UNITED STATES DEPARTMENT OF THE INTERIOR

GEOLOGICAL SURVEY

Text to accompany:

Open-File Report 79-085

1979

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

[Report includes 19 plates]

By

Colorado School of Mines Research Institute

CONTENTS

ILLUSTRATIONS

[Plates are in pocket]

Illustrations--Continued

3. Coal data sheet.
4. Isopach and structure contour map of the E coal bed.
5. Overburden isopach and mining-ratio map of the E coal bed.
6. Areal distribution and tonnage map of identified resources of the E coal bed.
7. Isopach and structure contour map of the X coal bed.
8. Overburden isopach and mining-ratio map of the X coal bed.
9. Areal distribution and tonnage map of identified resources of the X coal bed.
10. Isopach map of the upper and lower splits of the Sawyer coal bed.
11. Structure contour map of the Sawyer coal bed and its splits.
12. Overburden isopach and mining-ratio map of the upper split of the Sawyer coal bed.
13. Areal distribution and tonnage map of identified resources of the upper split of the Sawyer coal bed.
14. Overburden isopach and mining-ratio map of the lower split of the Sawyer coal bed.
15. Areal distribution and tonnage map of identified and hypothetical resources of the lower split of the Sawyer coal bed.
16. Isopach and structure contour map of the Knobloch coal bed.
17. Overburden isopach and mining-ratio map of the Knobloch coal bed.
18. Areal distribution and tonnage map of identified resources of the Knobloch coal bed.

Plate 19. Coal development-potential map for surface-mining methods.

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)	0.907	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 Elk Ridge quadrangle, Powder River County, Montana, (19 plates; U.S. Geological Survey Open-File Report 79-085). 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 Elk Ridge 7 1/2-minute quadrangle is in north-central Powder River County, Montana, about 45 miles (72 km) south of Miles City, a town in the Yellowstone River valley of eastern Montana. 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.

Accessibility

The Elk Ridge quadrangle is accessible from Miles City, Montana, by going south on U.S. Highway 312 a distance of 51 miles (82 km), thence westward and southwestward 9 miles (14 km) on the Little Pumpkin Creek Road to the north border of the quadrangle. The quadrangle is also accessible from Broadus, Montana, by going west from Broadus on U.S. Highway 212 about 22 miles (35 km) to the Pumpkin Creek Road and then north on the graveled Pumpkin Creek Road 7 miles (11 km) to the south border of the quadrangle. The Pumpkin Creek and Little Pumpkin

Creek Roads continue through the quadrangle and intersect a number of unimproved roads and trails that provide access to the remainder of the quadrangle.

Physiography

The Elk Ridge quadrangle is within the Missouri Plateau division of the Great Plains physiographic province. The upland plateau surface, however, has been almost completely dissected by the northerly flowing Pumpkin Creek and Little Pumpkin Creek and their tributaries. The southeastern part of the quadrangle is dissected and drained by Pumpkin Creek and its tributaries. The western and northern parts of the quadrangle are drained by Little Pumpkin Creek and its tributaries. These two streams join about 3 miles (5 km) northeast of the quadrangle, and Pumpkin Creek flows northward to join the Tongue River which empties into the Yellowstone River at Miles City.

