Text to Accompany:

Open-File Report 79-1033

1979

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

[Report includes 26 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 Baggs 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 Published and unpublished public information available through May, 1979, was used as the data base for this study.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 Baggs 15-minute quadrangle which is located in southwest Carbon County, approximately 7 miles (11 km) northeast of the town of Baggs and 40 airline miles (64 km) southwest of the town of Rawlins, Wyoming. The Morgan Ranch, located near the northeastern edge of the quadrangle, is unoccupied and the area is only seasonally occupied by sheepherders.

Accessibility

No major routes pass through the quadrangle. However, State Highway 789 passes within 3 miles (4.8 km) of the western edge of the quadrangle and intersects Interstate Highway 80 34 miles (55 km) to the north. An improved light-duty road makes a small loop into the northwest corner of the quadrangle and connects the quadrangle to State Highway 789 at Dad, Wyoming, and to light-duty roads to the east that go north to Rawlins and south to Dixon and Savery, Wyoming. Numerous unimproved dirt roads and trails provide access through the quadrangle.

The main east-west line of the Union Pacific Railroad, which passes through the cities of Rock Springs and Rawlins, is 32 airline miles (51 km) north of the quadrangle. This line, which connects Odgen, Utah, to the west with Omaha, Nebraska, to the east, provides railway service through southern Wyoming.

Physiography

The northeast quarter of the Baggs 15-minute quadrangle lies between 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. Numerous buttes can be found in the southwestern part of the quadrangle, the most prominent being Wild Horse Butte. Altitudes range from approximately 6,400 feet (1,951 m) along White Rock Draw in the southwestern corner of the quadrangle, to 7,520 feet (2,292 m) along the northeastern edge of the quadrangle.

The southern two thirds of the quadrangle are drained primarily by Deep Creek and its tributaries. Deep Creek empties into Muddy Creek south of the area. The extreme southeast corner of the quadrangle is drained by White Rock Draw which is also a tributary of Muddy Creek. The northern third of the quadrangle is drained to the west by Cherokee Creek and its tributaries. All of the 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 average annual precipitation in the area is 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 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, aspen, willow, juniper, grasses, sagebrush, greasewood, saltbush, serviceberry, bitterbrush, rabbitbrush, and other desert shrubs.

Land Status

The northeast quarter of the Baggs 15-minute quadrangle lies near the eastern edge of the proposed Rawlins Known Recoverable Coal Resource Area (KRCRA). The entire quadrangle lies within the proposed KRCRA boundary, and the Federal government owns the coal rights for approximately 95 percent of the land 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. Gill (1974) measured sections of the Mesaverde Group, Lewis Shale, Fox Hills Formation and Medicine Bow Formation in Carbon County, Wyoming. Barclay, Hettinger, and Edson of the U.S. Geological Survey, in an unpublished report (Barclay and others, 1978) containing geologic maps and tables of subsurface information, describe the stratigraphy and show the distribution of the coal-bearing formations in the proposed Rawlins (Little Snake River) KRCRA. Barclay and Shoaff (1977 and 1978) and Barclay (1979a) presented coal correlation diagrams 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 Doty Mountain, Browns Hill, Baggs, and Savery quadrangles during 1976, 1977, and 1978. Beaumont (1979) described the depositional environments of the Fort Union sediments in northwestern Colorado. Recent geologic mapping in this quadrangle has been done by Strong (no date) for a thesis. Detailed geologic mapping by Barclay of the U.S. Geological Survey is in progress.

Stratigraphy

The rock formations exposed in the northeast quarter of the Baggs 15-minute quadrangle range in age from Late Cretaceous to Miocene, and crop out across the quadrangle in northwest-trending bands. The Fort Union Formation, the Lance Formation, and the Mesaverde Group are known to be coal-bearing within the quadrangle.

The Steele Shale of Late Cretaceous age is present in the subsurface. In south-central Wyoming this formation generally 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 a depth of approximately 3,500 feet (1,067 m) in oil and gas wells drilled in the central part of the 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).

