Text to Accompany:

Open-File Report 79-1032

1979

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

[Report includes 28 plates]

Prepared for

UNITED STATES DEPARTMENT OF THE INTERIOR

GEOLOGICAL SURVEY

By

DAMES & MOORE

DENVER, COLORADO

CONTENTS

ILLUSTRATIONS

Illustrations--Continued

TABLES

INTRODUCTION

Purpose

This text is to be used in conjunction with Coal Resource Occurrence (CRO) and Coal Development Potential (CDP) Maps of the southeast 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 Published and unpublished public information available through May, 1979, was used as the data base for this study.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 southeast quarter of the Doty Mountain 15-minute quadrangle, which is located in southwestern Carbon County approximately 15 airline miles (24 km) north of the town of Baggs, and 32 airline miles (51 km) southwest of the city of Rawlins, Wyoming. The J. O. Ranch, which is only seasonally occupied, is located in the northwestern corner of the quadrangle.

Accessibility

A light-duty road connecting Wyoming Highway 789 to the southwest with Rawlins to the northeast crosses the northwestern corner of the quadrangle, and a second light-duty road crosses the southern third of the quadrangle. Interstate Highway 80, passing east-west through the city of Rawlins, lies about 26 miles (42 km) to the north of the quadrangle. Numerous dirt roads and trails provide access to the remainder of the quadrangle (U.S. Bureau of Land Management, 1971; Wyoming State Highway Commission, 1978).

The main east-west line of the Union Pacific Railroad crosses 25 miles (40 km) to the north of the quadrangle. This line, which connects Ogden, Utah, to the west with Omaha, Nebraska, to the east, provides railroad service across southern Wyoming.

Physiography

The southwest quarter of the Doty Mountain 15-minute quadrangle lies on the eastern rim of the Washakie Basin and the western flank of the Sierra Madre uplift. The landscape is characterized by high plateaus and ridges cut by deep canyons and ravines. Altitudes in the quadrangle range from less than 6,520 feet (1,987 m) on Wild Cow Creek in the southwestern corner, to 7,931 feet (2,417 m) on Cow Creek Butte in the northeastern corner of the quadrangle.

The southern third of the quadrangle is drained by Wild Cow Creek and Cherokee Creek. Cow Creek and its principal tributaries, Deep Gulch and Garden Gulch, drain the middle and northern parts of the quadrangle. All streams in the quadrangle flow westerly into Muddy Creek west of the quadrangle boundary. Streams in the quadrangle are intermittent and flow mainly in response to snowmelt in the spring.

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 southeast quarter of the Doty Mountain 15-minute quadrangle lies in the southeastern part of the proposed Rawlins (Little Snake River) Known Recoverable Coal Resource Area (KRCRA). Approximately 95 percent of the quadrangle lies within the proposed KRCRA boundary and the Federal government owns the coal rights for approximately nine-tenths of the 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. Barclay and Zimmerman (1976) and Barclay and Shoaff (1977) presented correlation diagrams for Almond Formation coal beds and discussed the stratigraphy of the Mesaverde Group in their reports on the results of coal-drilling by the U.S. Geological Survey in the southern part of the proposed Rawlins (Little Snake River) KRCRA during 1975 and 1976. In the classification minutes for the proposed Rawlins (Little Snake River) KRCRA, Barclay and others (1978) showed the distribution and discussed the stratigraphy of the coal-bearing formations in the KRCRA. Reports on more recent drilling in the area are being prepared (Barclay, 1979a and 1979b) and detailed geologic mapping in this quadrangle is in progress.

Stratigraphy

The rock formations exposed in the southeast quarter of the Doty Mountain 15-minute quadrangle range in age from Late Cretaceous to Miocene, and crop out across the quadrangle in bands that trend northeast to southeast. Only the Almond and Allen Ridge Formations of Late Cretaceous age are coal-bearing within the quadrangle.

The Steele Shale of Late Cretaceous age is present in the subsurface of the quadrangle. In south-central Wyoming, the Steel 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 1,600 to 3,000 feet (488 to 914 m) in oil and gas wells drilled in 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 (Gill and others, 1970).

