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

[Report includes 20 plates]

Prepared for

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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 southeast quarter of the Baggs 15-minute quadrangle, Carbon County, Wyoming, and Moffat County, Colorado. 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 Published and unpublished public information available through June, 1979, was used as the data base for this study.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 2 miles (3 km) east of the town of Baggs and 48 airline miles (77 km) southeast of the town of Rawlins, Wyoming. With the exception of the town of Dixon, Wyoming, located near the southeastern corner of the quadrangle, the area is relatively unpopulated.

Accessibility

Wyoming Highway 70 trends east-west across the southern third of the quadrangle. Just west of the area, Wyoming Highway 70 joins Wyoming Highway 789 which intersects Interstate Highway 80, 46 miles (80 km) to the north. The remainder of the quadrangle is accessible by a few light-duty roads radiating from the Dixon area, and numerous secondary dirt roads and trails.

The Denver and Rio Grande Western Railroad line, 34 airline miles (54 km) to the south, connects Craig and Denver, Colorado. The main southern line of the Union Pacific Railroad passes 48 airline miles (78 km) to the north. This line connects Ogden, Utah, to the west with Omaha, Nebraska, to the east.

Physiography

The southeast quarter of the Baggs 15-minute quadrangle lies on the southeastern rim of the Washakie Basin. The landscape within the quadrangle is characterized by high plateaus and ridges cut by deep, rocky canyons. Red Monument, Muddy Mountain, and Allen Hill are prominent features in the northern half of the quadrangle. Altitudes in the quadrangle range from approximately 6,280 feet (1,914 m) along the Little Snake River on the western edge of the quadrangle to 7,904 feet (2,409 m) at the highest point of Muddy Mountain.

The Little Snake River and its flood plain are prominent features in the southern half of the quadrangle. The river flows from east to west and its major tributaries in the quadrangle include Dutch Joe Creek, Cottonwood Creek, and Burbank Draw. Muddy Creek, in the northwestern part of the quadrangle, drains Deep Creek, Hicox Draw, Coal Mine Draw, and Young Draw and is itself a tributary of the Little Snake River. With the exception of the Little Snake River and Willow Creek in the southern part of the quadrangle, all streams in the quadrangle are intermittent and flow mainly in response to precipitation and 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, aspen, willow, juniper, grasses, sagebrush, greasewood, serviceberry, bitterbrush, saltbush, rabbitbrush, and other desert shrubs.

Land Status

The southeast quarter of the Baggs 15-minute quadrangle lies on the southern edge of the proposed Rawlins Known Recoverable Coal Resource Area (KRCRA). Less than three quarters of the quadrangle lie within the proposed KRCRA boundary, and the Federal government owns the coal rights for less than three quarters 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). Masursky (1962) included a description of the depositional environments of the Wasatch Formation in a publication on uranium-bearing coal in the eastern part of the Red Desert area. Henderson (1962) described Cretaceous stratigraphy and the geology of the Doty Mountain-Dad area of Wyoming. 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. Cronoble (1969) described the geology of the South

Baggs-West Side Canal gas field, part of which is located in the southwestern corner of the quadrangle. Gill and others (1970) described the stratigraphy and nomenclature of some of the Upper Cretaceous and Lower Tertiary rocks found in south-central Wyoming. Land (1972) discussed the depositional environments of the Fox Hills Sandstone and the Lance Formation. Barclay and Shoaff (1978) presented coal correlation diagrams and discussed the stratigraphy of the Mesaverde Group in their report on the results of coal-drilling by the U.S. Geological Survey in this and the adjacent Savery quadrangle during 1977. In a report on the minutes of the proposed revision of the Rawlins (Little Snake River) KRCRA, Barclay and others (1978) presented geologic maps showing the distribution of the cal-bearing formations and brief descriptions of the stratigraphy and coal geology of the KRCRA. Beaumont (1979) described the depositional environments of the Fort Union sediments in northwestern Colorado. Geologic mapping in this quadrangle has been done by Strong (no date) and by Hettinger (1978). Detailed geologic mapping by Barclay of the U.S. Geological Survey is in progress.