In this quadrangle the Haystack Mountains Formation is confined to the subsurface of the quadrangle. Gill (1974) measured the formation in the Browns Hill quadrangle to the east and recorded a total thickness of approximately 953 feet (290 m), and the lithologic descriptions given below are based on his section. In this section, as elsewhere in south-central Wyoming, the formation is 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, 1970). The Deep Creek Sandstone Member is approximately 125 feet (38 m) thick (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 and a minor amount of lenticular sandstone. 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 is approximately 153 feet (47 m) thick and consists of very thick intervals of cliff-forming sandstone and much thinner intervals of slope-forming shale. 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.

The Allen Ridge Formation conformably overlies the Haystack Mountains Formation and, in this quadrangle, is also found only in the subsurface. It is approximately 1,300 feet (396 m) thick and is divided into two members, a lower non-marine member 1,000 to 1,200 feet (305 to 366 m) thick, and an upper marginal-marine member 165 to 220 feet (50 to 67 m) thick (Barclay, 1979a). 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 is largely composed 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 in the northeastern corner of the quadrangle (Barclay, 1979b). 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. The Pine Ridge is 45 to 85 feet (14 to 26 m) thick in holes drilled in the quadrangle (Barclay, 1979a).

The Almond Formation crops out in the eastern half of the quadrangle and is the most important coal-bearing formation of the Mesaverde Group. It is estimated to be between 460 and 520 feet (140 and 158 m) thick in this quadrangle (Barclay, 1979a), and it consists predominantly of marginal-marine, shore-face to coastal -plain paludal deposits (Barclay, 1979, written communication). Most of the coal beds are found in the lower part of the formation.

The Lewis Shale of Late Cretaceous age conformably overlies the Almond Formation and crops out through the center of the quadrangle from the northwestern corner to the southeastern corner (Barclay, 1979b). The formation averages approximately 2,200 feet (671 m) thick where measured in oil and gas wells drilled in the northwest quarter of the Baggs 15-minute quadrangle. 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 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 Lewis Formation. The Fox Hills Sandstone crops out in the southwestern part of the quadrangle (Hettinger, 1978) and is composed of approximately 150 feet (46 m) of pale-yellowish-gray, very fine to fine-grained friable sandstone, and olive-gray to dark-gray sandy shale (Gill and others, 1970; Gill, 1974).

The Lance Formation conformably overlies the Fox Hills Sandstone and is exposed in the southwestern quarter of the quadrangle (Hettinger, 1978). It averages approximately 960 feet (293 m) thick where measured in eight oil and gas wells in the northwest quarter of the Baggs 15-minute quadrangle. 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. Barclay (1979, written communication) reported coal beds near the base of the Lance Formation in the southwestern corner of the quadrangle, as shown on plate 1. The Lance Formation-Fox Hills Sandstone contact (Hettinger, 1978) is shown on plate 1 as an aid in locating the area where other Lance coal beds may occur.

Unconformably overlying the Lance Formation, the Fort Union Formation of Paleocene age crops out (Hettinger, 1978) in the southwestern corner of the quadrangle. The formation averages approximately 1,730 feet (527 m) thick where penetrated by oil and gas wells in the northwest quarter of the Baggs 15-minute quadrangle. Barclay and others (1978) describe the Fort Union as consisting of interbedded sandstone, siltstone, and mudstone, carbonaceous shale, and coal.

The Browns Park Formation of Miocene age crops out on Wild Horse Butte and Deep Creek River in the western part of the quadrangle where it unconformably overlies beds of the Lewis Shale, Fox Hills Sandstone, and Lance Formation (Barclay, 1979, oral communication). The maximum thickness is probably between 40 and 80 feet (12 and 24 m) and consists of pebble and cobble conglomerate and conglomeratic sandstone in the lower 20 feet (6.1 m) and sandstone in the upper part (Barclay, 1979, oral communication).

Quaternary flood-plain, terrace, and landslide deposits occur in the quadrangle. Holocene alluvium covers the stream valleys of Deep Creek, Cherokee Creek, and their tributaries. Gravel deposits of Pleistocene-Holocene(?) age occur in the bluffs along Deep Creek. Quaternary landslide deposits are common on slopes underlain by the Lewis Shale (Barclay, 1979, written communication).

The Upper Cretaceous formations in the northeast quarter of the Baggs 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) found in the Haystack Mountains Formation of the Mesaverde Group 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 primarily contains deposits of transgressive-marine shale and regressive-marine (beach) sandstone in the southern part of the Little Snake River coal field (Gill, 1974; Barclay, 1976). Near Rawlins in the northern part of the coal field, lagoonal or bay-fill deposits above the regressive-marine sandstone are important (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.

