Warren (1959) for a persistent coal bed in the Birney-Broadus coal field which he apparently believed to be correlative with a bed of that name on Cook Creek Mountain in the Ashland coal field (Bass, 1932). The name was used by Bryson and Bass (1973) in the Moorhead coal field in the area of the Otter quadrangle.

The Cook bed ranges in thickness from about 6 feet (2 m) near Otter Creek to 23 feet (7 m) in the Bear Creek area.

The coal has good potential for development by surface mining as shown by mining-ratio values of less than 10 in large areas where the overburden is less than 200 feet (61 m) (CRO pl. 26).

Analyses have not been made of the coal in the Cook bed in this quadrangle.

Otter coal bed

(CRO pls. 29-33)

The Otter coal bed is a name applied by Bryson and Bass (1973) to a coal exposed in the vicinity of the Otter Post Office. Subsurface correlations suggest that they referred to the same coal as the Otter bed in some places and the Elk bed at other places. As shown by CRO plate 29 the Otter bed of the present report (Elk bed of Bryson and Bsss, 1973, in the Otter quadrangle) is 5 to 7 feet (1.5-2 m) thick in the northern part of the quadrangle, and has a measured thickness of 5 feet (1.5 m) and an inferred range of thickness of 5 to 9 feet (1.5-3 m) in the southern part of the quadrangle. Potential for strip mining is regarded as low, because the area beneath shallow overburden is small, and the coal is generally thin (CRO pl. 31).

Analyses have not been made of the coal in the Otter bed in this quadrangle.

Brewster-Arnold coal bed

(CRO pls. 34-38)

The Brewster-Arnold coal bed was named by Bass (1924) for a coal bed exposed at the Brewster-Arnold mine on the Tongue River about 15 miles (24 km) west of the Otter quadrangle. It has been traced into the subsurface of the Otter quadrangle by means of a few scattered oil and gas wells in the intervening area. Coal in the bed is 5 feet (1.5 m) thick as interpreted from the electric log of the well at locality 2 (CRO pl. 34). It is too deeply buried to have potential for surface mining.

Analyses have not been made of the coal in the Brewster-Arnold bed in this quadrangle.

Knobloch coal bed

(CRO pls. 39-43)

The Knobloch coal bed (misspelled Knoblock in early reports) was named by Bass (1924) for exposures along the Tongue River about 10 miles (16 km) southwest of Ashland, or about 15 miles (24 km) northwest of the Otter quadrangle. The coal bed identified as Knobloch in this report was referred to as the middle bench of the Knobloch by Matson and Blumer (1973, pls. 11A and 33).

The Knobloch thickens from 7 to 19 feet (2-6 m) northward in the quadrangle (CRO pl. 39). It contains large resources in the north part of the quadrangle, but it is everywhere too deeply buried for surface mining (CRO pl. 41).

Analyses have not been made of the coal in the Knobloch bed in this quadrangle.

Upper Flowers-Goodale coal bed

(CRO pls. 44-48)

The Flowers-Goodale coal bed was named by Bass (1932, p. 53-54) for two small mines located in the Brandenberg quadrangle about 39 miles (62.4 km) to the north in the Ashland coal field. It is thought that this bed is represented in the Otter quadrangle by two benches, about 70-90 feet (21-27 m) apart that converge and join in the subsurface to the north of this quadrangle.

The Upper Flowers-Goodale bed ranges in thickness from 5 to 15 feet (1.5-5 m) (CRO pl. 44) thickening generally northwestward. The coal is overlain by at least 650 feet (198 m) of overburden (CRO pl. 46) in the quadrangle, and it does not have potential for surface mining.

Lower Flowers-Goodale coal bed

(CRO pls. 49-53)

The Lower Flowers-Goodale bed ranges in thickness from 5 to 9 feet (1.5-3 m), increasing in thickness northward. Overburden everywhere exceeds 700 feet (213 m), and the coal is inaccessible for surface mining (CRO pl. 51).

Analyses have not been made of the coal in the Upper and Lower Flowers-Goodale beds in the quadrangle.

Kendrick coal bed

(CRO pls. 54-58)

The Kendrick coal bed was named by Culbertson (in Culbertson and Klett, 1979) for a persistent coal bed identified on electric and gamma ray logs of oil-and-gas drill holes in the Roundup Draw quadrangle, Wyoming, about 15 miles (24 km) to the southwest. It is at about the same stratigraphic position as the Terret coal bed of areas to the north. The Kendrick ranges in thickness from 4 to 10 feet (1.2-3 m) (CRO pl. 54), but in most of the quadrangle is more than 1,000 feet (305 m) below the surface (CRO pl. 56) and does not have potential for surface mining. In the Otter quadrangle, coal from the Kendrick bed has not been analyzed.

Coal Resources

Coal resource estimates in this report are restricted to the Reserve Base part of the Identified Coal Resource, which is the part most likely to be developed in the foreseeable future (See U.S. Geol. Survey Bull. 1450-B for a discussion of these terms.). The Reserve Base for subbituminous coal is coal that is 5 feet (1.5 m) or more thick, under less than 1,000 feet (305 m) of overburden, and within 3 miles (4.8 km) of a point of complete measurement of the coal bed. Reserve Base coal is further subdivided into categories according to its nearness to a point of measurement of the coal bed. Measured coal is coal within ¼ mile (0.4 km) of a point of measurement. Indicated coal extends ½ mile (0.8 km) beyond Measured coal to a distance of 3/4 mile (1.2 km) from the point of measurement, and Inferred coal extends 2¼ miles (3.6 km) beyond Indicated coal to a distance of 3 miles (4.8 km) from the point of measurement.