A high, rugged, forested range of hills, known as Elk Ridge, trends northward through the west-central part of the quadrangle, separating the drainage basins of Pumpkin Creek and Little Pumpkin Creek. Pumpkin Creek, which crosses the southeast corner of the quadrangle, has a flood plain 0.5 to 0.75 mile (0.8 to 1.2 km) wide. Little Pumpkin Creek, which crosses the northwest and southwest corners of the quadrangle, has a flood plain up to 0.5 mile (0.8 km) wide. Elk Ridge rises to a height of 4,180 feet (1,274 m), 1,060 feet (323 m) above the lowest elevation, 3,120 feet (951 m), on Cottonwood Creek at the north border of the quadrangle. The slopes on the west and east sides of Elk Ridge are very steep, and the coulees which descend them are 50 to 150 feet (15 to 46 m) deep, with precipitous sides. The lower slopes of Elk Ridge consist of intricately dissected mesas and broad benches capped by resistant reddish-colored clinker beds produced by the burning of thick coal beds. The northeast quarter of the quadrangle has moderate relief, but the remainder of the quadrangle is quite rugged. Total relief in the quadrangle is about 1,060 feet (323 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 about 16 inches (41 cm). The heaviest precipitation occurs from April to August. The largest average monthly precipitation pccirs 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 covers the Elk Ridge quadrangle except for limited areas along the eastern and northern borders of the quadrangle. The Boundary and Coal Data Map (pl. 2) shows the location of the KRCRA boundary 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 Elk Ridge quadrangle as part of the Ashland coal field. Brown and others (1954) mapped the Knobloch coal bed in the extreme northwest corner of the quadrangle as part of the Foster Creek coal deposit, and the Knobloch and Sawyer coal beds in the north-central part of the quadrangle as the Cottonwood Creek deposit. Gilmour and Williams (1969) mapped the northwestern part of the quadrangle as part of the Little Pumpkin Creek coal deposit, and the northern and eastern parts of the quadrangle as part of the Foster 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 the uppermost member of the Paleocene Fort Union Formation, the Tongue River Member. This unit is made up mainly of light-colored sandstone, sandy shale, carbonaceous shale, and coal. Much coal has burned along 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 by erosion, but about 1,400 feet (427 m) remains in 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 Elk Ridge quadrangle is in the northeastern part of the Powder River structural basin. Regionally, the strata dip southward or southeastward at an angle of less than 1 degree. Structure contour maps on top of the coal beds (pls. 4, 7, 11, and 16) show that the regional dip is in places modified and even reversed by small shallow, irregular folds. Some of the nonuniformity in

structure may be due to differential compaction and to irregularities in deposition in the coals and other beds as a result of their continental origin.

COAL GEOLOGY

The major coal beds in the Elk Ridge quadrangle are the Knobloch, Lower Sawyer, Upper Sawyer, C and D, X, and E coal beds. The Ferry clinker, formed by the burning of the Ferry coal bed, caps the highest ridges. In addition, there are several unnamed, thin, discontinuous, local coal beds of limited extent. All of these coal beds are in the Tongue River Member of the Paleocene Fort Union Formation. They are shown in outcrop on the Coal Data Map, plate 1, and in section on the Coal Data Sheet, plate 3. The lowermost of the named beds is the Knobloch coal bed. This coal is overlain by a noncoal interval of about 115 to 170 feet (35 to 52 m), the Lower Sawyer coal bed, a noncoal interval of 2 to 40 feet (0.61 to 12 m), the Upper Sawyer coal bed, a rock interval of about 110 feet (33.5 m) which in places contains two local coal beds, the C and D coal beds, a noncoal interval of about 75 feet (22.9 m), the X coal bed, a noncoal interval of about 110 feet (33.5 m), the E coal bed, a noncoal interval of about 260 feet (79 m), and the Ferry clinker bed. The Knobloch, Sawyer, Lower Sawyer, Upper Sawyer, X, and E coal beds contain economic coal resources.

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. Lignite A is a coal that has a heating value of 6,300 to 8,300 Btu per pound (14,654 to 19,306 kJ/kg) on a moist, mineral-matter-free basis. Subbituminous C coal has a heating value of 8,300 to 9,500 Btu per pound (19,306 to 22,097 kJ/kg) on a moist, mineral-matter-free basis. All coal analyses available at the present time for this and adjacent quadrangles were considered in making our decision to assign a rank of lignite to the coal in this quadrangle. The lignite-subbituminous boundary may be within the

quadrangle, but not enough data are presently known to allow us to determine that boundary line through the quadrangle with certainty. Therefore, a rank of lignite has been arbitrarily assigned by us to all of the coal in the entire quadrangle. Additional data to be outlined in the future may make a more precise determination of the location of this boundary possible.

