Text to Accompany:

Open-File Report 79-1383

1979

COAL RESOURCE OCCURRENCE AND COAL DEVELOPMENT POTENTIAL MAPS OF THE NORTHEAST QUARTER OF THE DOTY MOUNTAIN 15-MINUTE QUADRANGLE CARBON COUNTY, WYOMING

[Report includes 19 plates]

Prepared for

UNITED STATES DEPARTMENT OF THE INTERIOR

GEOLOGICAL SURVEY

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This report has not been edited for conformity with U.S. Geological Survey editorial standards or stratigraphic nomenclature.

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INTRODUCTION

Purpose

This text is to be used in conjunction with Coal Resource Occurrence (CRO) and Coal Development Potential (CDP) Maps of the northeast quarter of the Doty Mountain 15-minute quadrangle, Carbon County, Wyoming. This report was compiled to support the land planning work of the Bureau of Land Management (BLM) to provide a systematic coal resource inventory of Federal coal lands in Known Recoverable Coal Resource Areas (KRCRA's) in the western United States. This investigation was undertaken by Dames & Moore, Denver, Colorado, at the request of the U.S. Geological Survey under contract number 14-08-0001-17104. The resource information gathered for this report is in response to the Federal Coal Leasing Amendments Act of 1976 (P.L. 94-377). Published and unpublished public information available through May, 1979, was used as the data base for this study. No new drilling or field mapping was performed, nor was any confidential data used.

Location

In this report, the term "quadrangle" refers only to the northeast quarter of the Doty Mountain 15-minute quadrangle, which is located in southwestern Carbon County, Wyoming, approximately 25 airline miles (40 km) southwest of the city of Rawlins and 24 airline miles (39 km) north of the town of Dixon, Wyoming. Sulphur Springs Ranch, which is only seasonally occupied, is located along the northern edge of the quadrangle.

Accessibility

A northeast-trending light-duty road crosses the western two thirds of the quadrangle, connecting Wyoming Highway 789 to the southwest with Rawlins to the northeast. A second light-duty road crosses the northeastern corner of the quadrangle and connects other light-duty roads to the east that go to Saratoga, Rawlins, and Savery, Wyoming. Several unimproved dirt roads and trails provide satisfactory access to many areas within the quadrangle. Wyoming Highway 789 passes approximately 7 miles (11 km) west of the quadrangle boundary and intersects Interstate

Highway 80 approximately 17 airline miles (27 km) to the north (U.S. Bureau of Land Management, 1971; Wyoming State Highway Commission, 1978).

The main line of the Union Pacific Railroad passes through southern Wyoming approximately 16 airline miles (26 km) north of the quadrangle. This line connects Ogden, Utah, to the west with Omaha, Nebraska, to the east.

Physiography

The northeast quarter of the Doty Mountain 15-minute quadrangle lies on the eastern rim of the Washakie Basin. The landscape is characterized by sand dunes and low irregular terrain in the western two thirds of the quadrangle. The eastern third is more rugged with numerous gulches and draws. Numerous sand dunes forming the Sand Hills cover the central part of the quadrangle. Altitudes range from less than 6,760 feet (2,060 m) on Dry Cow Creek in the southwestern corner of the quadrangle, to 8,047 feet (2,453 m) in the northeastern corner of the quadrangle.

Muddy Creek and its tributaries, Olson Draw, Alamosa Gulch, and Hay Gulch, drain the northern third of the quadrangle. The southern half of the quadrangle is drained by Cow Creek and Dry Cow Creek. These creeks are tributaries of Muddy Creek which flows southwesterly into the Little Snake River near Baggs, Wyoming. With the exception of Muddy Creek, the streams are intermittent and flow mainly in response to snowmelt in the spring. Numerous springs occur throughout the quadrangle including the historical Sulphur Spring in the north-central part of the quadrangle.

Climate and Vegetation

The climate of south-central Wyoming is semiarid, characterized by low precipitation, rapid evaporation, and large daily temperature variations. Summers are usually dry and mild, and winters are cold. The annual precipitation in the area averages approximately 10 inches (25 cm). Approximately two thirds of the precipitation falls in the spring and summer during a seven-month period from April through October (Wyoming Natural Resources Board, 1966).

The average annual temperature in the area is 43°F (6°C). The temperature during January averages 21°F (-6°C) and typically ranges from 12°F (-11°C) to 31°F (-0.6°C). During July the average temperature is 68°F (20°C), and the temperature typically ranges from 51°F (11°C) to 84°F (29°C) (Wyoming Natural Resources Board, 1966).