The Haystack Mountains Formation is found in the subsurface of the quadrangle and can be divided 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 (Hale, 1961; Gill and others, 1979). Gill (1974) measured a total thickness of 953 feet (290 m) to the south in the Browns Hill quadrangle and his section is described below. The Deep Creek Sandstone Member is approximately 125 feet (38 m) thick in the measured section by Gill (1974) and is composed almost entirely of sandstone. The Espy Tongue, genetically a tongue of the Steele Shale, is approximately 315 feet (96 m) thick and consists of marine shale, limestone concretions, and thin sandstone beds. 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 measures approximately 153 feet (47 m) thick and consists of pale-yellowish-gray, thick cliff-forming regressive-marine sandstone units separated by much thinner intervals of slope-forming marine shales. The upper unnamed member of the Haystack Mountains Formation is composed of two sequences of transgressive-marine slope-forming shale, grading up into regressive-marine cliff-forming sandstone and is about 360 feet (110 m) thick. As interpreted from geophysical logs of oil and gas wells, several thin coal beds occur above the Hatfield Sandstone Member in this quadrangle.

The Allen Ridge Formation conformably overlies the Haystack Mountains Formation, and the upper part of the formation crops out along the eastern edge of the quadrangle (Barclay, 1979c). It is approximately 1,280 feet (390 m) thick and is subdivided into two members. The lower non-marine member is about 1,100 feet (335 m) thick, and the upper marginal-marine member is approximately 180 feet (55 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 shales, 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 along the eastern edge of the quadrangle (Barclay, 1979c). 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 55 feet (16.8 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 in the quadrangle (Barclay, 1979c). It is estimated to be approximately 460 feet (140 m) thick in this quadrangle (Barclay and Zimmerman, 1976), and it 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 the lower 600 feet (183 m) crop out along the western edge of this quadrangle (Barclay, 1979c). In south-central Wyoming, the shale of the Lewis 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 Dad Sandstone does not crop out in the quadrangle (Barclay, 1979, written communication).

The Browns Park Formation of Miocene age is the youngest formation in the quadrangle and crops out on high buttes and ridges near the eastern edge of the quadrangle where it unconformably overlies beds of the Mesaverde Group (Barclay, 1979c). The maximum measured thickness of the formation is 160 feet (49 m), exposed at Cow Creek Butte and consists of pebble and cobble conglomerate and conglomeratic sandstone in the lower part and sandstone in the upper part (Barclay, 1979, written communication).

Holocene deposits of alluvium cover the stream valleys of Cow Creek, Wild Cow Creek, Cherokee Creek, and their tributaries. Quaternary landslide deposits occur in terrain underlain by Mesaverde Group strata but are not extensive. Rare Pleistocene deposits of gravel occur on the sides of Deep Gulch (Barclay, 1979, written communication).

The Upper Cretaceous formations in the southeast 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 (Espy 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 Allen 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 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 basal conglomerate of the Browns Park Formation contains clasts derived from the Sierra Madre Range and is probably an alluvial fan or pediment deposit (Barclay, 1979, written communication). Minor uplift and subsequent erosion has significantly reduced the amount of area originally covered by the formation.

Structure

The southeast quarter of the Doty Mountain 15-minute quadrangle is located east of the Wamsutter Arch which divides the Washakie Basin to the south and the Great Divide Basin to the north. The strike of the beds is northeast in the northern part of the quadrangle and southeast in the southern part of the quadrangle. The dip of the beds averages 5° to the west.

A number of east-west trending faults in the quadrangle were mapped by Barclay (1979c). In the central part of the quadrangle, drill-hole information indicates the presence of a doubly-plunging anticline with an axis that trends north-south.

COAL GEOLOGY

Three formations -- the Haystack Mountains, Allen Ridge and Almond -- contain coal in the southeast quarter of the Doty Mountain 15-minute quadrangle. The Haystack Mountains Formation contains several thin coal beds that are less than 3 feet (0.9 m) thick. The Allen Ridge Formation contains a few thin coal beds in the lower non-marine member and several in the upper marine member, but none exceed Reserve Base thickness (5 feet or 1.5 m). The Almond Formation contains significant coal beds in its lower 150 feet (46 m). Six coal beds in the Almond Formation are isopached in this quadrangle. Three other coal beds exceeding Reserve Base thickness were encountered at one location only and have been treated as isolated data points (see Isolated Data Points section of this report).