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

Coal below the Knobloch coal bed

The deepest coal test hole in the Elk Ridge quadrangle, Hole FC-4, in the northeast corner of Sec. 11, T. 2 S., R. 48 E., was drilled to a total depth of 280 feet (85.3 m) which is about 300 feet (91 m) below the Knobloch coal bed. This hole penetrated traces of coal at depths of 109 feet (33 m), 129 feet (39 m), and 226 feet (69 m). These traces of coal are at approximate intervals of 129, 149, and 246 feet (39, 45, and 75 m) below the Knobloch coal bed. Based on these intervals, the two uppermost traces of coal may correlate with the Upper and Lower Flowers-Goodale coal beds, and the lowest trace of coal may correlate with the Terret coal bed. However, because these correlations cannot be substantiated, and because the coal beds are too thin to be of economic importance, they have not been mapped in this quadrangle.

Knobloch coal bed

The Knobloch coal bed was named by Bass (1924). The name of the coal bed was taken from the Knobloch Ranch and coal mine in the Birney Day School quadrangle located about 32 miles (51 km) west-southwest of the Elk Ridge quadrangle.

The Knobloch coal bed lies about 300 feet (91 m) above the base of the Tongue River Member and crops out in the northern and eastern parts of the Elk Ridge quadrangle (pl. 1). The Knobloch coal bed ranges in thickness from about 10 to 20 feet (3 to 6 m). The bed dips southward or southwestward at an angle of less than 1 degree. This dip is interrupted in places by minor, shallow folds. The thickness of overburden on the Knobloch coal bed ranges from zero at the outcrops to about 950 feet (290 m) in thickness (pl. 17).

The Montana Bureau of Mines and Geology cored the Knobloch coal in drill hole FC-b, sec. 29, T. 1 S., R. 48 E., in the north-central part of the Elk Ridge quadrangle. A chemical analysis of coal from depths of 48 to 59 feet (14.6 to 18 m) shows a heating value of 7,380 Btu per pound (7,166 kJ/kg), ash 6.66 percent, and sulfur 0.37 percent on an as-received basis (Matson and Blumer, 1973, p. 86). This heating value converts to about 7,907 Btu per pound (18,392 kJ/kg) on a moist, mineral-matter-free basis, indicating that the coal is lignite A in rank.

Sawyer coal bed

The Lower Sawyer coal bed was mapped by Bass (1932, pl. 3) as his A coal bed and described from exposures in the Ashland coal field. A type locality was not given. Bass states that the A coal bed may coalesce with the Sawyer bed east of the Pumpkin Creek valley. Bass (1932, p. 102) further states that in T. 2 S, R. 48 E. the A and Sawyer coal beds are separated by only a small interval and appear to have been burned together in most localities and to have formed one thick bed of clinker. Carmichael (Matson and Blumer, 1973, p. 84) considers the A coal bed as defined by Bass to be distinct in the northern part of the Elk Ridge quadrangle, but combined with the Sawyer bed in the southern part of the quadrangle. In the Box Elder Creek quadrangle, east of the Elk Ridge quadrangle, and in the Samuelson Ranch quadrangle to the south, there is additional evidence

that the A and Sawyer coal beds coalesce. Because this evidence appears adequate we have shown the A coal bed as the Lower Sawyer (Sa_2) coal bed. The inferred split line along which the Lower and Upper Sawyer coal beds coalesce is shown on plate 10.

The Sawyer coal bed was first described by Dobbin (1930, p. 28) from exposures in the Forsyth coal field, possibly in the Rough Draw or Black Spring quadrangles where the Sawyer is well exposed. These quadrangles are about 43 miles (69 km) west of the Elk Ridge quadrangle.

