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

[Report includes 25 plates]

By

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To convert	Multiply by	To obtain
feet	0.3048	meters (m)
miles	1.609	kilometers (km)
acres	0.40469	hectares (ha)
tons (short)	0.9072	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 Samuelson Ranch quadrangle, Powder River County, Montana, (25 plates; U.S. Geological Survey Open-File Report 79-097). 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 Samuelson Ranch 7 1/2-minute quadrangle is in northwestern Powder River County, Montana, about 53 miles (85 km) south of Miles City, a town in the Yellowstone River valley of eastern Montana. U.S. Interstate Highway 94 and the main east-west routes of the Chicago, Milwaukee, St. Paul, and Pacific Railroad and the Burlington Northern Railroad follow the Yellowstone River and pass through Miles City. The Samuelson Ranch quadrangle is 17 miles (27 km) northwest of Broadus, Montana, a small town on east-west U.S. Highway 212.

Accessibility

The quadrangle is accessible from Ashland, Montana, by traveling east on U.S. Highway 212 about 20 miles (32 km) to the west border of the quadrangle. The quadrangle is also accessible from Broadus, Montana, by traveling west on U.S. Highway 212 about 17 miles (27 km) to the east border of the quadrangle. The highway continues across the south-central part of the quadrangle. A

secondary road parallels Pumpkin Creek in a northeast-southwest direction through the quadrangle and provides access to the remainder of the quadrangle. The nearest railroad is at the Big Sky coal mine in the Colstrip SE quadrangle, about 27 miles (43 km) to the northwest. A spur of the Burlington Northern Railroad runs northward and connects this mine with the main east-west route of the railroad about 35 miles (56 km) farther north-northwestward in the Yellowstone River valley.

Physiography

The Samuelson Ranch quadrangle is within the Missouri Plateau division of the Great Plains physiographic province. Most of the quadrangle is drained and dissected by Pumpkin Creek which flows northeastward through the quadrangle and continues northeastward and northward to join the Tongue River about 15 miles (24 km) south-southeast of Miles City. The Tongue River flows northward and empties into the Yellowstone River at Miles City. Pumpkin Creek flows through a valley 0.5 to 0.75 mile (0.8 to 1.2 km) wide from which the valley walls ascend at a gentle slope for miles (km) on each side of the stream. The relief is moderate on this gently rolling, treeless surface. The rounded intertributary hills and ridges rise about 150 feet (46 m) above the narrow tributary valleys. In the northwestern part of the quadrangle, the surface rises steeply about 400 feet (122 m) to a dissected plateau at about 4,100 feet (1,250 m) in elevation. This plateau is heavily timbered, and is part of the Custer National Forest.

The lowest elevation, about 3,250 feet (991 m), is on Pumpkin Creek near the northeast corner of the quadrangle. The highest elevation, about 4,120 feet (1,256 m), is on the plateau near the northwestern corner of the quadrangle. Topographic relief is about 870 feet (265 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 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 entire Samuelson Ranch quadrangle. The northwest corner of the quadrangle lies within the Custer National Forest. Plate 2 shows the land ownership status. There were no outstanding Federal coal leases or prospecting permits recorded as of 1977.

GENERAL GEOLOGY

Previous work

Wagemann (1910) made notes on a few coal occurrences during a reconnaissance of the Custer National Forest. Bass (1932, pl. 3) mapped most of the Samuelson Ranch quadrangle as part of the Ashland coal field. Brown and others (1954, fig. 26) mapped some of the northern part of the quadrangle as the Pumpkin Creek deposit of strippable coal in the Sawyer coal bed. Warren (1959, pl. 19) mapped the southern part of the quadrangle as part of the Birney-Broadus coal field. Carmichael (in Matson and Blumer, 1973, pl. 15) mapped almost all of the quadrangle as the Pumpkin Creek deposit. Ayler, Smith, and Deutman (1969) reviewed the strippable coal reserves of the Pumpkin Creek deposit based on Carmichael's

map. Matson and Blumer (1973, pl. 25-A) also mapped the southern two tiers of sections as part of the Sonnette coal deposit.