Reserves are the recoverable part of the Reserve Base. For strippable coal in this quadrangle the coal reserve is considered to be 85 percent of the part of the Reserve Base that is under 200 feet (61 m) or less of overburden.

The total Reserve Base for federally owned coal is estimated to be about 2.6 billion short tons (2.36 billion metric tons) as shown listed by section on CRO plate 2 and by individual coal bed and resource category on table 1. About 5 percent of this large amount is classified as Measured; 24 percent as Indicated; and 71 percent as Inferred as summarized in the tabulation below:

Summary of estimated Reserve Base for Federal coal lands according to reliability of the estimate, Otter quadrangle

(In millions of short tons. To convert to metric tons, multiply by 0.907.)

	Overburden 0-200 feet	Overburden 200-1,000 feet	Percent total
Measured	90	48	5
Indicated	360	263	24
Inferred	560	1,304	71

Table 1.--Estimated Reserve Base for surface-mining (0-200 feet overburden) and underground-mining (200-1,000 feet overburden) methods for Federal coal lands in the Otter quadrangle, Montana

[In thousands of short tons, rounded. Multiply by 0.907 to convert to metric tons]

Coal bed name	Overburden 0-200 feet			Total (rounded)	Overburden 200-1,000 feet			Total (rounded)	Grand Total (rounded)
	Measured	Indicated	Inferred		Measured	Indicated	Inferred		
Anderson	17,000	34,000	2,200	53,000	4,800	5,500	---	10,000	64,000
Dietz	17,000	83,000	46,000	150,000	---	2,200	14,000	16,000	170,000
Canyon	38,000	140,000	340,000	520,000	18,000	100,000	150,000	270,000	790,000
Local	4,600	23,000	5,700	33,000	---	20	---	20	33,000
Cook	11,000	73,000	142,000	230,000	21,000	110,000	330,000	460,000	690,000
Otter	2,200	6,600	25,000	34,000	590	5,600	59,000	65,000	99,000
Brewster-Arnold	---	---	---	---	530	4,100	64,000	69,000	69,000
Knobloch	---	---	---	---	2,100	33,000	440,000	475,000	475,000
Upper Flowers-Goodale	---	---	---	---	630	2,100	150,000	153,000	153,000
Lower Flowers-Goodale	---	---	---	---	---	---	76,000	76,000	76,000
Kendrick	---	---	---	---	---	---	21,000	21,000	21,000
Total (rounded)	90,000	360,000	560,000	1,000,000	48,000	263,000	1,300,000	1,600,000	2,600,000

COAL DEVELOPMENT POTENTIAL

Development potential for surface-mining methods

Areas where the 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 strip mining and were assigned a high, moderate, or low development potential based on the mining ratio (cubic yards of overburden per short ton of recoverable coal). The formula used to calculate mining ratios for subbituminous coal is as follows:

$$MR = \frac{t_o\ (0.91)}{t_c\ (rf)}$$

Where MR = mining ratio
t_o = thickness of overburden
t_c = thickness of coal
rf = recovery factor (0.85)

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, 11, 16, 21, 26, and 31. These mining-ratio values for each development-potential category are based on economic and technological criteria; they are applicable only to this quadrangle, and were derived in consultation with A. F. Czarnowsky, Area Mining Supervisor, U.S. Geological Survey.

Reserve Base for federally owned coal beneath 200 feet (61 m) or less of overburden in the various development-potential categories totals about 1 billion short tons (0.9 billion metric tons), as shown in table 2.

Development potential for underground-mining methods

The Reserve Base for federally owned coal beneath 200-1,000 feet (61-305 m) of overburden is estimated to be about 1.6 billion short tons (1.46 billion metric tons), as shown on table 1. Coal at these depths is available for underground mining. Coal is not presently being mined underground in the Powder River Basin, and recovery factors have not been established. Therefore, the development potential was not evaluated and is considered to be low.

Table 2.--Development potential of the estimated Reserve Base for surface-mining methods (0-200 feet overburden) for Federal coal lands in the Otter quadrangle, Montana

[In thousands of short tons. Development potentials are based on mining ratios (cubic yards of overburden/ton of underlying coal). To convert short tons to metric tons, multiply by 0.9072; to convert mining ration in yd^3/ton coal to m^3/t, multiply by 0.842]

Coal bed	High development potential (0-10 mining ratio)	Moderate development potential (10-15 mining ratio)	Low development potential (>15 mining ratio)	Total (rounded)
Anderson-------	53,000	------	------	53,000
Dietz----------	63,000	47,000	36,000	150,000
Canyon---------	510,000	------	------	510,000
Local----------	17,000	11,000	6,500	35,000
Cook-----------	130,000	59,000	37,000	230,000
Otter----------	11,000	5,100	18,000	34,000
Brewster-Arnold-------	-------	------	------	-------
Knobloch-------	-------	------	------	-------
Upper Flowers-Goodale------	-------	------	------	-------
Lower Flowers-Goodale------	-------	------	------	-------
Kendrick-------	-------	------	------	-------
Total (rounded)----	780,000	120,000	98,000	1,000,000

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