Chemical analyses of coals.--Chemical analyses were not available for coals in the Almond and Allen Ridge Formations in this quadrangle, but representative analyses from other parts of the Rawlins (Little Snake

River) KRCRA are listed in table 1. In general, coals in the Almond Formation rank as subbituminous A and coals from the Allen Ridge Formation rank as high-volatile C bituminous on a moist, mineral-matter-free basis according to ASTM Standard Specification D 388-77 (American Society for Testing and Materials, 1977).

Dotted lines shown on some of the derivative maps represent a limit of confidence beyond which isopach, structure contour, overburden isopach and mining ratio, and areal distribution and identified resources maps are not drawn because of insufficient data, although it is believed that the coal beds may continue to be greater than Reserve Base thickness beyond the dotted lines.

Coal Beds of the Almond Formation

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

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 the northeast quarter of the Doty Mountain 15-minute quadrangle. Two coal beds, the Robertson [1] and the Robertson [2] have been identified in this quadrangle.

The Robertson [1], the lower of the two Robertson coal beds, is thick and extends over most of the quadrangle, as shown on plate 4 (Barclay, 1979c). It ranges in thickness from 2 to 16 feet (0.6 to 4.9 m) where measured along the outcrop and in drill holes, averaging approximately 10 feet (3.0 m) in thickness in the central part of the quadrangle and thinning to the north and south. Shale partings are not common in this coal bed, but thin partings ranging from 0.5 to 2.0 feet (0.2 to 0.6 m) thick have been reported at isolated locations.

The Robertson [2] coal bed is introduced stratigraphically above the Robertson [1] in the northern part of this quadrangle (plate 8) and it ranges in thickness from 2.0 feet (0.6 m) to a maximum of 5.5 feet (1.7 m), excluding a rock parting that is 1.0 feet (0.3 m) thick. This coal bed extends north into the northeast quarter of the Doty Mountain 15-minute quadrangle where measured thicknesses ranging from 2.5 to 9.5 feet (0.8 to 2.9 m) have been reported.

In general, the Robertson coal bed(s) appear to be laterally persistent over a wide area. It has been tentatively identified in oil and gas wells at a depth of 1,400 feet (427 m) in the southwest quarter of the Doty Mountain 15-minute quadrangle to the west, and has been traced south into the Baggs 15-minute quadrangle.

Almond [Local 3] Coal Bed

The Almond [Local 3] coal bed is 36 feet (11.0 m) stratigraphically above the Robertson [1] coal bed. It is 6 feet (1.8 m) thick where measured in a single oil and gas well in sec. 22, T. 16 N., R. 91 W. (plate 11). In the southwest quarter of the Doty Mountain 15-minute quadrangle to the west, this coal bed is designated the Almond [2] and ranges in thickness from 4 to 7 feet (1.2 to 2.4 m).

Almond [Local 1] Coal Bed

The Almond [Local 1] coal bed is located along the northern edge of the quadrangle and lies approximately 15 feet (4.6 m) stratigraphically above the Robertson [2] coal bed. It ranges from 1 to 5 feet (0.3 to 1.5 m) in thickness where penetrated by drill holes, and is isopached in the northeast corner of the quadrangle (plate 11) based on data projected from the northeast quarter of the Doty Mountain 15-minute quadrangle. In that quadrangle, the coal bed has a maximum thickness of 6 feet (1.8 m).

Almond [1] Coal Bed

The Almond [1] coal bed lies approximately 70 to 115 feet (21 to 35 m) stratigraphically above the Robertson [1] coal bed. This coal bed is thick and extensive over the northern and southern parts of the quadrangle as shown on plate 14. It ranges in thickness from 2.5 to 15 feet (0.8 to 4.6 m) in the southern half of the quadrangle with an average thickness of approximately 8 feet (2.4 m). In the northern part of the quadrangle, this coal bed has a maximum measured thickness of 14 feet (4.3 m) and averages about 10 feet (3.0 m) in thickness. Rock partings are not common in this coal bed although a few have been reported that range from 0.5 to 4.0 feet (0.2 to 1.2 m) thick at isolated locations.

Extending into adjacent quadrangles to the north, west, and south, this coal bed maintains thicknesses averaging from 8 to 11.5 feet (2.4 to 3.5 m). To the north in the northeast quarter of the Doty Mountain 15-minute quadrangle, this coal bed is designated the Almond [2] and ranges in thickness from 8 to 14 feet (2.4 to 4.3 m). In the southwest quarter of the Doty Mountain 15-minute quadrangle to the west, the coal bed is equivalent to the Almond [4] and has a maximum reported thickness of 16 feet (4.9 m). To the south in the northeast quarter of the Baggs 15-minute quadrangle, this coal bed has the same Almond [1] designation and ranges in thickness from 3.5 to 13 feet (1.1 to 4.0 m).