In the Elk Ridge quadrangle, the Lower Sawyer coal bed (A coal bed of Bass) is about 115 to 170 feet (35 to 52 m) above the Knobloch coal bed and crops out extensively in the quadrangle (pls. 1 and 3). The isopach map of the Lower Sawyer (pl. 10) shows that the coal ranges from about 12 to 36 feet (3.7 to 11 m) in thickness. The structure contour map (pl. 11) indicates that the Lower Sawyer dips southwestward at an angle of less than 1 degree per mile. The thickness of overburden on the Lower Sawyer coal bed (pl. 14) ranges from zero at the outcrops to about 780 feet (238 m). This overburden includes the higher coal beds where they are present.

The separation between the Lower and Upper Sawyer coal beds ranges from 2 feet (0.6 m) in drill hole US77135, sec. 29, T. 2 S, R. 48 E., near the southern border of the quadrangle (pls. 1 and 3) to 40 feet (12 m) between outcrops in the northern part of the quadrangle. The isopach map (pl. 10) shows that the Upper Sawyer coal bed ranges from about 5 to 13.5 feet (1.5 to 4.1 m) in thickness. The structure contour map (pl. 11) indicates that the coal bed dips southwestward at an angle of less than 1 degree. The thickness of overburden on the Upper Sawyer coal bed ranges from zero at the outcrops to about 750 feet (229 m). This overburden in places includes the higher coal beds.

There is no known publicly available chemical analysis of the Sawyer coal in the Elk Ridge quadrangle. An analysis of the Sawyer coal from a depth of 123 to

155.5 feet (37.5 to 47.4 m) in drill hole PC-3, sec. 28, T. 2 S., R. 49 E. in the Box Elder Creek quadrangle about 3 miles (4.8 km) east of the Elk Ridge quadrangle shows ash 6.81 percent, sulfur 0.30 percent, and heating value 7,490 Btu per pound (17,422 kJ/kg) on an as-received basis (Matson and Blumer, 1973, p. 83). This heating value converts to about 8,037 Btu per pound (18,695 kJ/kg) on a moist, mineral-matter-free basis, indicating that the coal at this location is lignite A in rank. Because of the proximity of this location to the Elk Ridge quadrangle, it is assumed that the Sawyer coal in the Elk Ridge quadrangle is similar and is lignite A in rank.

C and D coal beds

The C and D coal beds were named by Bass (1932, p. 55) after exposures in the Ashland coal field, possibly in the Beaver Creek School or Cook Creek Reservoir quadrangles, 6 to 12 miles (9.6 to 19 km) west of the Elk Ridge quadrangle. A type locality was not given. Bass (1932, p. 55) states that the C bed is of little economic importance because it contains an abundance of silicified tree stumps and fragments of logs. Bass represented the outcrops of the C and D beds as a single line in most localities on his map. These beds have been mapped only locally in the west-central part of the quadrangle, where the only measurement indicates a thickness of 2.4 feet (0.7 m). Because of their thinness economic coal resources have not been assigned to the C and D coal beds.

X coal bed

The X coal bed was first described by Bass (1932, p. 55) after exposures in the Ashland coal field, possibly in the Elk Ridge quadrangle. A type locality was not given. The X coal bed crops out in the central and western parts of the Elk Ridge quadrangle about 75 feet (23 m) above the D coal bed and about 200 feet (61 m) above the Upper Sawyer coal bed. The X coal bed dips northwestward, westward, or southwestward, at an angle of less than 1 degree, and ranges from about

3 to 6.3 feet (0.9 to 1.9 m) in thickness (pl. 7). The thickness of overburden on the X coal bed (pl. 8) ranges from zero at the outcrops to about 500 feet (152 m). In places, this overburden includes the E coal bed.

There is no known publicly available chemical analysis of the X coal bed in or close to the Elk Ridge quadrangle. It is assumed that the X coal is similar to the closely associated coals in this quadrangle and is lignite A in rank.