Winds are usually from the southwest and the west-southwest with an average annual velocity of approximately 12 miles per hour (19 km per hr) (U.S. Bureau of Land Management, 1978).

Principal types of vegetation in the quadrangle include cottonwood, willow, aspen, grasses, sagebrush, greasewood, serviceberry, bitterbrush, saltbush, rabbitbrush, and other desert shrubs.

Land Status

The northeast quarter of the Doty Mountain 15-minute quadrangle lies on the southeastern edge of the proposed Rawlins (Little Snake River) Known Recoverable Coal Resource Area (KRCRA). Approximately 85 percent of the quadrangle lies within the KRCRA boundary and the Federal government owns the coal rights for less than two thirds of this area as shown on plate 2. No outstanding Federal coal leases, prospecting permits or licenses occur within the quadrangle.

GENERAL GEOLOGY

Previous Work

Ball and Stebinger described the geology and mineral resources of the eastern part of the Little Snake River coal field in 1910. The stratigraphy and depositional environments of Upper Cretaceous rocks in Wyoming and adjacent areas were described by Hale (1961), Haun (1961), Lewis (1961), and Weimer (1961). Welder and McGreevy (1966) conducted a ground-water reconnaissance of the Great Divide and Washakie Basins of southwestern Wyoming and their report contains a geologic map of the region. Gill and others (1970) described the stratigraphy and nomenclature of some of the Upper Cretaceous and Lower Tertiary rocks found in south-central Wyoming, and Land (1972) discussed the depositional environments of the Fox Hills Sandstone and the Lance Formation. Barclay and Zimmerman (1976) and Barclay and Shoaff (1977) showed correlations for coal beds in the Almond Formation and described the stratigraphy of the formations that were drilled by the U.S. Geological Survey in the eastern part of the Doty Mountain 15-minute quadrangle during 1975 and 1976. In the classification minutes for the proposed Rawlins (Little Snake River) KRCRA, Barclay and others (1978) presented geologic maps showing the distribution of the coal-bearing formations and brief discussions of the stratigraphy and coal geology of the KRCRA. Reports on coal-drilling by the U.S. Geological Survey in the eastern part of the Doty Mountain quadrangle in 1977 and 1978 are in preparation (Barclay, 1979c and 1979d). Geologic mapping of this area by Barclay and Hettinger of the U.S. Geological Survey is in progress.

Stratigraphy

The rock formations exposed in the northeast quarter of the Doty Mountain 15-minute quadrangle range in age from Late Cretaceous to Miocene, and crop out across the quadrangle in northeast-trending bands. The Mesaverde Group, the Fox Hills Sandstone, and the Lance Formation are known to be coal-bearing in the quadrangle.

In this quadrangle, the Steele Shale of Late Cretaceous age is only in the subsurface. In south-central Wyoming, this formation consists of dark-gray marine shale with sparse layers of gray-weathering limestone concretions and thin beds of very fine grained sandstone and siltstone (Gill and others, 1970). The upper part of the Steele Shale was encountered at depths ranging from approximately 1,800 to 2,800 feet (549 to 853 m) in three oil and gas wells drilled in the southeastern part of this quadrangle.

The Steele Shale is conformably overlain by and laterally intertongues with the Mesaverde Group of Late Cretaceous age. The Mesaverde Group is subdivided into four formations which are, in ascending order, the Haystack Mountains, the Allen Ridge, the Pine Ridge Sandstone, and the Almond (Hale, 1961; Gill and others, 1970).

Only the upper part of the Haystack Mountains Formation crops out along the eastern edge of the quadrangle with the remainder of the formation present in the subsurface. It is approximately 845 feet (258 m) thick where measured in an oil and gas well in sec. 30, T. 17 N., R. 90 W. (Barclay, 1979, written communication). The Haystack Mountains Formation is subdivided into four members which are, in ascending order, the Deep Creek Sandstone Member, the Espy Tongue, the Hatfield Sandstone Member, and an upper unnamed member. The Deep Creek Sandstone Member is approximately 85 feet (26 m) thick in the quadrangle, and is composed mostly of sandstone. The Espy Tongue, genetically a tongue of the Steele Shale, is approximately 250 feet (76 m) thick and consists of dark-gray marine shale, minor sandstone, and a few limestone-concretion horizons. The Espy Tongue has a sharp contact with the Deep Creek Sandstone Member, and a gradational contact with the overlying Hatfield Sandstone Member. The Hatfield Sandstone Member, approximately 180 feet (55 m) thick, is described by Gill and others (1970) as consisting of pale-yellowish-gray cliff-forming sandstone. The upper unnamed member of the Haystack Mountains Formation is approximately 330 feet (101 m) thick. In this area and to the north near Rawlins it is composed of interbedded shale, siltstone, and sandstone (Gill and others, 1970). Thin coal beds are also present, occurring directly above the Hatfield Sandstone Member.