Almond [Local 2] Coal Bed

The Almond [Local 2] coal bed is located in the east-central part of the quadrangle (plate 8) and does not correlate with coal beds in adjacent quadrangles. The coal bed ranges in thickness from 4 to 7 feet (1.2 to 2.1 m) where identified in four coal test holes.

Almond [2] Coal Bed

The Almond [2] coal bed occurs from 60 to 115 feet (18 to 35 m) stratigraphically above the Almond [1] coal bed. The Almond [2] coal bed is equivalent to the Almond [4] coal bed in the northeast quarter of the Doty Mountain 15-minute quadrangle, the Almond [3] in the Browns Hill quadrangle, and the Almond [2] coal bed in the southwest quarter of the Doty Mountain and the northeast quarter of the Baggs 15-minute quadrangles.

In the southern half of the quadrangle, the Almond [2] coal bed is split by as much as 10 feet (3.0 m) of rock near the outcrop, but the split thins to the west and south. North and east of the split lines (plate 18), cumulative coal thicknesses range from 3.5 to 10 feet (1.1 to 3.0 m); south and west of the split lines, the Almond [2] is a single bed with thicknesses ranging from 8.5 to 10 feet (2.6 to 3.0 m). The lower split averages approximately 3.5 feet (1.1 m) thick with a maximum measured thickness of 8.5 feet (2.6 m). The upper split averages approximately 4.2 feet (1.3 m) thick and has a maximum measured thickness of 6 feet (1.8 m). Except for a thickness of 10 feet (3.0 m) recorded in one drill hole in sec. 12, T. 16 N., R. 91 W., the coal bed is less than Reserve Base thickness over most of the northern half of the quadrangle.

To the south in the northeast quarter of the Baggs 15-minute quadrangle, the Almond [2] coal bed ranges in thickness from 3.5 to 11.0 feet (1.1 to 3.4 m) and contains occasional thin rock partings that are neither significant nor persistent.

Almond [Local 4] Coal Bed

The Almond [Local 4] coal bed lies about 30 feet (9.1 m) stratigraphically above the Almond [1] coal bed, where identified in one oil and gas well in sec. 22, T. 16 N., R. 91 W., and has a measured thickness of 10 feet (3.0 m) as shown on plate 8. In the southwest quarter of the Doty Mountain 15-minute quadrangle to the west, the Almond [Local 4] coal bed is equivalent to the Almond [6] coal bed and ranges in thickness from 5 to 13 feet (1.5 to 4.0 m).

Garden Gulch Coal Bed

The Garden Gulch (Barclay, 1979c) coal bed crops out over much of the northern half of the quadrangle and ranges in thickness from 1.0 to 6.5 feet (0.3 to 2.0), as shown on plate 23. Rock partings, ranging from 0.5 to 4.5 feet (0.2 to 1.4 m), have been reported at many locations. This coal bed extends into the northeast quarter of the Doty Mountain 15-minute quadrangle to the north, but is not known to exceed Reserve Base thickness in that quadrangle.

Isolated Data Points

In instances where single or isolated measurements of coal beds thicker than 5 feet (1.5 m) are encountered, the standard criteria for construction of isopach, structure contour, mining ratio, and overburden isopach maps are not available. The lack of data concerning these beds limits the extent to which they can be reasonably projected in any direction and usually precludes correlations with other, better known beds. For this reason, isolated data points are included on a separate sheet (in U.S. Geological Survey files) for non-isopached coal beds. The isolated data points occurring in this quadrangle are listed below. Coal beds identified by bracketed numbers are not formally named, but have been given bracketed numbers for identification purposes in this quadrangle only.

Source	Location	Coal Bed	Thickness
U.S. Natural Gas Corp.	sec. 10, T. 15 N., R. 91 W.	Al[L7]	8 ft (2.4 m)
Barclay, 1979b, U.S. Geological Survey, unpublished data	sec. 20, T. 15 N., R, 90 W.	Al[L6]	6 ft (1.8 m)
Davis Oil Co.	sec. 22, T. 16 N., R. 91 W.	Al[L5]	7 ft (2.1 m)

COAL RESOURCES

Information from oil and gas wells, coal test holes drilled by the U.S. Geological Survey, and measured sections by Barclay (1979c), were used to construct outcrop, isopach, and structure contour maps of the coal beds in the southeast quarter of the Doty Mountain 15-minute quadrangle.

