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COAL RESOURCE OCCURRENCE AND COAL DEVELOPMENT POTENTIAL MAPS OF THE LACEY GULCH QUADRANGLE, ROSEBUD COUNTY, MONTANA

(Report includes 49 plates)

By

W. J. Mapel, B. K. Martin, and B. A. Butler

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COAL RESOURCE OCCURRENCE

Introduction

Purpose

This text is for use in conjunction with two sets of maps: (1) Coal resource occurrence (CRO) maps of the Lacey Gulch quadrangle, Rosebud County, Montana (CRO plates 1-48), and (2) a coal development potential (CDP) map of the Lacey Gulch quadrangle, Rosebud County, Montana (CDP plate 49). The two sets of maps have been prepared as part of a systematic coal resource inventory of Federal coal lands in Known Recoverable Coal Resource Areas (KRCRA's) in the western United States. They are intended to support land-use planning and coal leasing activities of the Bureau of Land Management as required by their Energy Minerals Activities Recommendation System (EMARS). Coal beds considered in the resource inventory are only those beds 5 feet (1.5 m) or more thick, and under less than 1,000 feet (305 m) of overburden (Reserve Base of subbituminous coals); thinner or deeper beds that at present are not shown by the maps (CRO plates 4-48) or included in the resource estimates.

Location

The Lacey Gulch 7½-minute quadrangle lies on the divide between the Tongue River and Hanging Woman Creek in southern Rosebud County, Montana. It is about 30 miles (50 km) south of Ashland, Montana, and about 5 miles (8 km) south of the settlement of Birney.

Accessibility

An all-weather county road forks from Montana Route 212 at Ashland and connects Ashland with Birney and other points to the south along the Tongue River in Montana. A branching graded road extends from Birney southward, part way up Hanging Woman Creek east of the quadrangle and a graded road connecting Birney with Decker, Montana to the southwest, crosses the southern part of the quadrangle. These roads and connecting roads and trails provide access to most parts of the quadrangle.

The Burlington Northern Railroad operates and maintains east-west routes through Sheridan, Wyoming, about 45 miles (70 km) to the south, and Forsyth, Montana, about 70 miles (110 km) to the north.

Physiography

A broadly rolling upland surface that forms much of the Tongue River-Hanging Woman Creek divide occupies the southern part of the quadrangle. The divide narrows irregularly northward in the northern part of the quadrangle where it is highly dissected at its margins by steep, sided canyons of streams flowing northwestward to the Tongue River and eastward to Hanging Woman Creek. Maximum local topographic relief is about 650 feet from a point low on the valley sides of Hanging Woman Creek to the crest of the divide in the northcentral part of the quadrangle.

Climate

Southeastern Montana in the vicinity of the Lacey Gulch quadrangle has a semi-arid climate. Average annual precipitation at Ashland is about 14 inches (36 cm) and the annual variation in temperature is commonly from 100^{o}F to -30^{o}F (39^{o}C to -38 C).

Land Status

The quadrangle lies in the central part of the Powder River Basin KRCRA. The Federal Government owns most of the coal rights.

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

General geology

Sources of data

Baker (1929) mapped the area of the Lacey Gulch quadrangle as part of the much larger northward extension of the Sheridan coal field, which lies mainly to the southwest. Matson and others (1973) described strippable coal deposits in the Anderson coal bed within or adjacent to the eastern and southern margins of the quadrangle along the valley of Hanging Woman Creek. Sarnecki (1977) remapped the quadrangle on a topographic base at a scale of 1:24,000, incorporating the earlier work. Sarnecki's (1977) map, with some local modifications, is the basis of the present work. In particular, the outcrops of the Canyon and Cook coal beds shown on CRO plate 1 in the northwestern corner of the quadrangle have been modified from Sarnecki's (1977) map on the basis of additional field work in the summer of 1977, and subsurface correlations of several of the coal beds identified in the logs of oil and gas wells in the quadrangle (CRO pls. 1 and 3) are changed from those suggested by Sarnecki (1977) to conform more nearly with unpublished correlations in wells in nearby areas to the south and east. The mapping of faults by Sarnecki (1977) in the southeastern corner of the quadrangle is modified in the present work to agree more closely with the structural interpretation of Matson and others (1973, pl. 9).