The Allen Ridge Formation conformably overlies the Haystack Mountains Formation and crops out along the eastern edge of the quadrangle (Barclay, 1977a). It is approximately 1,300 feet (396 m) thick and is subdivided into two informal members, a lower non-marine member about 1,130 feet (344 m) thick, and an upper marginal-marine member about 170 feet (52 m) thick (Barclay, 1979, oral communication). The lower non-marine member is largely composed of continental fluviatile deposits of thick lenticular sandstone beds, and thinly to thickly interbedded siltstone, sandstone, mudstone, and carbonaceous shale (Barclay and Shoaff, 1977). The upper member consists of marginal-marine lagoonal-paludal deposits of thick, bioturbated organic-rich brown shale, thin sandstone beds and coal (Barclay and Shoaff, 1978).

The Pine Ridge Sandstone, which unconformably overlies the Allen Ridge Formation (Gill and others, 1970), crops out in the eastern part of the quadrangle (Barclay, 1979a). According to Barclay and Shoaff (1978), the Pine Ridge is a continental fluviatile deposit consisting of sandstone and a subordinate amount of carbonaceous siltstone and mudstone. Because of the difficulty in recognizing this formation in outcrop, it has not been mapped in detail. An average thickness of about 80 feet (24.4 m) in this quadrangle is reported by Barclay (1979, oral communication).

The Almond Formation crops out in the eastern half of the quadrangle and is the most important coal-bearing formation of the Mesaverde Group (Barclay, 1979a). It is estimated to be about 450 feet (137 m) thick in this quadrangle and consists predominantly of marginal-marine, foreshore to coastal-plain paludal deposits (Barclay, 1979, written communication). Most of the coal beds occur in the lower part of the formation.

The Lewis Shale of Late Cretaceous age conformably overlies the Almond Formation and crops out in the central part of the quadrangle (Barclay, 1979a). The formation ranges in thickness from 2,170 to 2,210 feet (661 to 674 m) where penetrated by oil and gas wells in the adjacent Fillmore Ranch quadrangle. Further north in the Rawlins Peak 15-minute quadrangle, the formation is about 2,310 feet (704 m) thick in a section measured by Gill and others (1970) in sec. 14, T. 22 N., R. 89 W. Shale within the formation is gray to olive-gray, silty to sandy, and, locally, contains fossiliferous limestone or siltstone concretions. The middle and upper parts of the Lewis Shale contain a distinctive and widespread unit of interstratified sandstone and sandy shale called the Dad Sandstone Member, a tongue of the overlying Fox Hills Sandstone (Gill and others, 1970).

The Fox Hills Sandstone of Late Cretaceous age intertongues with the underlying marine Lewis Shale and with the overlying brackish-water and fluviatile sandstone and shale of the Lance Formation (Hettinger, 1979) The Fox Hills Sandstone is composed of approximately 150 to 170 feet (46 to 52 m) of thick units of pale-yellowish-gray, very fine to fine-grained friable sandstone, and thin units of olive-gray to dark-gray sandy shale (Gill and others, 1970). The formation contains minor coal beds where it crops out in the northwestern corner of the quadrangle (Hettinger, 1979).

The Lance Formation conformably overlies the Fox Hills Sandstone and is exposed in the northeastern corner of the quadrangle (Hettinger, 1979). Approximately 1,200 feet (366 m) of the formation is exposed, as calculated from the geologic map provided by Hettinger (1979). The Lance Formation ranges in thickness from 1,200 to 1,500 feet (366 to 457 m) where measured in oil and gas wells drilled in the Duck Lake quadrangle to the west. According to Haun (1961), the formation consists of a non-marine sequence of carbonaceous shale, sandstone, and siltstone with coal beds occuring immediately above the contact with the Fox Hills Sandstone.

The Browns Park Formation of Miocene age is present along the eastern edge of the quadrangle where it unconformably overlies Mesaverde Group strata (Barclay, 1979a). Its maximum thickness is probably between 60 and 80 feet (18.3 and 24.4 m), and it consists of pebble and cobble conglomerate and conglomeratic sandstone in the lower half and sandstone in the upper half (Barclay, 1979, written communication).