Traces of coal bed outcrops shown by previous workers on planimetric maps which lack topographic control have been modified to fit the modern topographic map of the quadrangle.

Stratigraphy

A generalized columnar section of the coal-bearing rocks in shown on the Coal Data Sheet (pl. 3) of the CRO maps. The exposed bedrock units belong to the Tongue River Member, the uppermost member, of the Fort Union Formation (Paleocene). This member consists of light-colored sandstone, sandy shale, carbonaceous shale, and coal beds. The thicker coal beds have burned along the outcrop and have baked and fused the overlying rock into reddish-colored clinker or slag. The upper part of the Tongue River Member has been removed by erosion, but about 1,200 feet (366 m) of the middle and lower parts of the member remains in the Samuelson Ranch 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 Samuelson Ranch quadrangle is in the northeastern part of the Powder River structural basin. The strata, in general, dip southwestward at an angle of less than 1 degree. In places the regional structure is modified by low-relief folds, as shown by the structure contour maps on top of the coal beds (see list of illustrations). Some of the nonuniformity in structure may be due to differential compaction and to irregularities in deposition of the coal and other beds as a result of their continental origin.

COAL GEOLOGY

The coal beds in the Samuelson Ranch quadrangle are shown in outcrop on the Coal Data Map (pl. 1) and in section on the Coal Data Sheet (pl. 3). All of the mapped coal beds occur in the middle and lower parts of the Tongue River Member of the Fort Union Formation (Paleocene). No commercial coals are known to exist below the Tongue River Member.

The lowermost major coal bed is the Broadus which lies about 180 feet (55 m) above the base of the Tongue River Member. The Broadus coal bed is overlain by a shale and sandstone interval of about 120 feet (36 m), which contains one or two local beds, the Knobloch coal bed, a noncoal interval of about 175 feet (53 m), the lower split of the Sawyer coal bed, a noncoal interval of from 1 to 51 feet (0.3 to 15.5 m), the upper split of the Sawyer coal bed, a sandstone and shale interval containing several local coal beds, including the X coal bed, of about 360 feet (110 m), the Pawnee coal bed, a noncoal interval of about 130 feet (40 m), the lower split of the Cook coal bed, a noncoal interval of about 50 feet (15 m), the upper split of the Cook coal bed, a noncoal interval of about 100 feet (30 m), and the Ferry coal bed which has been almost completely burned to clinker in this quadrangle.

The coal found along the eastern flank of the Powder River Basin in Montana increases in rank from lignite in the east to subbituminous in the deeper parts of the basin to the west. All coal analyses available at the present time from this and from adjacent quadrangles were considered in our decision to assign a rank of lignite A to all of the coal beds in this quadrangle. The lignite subbituminous boundary may fall somewhere within this quadrangle, but not enough data are presently available to allow our drawing that boundary with certainty. Therefore, a rank of lignite A has been arbitrarily assigned to all of the coal in the entire quadrangle. Additional data to be obtained in the future may make a more precise determination of this boundary line possible.

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

Broadus coal bed

The Broadus coal bed, which was first described by Warren (1959, p. 570), derives its name from exposures near the town of Broadus in the Broadus quadrangle about 17 miles (27 km) east-southeast of the Samuelson Ranch quadrangle. The Broadus coal bed occurs about 180 feet (55 m) above the base of the Tongue River Member. This coal bed does not crop out in the Samuelson Ranch quadrangle, but it has been penetrated by deeper drill holes in the southern part of the quadrangle and it has been projected into the quadrangle from the Leslie Creek quadrangle to the east where it has also been penetrated by drill holes. The isopach and structure contour map of the Broadus coal bed (pl. 22) shows that the Broadus coal ranges from about 4 to 24 feet (1.2 to 7.3 m) in thickness and dips southwestward at an angle of less than 1 degree. Overburden on the Broadus

coal bed (pl. 23) ranges from about 200 to more than 1,000 feet (61 to 305 m) in thickness.