Information on coal-bed thicknesses are from measurements at outcrops, measurements in 10 shallow coal test holes, and measurements from the resistivity logs of 3 oil and gas test wells. Resistivity logs are useful for identifying coal because coal beds generally have high resistivity; however, some other types of rocks, such as limestone and some kinds of sandstone also have high resistivity, so identifications based solely on resistivity are uncertain.

Stratigraphy

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, and are Paleocene in age.

The Tongue River Member of the Fort Union Formation is about 2,100 feet (640 m) thick in the Lacey Gulch quadrangle and consists of interbedded lenticular beds of yellowish-gray to light-gray fine- to very fine grained sandstone, light- to dark-gray siltstone and clayey siltstone, gray shale and claystone, brown carbonaceous shale, and persistent beds of coal. The top of the Tongue River Member of the Fort Union Formation is the top of the Roland coal bed of Baker (1929).

A sequence about 125 feet (40 m) thick, consisting of sandstone, shale, and minor amounts of fresh-water limestone, conformably overlies the Tongue River Member of the Fort Union Formation in a small area in the southwestern corner of the quadrangle and is assigned to the Wasatch Formation of Eocene age. The Wasatch and underlying Fort Union Formations are lithologically similar except that in the Lacey Gulch quadrangle, the Wasatch lacks coal.

Rocks comprising the Fort Union and Wasatch Formations were deposited at elevations of perhaps a few tens of feet above sea level in a vast area of shifting flood plains, sloughs, swamps, and lakes that occupied the Northern Great Plains in early Tertiary time.

Representative samples of the sedimentary rocks overlying and interbedded with minable coal beds in the eastern and northern Powder River Basin have been analyzed for their trace element content by the U.S. Geological Survey and the results summarized by the Department of Agriculture and others (1974) and by Swanson (in Mapel and others, 1977, pt. A, p. 42-44). The rocks contain no greater amounts of trace elements of environmental concern than do similar rock types found throughout other parts of the western United States.

Structure

The quadrangle is in the trough of the Powder River structural basin just about on the basin axis, which in Montana trends generally northward. Regional dip is generally toward the south at less than 1°. Structural relief within the quadrangle on the Canyon coal bed is about 250 feet (75 m), as shown on CRO plate 25.

Very low amplitude folds are superimposed on the regional southward dip. The principal one of these is a shallow southeastward plunging synclinal trough that trends northwestward across the west-central part of the quadrangle. This fold is most pronounced in the near-surface Anderson and Dietz coal beds (CRO pls. 15 and 20). A low dome brings the Dietz coal bed to the surface locally in the NE¼ sec. 13, T. 8 S., R. 42 E.

An eastward trending fault about 2 miles (3.2 km) long cuts the Fort Union Formation in the southeastern corner of the quadrangle. This fault offsets the Anderson coal bed about 70 feet (21 m), upthrown to the north. The fault terminates on the east against a short northeastward trending fault having an offset of 20-30 feet (6-12 m), upthrown to the southeast.

Coal geology

Twenty-four coal beds, ranging in thickness from 1 to about 30 feet (0.3-9.1 m) were identified on the surface or in the subsurface in the Lacey Gulch quadrangle (CRO pl. 3). Of these, eleven, or about half, are thin coals of limited extent. The other twelve are thick and extensive enough to be included in calculations of the Reserve Base.

The uppermost coal is the Roland coal bed of Baker (1929). This coal is successively underlain by an interval about 200-220 feet (60-67 m) thick containing a local coal bed in the middle part; the Smith coal bed; a non-coal interval about 50-120 feet (15-37 m) thick; the Anderson coal bed; a non-coal interval as much as 80 feet (25 m) thick; the Dietz coal bed; an interval about 180-220 feet thick containing the thin Cox coal bed and at least one local coal bed; the Canyon coal bed; a non-coal interval about 45-80 feet (14-24 m) thick: the Cook coal bed; a non-coal interval 25-35 feet (8-11 m) thick; the Upper Otter coal bed; a non-coal interval about 15-20 feet (4.5-6 m) thick; the Lower Otter coal bed; an interval about 130 feet (40 m) thick containing 2 local coal beds; the Wall coal bed; an interval about 70 feet (21 m) feet thick containing a local coal bed; the Pawnee coal bed; a non-coal interval 100-150 feet (30-46 m) thick; the Brewster-Arnold coal bed; an interval about 600-650 feet (180-200 m) thick containing at least one local coal bed near the top; the Flowers-Goodale coal bed; an interval about 170 feet (52 m) thick containing a local coal bed near the middle; and the Kendrick coal bed.