Active and inactive Holocene sand dunes cover a large part of the central area of the quadrangle, and Holocene deposits of alluvium cover the stream valleys of Olson Draw, Cow Creek, Muddy Creek, and their tributaries.

The Upper Cretaceous formations in the northeast quarter of the Doty Mountain 15-minute quadrangle indicate the transgressions and regressions of a broad, shallow, north-south-trending seaway that extended across central North America. These formations accumulated near the western edge of the sea and reflect the location of the shoreline. More particularly, the formations in the Mesaverde Group reflect the many fluctuations of the shoreline in a series of marine, marginal-marine, and non-marine beds deposited on or near eastwardly-prograding deltas (Weimer, 1960 and 1961).

In south-central Wyoming, the thick marine sandstones (the Deep Creek and Hatfield Sandstone Members) occurring in the Haystack Mountains Formation were deposited in nearshore and offshore environments as marine beach or barrier bar deposits. These alternate with marine shale (Espey Tongue) deposited in a deeper-water marine environment. The upper unnamed member of the Haystack Mountains Formation contains deposits of marine shale, beach sandstone, and lagoonal sandstone and mudstone (Gill and others, 1970).

All of the Allens Ridge Formation, except the upper marginal-marine member, was deposited in a non-marine fluvial environment (Barclay, 1979, oral communication).

The Pine Ridge Sandstone was deposited by meandering streams over a broad area of uplifted and eroded non-marine and marine rocks (Gill and others, 1970).

The Almond Formation consists predominantly of marginal-marine deposits. The lower part of the formation is characterized by thick coal beds, and the upper part by shale and sandstone deposited by alternating transgressive-regressive cycles, respectively, of a Late Cretaceous interior sea (Barclay and Shoaff, 1978).

Deposition of the Lewis Shale generally marks a landward progression of the Lewis sea, the final marine transgression of the Cretaceous. An exception is the Dad Sandstone Member which probably represents a later growth stage of the Rawlins delta within the Lewis Shale (Weimer, 1961, p. 27).

The Fox Hills Sandstone represents a transitional depositional environment between the deep-water marine environment of the Lewis Shale and the lagoonal and continental environments of the Lance Formation (Gill and others, 1970). Deposition of the Fox Hills Sandstone sediments occurred in shallow marine, barrier bar, beach, estuarine, and tidal channel environments (Land, 1972).

During the gradual recession of the last Cretaceous sea, marking the close of Cretaceous time, carbonaceous shales, mudstones, and coal beds of the Lance Formation were deposited in broad areas of estuarine, marsh, lagoonal, and coastal swamp environments (Land, 1972).

The basal conglomerate in the lower part of the Browns Park Formation contain pebble- to boulder-sized clasts derived from the Sierra Madre Range (Barclay, 1979, written communication). Subsequent minor uplift and erosion has significantly reduced the amount of area covered by the formation.

Structure

The northeast quarter of the Doty Mountain 15-minute quadrangle is located southeast of the Wamsutter Arch which divides the Washakie Basin to the south and the Great Divide Basin to the north. Throughout the quadrangle, the beds strike northeasterly and dip 8° to 17° to the northwest.

Three minor faults were mapped in this quadrangle by Barclay (1979a). Two are located in the northeastern corner and one in the south-central part of the quadrangle.

COAL GEOLOGY

Five formations contain coal in the northeast quarter of the Doty Mountain 15-minute quadrangle. They are, in ascending order, the Haystack Mountains, the Allen Ridge, the Almond, the Fox Hills, and the Lance Formations. In the Haystack Mountains Formation, two coal beds overlie the Hatfield Sandstone Member. These coal beds were not isopached because they are less than Reserve Base thickness (5.0 feet or 1.5

meters) where penetrated in oil and gas wells. The Allen Ridge Formation contains a few thin coal beds in the lower non-marine member and several in the upper marginal-marine member that underlies the Pine Ridge Sandstone. None of the Allen Ridge coal beds are of Reserve Base thickness. The Almond Formation is the most important coal-bearing formation in the quadrangle. Coal beds generally occur throughout the formation, but the most significant and widespread coals are located within the basal 150 feet (46 m) of the formation. Several coal beds of the Fox Hills Sandstone and Lance Formation were identified in the quadrangle, but only the Lance Formation contains a coal bed exceeding Reserve Base thickness.