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).

After the final withdrawal of the Cretaceous sea, thick sections of detrital material, eroded from older formations, were deposited as the Fort Union Formation. The coarse sandstones and conglomerates of the lower sandy unit indicate a braided stream environment, and the interbedded sandstones, siltstones, shales, and coal beds of the upper part of the formation represent the development of broad, thick floodplain and backswamp deposits (Beaumont, 1979).

The basal conglomerate of the Browns Park Formation contains pebble- to boulder-sized clasts derived from the Sierra Madre Range and is probably an alluvial fan or pediment deposit formed in response to late Tetiary uplift and erosion of the range (Barclay, 1979, written communication). Minor post-Browns Park uplift and subsequent erosion has significantly reduced the amount of area originally covered by the formation.

Structure

The northeast quarter of the Baggs 15-minute quadrangle is located west of the Sierra Madre uplift and east of the Washakie Basin. The dip of the beds ranges from approximately 5° southwest to 20° west. No faults were mapped within the quadrangle.

COAL GEOLOGY

Four formations contain coal in this quadrangle. They are, in ascending order, the Allen Ridge, Almond, Lance, and Fort Union Formations. The Allen Ridge Formation contains a few thin coal beds in the lower non-marine member and several coal beds in the upper marginal-marine member, but only at one location does an Allen Ridge coal bed -- a bed of the marginal-marine member -- exceed Reserve Base thickness (5 feet or 1.5 m) and this location has been treated as an isolated data point (see Isolated Data Points section of this report). The Almond Formation is the most significant coal-bearing formation in the quadrangle. Coal beds generally occur throughout the formation, but the most significant and widespread coal beds are located within the basal 150 feet (46 m). The Lance Formation contains coal beds at the base of the formation. However, only one measurement of a Lance coal bed exceeding Reserve Base thickness in this quadrangle (indexed data point No. 19) has been reported and the location of the measurement is on non-Federal land. The Fort Union Formation contains numerous coal beds in a zone approximately 600 feet (183 m) thick.

<u>Chemical analyses of coal</u>.--Chemical analyses were not available for coals in the Fort Union, Lance, 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 of the Allen Ridge Formation rank as high-volatile C bitumious, coals of the Almond Formation rank subbituminous A, coals of the Lance Formation and coals of the Fort Union Formation rank subbituminous B and C. These coals have been ranked on a moist, mineral-matter-free basis according to ASTM Standard Specification D 388-77 (American Society for Testing and Materials, 1977).

Coal beds designated with bracketed numbers are not formally named, but have been given bracketed numbers for identification purposes in this quadrangle only. The same coal bed may have a different designation in another quadrangle. Coal beds that are local and of limited areal extent are also designated with the letter L (Local) on plates 1 and 3.

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, even where it is believed that the coal beds may be greater than Reserve Base thickness beyond the dotted lines.

Coal Beds of the Almond Formation

Coal beds of the Almond Formation crop out in the northeastern corner of the quadrangle. With the exception of the Robertson coal bed, bracketed numbers are used to identify seven coal beds exceeding Reserve Base thickness in this quadrangle.

Robertson Coal Bed

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 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, the Robertson coal bed was mapped as a single bed, even though in some drill holes the coal bed appeared to be split into three separate beds. Where this occurred, the thickest coal measurement was used to draw the isopach and structure contour maps. The coal bed ranges in thickness from 2 to 11.5 feet (0.6 to 3.5 m) where measured in drill holes (plate 4). Shale partings are not common in this coal bed, but thin partings ranging from 0.5 to 3.0 feet (0.2 to 0.9 m) have been reported at isolated locations.

In the southeast quarter of the Doty Mountain 15-minute quadrangle to the north, the Robertson coal bed is designated the Robertston [1] coal bed and is generally less than Reserve Base thickness along the southern quadrangle boundary, but thickens to the north and averages approximately 10 feet (3.0 m) thick in the central part of the quadrangle. In the Browns Hill quadrangle to the east, the Robertson coal bed ranges in thickness from 3.5 to 16 feet (1.1 and 4.9 m) and averages about 9 feet (2.7 m).