Coal resources were calculated using data obtained from the coal isopach maps (plates 4, 8, 11, 14, 18, and 23). 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 7, 10, 13, 17, 22, and 26, and are rounded to the nearest 10,000 short tons (9,072 metric tons). Only Reserve Base tonnages (designated as inferred resources) are calculated for areas influenced by isolated data points. Coal Reserve Base tonnages per Federal section are shown on plate 2 and total approximately 915.95 million short tons (830.95 million metric tons) for the entire quadrangle, including tonnages from the isolated data points. 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, and to those areas influenced by isolated data points. Limited knowledge pertaining to the areal distribution, thickness, depth, and attitude of the coals in these areas prevents accurate evaluation of the development potential in the high, moderate, or low categories. The areas influenced by isolated data points in this quadrangle contain approximately 1.73 million short tons (1.57 million metric tons) of coal available for surface mining.

The coal development potential for surface mining methods is shown on plate 27. Of the Federal land areas having a known development potential for surface mining methods, 68 percent are rated high, 13 percent is 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. Unfaulted 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 those areas influenced by isolated data points and to the areas where coal beds of Reserve Base thickness are not known, but may occur. The areas influenced by isolated data points in this quadrangle contain approximately 13.14 million short tons (11.92 million metric tons) of coal available for conventional subsurface mining.

The coal development potential for subsurface mining methods is shown on plate 28. Of the Federal land areas having a known development potential for conventional subsurface mining methods, approximately 99 percent are rated high, and 1 percent are rated moderate. The remaining Federal land within the proposed KRCRA boundary is classified as having unknown development potential for conventional subsurface mining methods.

Areas where coal beds dip in excess of 15° have also been assigned an unknown development potential for conventional subsurface mining methods in this quadrangle. These areas could have been rated for in-situ development potential, but since only 1.83 million short tons (1.66 million metric tons) may be available for the in-situ process, both surface and conventional subsurface mining methods take precedence in this case.

Based on criteria provided by the U.S. Geological Survey, coal beds of Reserve Base thickness dipping between 15° and 35°, regardless of tonnage, have low development potential for in-situ mining methods. Coal lying between the 200-foot (61-m) overburden isopach and the outcrop is not included in total coal tonnages available because it is needed for cover and containment in the in-situ process.

All of the Federal lands where the dip of the coal beds exceeds 15° are rated low for in-situ development potential because only approximately 1.83 million short tons (1.66 million metric tons) of coal distributed through two different coal beds are believed to be available for in-situ mining. The remaining Federal lands within the proposed KRCRA boundary are classified as having unknown development potential for in-situ mining methods.

Table 1. -- Chemical analyses of coals in the southeast 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
Average of 21 samples from Little Snake River coal field (Hatch and Barclay, 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
C, moisture free

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 southeast Doty Mountain quadrangle, Carbon County, Wyoming.

Coal Bed or Zone	High Development Potential	Moderate Development Potential	Low Development Potential	Unknown Development Potential	Total
Garden Gulch	14,080,000	20,550,000	14,790,000	-0-	49,420,000
Almond {Local 4}	-0-	-0-	-0-	-0-	-0-
Almond {2}	9,920,000	13,650,000	35,590,000	-0-	59,160,000
Almond {Local 2}	1,770,000	1,260,000	5,460,000	-0-	8,490,000
Almond {1}	14,330,000	11,080,000	21,420,000	-0-	46,830,000
Almond {Local 1}	100,000	220,000	840,000	-0-	1,160,000
Almond {Local 3}	-0-	-0-	-0-	-0-	-0-
Robertson {2}	50,000	120,000	460,000	-0-	630,000
Robertson {1}	22,330,000	12,930,000	18,270,000	-0-	53,530,000
Isolated Data Points	-0-	-0-	-0-	1,730,000	1,730,000
Totals	62,580,000	59,810,000	96,830,000	1,730,000	220,950,000

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 southeast Doty Mountain quadrangle, Carbon County, Wyoming.