Chemical analyses of coal.--Chemical analyses were not available for coals in the Lance, Almond, and Allen Ridge Formations in this quadrangle, but representative analyses from other parts of the proposed Rawlins (Little Snake River) KRCRA are listed in table 1. In general, coals of the Allen Ridge Formation rank as high-volatile C bituminous, coals of the Almond Formation rank subbituminous A, and coals of the Lance Formation rank subbituminous B on a moist, mineral-matter-free basis according to ASTM Standard Specification D 388-77 (American Society for Testing and Materials, 1977).

Coal Beds of the Almond Formation

Coal beds of the Almond Formation crop out in the eastern half of the quadrangle. With the exception of two coal beds, the Robertson and the Garden Gulch, bracketed numbers were used to identify coal beds of Reserve Base thickness in this quadrangle. Coal beds that are local and of limited areal extent are designated with the letter L (Local) on plates 1 and 3. The coal beds identified with bracketed numbers in this quadrangle may have a different designation in another quadrangle.

Robertson Coal Bed(s)

The Robertson coal bed, or zone of coal beds, is defined by Barclay (1979, oral communication) as the first areally persistant coal bed or zone of coal beds above the contact of the Almond Formation and the underlying Pine Ridge Sandstone. For the purpose of calculating Reserve Base tonnages, the Robertson bed is defined in this report as the first areally persistant coal bed above the Pine Ridge Sandstone that exceeds Reserve Base thickness. Other coal beds with an alpha-numeric designation may possibly be part of the Robertson zone of coal beds. The name of the coal bed was suggested by Barclay and was derived from the Robertson mine described by Ball and Stebinger (1910) in sec. 4, T. 17 N., R. 90 W.

In this quadrangle, information from drill-hole and measured-sections indicate that in the northern part, the Robertson coal bed (plate 7) occurs as a single bed with thicknesses that range from 6 to 19 feet (1.8 to 5.8 m). In the southern part of the quadrangle, the Robertson [2] coal bed ranges from 2.5 to 9.5 feet (0.8 to 2.9 m) thick as shown on plate 4.

In the adjacent southeast quarter of the Doty Mountain 15-minute quadrangle to the south, a coal bed identified as the Robertson [1] coal bed is introduced stratigraphically below the Robertson [2] coal bed. The Robertson [2] coal bed pinches out in the northern part of that quadrangle.

In the Fillmore Ranch quadangle to the north, the Robertson coal bed has been correlated with the Z coal bed. It occurs as a single coal bed with a maximum thickness of 18 feet (5.5 m).

Almond [Local 1] Coal Bed

The Almond [Local 1] coal bed lies approximately 15 feet (4.6 m) stratigraphically above the Robertston [2] coal bed in the southern part of this quadrangle. It is possible that this coal bed is a split of the Robertson coal bed, but more subsurface exploration in the central part of the quadrangle is necessary to confirm the correlation. This coal bed reaches a maximum measured thickness of 6 feet (1.8 m) as shown on plate 7, but averages only approximately 4.5 feet (1.4 m) in this quadrangle. It pinches out in the northern part of the southeast quarter of the Doty Mountain 15-minute quadrangle to the south.

Almond [1] Coal Bed

The Almond [1] coal bed occurs approximately 40 feet (12.2 m) stratigraphically above the Robertson coal bed and has been located only in the northern part of the quadrangle. This coal bed has been correlated with the Y coal bed in the Fillmore Ranch quadrangle to the north. In this quadrangle, the Almond [1] coal bed ranges in reported thicknesses from 3 to 16 feet (0.9 to 4.9 m), averaging approximately 12 feet (3.7 m) thick (plate 11). In the Fillmore Ranch quadrangle to the north, the Y bed averages 13 feet (4.0 m) thick where isopached in the quadrangle.

Almond [2] Coal Bed

The Almond [2] coal bed occurs in approximately the same stratigraphic interval as the Almond [1] coal bed, but is located in the southern part of the quadrangle. Lack of data in the central part of the quadrangle prevents the correlations of coal beds between the northern and southern parts. It is possible that the Almond [1] and [2] coal beds are equivalent in this quadrangle, but additional geologic data is required for verification. The Almond [2] coal bed ranges in thickness from 8 to 14 feet (2.4 to 4.3 m) where measured in drill holes in this quadrangle as shown on plate 11. However, to the south in the southwest quarter of the Doty Mountain 15-minute quadrangle where this coal bed is designated as the Almond [1], the maximum measured thickness is 15 feet (4.6 m).