Almond [Local 2] Coal Bed

The Almond [Local 2] coal bed (plate 7) was penetrated by oil and gas wells in the central part of the quadrangle approximately 20 feet (6.1 m) stratigraphically above the Robertson coal bed. It has a maximum measured thickness of 6 feet (1.8 m) in three of the wells and is not known to correlate with coal beds in other quadrangles.

Almond [1] Coal Bed

The Almond [1] coal bed is approximately 100 feet (30 m) stratigraphically above the Robertson coal bed. In this quadrangle, the coal bed ranges from 3.5 to 13 feet (1.1 to 4.0 m) thick and averages approximately 8.5 feet (2.6 m) thick (plate 10). The Almond [1] coal bed in this quadrangle correlates with the Almond [1] coal bed in the adjacent southeast quarter of the Doty Mountain 15-minute quadrangle to the north and the adjacent Browns Hills quadrangle to the east.

In the southeast quarter of the Doty Mountain 15-minute quadrangle, the Almond [1] coal bed averages approximately 8 feet (2.4 m) in thickness in the southern and 11 feet (3.4 m) in the northern parts of the quadrangle. In the Browns Hill quadrangle, the coal bed ranges from 2 to 12.5 feet (0.6 to 3.8 m) thick and averages about 8 feet (2.4 m).

Almond [Local 4] Coal Bed

The Almond [4] coal bed (plate 7) lies from 5 to 20 feet (1.5 to 6.1 m) stratigraphically above the Almond [1] coal bed and ranges in thickness from 2 to 7 feet (0.6 to 2.1 m) where measured in coal test holes drilled in the northeast part of the quadrangle. To the east, in the Browns Hills quadrangle, the Almond [Local 4] coal bed is equivalent to the Almond [2] coal bed and averages approximately 6 feet (1.8 m) in thickness.

Almond [Local 5] Coal Bed

The Almond [Local 5] coal bed (plate 13) is approximately 90 feet (27 m) stratigraphically above the Almond [1] coal bed and ranges in thickness from 5 to 10 feet (1.5 to 3.0 m) where penetrated by oil and gas wells drilled in the central part of the quadrangle. This coal bed is not known to correlate with coal beds in other quadrangles.

Almond [2] Coal Bed

The Almond [2] coal bed (plate 16) is approximately 70 feet (21 m) stratigraphically above the Almond [1] coal bed and ranges from 3.5 to 11 feet (1.1 to 3.4 m) in thickness where measured in drill holes in the northeast part of the quadrangle. Thin rock partings, ranging from 1 to 2 feet (0.3 to 0.6 m) thick, have been reported at isolated locations. To the north in the southeast quarter of the Doty Mountain 15-minute quadrangle, this coal bed is designated the Almond [2], and in the Browns Hill quadrangle this coal bed is designated the Almond [3].

In the southeast quarter of the Doty Mountain 15-minute quadrangle, the Almond [2] coal bed is split along the outcrop but is a single bed at depth. The average thickness of the upper split is approximately 4.2 feet (1.3 m) and the average thickness of the lower split is approximately 3.5 feet (1.1 m). Where the coal bed is not split, the thickness averages approximately 9 feet (2.7 m). In the Browns Hill quadrangle, this coal bed ranges in thickness from 2 to 6 feet (0.6 to 1.8 m) and averages approximately 3.5 feet (1.1 m).

Almond [3] Coal Bed

The Almond [3] coal bed (plate 13) is approximately 10 feet (3.0 m) stratigraphically above the Almond [2] coal bed. In the northeast part of the quadrangle, the coal bed ranges in thickness from 2 to 5.5 feet (0.6 to 1.7 m) where penetrated by coal test holes. However, based on data projected into this quadrangle from the Browns Hill quadrangle to the east, where the coal bed is designated the Almond [4], it is believed that the coal bed could be as much as 8 feet (2.4 m) thick along the east-central quadrangle boundary. Occasional thin rock partings varying from 0.5 to 2.5 feet (0.2 to 0.8 m) occur at isolated locations.

In the Browns Hill quadrangle, this coal bed ranges from 2.5 to 10 feet (0.8 to 3.0 m) in thickness and contains rock partings up to 2.5 feet (0.8 m) thick.

Coal Beds of the Fort Union Formation

Coal beds in the Fort Union Formation crop out in the southwestern corner of the quadrangle and seven coal beds have been isopached based on holes drilled by Urangesellschaft U.S.A., Inc., in this quadrangle and from data projected into this quadrangle from the southeast quarter of the Baggs 15-minute quadrangle to the south.