Coal-bed thicknesses shown on the CRO maps are the bed thicknesses reported at outcrops or in the drill holes rounded to the nearest foot, partings excluded. The coal beds generally are free of partings. For detailed measurements of beds exposed at the outcrop, see Baker (1929) and Sarnecki (1977).

In the past, several of the thicker coal beds have caught fire at the outcrop and have burned under shallow cover for varying distances, some for a mile (1.6 km) or more. The heat from the burning coal has baked and fused the overlying rocks to form a resistant reddish rock called clinker (also called scoria, red shale, and other names locally). Clinker resulting from near-surface burning of the Anderson coal bed is as much as 100 feet (30 m) thick and caps large areas on the Tongue River-Hanging Woman Creek divide.

The only analyses of fresh coals in the Lacey Gulch quadrangle are from drill cores of the Anderson bed in sec. 12, T. 8 S., R. 42 E. (Matson and others, 1973, p. 53). Based on the analyses from this locality, and on analyses of coal samples collected at nearby localities outside the quadrangle, the rank of the coal in the Lacey Gulch quadrangle varies from high in the range of subbituminous C to low in the range of subbituminous B.

The trace element content of coals in the Lacey Gulch 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, pl. 147).

Roland coal bed of Baker (1929)

(CRO pls. 4-8)

The Roland coal bed was named by Taff (1909) in the Sheridan coal field, Wyoming. A coal assumed to be the same bed was called the Roland bed in the northward extension of the Sheridan coal field, Montana by Baker (1929). Subsequent work in the Sheridan coal field has shown that the Roland bed of Baker (1929) lies about 125 feet above the original Roland bed of Taff (1909) (B. E. Law, personal communication, 1972).

The top of the Roland bed of Baker (1929) is generally used in southern Montana as the contact between the Fort Union and overlying Wasatch Formations.

The Roland bed of Baker (1929) crops out on high ridges in the extreme southwestern part of the Lacey Gulch quadrangle where it ranges in thickness from less than 5 feet (1.5 m) to about 7 feet (2.1 m) (CRO pl. 4). The coal is everywhere beneath less than 200 feet (61 m) of overburden (CRO pl. 6); however, the area underlain by the bed is small and resources of coal having potential for surface mining are correspondingly small.

Analyses have not been made of coal in the Roland bed of Baker (1929) in the quadrangle.

Smith coal bed

(CRO pls. 9-13)

The Smith coal bed was named by Taff (1909) in the Sheridan coal field, Wyoming, and was traced into the area of the Lacey Gulch quadrangle by Baker (1929). It is present in the southwestern part of the Lacey Gulch quadrangle where it ranges in thickness from less than 5 feet (1.5 m) to an estimated 14 feet (4.3 m) (CRO pl. 9). The coal is thickest along the western side of the quadrangle, and thins generally eastward. Overburden is less than 200 feet (61 m) in most of the area underlain by the Smith coal bed (CRO pl. 11). Overburden reaches a maximum of slightly more than 300 feet (91 m) at a few places along the southern edge of the quadrangle.

Chemical analyses have not been made of the Smith coal bed in the quadrangle.

Anderson coal bed

(CRO pls. 14-18)

The Anderson coal bed was named by Baker (1929), probably for outcrops of the bed along Anderson Creek in the southern part of the adjacent Spring Gulch quadrangle to the west. The bed contains as much as 30 feet (9.1 m) of coal in drill holes in the southeastern part of the Lacey Gulch quadrangle, and it is 21 feet (6.4 m) thick in an outcrop in the central part of the quadrangle (CRO pl. 14). Based on this information, and on information from scattered drill holes in the adjacent Spring Gulch quadrangle to the west, the coal thins from 30 feet (9.1 m) in the southeastern part of the Lacey Gulch quadrangle northwestward to less than 18 feet (6.1 m) at places along the western side, as shown by CRO plate 14.