E coal bed

The E coal bed was first described by Bass (1932, p. 55) from exposures in the Ashland coal field. A type locality was not given. In the Elk Ridge quadrangle, the E coal bed is about 200 feet (61 m) above the X coal bed. The E coal bed crops out at elevations of about 3,720 to 3,760 feet (1,134 to 1,146 m) on Elk Ridge in the southwestern part of the quadrangle. The E coal bed ranges from about 6 to 16 feet (1.8 to 4.9 m) in thickness and is practically flat (pl. 4). The thickness of overburden on the E coal bed ranges from zero at the outcrop to about 400 feet (122 m) (pl. 5).

There is no known publicly available chemical analysis of the E coal bed in the Elk Ridge quadrangle. It is assumed that the E coal is similar to closely associated coals in this quadrangle and is lignite A in rank.

Local coal beds

The local coal beds shown on plates 1 and 3 are thin and of very limited extent, and consequently have not been assigned economic coal resources.

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 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. Hypothetical Resources of lignite are in lignite beds which are 5 feet (1.5 m) or more thick, under less than 1,000 feet (305 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 or under less than 1,000 feet (305 m) of overburden for lignite.

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 or lignite that is under less than 200 feet (61 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, or lignite that is under more than 200 feet (61 m), but less than 1,000 feet (305 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 factory of 85 percent). Therefore, 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 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) or a conversion factor of 1,750 short tons of lignite per acre-foot (12,870 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, 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 227.48 million short tons (206.32 million t). The total tonnage of federally owned surface-minable Hypothetical coal is estimated to be 2.75 million short tons (2.49 million t). As shown by table 2, the total federally owned underground-minable Reserve Base coal is estimated to be 463.67 million short tons (420.55 million t). The total federally owned, underground-minable Hypothetical coal is estimated to be 0.36 million short tons (0.33 million t). The total tonnage of surface- and underground-minable Reserve Base coal is 691.15 million short tons (626.87 million t), and the total of surface- and underground-minable Hypothetical coal is 3.11 million short tons (2.82 million t).

The total tonnages per section for both Reserve Base coal and Hypothetical coal, including both surface- and underground-minable coal, are shown on plate 2 in the northwest corner of the federally owned coal land of each section. All numbers are rounded to the nearest one-hundredth of a million short tons. About 10 percent of the Reserve Base tonnage is classed as Measured, 43 percent as Indicated, and 47 percent as Inferred.

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, or where lignite beds of the same thickness are overlain by 200 feet (61 m) or less of overburden. 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 lignite is:

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

where MR = mining ratio
t_o = thickness of overburden, in feet
t_c = thickness of lignite, in feet
rf = recovery factor = 0.85 in this area
cf = conversion factor = 0.922 cu. yds./ short ton for lignite

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 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 tract.

In areas of moderate to 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 low development potential abutting against areas of high development potential.

The coal development potential of Federal coal lands for surface mining is shown on the CDP map (pl. 19). Most of the Federal coal lands in this quadrangle have a high development potential for surface mining.

The Knobloch coal bed (pl. 17) has a wide area of high development potential in the eastern and northern parts of the quadrangle extending from the coal boundary to the 10 mining-ratio contour. An area of moderate development potential is located upslope between the 10 and 15 mining-ratio contours, or between the 10 mining-ratio contour and the 200-foot overburden. Areas of low development potential extend from the 15 mining-ratio contour to the 200-foot overburden isopach. The overburden in places contains higher coal beds.

The Lower Sawyer coal bed (pl. 14) has a wide area of high development potential extending from the coal boundary to the arbitrary stripping limit at the 200-foot overburden isopach in the southern part of the quadrangle. In the northern part of the quadrangle, the wide area of high development potential extends from the boundary of the coal to the 10 mining-ratio contour. Between the 10 mining-ratio contours and the 200-foot overburden isopach (or locally between the 10 and 15 mining-ratio contours) is a narrow area having a moderate development potential. The overburden in places contains higher coal beds.