There is no known, publicly available chemical analysis of the Broadus coal in the Samuelson Ranch quadrangle. However, an analysis of the Broadus coal from a depth of 92 to 117 feet (28 to 36 m) in drill hole BR-6C, sec. 7, T. 3 S., R. 50 E., in the Olive quadrangle about 7 miles (11.3 km) east of the Samuelson Ranch quadrangle shows ash 6.90 percent, sulfur 0.24 percent, and heating value 7,550 Btu per pound (17,560 kJ/kg) on an as-received basis (Matson and Blumer, 1973, p. 91). This heating value converts to about 8,110 Btu per pound (18,864 kJ/kg) on a moist, mineral-matter-free basis, indicating that the Broadus coal at that location is lignite A in rank. It is assumed that the Broadus coal in the Samuelson Ranch quadrangle is similar and is also lignite A in rank.

Local coal beds below the Knobloch coal bed

Two thin coal beds at depths of 604 to 606 feet (184.1 to 184.7 m), 630 to 634 feet (192 to 193.2 m), are shown on the geophysical logs of the Wolf Exploration No. 17 NPRR oil-and-gas test hole in the SE ¼ SE¼, sec. 1, T. 4 S., R. 47 E. (pls. 1 and 3). These thin coal beds are at intervals of 43 and 69 feet (13.1, and 21.03 m) below the base of the Knobloch coal bed, respectively. The correlation of these thin coal beds with coal beds which have been named from surface outcrops is questionable and, therefore, they have been designated as local coal beds. Because these local beds are thin, they have not been assigned economic coal resources.

Knobloch coal bed

The Knobloch coal bed was named by Bass (1924) from a small coal mine on the Knobloch Ranch located in the Tongue River valley in the Birney Day School quadrangle, about 28 miles (45 km) west-southwest of the Samuelson Ranch quadrangle. The Knobloch coal bed does not crop out in the Samuelson Ranch quadrangle but has

been penetrated by several drill holes. The isopach and structure contour map (pl. 19) shows that the Knobloch coal bed ranges in thickness from 7 to about 20 feet (2.1 to 6.1 m) and dips southwestward at an angle of less than 1 degree. Overburden on the Knobloch coal bed (pl. 20) ranges from about 60 feet (18 m) along Pumpkin Creek in the northeastern part of the quadrangle to about 1,000 feet (305 m) in the northwestern part of the quadrangle.

There is no known, publicly available chemical analysis for the Knobloch coal in the Samuelson Ranch quadrangle. A chemical analysis of the Knobloch coal from drill hole FC-6, sec. 29, T. 1 S., R. 48 E., in the Elk Ridge quadrangle about 1.5 miles (2.4 km) north of the Samuelson Ranch quadrangle, shows ash 6.66 percent, sulfur 0.37 percent, and heating value 7,380 Btu per pound (17,166 kJ/kg) on an as-received basis. This heating value converts to about 7,906 Btu per pound (18,389 kJ/kg) on a moist, mineral-matter-free basis, indicating that the Knobloch coal at that location is lignite A in rank. Because of the proximity of the sample, all of the Knobloch coal in the Samuelson Ranch quadrangle is assumed to be lignite A in rank.