Much of the Anderson bed is under less than 200 feet (61 m) of overburden. Coal in fairly large areas, particularly in the southeastern and central parts of the quadrangle, has good potential for surface mining (CRO pl. 16).

Chemical analyses have been made of cores of the Anderson bed collected from drill holes at localities 8 and 13 (CRO pl. 1). The samples contained 0.13-0.33 percent sulfur; 3.3-4.0 percent ash; and had a heat value of 8235-8804 Btu per pound on the as-received basis, as reported by Matson and others (1973, p. 53).

Dietz coal bed and lower split of the Dietz bed

(CRO pls. 19-23)

The name Dietz is used in this report as it was applied by Baker (1929) in the northern extension of the Sheridan coal field. The name is from the adjacent Sheridan coal field where Taff (1909) recognized and named, in descending order, the Dietz 1, 2, and 3 coal beds. Baker (1929, p. 35-36) correlated his Dietz bed with the Dietz 1 bed of Taff (1909). The stratigraphic relations of coal in the Dietz interval within the two coal fields is complex, and the exact correlations are uncertain.

The Dietz bed is as much as 15 feet (4.6 m) thick in the central part of the Lacey Gulch quadrangle, and it is 10-13 feet (3.0-4.0 m) thick in the southeastern part. It thins to less than 5 feet locally in outcrops in the northeastern part (CRO pl. 19). The coal bed contains a shale parting 1-2 feet (0.3-0.6 m) thick in the southeastern corner of the quadrangle. Information from drilling in the adjacent Pine Butte School and Forks Ranch quadrangles to the south and southeast, respectively, indicates that the parting rapidly increases in thickness southward, splitting the coal into two beds. Coal in the lower split is locally more than 5 feet (1.5 m) thick in the southeasternmost part of the quadrangle, where it has been mapped separately (CRO pl. 19). The upper split is everywhere less than 5 feet (1.5 m) thick and is too thin to be considered part of the Reserve Base.

Coal in the Dietz bed is available for surface mining in highly irregular but fairly large areas in the central and southeastern parts of the quadrangle where the coal generally is more than 10 feet (3.0 m) thick. A small amount of coal in the lower split of the Dietz bed is available for surface mining in the southeastern corner of the quadrangle (CRO pl. 17).

Analyses have not been made of the Dietz coal bed of the lower split of the Dietz bed in the Lacey Gulch quadrangle.

Canyon coal bed

(CRO pls. 24-28)

The Canyon coal bed was named by Baker (1929) for outcrops in the northern extension of the Sheridan coal field. The same coal is referred to as the Upper Canyon coal bed by Culbertson and others (1976) in the Stroud Creek quadrangle, which is adjacent to the Lacey Gulch quadrangle to the east. It is the bed mapped as the Canyon bed by Sarnecki (1977) in most of the Lacey Gulch quadrangle except in the northwestern part. In that part of the quadrangle, in T. 7 S., R. 42 E., a thin coal bed mapped by Sarnecki (1977) as the Canyon bed is considered in this report to be a local coal bed about 30-40 feet (9.1-12.2 m) above the Canyon bed.

The Canyon bed is irregular in thickness in the Lacey Gulch quadrangle (CRO pl. 24). It is as much as 16 feet (4.9 m) thick in drill holes in the southern part of the quadrangle in secs. 13 and 14, T. 8 S., R. 42 E., and as much as 12 feet (3.7 m) thick at an outcrop and in a nearby drill hole in the northwestern part in secs. 17 and 20, T. 7 S., R. 42 E. The coal thins to less than 5 feet (1.5 m) thick in the northwestern part of the quadrangle. At most places, the Canyon bed is too deeply buried to have potential for surface mining except for a narrow band adjacent to the outcrop in the northern and along the eastern sides of the quadrangle (CRO pl. 26).

Chemical analyses have not been made of the Canyon bed in the Lacey Gulch quadrangle.