Fort Union [1] Coal Bed

The Fort Union [1] coal bed (plate 4) is, stratigraphically, the lowest isopached coal bed in the Fort Union Formation in this quadrangle. It is 11 feet (3.4 m) thick in the one drill hole in this quadrangle and 17 feet (5.2 m) thick in the quadrangle to the south.

Fort Union [2] Coal Bed

The Fort Union [2] coal bed (plate 7) is 24 feet (7.3 m) stratigraphically above the Fort Union [1] coal bed. It is 7.5 feet (2.3 m) thick in this quadrangle and 16 feet (4.9 m) thick in the southeast quarter of the Baggs 15-minute quadrangle.

Fort Union [3] Coal Bed

The Fort Union [3] coal bed is 8 feet (2.4 m) stratigraphically above the Fort Union [2] coal bed and is 9 feet (2.7 m) thick in this quadrangle, as shown on plate 10. It is 11 feet (3.4 m) thick where measured in the northwest corner of the quadrangle to the south.

Fort Union [4] Coal Bed

The Fort Union [4] coal bed lies 27 feet (8.2 m) above the Fort Union [3] coal bed and is 6.5 feet (2.0 m) thick and contains a rock parting 0.5 feet (0.2 m) thick where penetrated by the Urangesellschaft drill hole (plate 13). To the south of this quadrangle the coal bed is less than Reserve Base thickness.

Fort Union [5] Coal Bed

The Fort Union [5] coal bed (plate 16) is 11 feet (3.4 m) stratigraphically above the Fort Union [4] coal bed and ranges in thickness from 3 to 5 feet (1.0 to 1.5 m) where measured along the outcrop and in a drill hole in the southeast corner of this quadrangle. A rock parting 1 foot (0.3 m) thick was encountered in the drill hole. To the south in the southeast quarter of the Baggs 15-minute quadrangle, the Fort Union [5] is 9 feet (2.7 m) thick where penetrated in a drill hole in the northern part and has a maximum thickness of 18 feet (5.5 m) where measured along the outcrop in the central part of that quadrangle.

Fort Union [6] Coal Bed

The Fort Union [6] coal bed (plate 19) lies approximately 135 feet (41 m) stratigraphically above the Fort Union [5] coal bed and ranges in thickness from 7 to 13 feet (2.1 to 4.0 m) where measured at the outcrop and in drill holes.

In the southeast quarter of the Baggs 15-minute quadrangle to the south, this coal bed is 12 feet (3.7 m) thick where measured along the outcrop and was not penetrated by drill holes in that quadrangle. To the west in the northwest quarter of the Baggs 15-minute quadrangle, this coal bed is designated the Fort Union [1] and ranges from 3 to 8 feet (1.0 to 2.4 m) where encountered in oil and gas wells.

To the south in the southeast quarter of the Baggs 15-minute quadrangle, the coal bed is 12 feet (3.7 m) thick where measured along the outcrop, but was not encountered in any drill holes. To the west in the northwest quarter of the Baggs 15-minute quadrangle, this coal bed is designated the Fort Union [1] and averages approximately 5.3 (1.6 m) thick in oil and gas wells.

Fort Union [7] Coal Bed

The Fort Union [7] coal bed (plate 22) is located approximately 30 feet (9 m) stratigraphically above the Fort Union [6] coal bed and ranges in thickness from 6 to 16 feet (1.8 to 4.9 m) where measured along the outcrop and in drill holes. Unlike the other Fort Union coal beds in this quadrangle, the Fort Union [7] coal bed has not been identified in the quadrangles to the south. However, this coal bed extends westward into the northwest quarter of the Baggs 15-minute quadrangle, where the coal bed is designated the Fort Union [2], and has been identified in oil and gas wells.

Isolated Data Points

In instances where 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. Also, where the inferred limit of influence from the isolated data point is entirely within non-Federal land areas, isolated data point maps are not constructed for the coal bed. Areas of influence mapped in this quadrangle include the two isolated data points described on the next page. Coal beds identified by bracketed numbers are not formally named, but are used for identification purposes in this quadrangle only.