Sawyer coal bed

The Sawyer coal bed was described by Dobbin (1930, p. 28) after exposures in the foothills of the Little Wolf Mountains in the Forsyth coal field (Rough Draw and Black Spring quadrangles) about 45 miles (72 km) west-northwest of the Samuelson Ranch quadrangle. The Sawyer coal bed crops out in the northeastern part of the Samuelson Ranch quadrangle in the valleys of Pumpkin Creek and its tributaries. The isopach map (pl. 13) shows that in the central part of the quadrangle the Sawyer coal is essentially one bed, 20 to 35 feet (6.1 to 10.7 m) in thickness, although it contains, in places, a shale parting 1 or 2 feet (0.3 to 0.6 m) thick. In the northern and southern parts of the quadrangle, the shale parting increases in thickness and the Sawyer coal is considered to be split

into an upper and a lower coal bed. In the southern part of the quadrangle, the interval between the upper and the lower Sawyer coal beds (pls. 1 and 3) is as much as 51 feet (15.5 m). The Upper Sawyer coal bed ranges from about 10 to 24 feet (3 to 7.3 m) in thickness, and the Lower Sawyer coal bed ranges from about 5 to 24 feet (1.5 to 7.3 m) in thickness. The structure contour map (pl. 14) shows that the Sawyer coal bed and its splits dip southwestward at an angle of less than 1 degree, although this dip is modified in places by low-relief folding. Overburden on the Sawyer coal bed and its upper split (pl. 15) ranges from 0 feet at the outcrops to about 780 feet (0-238 m) in thickness. Overburden on the Lower Sawyer coal bed (pl. 17) ranges from 0 feet at the outcrops to about 550 feet (0-168 m) in thickness. This overburden, in places, includes the Upper Sawyer and higher coal beds.

Bass (1932, pl. 3) mapped the Lower Sawyer coal bed as the A coal bed, although he states (1932, p. 54) that the two beds may coalesce. V. M. Carmichael (in Matson and Blumer, 1973, pl. 15) mapped the approximate line of split in the southern part of the Samuelson Ranch quadrangle.

A chemical analysis of the Sawyer coal at a depth of 105 to 142 feet (32 to 43 m) in drill hole PC-23, sec. 21, T. 3 S., R. 48 E. in the Samuelson Ranch quadrangle shows ash 8.45 percent, sulfur 0.45 percent, and heating value 7,550 Btu per pound (17,561 kJ/kg) on an as-received basis (Matson and Blumer, 1973, p. 83). This heating value converts to about 8,247 Btu per pound (19,183 kJ/kg) on a moist, mineral-matter-free basis, indicating that the Sawyer coal at this location is high lignite A in rank.

X coal bed and associated local coal beds

Several thin coal beds occur in the interval between the Sawyer and Pawnee coal beds; the Pawnee is the next major coal bed above the Sawyer. One of these thin coal beds appears to correlate with the X coal bed which occurs in

quadrangles to the north and west. The X coal bed was first described by Bass (1932, p. 55) from exposures in the Ashland coal field. The bed is less than 5 feet (1.5 m) thick in the Samuelson Ranch quadrangle, so no economic resource estimate was prepared. The other nearby thin coal beds appear to be quite localized, and no economic resource estimates were assigned to them.

Pawnee coal bed

The Pawnee coal bed was first described by Warren (1959, p. 572) when he remapped it (1959, p. 19) in the southeastern part of the adjacent Home Creek Butte quadrangle and the southern part of the Samuelson Ranch quadrangle (1959, pl. 20). Bass (1932, pl. 3) mapped a number of local coal beds along the west edge of the quadrangle; one of these has been correlated with the Pawnee in this report. Matson and Blumer (1973, pl. 25-A) also mapped and sampled the Pawnee coal bed in the southern part of the Samuelson Ranch quadrangle as part of the Sonnette coal field mapping.

The Pawnee coal bed occurs about 360 feet (110 m) above the Sawyer coal bed. The isopach and structure contour map of the Pawnee bed (pl. 10) shows that the coal ranges in thickness from about 4 to 10 feet (1.2 to 3.0 m). The bed dips slightly to the southwest and it is locally faulted and folded by broad low-relief synclinal structures. Overburden (pl. 11) ranges in thickness from 0 feet at the outcrops to more than 400 feet (0 to 122 m).