Cook coal bed

(CRO pls. 29-33)

The Cook coal bed was named by Bass (1932) for outcrops in the Ashland coal field, which lies several miles northeast of the Lacey Gulch quadrangle. The Cook bed is less than 5 feet (1.5 m) thick in outcrops in most of the northern part of the Lacey Gulch quadrangle. It thickens rather abruptly to about 10 feet (3.0 m) at its southernmost exposure in the valley of Hanging Woman Creek in sec. 30, T. 7 S., R. 43 E. Scattered and very sparse information from drilling, mostly in areas south and east of the Lacey Gulch quadrangle suggests that the bed may be 5 feet (1.5 m) to as much as 13 feet (4.0 m) thick in the subsurface in the central and southern parts of the quadrangle (CRO pl. 29). Drilling information is inadequate to more than indicate generally the distribution and depth of the coal in most parts of the quadrangle.

Resources of coal in the Cook bed available for surface mining are small, and are confined to a narrow band next to outcrops of the bed in the northwestern part of the quadrangle and along the valley of Hanging Woman Creek in the eastern part (CRO pl. 31).

Chemical analyses have not been made of the Cook coal bed in the Lacey Gulch quadrangle.

Lower Otter coal bed

(CRO pls. 4-8)

The name Lower Otter was used by Culbertson and others (1976) for a coal mapped as the Otter bed by Bryson and Bass (1973) on the east side of Hanging Woman Creek in the Moorhead coal field about a mile (1.6 km) east of the Lacey Gulch quadrangle. A thin coal 15-30 feet (4.6-9.1 m) above the Lower Otter was called the Upper Otter bed by Culbertson and others (1976), and coal beds in this interval were included in an Otter zone by Sarnecki (1977).

Coals in the Otter zone are less than 5 feet (1.5 m) thick in outcrops and drill holes in the northern part of the Lacey Gulch quadrangle (Sarnecki, 1977); however, a coal identified as the Lower Otter bed is about 5 feet (1.5 m) thick in a drill hole at locality 3, and a bed at the same horizon is about 5 feet (1.8 m) thick in a drill hole at locality 7, both in the southern part of the quadrangle. On the basis of the information from these two holes, the Lower Otter bed is assumed to underlie several square miles in the southeastern part of the quadrangle with a thickness of slightly more than 5 feet (1.5 m) (CRO pl. 4).

The Lower Otter bed has potential for surface mining in a small area in sec. 6, T. 8 S., R. 43 E., along the east side of the quadrangle (CRO pl. 6).

Wall coal bed

(CRO pls. 34-38)

The Wall coal bed was named by Baker (1929) for exposures of the coal along Wall Creek, about 1 mile (1.6 km) north of the Lacey Gulch quadrangle. Coal in the bed is as thick as 31 feet (9.4 m) in a drill hole at locality 1 in the northwestern part of the quadrangle (CRO pls. 1 and 34). It is estimated to be nearly 25 feet (7.6 m) thick in an oil and gas test well in the southeastern part of the adjacent Spring Gulch quadrangle about 2 miles (3.2 km) west of the Lacey Gulch quadrangle. The coal thins from these localities irregularly eastward to less than 5 feet (1.5 m) thick in outcrops in the northeastern part of the Lacey Gulch quadrangle, and to an estimated 7 feet (2.1 m) thick in the subsurface in the southeastern part of the quadrangle (CRO pl. 34).

The Wall coal bed has possibilities for surface mining mainly in the northwestern part of the quadrangle where the coal is estimated to be beneath less than 200 feet (61 m) of overburden and to range in thickness from 8 to 22 feet (2.4-6.7 m) in a very irregularly shaped area of about 2 square miles (5.2 sq km) (CRO pls. 34 and 36).

Chemical analyses have not been made of coal from the Wall bed in the Lacey Gulch quadrangle. Seven samples of coal from the Wall bed, collected from a drill hole in sec. 21, T. 7 S., R. 41 E., 5 miles (8 km) west of the quadrangle, showed sulfur in the range of 1.4-3.5

percent; ash in the range of 2.5-5.1 percent; and heat value in the range of 8,910-9,566 Btu per pound on the as-received basis (Matson and others, 1973, p. 40, drill hole SH7013).