Almond [3] Coal Bed

The Almond [3] coal bed is located in the northern part of the quadrangle, occuring approximately 30 feet (9 m) stratigraphically above the Almond [1] coal bed. This coal bed has been correlated with the X coal bed in the Fillmore Ranch quadrangle to the north. The average thickness of the Almond [3] coal bed is 6 feet (1.8 m) where measured in drill holes in this quadrangle (plate 15). In the Fillmore Ranch quadrangle, the X coal bed attains a maximum measured thickness of 9.5 feet (2.9 m), thinning gradually to the north.

Almond [4] Coal Bed

The Almond [4] coal bed and the Almond [3] coal bed occur at approximately the same stratigraphic interval; however, the lack of data in the central part of the quadrangle prevents correlation. The Almond [4] coal bed is located in the southern part of the quadrangle (plate 15) while the Almond [3] coal bed is located in the northern part of the quadrangle. The Almond [4] coal bed is equivalent to the Almond [2] coal bed in the southeast quarter of the Doty Mountain 15-minute quadrangle to the south. In this quadrangle, the Almond [4] coal bed ranges in thickness from 2 to 5.5 feet (0.6 to 1.7 m). To the south, in the southeast quarter of the Doty Mountain 15-minute quadrangle, the Almond [2] coal bed thickens and thins irregularly, having a maximum reported thickness of 10 feet (3.0 m) in the southern part of the quadrangle.

Coal Beds of the Lance Formation

Coal beds in the Lance Formation crop out in the northwestern corner of the quadrangle. Only one coal bed, the Lance [1], exceeds Reserve Base thickness.

Lance [1] Coal Bed

The Lance [1] coal bed occurs at the base of the Lance Formation overlying the Fox Hills Sandstone. Measured sections by Hettinger (1979) indicate that the coal bed is commonly split with a maximum interburden thickness of 38 feet (11.6 m). Where the coal bed is not split, the maximum thickness is 16.5 feet (5.0 m), excluding a parting 1.0 foot (0.3 m) thick. Where the coal bed splits, the lower split attains a maximum measured thickness of 7.5 feet (2.3 m) and the upper split reaches a maximum thickness of 9.3 feet (2.8 m). Numerous partings of up to 3 feet (0.9 m) thick are present in the coal splits. The isopach map of the Lance [1] coal bed, including its lower split, is shown on plate 4; the isopach map of its upper split is shown on plate 7. In the Fillmore Ranch quadrangle to the north, measurements of Lance Formation coal greater than Reserve Base thickness were treated as isolated data points because of a general lack of data.

COAL RESOURCES

Information from oil and gas wells, coal test holes from Rocky Mountain Energy Company (Barclay, 1979b) and the U.S. Geological Survey, and measured sections (Hettinger, 1979) were used to construct outcrop, isopach, and structure contour maps of the coal beds in this quadrangle.

Coal resources were calculated using data obtained from the coal isopach maps (plates 4, 7, 11, and 15). The coal bed acreage (measured by planimeter) multiplied by the average isopached thickness of the coal bed, and by a conversion factor of 1,770 short tons of coal per acre-foot (13,018 metric tons per hectare-meter) for subbituminous coal or 1,800 short tons of coal per acre-foot (13,238 metric tons per hectare-meter) for bituminous coal yields the coal resources in short tons for each isopached coal bed. Coal beds thicker than 5 feet (1.5 m) that lie less than 3,000 feet (914 m) below the ground surface are included. These criteria differ somewhat from those used in calculating Reserve Base and Reserve tonnages as stated in U.S. Geological Survey Bulletin 1450-B which calls for a minimum thickness of 28 inches (70 cm) for bituminous coal and a maximum depth of 1,000 feet (305 m) for both bituminous and subbituminous coal.

Reserve Base and Reserve tonnages for the isopached beds are shown on plates 6, 10, 14, and 17, and are rounded to the nearest 10,000 short tons (9,072 metric tons). Coal Reserve Base tonnages per Federal section are shown on plate 2 and total approximately 154.91 million short tons (140.53 million metric tons) for the entire quadrangle. Reserve Base tonnages in the various development potential categories for surface and subsurface mining methods are shown in tables 2 and 3. The source of each indexed data point shown on plate 1 is listed in table 4.

Dames & Moore has not made any determination of economic recoverability for any of the coal beds described in this report.