There is no known, publicly available chemical analysis of the Pawnee coal from within the Samuelson Ranch quadrangle. However, an analysis of the Pawnee coal from a depth of 70 to 80 feet (21.3 to 24.4 m) in drill hole SH-7114, sec. 20, T. 4 S., R. 48 E. in the Sonnette quadrangle, about 1.5 miles (2.4 km) south of the Samuelson Ranch quadrangle, shows ash 4.42 percent, sulfur 1.49 percent, and a heating value of 7,364 Btu per pound (17,129 kJ/kg) on an as-received basis. This converts to 7,705 Btu per pound (17,920 kJ/kg) on a moist,

mineral-matter-free basis. This indicates that the Pawnee is lignite A in rank at that location, and because of its proximity, it is assumed that the Pawnee is lignite A in rank at the Samuelson Ranch quadrangle.

Cook coal bed

The name Cook coal bed was first used by Bass (1932, p. 59-60) for exposures of coal on Cook Mountain about 13 miles (21 km) west-northwest of the Samuelson Ranch quadrangle, in the Cook Creek Reservoir quadrangle. Bass (1932, pl. 3) did not map the Cook bed in the Samuelson Ranch quadrangle. Warren (1959, pl. 19) mapped the Cook coal bed in the southern part of the quadrangle.

The Cook coal bed consists of two splits separated by about 60 feet (18.3 m) of sandstones and shales. The upper split (pl. 4) ranges from about 4 to 5.5 feet (1.2 to 1.7 m) in thickness. The lower split (pl. 7) ranges from about 4.1 to 6.1 feet (1.2 to 1.8 m) thick. Overburden on the upper split (pl. 5) ranges from 0 feet at the outcrops to about 100 feet (0-30 m) in thickness. Overburden on the lower split (pl. 8) is about the same. Both splits are essentially flat-lying in the Samuelson Ranch quadrangle.

There is no known, publicly available chemical analysis for the Cook coal in the Samuelson Ranch quadrangle. However, chemical analyses of this coal from depths of 72 to 82 feet (22 to 25 m) and from 114 to 119 feet (34 to 36 m) in coal test hole SH-7117, sec. 7, T. 5 S., R. 48 E., about 5.7 miles (9.2 km) south of the quadrangle in the Sonnette quadrangle, are available (Matson and Blumer, 1973, p. 110). The data show that the upper split has values of 6.500 percent ash, 0.736 percent sulfur, and a heating value of 7,186 Btu per pound (16,715 kJ/kg) on an as-received basis. This converts to about 7,686 Btu per pound (17,888 kJ/kg) on a moist, mineral-matter-free basis. The lower split has 8.967 percent ash, 1.655 percent sulfur, and 7,000 Btu per pound (16,282 kJ/kg) on an as-received basis. This converts to about 7,690 Btu per pound (17,886 kJ/kg) on

a moist, mineral-matter-free basis. These analyses indicate that both the upper and lower splits are lignite A in rank. Because of the proximity of that sample location, all of the Cook coal in the Samuelson Ranch quadrangle is assumed to be of lignite A in rank.

Local coal beds above the Cook coal bed

Several thin local coal beds were mapped by various workers above the Cook bed. However, these are too thin and discontinuous to warrant economic resource calculations.

Ferry clinker bed

The highest hills in the Samuelson Ranch quadrangle are capped by a reddish-colored clinker bed created by the burning of the Ferry coal bed. No Ferry coal was reported in the quadrangle.

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 and published 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 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 factor of 85 percent). Thus, these 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 in feet 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, for each coal bed 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 317.16 million short tons (287.73 million t). There is no federally owned, surface-minable Hypothetical coal. As shown by table 2, the total federally owned, underground-minable Reserve Base coal is estimated to be 769.55 million short tons (698.14 million t). The total federally owned, underground-minable Hypothetical coal is estimated to be 21.07 million short tons (19.11 million t). The total tonnage of surface- and underground-minable Reserve Base coal is 1,086.71 million short tons (985.86 million t), and the total of surface- and underground-minable Hypothetical coal is 21.07 million short tons (19.11 million t).