Source	Location	Coal Bed	Thickness
Barclay, 1979a	sec. 10, T. 14 N., R. 90 W.	AR[L1]	5.5 ft (1.7 m)
	From NW 1/4 Doty Mountain Quadrangle		
Strong, (no date)	sec. 27, T. 14 N., R. 91 W.	FU[3]	8 ft (2.4 m)

COAL RESOURCES

Information from oil and gas wells, coal test holes drilled by the U.S. Geological Survey (Barclay, 1979a) and Urangesellschaft U.S.A., Inc. (1978), and measured sections (Strong, no date), 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, 10, 13, 16, 19, and 22). 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, 9, 12, 15, 18, 21, and 24, 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 404.78 million short tons

(367.22 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 on the following page:

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

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 coal beds 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 0.30 million short tons (0.27 million metric tons) of coal available for surface mining.

The coal development potential for surface mining methods is shown on plate 25. Of the Federal land areas having a known development potential for surface mining methods, 57 percent are rated high, 2 percent are rated moderate, and 41 percent are rated low. The remaining

Federal lands within the quadrangle 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 points and to the areas where coal beds of Reserve Base thickness are not known, but may occur. The area influenced by the isolated data point in this quadrangle contains 4.98 million short tons (4.52 million metric tons) of coal available for conventional subsurface mining.

The coal development potential for subsurface mining methods is shown on plate 26. Of the Federal land areas having a known development potential for conventional subsurface mining methods, 83 percent are rated high and 17 percent are rated moderate. The remaining Federal land is classified as having unknown development potential for conventional subsurface mining methods.

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 37.16 million short tons (33.71 million metric tons) of coal distributed through seven 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 northeast quarter of the Baggs 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
SW¼, NW¼, sec. 5, T. 17 N., R. 91 W., (RMEC, CB-96)	Fillmore Ranch	A	22.7	30.4	42.1	4.8	0.2	-	-	-	-	-	9,206
		C	0.0	39.3	54.5	6.2	0.3	-	-	-	-	-	11,902
NE¼, NW¼, sec. 33, T. 18 N., R. 91 W., (RMEC, CB-77)	Muddy Creek	A	22.9	30.1	41.7	5.4	0.3	-	-	-	-	-	9,043
		C	0.0	39.0	54.0	6.9	0.4	-	-	-	-	-	11,726
NE¼, NE¼, sec. 5, T. 17 N., R. 91 W., (RMEC, CB-86)	Separation Creek	A	22.3	0.0	0.0	10.1	0.8	-	-	-	-	-	8,699
		C	0.0	0.0	0.0	13.0	1.1	-	-	-	-	-	11,193
NE¼, SE¼, sec. 33, T. 18 N., R. 91 W., (RMEC, CB-81)	Red Rim	A	24.3	29.7	33.5	7.6	0.7	-	-	-	-	-	8,646
		C	0.0	39.2	50.8	10.1	0.9	-	-	-	-	-	11,416
NE¼, SW¼, sec. 6, T. 20 N., R. 88 W., Old Nebraska Mine, (Ball, 1909)	Lance-Fox Hills Formation, undifferentiated	A	19.2	36.46	40.56	3.78	0.34	5.74	58.88	1.34	29.92	5,401	9,722
		B	17.3	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 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 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 northeast quarter of the Baggs 15-minute quadrangle, Carbon County, Wyoming.

Coal Bed	High Development Potential	Moderate Development Potential	Low Development Potential	Unknown Development Potential	Total
Fort Union [7]	1,210,000	680,000	580,000	-0-	2,470,000
Fort Union [6]	1,160,000	920,000	960,000	-0-	3,040,000
Fort Union [5]	120,000	70,000	200,000	-0-	390,000
Fort Union [4]	250,000	210,000	640,000	-0-	1,100,000
Fort Union [3]	730,000	770,000	700,000	-0-	2,200,000
Fort Union [2]	900,000	600,000	410,000	-0-	1,910,000
Fort Union [1]	1,600,000	700,000	370,000	-0-	2,670,000
Almond [3]	150,000	120,000	650,000	-0-	920,000
Almond [2]	1,280,000	1,040,000	3,990,000	-0-	6,310,000
Almond [Local 5]	-0-	-0-	-0-	-0-	-0-
Almond [Local 4]	820,000	80,000	940,000	-0-	1,840,000
Almond [1]	1,330,000	1,030,000	3,080,000	-0-	5,440,000
Almond [Local 2]	-0-	-0-	-0-	-0-	-0-
Robertson	410,000	400,000	330,000	-0-	1,140,000
Isolated Data Points	-0-	-0-	-0-	300,000	300,000
Totals	9,960,000	6,620,000	12,850,000	300,000	29,730,000

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 Baggs 15-minute quadrangle, Carbon County, Wyoming.