Coal Bed or Zone	High Development Potential	Moderate Development Potential	Low Development Potential	Unknown Development Potential	Total
Garden Gulch	440,000	-0-	-0-	-0-	440,000
Almond {Local 4}	10,300,000	-0-	-0-	-0-	10,300,000
Almond {2}	122,700,000	-0-	-0-	1,230,000*	123,930,000
Almond {Local 2}	410,000	-0-	-0-	-0-	410,000
Almond {1}	277,620,000	-0-	-0-	600,000*	278,220,000
Almond {Local 1}	450,000	-0-	-0-	-0-	450,000
Almond {Local 3}	6,570,000	-0-	-0-	-0-	6,570,000
Robertson {2}	3,050,000	-0-	-0-	-0-	3,050,000
Robertson {1}	258,490,000	-0-	-0-	-0-	258,490,000
Isolated Data Points	-0-	-0-	-0-	13,140,000	13,140,000
Totals	680,030,000	-0-	-0-	14,970,000	695,000,000

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

*Tonnages for coal beds dipping greater than 15 degrees.

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

Plate 1 Index Number	Source	Data Base
1	Barclay and Shoaff, 1977, U.S. Geological Survey Open-File Report 77-171	Drill hole No. DM-D25
2	Barclay, 1979b, U.S. Geological Survey open-file report, in preparation	Drill hole No. DM-D64
3	↓	Drill hole No. DM-D48
4	↓	Drill hole No. DM-D65
5	↓	Drill hole No. DM-D32
6	↓	Drill hole No. DM-D60
7	↓	Drill hole No. DM-D51
8	Kissinger Petroleums Corp.	Oil/gas well No. 4-10 Federal
9	Barclay, 1979b, U.S. Geological Survey open-file report, in preparation	Drill hole No. DM-D50
10	Barclay and Zimmerman, 1976, U.S. Geological Survey Open-File Report 76-510	Drill hole No. DM-D26
11	Barclay, 1979b, U.S. Geological Survey open-file report, in preparation	Drill hole No. DM-D52
12	Barclay and Zimmerman, 1976, U.S. Geological Survey Open-File Report 76-510	Drill hole No. DM-D27A
13	↓	Drill hole No. DM-D27
14	Barclay, 1979b, U.S. Geological Survey open-file report, in preparation	Drill hole No. DM-D53
15	Barclay and Zimmerman, 1976, U.S. Geological Survey Open-File Report 76-510	Drill hole No. DM-D28

Page 1 of 5

Table 4. -- Continued

Plate 1 Index Number	Source	Data Base
16	Barclay, 1979b, U.S. Geological Survey open-file report, in preparation	Drill hole No. DM-D63
17	↓	Drill hole No. DM-D54
18	↓	Drill hole No. DM-D31
19	↓	Drill hole No. DM-D61
20	McCulloch Oil of California	Oil/gas well No. 13-2 Unit
21	Barclay, 1979b, U.S. Geological Survey open-file report, in preparation	Drill hole No. DM-D56
22	U.S. Natural Gas	Oil/gas well No. 34-10 Unit
23	Sinclair Oil and Gas Co.	Oil/gas well No. 1 Dad-Unit
24	Barclay, 1979b, U.S. Geological Survey open-file report, in preparation	Drill hole No. DM-D55
25	↓	Drill hole No. DM-D49
26	↓	Drill hole No. DM-D57
27	G. H. Vaughn, Jr., Co.	Oil/gas well No. 1-A Gov't
28	Continental Oil Co.	Oil/gas well No. 14-1 Gov't
29	Barclay, 1979b, U.S. Geological Survey open-file report, in preparation	Drill hole No. Y-1 Federal
30	↓	Drill hole No. DM-33