Pawnee coal bed

(CRO pls. 4-8)

The Pawnee coal bed in the Lacey Gulch quadrangle is the same coal bed that Warren (1959) called the Pawnee bed in outcrops along the east side of Hanging Woman Creek a short distance northeast of the quadrangle. The coal is locally about 6 feet (1.8 m) thick on the west side of Hanging Woman Creek in the Stroud Creek quadrangle in sec. 17, T. 7 S., R. 43 E. (Culbertson and others, 1976). It is projected westward into the Lacey Gulch quadrangle into parts of secs. 17, 18, 19, and 20 with a thickness of about 5 feet (1.5 m) on this basis (CRO pl. 4). A coal bed estimated to be 7 feet (2.1 m) thick was tentatively identified as the Pawnee bed in a drill hole at locality 2, sec. 22, T. 7 S., R. 42 E. (CRO pls. 1 and 4). A limited area in the vicinity of this hole is also assumed to be underlain by coal of the Pawnee bed with a thickness slightly in excess of 5 feet (1.5 m) (CRO pl. 4). The bed was not recognized in the subsurface in the southern part of the Lacey Gulch quadrangle.

The Pawnee coal bed is about 5 feet (1.5 m) thick and under less than 200 feet (61 m) of overburden in the small area near its outcrop in secs. 17, 18, 19, and 20, T. 7 S., R. 43 E. (CRO pl. 6) where a small amount of coal is available for surface mining.

Chemical analyses have not been made of coal from the Pawnee coal bed in the Lacey Gulch quadrangle.

Brewster-Arnold coal bed

(CRO pls. 39-43)

The Brewster-Arnold coal bed was named by Bass (1924) for coal at the Brewster-Arnold mine a few miles north of the Lacey Gulch quadrangle. The bed is estimated to be about 15 feet (4.6 m) thick in the subsurface in the northwestern corner of the quadrangle, based on information from drilling in adjacent areas (Matson and others, 1973, pl. 7). The coal thins from the northwestern corner of the quadrangle eastward and southeastward (CRO pl. 39). It is less than 5 feet (1.5 m) thick in outcrops in the northeastern part of the quadrangle (Sarnecki, 1977). The thickness of the coal is uncertain in most parts of the quadrangle, however, because of the very limited number of drill holes that have penetrated the bed.

The Wall bed is beneath less than 200 feet (61 m) of overburden in a very small area in sec. 8, T. 7 S., R. 42 E., where it may have good potential for surface mining. Depth to the coal is more than 1,000 feet (305 m) in the southwestern part of the quadrangle (CRO pl. 41).

Chemical analyses have not been made of coal from the Brewster-Arnold bed in the Lacey Gulch quadrangle; however, two samples of coal from the bed, collected from a drill hole in sec. 31, T. 6 S., R. 42 E., about 1.5 miles (2.4 km) northwest of the quadrangle, had an average of 0.53 percent sulfur; 3.8 percent ash; and an average heat value of 9,290 Btu per pound on an as-received basis (Matson and others, 1973, p. 43, drill hole SH-44).

Flowers-Goodale coal bed

(CRO pls. 44-48)

The Flowers-Goodale coal bed was named by Bass (1932) for outcrops in the Ashland coal field several miles northeast of the Lacey Gulch quadrangle. The coal is beneath less than 1,000 feet (305 m) of overburden only in the northwestern corner of the quadrangle and at places along the eastern side (CRO pl. 46). The coal may be as much as 20 feet (6.1 m) thick adjacent to the valley of Hanging Woman Creek in sec. 7, T. 7 S., R. 43 E., based on the log of a nearby oil and gas test hole to the northeast. Available information indicates the coal is thinner elsewhere in the quadrangle as shown on CRO plates 3 and 44. The coal is everywhere too deeply buried to have potential for surface mining (CRO pl. 46).

Chemical analyses have not been made of coal from the Flowers-Goodale bed in the Lacey Gulch quadrangle.

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 1,000 feet (305 m) or less of overburden, and within 3 miles (4.8 km) of a complete measurement of the coal bed. Reserve Base coal is further subdivided into categories according to its nearness to a measurement of the coal bed. Measured coal is coal within ¼ mile (0.4 km) of a measurement, Indicated coal extends ½ mile (0.8 km) beyond Measured coal to a distance of 3/4 mile (1.2 km) from the measurement, and Inferred coal extends 2¼ miles (3.6 km) beyond Indicated coal to a distance of 3 miles (4.8 km) from the measurement.