About 18 percent of the surface-minable Reserve Base tonnage is classed as Measured, 61 percent as Indicated, and 21 percent as Inferred. About 2 percent of the underground-minable Reserve Base tonnage is Measured, 16 percent is Indicated, and 82 percent is Inferred.

The total tonnages per section for both Reserve Base and Hypothetical coal, including both surface- and underground-minable coal are shown in the northwest corner of the Federal coal lands in each section on plate 2. All numbers on plate 2 are rounded to the nearest one-hundredth of a million short tons.

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 (the stripping limit), or where lignite beds of the same thickness are overlain by 200 feet (61 m) or less of overburden (the stripping limit). Areas having a potential for surface mining were assigned a high, moderate, or low development potential based on their mining-ratio values (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 of 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 (16.2-ha) 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 high development potential abutting against areas of low development potential.

The coal development potential for surface-mining methods in the Samuelson Ranch quadrangle is shown on the Coal Development Potential Map (pl. 25). Almost all of the Federal coal lands in the quadrangle has a high development potential for surface mining. The coal beds that have development potential, in ascending order, are: Knobloch, Sawyer, Pawnee, and Cook.

The Knobloch coal bed (pl. 20) occurs over most of the quadrangle and generally has a low development potential because of the depth of overburden. However, a large area of moderate to high development potential occurs in the northeast corner of the quadrangle in the Pumpkin Creek valley.

The Sawyer coal beds (pls. 15 and 17) occur over most of the quadrangle. Overburden thicknesses are such that large areas of the coal bed have a high development potential, while a band of moderate development potential occurs along the west side of the quadrangle.

The Pawnee coal bed (pl. 11) occurs in small isolated areas along the southern and western boundaries of the quadrangle. Narrow bands of high and moderate development potential occur along the outcrops, but most of the bed has a low development potential where thicker overburden overlies it.

The Cook coal bed occurs in several small isolated buttes. Its development potential is low.

About 68 percent of the Federal coal lands has a high development potential, 9 percent has a moderate development potential, 2 percent has a low development potential, and 21 percent has no development potential.

Development potential for underground mining and in situ gasification

Subbituminous coal beds 5 feet (1.5 m) or more in 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 for purposes of this report is rated as low, and a Coal Development Potential map for underground mining was not made.

In-situ gasification of coal on a commercial scale has not been done in the United States. Therefore, the development potential for in-situ gasification of

coal found below the surface-mining limit in this area is rated as low, 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 Samuelson Ranch 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				
Upper Cook	100,000	60,000	60,000	220,000
Lower Cook	160,000	60,000	0	220,000
Pawnee	3,020,000	2,520,000	5,350,000	10,890,000
Upper Sawyer	187,810,000	5,930,000	20,170,000	213,910,000
Lower Sawyer	14,340,000	16,200,000	12,460,000	43,000,000
Knobloch	12,030,000	20,680,000	16,210,000	48,920,000
Broadus	0	0	0	0
Total	217,460,000	45,450,000	54,250,000	317,160,000

Table 2.--Underground-minable coal resource tonnage (in short tons) by development-potential category for Federal lands in the Samuelson Ranch 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				
Pawnee	0	0	6,630,000	6,630,000
Upper Sawyer	0	0	302,150,000	302,150,000
Lower Sawyer	0	0	41,590,000	41,590,000
Knobloch	0	0	271,000,000	271,000,000
Broadus	0	0	148,180,000	148,180,000
Total	0	0	769,550,000	769,550,000
Hypothetical Resource tonnage				
Knobloch	0	0	20,310,000	20,310,000
Broadus	0	0	760,000	760,000
Total	0	0	21,070,000	21,070,000
Grand Total	0	0	790,620,000	790,620,000

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