Page 2 of 5

Table 4. -- Continued

Plate 1 Index Number	Source	Data Base
31	Exeter Exploration-Equity Oil-Inter American Petroleum	Oil/gas well No. 13-14 Cherokee Creek-Federal
32	U.S. Natural Gas Corp.	Oil/gas well No. 23-15 Cherokee Creek-Federal
33	↓	Oil/gas well No. 32-23 Gov't
34	Barclay and Shoaff, 1977, U.S. Geological Survey Open-File Report 77-171	Drill hole No. DM-D58
35	Barclay, 1979b, U.S. Geological Survey open-file report, in preparation	Drill hole No. DM-D62
36	Barclay, 1979a, U.S. Geological Survey open-file report, in preparation	Drill hole No. DM-D12
37	↓	Drill hole No. DM-D16
38	↓	Drill hole No. DM-D37
39	National CO-OP Refinery Assn.	Oil/gas well No. 1 Sayler-Gov't
40	Barclay, 1979a, U.S. Geological Survey open-file report, in preparation	Drill hole No. DM-D17
41	↓	Drill hole No. DM-D11
42	Barclay and Zimmerman, 1976, U.S. Geological Survey Open-File Report 76-510	Drill hole No. DM-D18
43	Barclay, 1979a, U.S. Geological Survey open-file report, in preparation	Drill hole No. DM-D39
44	↓	Drill hole No. DM-D34
45	↓	Drill hole No. DM-D44

Table 4. -- Continued

Plate 1 Index Number	Source	Data Base
46	Barclay and Zimmerman, 1976, U.S. Geological Survey Open-File Report 76-510	Drill hole No. DM-D20
47	Davis Oil Company	Oil/gas well No. 1 Ilabelle-Federal
48	Barclay, 1979a, U.S. Geological Survey open-file report, in preparation	Drill hole No. DM-D40
49	↓	Drill hole No. DM-D41
50	↓	Drill hole No. DM-D42
51	↓	Drill hole No. DM-D43
52	Exploration Drilling Co.	Oil/gas well No. 1 Unit
53	Amerada Petreleum Corp.	Oil/gas well No. 1 Unit
54	Barclay, 1979a, U.S. Geological Survey open-file report, in preparation	Drill hole No. DM-D29
55	True Oil Co.	Oil/gas well No. 31-31 Pan American
56	Benson, Montin, and Greer	Oil/gas well No. J-31 Deep Creek
57	Amerada Petroleum Corp.	Oil/gas well No. 2 Unit
58	Barclay, 1979a, U.S. Geological Survey open-file report, in preparation	Drill hole No. DM-D46
59	↓	Drill hole No. DM-D47

Table 4. -- Continued

Plate 1 Index Number	Source	Data Base
60	Barclay and Shoaff, 1977, U.S. Geological Survey Open-File Report No. 77-171	Drill hole No. DM-D21
61	Barclay, 1979a, U.S. Geological Survey open-file report, in preparation	Drill hole No. DM-D19
62	↓	Drill hole No. DM-D30
63	Davis Oil Co.	Oil/gas well No. 1 Deep Gulch Unit
64	Barclay and Zimmerman, 1976, U.S. Geological Survey Open-File report 76-510	Drill hole No. DM-D22
65	Barclay, 1979a, U.S. Geological Survey open-file report, in preparation	Drill hole No. DM-D22A
66	↓	Drill hole No. DM-D45
67	↓	Drill hole No. DM-D23
68	Ashland Exploration Co.	Oil/gas well No. 3 Deep Gulch Unit
69	Barclay, 1979a, U.S. Geological Survey open-file report, in preparation	Drill hole No. DM-D59A
70	↓	Drill hole No. DM-D24
71	↓	Drill hole No. DM-D66

Page 5 of 5

REFERENCES

American Society for Testing and Materials, 1977, Standard specification for classification of coals by rank, in Gaseous fuels; coal and coke; atmospheric analysis: ASTM Standard Specification D 388-77, pt. 26, p. 214-218.

Ball, M. W., and Stebinger, Eugene, 1910, The eastern part of the Little Snake River coal field, Wyoming, in Coal fields in Wyoming: U.S. Geological Survey Bulletin 381-B, p. 186-213.

Barclay, C. S. V., 1979a, Geophysical logs and coal sections of holes drilled in T. 16 N., Rs. 90-91 W., in the Doty Mountain and Ketchum Buttes quadrangles, Carbon County, Wyoming, during 1977 and 1978: U.S. Geological Survey open-file report, in preparation.

______1979b, Geophysical logs and coal sections of holes drilled in T. 15 N., Rs. 90-91 W., in the Doty Mountain and Ketchum Buttes quadrangles, Carbon County, Wyoming, during 1977 and 1978: U.S. Geological Survey open-file report, in preparation.

______1979c, Preliminary geologic map of the southeast quarter of the Doty Mountain 15-minute quadrangle, Carbon County, Wyoming: U.S. Geological Survey open-file report, in preparation.