Reserves are the recoverable part of the Reserve Base. For strippable coal in this quadrangle, the coal reserves are 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 in the Lacey Gulch quadrangle is estimated to be about 3.1 billion short tons (2.8 billion t) as shown listed by section on CRO plate 2 and by individual coal bed and resource category on table 1. About 4 percent of this large amount is classified as Measured; 23 percent as Indicated; and 73 percent as Inferred.

Table 1.--Estimated Reserve Base for Federal coal lands in the Lacey Gulch quadrangle, Rosebud County, Montana.

(In thousands of short tons, rounded. Multiply by 0.907 to convert to metric tons)

Coal bed name	Overburden 0-200 feet				Overburden 200-1,000 feet				Grand total (rounded)
	Measured	Indicated	Inferred	Total (rounded)	Measured	Indicated	Inferred	Total (rounded)	
Roland of Baker (1929)----	400	1,800	500	2,700	--------	---------	--------	---------	2,700
Smith-------	2,500	19,700	47,700	69,900	--------	200	21,300	21,500	91,000
Anderson----	27,300	79,000	186,000	292,000	1,100	33,000	120,000	154,000	446,000
Dietz-------	15,000	105,000	179,000	299,000	6,800	37,300	76,300	120,000	419,000
Lower split of the Dietz-----	------	4,000	-------	4,000	--------	3,500	--------	3,500	7,500
Canyon------	13,900	36,100	26,700	76,700	18,800	158,000	321,000	498,000	575,000
Cook--------	3,960	16,700	8,500	29,000	4,160	52,300	238,000	294,000	323,000
Lower Otter-	------	------	-------	-------	520	3,800	22,100	26,400	26,400
Wall--------	------	------	19,300	19,300	14,800	108,000	546,000	669,000	688,000
Pawnee------	100	------	-------	100	1,500	8,200	11,000	20,700	20,800
Brewster-Arnold----	------	------	200	200	4,100	40,500	366,000	411,000	411,000
Flowers-Goodale---	------	------	-------	-------	-------	4,700	27,300	32,000	32,000
Total (rounded)	63,000	262,000	468,000	793,000	51,800	449,000	1,750,000	2,250,000	3,000,000

COAL DEVELOPMENT POTENTIAL

Development potential of coal recoverable by surface-mining methods.

Areas where the coal beds are more than 5 feet (1.5 m) thick and are overlain by 200 ft (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 ton of recoverable coal). The formula used to calculate mining ratios for subbituminous coal is as follows:

$$MR = \frac{t_o\ (0.911)}{t_c\ (rf)}$$

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, 31, and 36. The mining-ratio values for each development-potential category are based on economic technological criteria, and were derived in consultation with A. F. Czarnowsky, Area Mining Supervisor, U.S. Geological Survey.

Reserve Base for federally owned coal beneath less than 200 feet (61 m) of overburden in the various development-potential categories totals slightly less than 800 million short tons, distributed by bed as shown in table 2.

Each quarter section or lot underlain by federally owned coal in the Lacey Gulch quadrangle is classified according to its potential for surface mining on CDP plate 49.

Development potential of coal recoverable by 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 2.3 billion short tons, as shown on table 1. Coal at these depths is available for underground mining. Coal is not now being mined underground in the Powder River Basin, and recovery factors have not been established. The development potential was not evaluated.

Table 2.--Potential for surface mining of coal in the estimated Reserve Base, Federal coal land, Lacey Gulch quadrangle.

(In thousands of short tons, rounded. Development potentials are based on mining ratios (cubic yards of overburden/short ton of underlying coal). To convert short tons to metric tons, multiply by 0.907; to convert mining ratios in yd^3/ short 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)
Roland of Baker (1929)---	1,800	770	130
Smith------	30,000	17,000	23,000
Anderson---	293,000	2,000	------
Dietz------	165,000	91,000	41,000
Lower split of Dietz----	-------	300	3,700
Canyon-----	38,000	6,000	33,000
Cook-------	8,000	8,000	13,000
Wall-------	10,500	5,500	3,000
Pawnee-----	50	60	50
Brewster-Arnold---	8	14	------
TOTAL (rounded)--	546,000	130,000	117,000

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