Coal Bed	High Development Potential	Moderate Development Potential	Low Development Potential	Unknown Development Potential	Total
Fort Union [7]	-0-	-0-	-0-	7,040,000*	7,040,000
Fort Union [6]	-0-	-0-	-0-	6,050,000*	6,050,000
Fort Union [5]	10,000	-0-	-0-	90,000*	100,000
Fort Union [4]	10,000	-0-	-0-	3,210,000*	3,220,000
Fort Union [3]	290,000	-0-	-0-	5,660,000*	5,950,000
Fort Union [2]	280,000	-0-	-0-	5,990,000*	6,270,000
Fort Union [1]	450,000	-0-	-0-	9,120,000*	9,570,000
Almond [3]	8,780,000	-0-	-0-	-0-	8,780,000
Almond [2]	53,070,000	-0-	-0-	-0-	53,070,000
Almond [Local 5]	4,060,000	8,330,000	-0-	-0-	12,390,000
Almond [Local 4]	3,850,000	-0-	-0-	-0-	3,850,000
Almond [1]	124,310,000	28,950,000	-0-	-0-	153,260,000
Almond [Local 2]	-0-	4,020,000	-0-	-0-	4,020,000
Robertson	54,890,000	41,610,000	-0-	-0-	96,500,000
Isolated Data Points	-0-	-0-	-0-	4,980,000	4,980,000
Totals	250,000,000	82,910,000	-0-	42,140,000	375,050,000

*Tonnages for coal beds dipping greater than 15 degrees.

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	Strong, (no date), Master's thesis, in preparation	Measured Section
2	Urangesellschaft, U.S.A., Inc., 1978, unpublished data	Drill hole No. WH 15-1
3	Barclay and Shoaff, 1977, U.S. Geological Survey Open-File Report 77-171	Drill hole No. B-D17
4	Barclay, 1979a, U.S. Geological Survey open-file report [in press]	Drill hole No. B-D19
5	Chandler and Simpson	Oil/gas well No. 1 Gov't
6	Texas Oil & Gas Co.	Oil/gas well No. L-1 Texas Oil & Gas-Federal
7	Barclay, 1979a, U.S. Geological Survey open-file report [in press]	Drill hole No. B-D20
8	Ashland Oil, Inc.	Oil/gas well No. 1-18 Ashland-Federal
9	Barclay, 1979a, U.S. Geological Survey open-file report [in press]	Drill hole No. B-D18
10	Sun Oil Co.	Oil/gas well No. 1 Browning-Gov't
11	U.S. Natural Gas Corp.	Oil/gas well No. 12-12 Federal
12	Ashland Oil & Refining Co.	Oil/gas well No. 1-12 Federal
13	American Quasar Petroleum, Inc.	Oil/gas well No. 1 Browning Federal
14	↓	Oil/gas well No. 2 Browning Federal

Table 4. -- Continued

Plate 1 Index Number	Source	Data Base
15	Strong, (no date), Master's thesis, in preparation	Measured Section
16	Urangesellschaft U.S.A., Inc., 1978, unpublished data	Drill hole No. WH 54-1
17	↓	Drill hole No. WH 39-1
18	↓	Drill hole No. WH 30-1
19	Hettinger, 1978, U.S. Geological Survey, unpublished data	Measured Section
20	Barclay, 1979a, U.S. Geological Survey open-file report [in press]	Drill hole No. B-D11
21	↓	Drill hole No. B-D14
22	↓	Drill hole No. B-D15A
23	Barclay and Shoaff, 1977, U.S. Geological Survey Open-File Report 77-171	Drill hole No. B-D15
24	Barclay, 1979a, U.S. Geological Survey open-file report [in press]	Drill hole No. B-D16A
25	↓	Drill hole No. B-D13
26	↓	Drill hole No. B-D12
27	↓	Drill hole No. B-D21
28	↓	Drill hole No. B-D22

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