Barclay, C. S. V., and Zimmerman, S. C., 1976, Lithologic and geophysical logs of holes drilled in the eastern part of the Doty Mountain quadrangle, Carbon County, Wyoming, by the U.S. Geological Survey during 1975: U.S. Geological Survey Open-File Report 76-510, 108 p.

Barclay, C. S. V., and Shoaff, L. A., 1977, Lithologic and geophysical logs of holes drilled in the Doty Mountain, Browns Hill, and Baggs quadrangles, Carbon County, Wyoming, during 1976: U.S. Geological Survey Open-File Report 77-171, 77 p.

______1978, Lithologic and geophysical logs of holes drilled in the Savery quadrangle and in the southeastern part of the Baggs quadrangle, Carbon County, Wyoming, during 1977: U.S. Geological Survey Open-File Report 78-660, 50 p.

Barclay, C. S. V., Jobin, D. A., and Storrs, J. P., 1978, Minutes for the revision of the Rawlins (Little Snake River) Known Recoverable Coal Resource Area, Carbon and Sweetwater Counties, Wyoming, January 31, 1978: U.S. Geological Survey Conservation Division, unpublished report, 15 p.

Gill, J. R., 1974, Stratigraphic sections of the Mesaverde Group, Lewis Shale, Fox Hills Formation, and Medicine Bow Formation, Carbon County, Wyoming: U.S. Geological Survey Open-File Report 74-1038.

References--Continued

Gill, J. R., Merewether, E. A., and Cobban, W. A., 1970, Stratigraphy and nomenclature of some Upper Cretaceous and Lower Tertiary rocks in south-central Wyoming: U.S. Geological Survey Professional Paper 667, 53 p.

Hale, L. A., 1961, Late Cretaceous (Montanan) stratigraphy, eastern Washakie Basin, Carbon County, Wyoming, in Symposium on the Late Cretaceous rocks of Wyoming and adjacent areas, Wyoming Geological Association Guidebook, 16th Annual Field Conference, 1961: p. 129-137.

Hatch, J. R., and Barclay, C. S. V., 1979, Chemical analyses of deep core coal and shale samples from the Almond Formation, Washakie Basin, Sweetwater County, Wyoming: U.S. Geological Survey Open-File Report 79-1249, 16 p.

Haun, J. D., 1961, Stratigraphy of post-Mesaverde Cretaceous rocks, Sand Wash Basin and vicinity, Colorado and Wyoming, in Symposium on the Late Cretaceous rocks of Wyoming and adjacent areas, Wyoming Geological Association Guidebook, 16th Annual Field Conference, 1961: p. 116-124.

Lewis, J. L., 1961, The stratigraphy and depositional history of the Almond Formation in the Great Divide Basin, Sweetwater County, Wyoming, in Symposium on the Late Cretaceous rocks of Wyoming and adjacent areas, Wyoming Geological Association Guidebook, 16th Annual Field Conference, 1961: p. 87-95.

U.S. Bureau of Land Management, 1971, BLM Public lands guide, Rawlins district, Wyoming: Ogden, Utah, scale 1:337,920.

______1978, Draft environmental statement, proposed domestic livestock grazing management program for the Seven Lakes area: U.S. Bureau of Land Management, Rawlins district, Wyoming, v. 1.

U.S. Bureau of Mines and U.S. Geological Survey, 1976, Coal resource classification system of the U.S. Bureau of Mines and U.S. Geological Survey: U.S. Geological Survey Bulletin 1450-B, 7 p.

Weimer, R. J., 1960, Upper Cretaceous stratigraphy, Rocky Mountain area: American Association of Petroleum Geologists Bulletin, v. 44, no. 1, p. 1-20.

______1961, Uppermost Cretaceous rocks in central and southern Wyoming, and northwest Colorado, in Symposium on the Late Cretaceous rocks of Wyoming and adjacent areas, Wyoming Geological Association Guidebook, 16th Annual Field Conference, 1961: p. 17-28.

References--Continued

Welder, G. E., and McGreevy, L. J., 1966, Ground-water reconnaissance of the Great Divide and Washakie Basins and some adjacent areas, southwestern Wyoming: U.S. Geological Survey Hydrologic Investigations Atlas HA-219.

Wyoming Natural Resources Board, 1966, Wyoming weather facts: Cheyenne, p. 14-15.

Wyoming State Highway Commission, 1978, Wyoming official highway map: Cheyenne, Wyoming, approximate scale 1:140,000.