COAL DEVELOPMENT POTENTIAL

Coal development potential areas are drawn so as to coincide with the boundaries of the smallest legal land subdivisions shown on plate 2. In sections or parts of sections where no land subdivisions have been surveyed by the BLM, approximate 40-acre (16-ha) parcels have been used to show the limits of the high, moderate, or low development potentials. A constraint imposed by the BLM specifies that the highest development potential affecting any part of a 40-acre (16-ha) lot, tract, or parcel be applied to that entire lot, tract, or parcel. For example, if 5 acres (2 ha) within a parcel meet criteria for a high development potential, 25 acres (10 ha) a moderate development potential, and 10 acres (4 ha) a low development potential, then the entire 40 acres (16 ha) are assigned a high development potential.

Development Potential for Surface Mining Methods

Areas where the coal beds of Reserve Base thickness are overlain by 200 feet (61 m) or less of overburden are considered to have potential for surface 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 surface mining of coal is shown below:

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

where MR = mining ratio

t_o = thickness of overburden in feet

t_c = thickness of coal in feet

rf = recovery factor (85 percent for this quadrangle)

cf = conversion factor to yield MR value in terms of cubic yards of overburden per short tons of recoverable coal:
0.911 for subbituminous coal
0.896 for bituminous coal

Note: To convert mining ratio to cubic meters of overburden per metric ton of recoverable coal, multiply MR by 0.8428.

Areas of high, moderate, and low development potential for surface mining methods are defined as areas underlain by coal beds having respective mining ratio values of 0 to 10, 10 to 15, and greater than 15. These mining ratio values for each development potential category are based on economic and technological criteria and were provided by the U.S. Geological Survey.

Areas where the coal data is absent or extremely limited between the 200-foot (61-m) overburden line and the outcrop are assigned unknown development potentials for surface mining methods. This applies to areas where coal beds 5 feet (1.5 m) or more thick are not known, but may occur. Limited knowledge pertaining to the areal distribution, thickness, depth, and attitude of the coal beds in these areas prevents accurate evaluation of the development potential in the high, moderate, or low categories.

The coal development potential for surface mining methods is shown on plate 18. Of the Federal land areas having a known development potential for surface mining methods, 66 percent are rated high, 15 percent are rated moderate, and 19 percent are rated low. The remaining Federal lands within the proposed KRCRA boundary are classified as having unknown development potential for surface mining methods.

Development Potential for Subsurface and In-Situ Mining Methods

Areas considered to have a development potential for conventional subsurface mining methods are those areas where the coal beds of Reserve Base thickness are between 200 and 3,000 feet (61 and 914 m) below the ground surface and have dips of 15° or less. Coal beds lying between 200 and 3,000 feet (61 and 914 m) below the ground surface, dipping greater than 15°, are considered to have a development potential for in-situ mining methods.

Areas of high, moderate, and low development potential for subsurface mining methods are defined as areas underlain by coal beds at depths ranging from 200 to 1,000 feet (61 to 305 m), 1,000 to 2,000 feet (305 to 610 m), and 2,000 to 3,000 feet (610 to 914 m), respectively.

Areas where the coal data is absent or extremely limited between 200 and 3,000 feet (61 and 914 m) below the ground surface are assigned unknown development potentials. This applies to areas where coal beds of Reserve Base thickness are not known, but may occur.

The coal development potential for subsurface mining methods is shown on plate 19. All of the Federal land areas having a known development potential for conventional subsurface mining methods are rated high. The remaining Federal land within the proposed KRCRA boundary is classified as having unknown development potential for conventional subsurface mining methods.

Because the coal beds in this quadrangle have dips less than 15°, all Federal land areas within the proposed KRCRA boundary have been rated as having unknown development potential for in-situ mining methods.

Table 1. -- Chemical analyses of coals in the northeast quarter of the Doty Mountain 15-minute quadrangle, Carbon County, Wyoming.

Location	COAL BED NAME	Form of Analysis	Proximate				Ultimate					Heating Value	
			Moisture	Volatile Matter	Fixed Carbon	Ash	Sulfur	Hydrogen	Carbon	Nitrogen	Oxygen	Calories	Btu/Lb
NE¼, SW¼, sec. 6, T. 20 N., R. 88 W., Old Nebraska Mine (Ball, 1909)	Lance-Fox Hills Formation, undifferentiated	A	19.20	36.46	40.56	3.78	0.34	5.74	58.88	1.34	29.92	5,401	9,722
		B	17.30	37.32	41.51	3.87	0.35	5.61	60.27	1.37	28.53	5,528	9,951
Average of 21 samples from Little Snake River coal field (Hatch and Barcley, 1979)	Almond Formation, undifferentiated	A	15.4	28.6	37.6	18.7	0.6	5.1	49.4	1.1	25.1	4,731	8,510
Southeastern part of the Rawlins KRCRA (Ball and Stebinger, 1910)	Allen Ridge Formation, undifferentiated	A	-	-	-	6.94	2.25	-	-	-	-	-	11,218