The Upper Sawyer coal bed (pl. 12) has a band of high development potential in the central part of the quadrangle from the boundary of this coal to the 10 mining-ratio contour. A narrow band of moderate development potential occurs between the 10 and 15 mining-ratio contours. A wide band of low development potential extends from the 15 mining-ratio contour upslope to the 200-foot overburden isopach. This overburden in places contains higher coal beds.

The X coal bed (pl. 8) occurs on a topographic ridge in the southwestern part of the quadrangle. There is a narrow band of high development potential (mining-ratio values 0 to 10) which almost circles the ridge. Another narrow

band of moderate development potential (mining-ratio values 10-15) occurs upslope from the high development-potential area. Still farther upslope, a wide band of low development potential occurs between the 15 mining-ratio contour and the 200-foot overburden isopach. This overburden in places contains the overlying E coal bed.

The E coal bed (pl. 5) occurs on ridges in the southwestern part of the quadrangle. There are bands of high development potential (mining-ratio values 0-10), moderate development potential (mining-ratio values 10-15), and low development potential (between the 15 mining-ratio contour and the 200-foot overburden isopach).

There are some tracts of Federal coal land in the northern part of the quadrangle which have no development potential because the coal beds have been removed by erosion. The tracts of no development potential in the southwestern part of the quadrangle are results of the absence of the upper coal beds and the thick overburden on the lower beds.

About 77 percent of the Federal coal land in the Elk Ridge quadrangle has a high coal development potential for surface mining, 2 percent has a moderate development potential, 1 percent has a low development potential, and 20 percent has no development potential.

Development potential for underground mining and in-situ gasification

Subbituminous coal beds 5 feet (1.5 m) or more thickness lying more than 500 feet (152 m) but less than 3,000 feet (914 m) below the surface and lignite beds of the same thickness lying more than 200 feet (61 m) but less than 1,000 feet (305 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 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 200-foot 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 Elk Ridge 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				
E	7,200,000	3,930,000	5,890,000	17,020,000
X	1,960,000	2,490,000	7,710,000	12,160,000
Sawyer and Upper Split	12,340,000	5,740,000	18,050,000	36,130,000
Lower Sawyer	87,210,000	4,740,000	0	91,950,000
Knobloch	43,470,000	13,100,000	13,650,000	70,220,000
Total	152,180,000	30,000,000	45,300,000	227,480,000
Hypothetical Resource tonnage				
Lower Sawyer	2,750,000	0	0	2,750,000
Total	2,750,000	0	0	2,750,000
Grand Total	154,930,000	30,000,000	45,300,000	230,230,000

Table 2.--Underground-minable coal resource tonnage (in short tons) by development-potential category for Federal lands in the Elk Ridge 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				
E	0	0	5,010,000	5,010,000
X	0	0	5,550,000	5,550,000
Sawyer and Upper Split	0	0	58,220,000	58,220,000
Lower Sawyer	0	0	223,000,000	223,000,000
Knobloch	0	0	171,890,000	171,890,000
Total	0	0	463,670,000	463,670,000
Hypothetical Resource tonnage				
Knobloch	0	0	360,000	360,000
Total	0	0	360,000	360,000
Grand Total	0	0	464,030,000	464,030,000

REFERENCES

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.

Brown, Andrew, Culbertson, W. C., Dunham, R. J., Kepferle, R. C., and May, P. R., 1954, Strippable coal in Custer and Powder River Counties, Montana: U.S. Geological Survey Bulletin 995-E, p. 151-199.

Dobbin, C. E., 1930, The Forsyth coal field, Rosebud, Treasure, and Big Horn Counties, Montana: U.S. Geological Survey Bulletin 812-A, p. 1-55.

Gilmour, E. H., and Williams, L. A., 1969, Geology and coal resources of the Foster Creek coal deposit, eastern Montana: Montana Bureau of Mines and Geology Bulletin 73, 9 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., 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.