Form of Analysis: A, as received
B, air dried

Note: To convert Btu/pound to kilojoules/kilogram, multiply by 2.326

Table 2. -- Coal Reserve Base data for surface mining methods for Federal coal lands (in short tons) in the northeast quarter of the Doty Mountain 15-minute quadrangle, Carbon County, Wyoming.

Coal Bed or Zone	High Development Potential	Moderate Development Potential	Low Development Potential	Unknown Development Potential	Total
Lance {1}	90,000	60,000	50,000	-	200,000
Almond {4}	-0-	60,000	630,000	-	690,000
Almond {3}	90,000	50,000	1,410,000	-	1,550,000
Almond {2}	8,500,000	8,440,000	3,160,000	-	20,100,000
Almond {1}	1,710,000	1,490,000	260,000	-	3,460,000
Almond {Local 1}	160,000	120,000	1,090,000	-	1,370,000
Robertson {2}	330,000	240,000	930,000	-	1,500,000
Robertson	880,000	750,000	600,000	-	2,230,000
Totals	11,760,000	11,210,000	8,130,000	-	31,100,000

NOTE: To convert short tons to metric tons, multiply by 0.9072.

Table 3. -- Coal Reserve Base data for subsurface mining methods for Federal coal lands (in short tons) in the northeast quarter of the Doty Mountain 15-minute quadrangle, Carbon County, Wyoming.

Coal Bed or Zone	High Development Potential	Moderate Development Potential	Low Development Potential	Unknown Development Potential	Total
Lance {1}	270,000	-	-	-	270,000
Almond {4}	3,230,000	-	-	-	3,230,000
Almond {3}	2,100,000	-	-	-	2,100,000
Almond {2}	69,080,000	-	-	-	69,080,000
Almond {1}	8,910,000	-	-	-	8,910,000
Almond {Local 1}	5,830,000	-	-	-	5,830,000
Robertson {2}	17,660,000	-	-	-	17,660,000
Robertson	16,730,000	-	-	-	16,730,000
Totals	123,810,000	-	-	-	123,810,000

NOTE: To convert short tons to metric tons, multiply by 0.9072.

Table 4. -- Sources of data used on plate 1

Plate 1 Index Number	Source	Data Base
1	Barclay, 1979c, U.S. Geological Survey open-file report, in preparation	Drill hole No. DM-D35
2	Barclay and Zimmerman, 1976, U.S. Geological Survey, Open-File Report 76-510	Drill hole No. DM-D14
3	Barclay, 1979c, U.S. Geological Survey open-file report, in preparation	Drill hole No. DM-D13
4	U.S. Natural Gas Corp.	Oil/gas well, Horse Gulch Unit No. 1
5	Barclay, 1979c, U.S. Geological Survey open-file report, in preparation	Drill hole No. DM-D15
6	↓	Drill hole No. DM-D36
7		Drill hole No. DM-D38
8	Ball and Stebinger, 1909, U.S. Geological Survey Bulletin 381-B, p. 201	Measured Section No. 5340
9	Barclay, 1979b, U.S. Geological Survey, written communication	Drill hole No. 1AS
10	↓	Drill hole No. 2AS
11	McCulloch Oil Corp.	Oil/gas well No. 1 State-Tuttle
12	Carter and Carter	Oil/gas well No. 30-1 Gov't

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Table 4. -- Continued

Plate 1 Index Number	Source	Data Base
13	Barclay 1979b, U.S. Geological Survey, written communication	Drill hole No. 3AS
14	↓	Drill hole No. 142
15	↓	Drill hole No. 141
16	↓	Drill hole No. 1As
17	↓	Drill hole No. 4RW-7
18	↓	Drill hole No. 140
19	↓	Drill hole No. 2As
20	Hettinger, 1979, U.S. Geological Survey, written communication	Measured Section No. 1
21	↓	Measured Section No. 2
22	↓	Measured Section No. 3
23	↓	Measured Section No. 4
24	↓	Measured Section No. 5
25	↓	Measured Section No. 6
26	↓	Measured Section No. 7

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