Stratigraphy

The rock formations exposed in the southeast 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 Lance, Almond, and Allen Ridge Formations of Late Cretaceous age and the Fort Union Formation of Paleocene age are coal-bearing within the quadrangle.

In most of the Little Snake River coal field, the Mesaverde Group of Late Cretaceous age can be subdivided into four formations which are, in ascending order, the Haystack Mountains, the Allen Ridge, the Pine Ridge Sandstone, and the Almond. In some areas in the southern part of the coal field where this quadrangle is located, the Pine Ridge Sandstone is commonly missing (Barclay and Shoaff, 1978).

In this quadrangle, the Haystack Mountains Formation, which conformably overlies the Steel Shale, is confined to the subsurface. Thickness and lithologic descriptions of the Haystack Mountains Formation given below are based on interpretations of logs from the Caulkins Oil Company-Alpine Oil Company No. 1 Wren gas well in sec. 12, T., 13 N., R. 91 W. (Barclay, 1979, written communication). The Haystack Mountains Formation is approximately 940 feet (287 m) thick and 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 is approximately 115 feet (35 m) thick and is mostly composed of sandstone. The Espy Tongue, genetically a tongue of the Steele Shale, is approximately 350 feet (107 m) thick and consists of shale and subordinate sandstone. The Hatfield Sandstone Member, approximately 135 feet (41 m) thick, is composed of thick sandstone intervals separated by much thinner shale intervals. The upper unnamed member of the Haystack Mountains Formation is composed of about 340 feet (104 m) of interbedded shale and sandstone.

The Allen Ridge Formation is not exposed in this quadrangle. In the Wren No. 1 gas well it is about 840 feet (256 m) thick if the Pine Ridge Sandstone is absent and about 1,100 feet (335 m) thick if the Pine Ridge Sandstone is present. Where it crops out in the Savery quadrangle, the Allen Ridge is composed of continental fluviatile sequences of sandstone, siltstone, mudstone, and thin carbonaceous shale and coal beds (Barclay and Shoaff, 1978). In those parts of the Little Snake River coal field where the overlying Pine Ridge Sandstone occurs, some marginal-marine lagoonal-paludal deposits of thick, bioturbated organic-rich brown shale, thin sandstone beds and coal, which are included in the Almond Formation where the Pine Ridge is absent, are assigned to an upper informal marine member of the Allen Ridge Formation (Barclay and Shoaff, 1978).

In the central and northern parts of the Little Snake River coal field, the Pine Ridge Sandstone is composed of continental fluviatile deposits of sandstone and a subordinate amount of carbonaceous siltstone and mudstone (Barclay and Shoaff, 1978) and unconformably overlies the Allen Ridge Formation (Gill and others, 1970). Barclay and Shoaff (1978) indicate that the drilled interval from 550 to 622 feet (168 to 190 m) in drill hole B-D25 (indexed data point No. 11 on plate 1) may contain the

Pine Ridge Sandstone. In the No. 1 Wren gas well, the Pine Ridge Sandstone is not readily apparent, but could be the 50-foot (15-m) interval between the depths of 4,030 and 4,080 feet (1,228 and 1,244 m).

The uppermost 20 to 40 feet (6 to 12 m) of the Almond Formation crops out along the eastern edge of the quadrangle. Where it crops out to the east in the Savery quadrangle, the Almond consists predominantly of marginal-marine, foreshore to coastal-plain paludal deposits (Barclay, 1979, written communication). Most of the coal beds are found in the lower part of the formation. Barclay and Shoaff (1978) use an areally-persistent marine sandstone, informally named the sandstone of Loco Creek, as the basal unit of the Almond Formation in the southeastern part of the Rawlins (Little Snake River) KRCRA. This sandstone becomes the base of the marine member of the Allen Ridge Formation where it can be traced into areas where the Pine Ridge Sandstone is identified. The Almond Formation is approximately 790 feet (241 m) thick along the eastern edge of this quadrangle (Barclay and Shoaff, 1978) and is judged to be 560 feet (171 m) in the Wren No. 1 gas well if the Pine Ridge Sandstone is present (Barclay, 1979, written communication).

The Lewis Shale of Late Cretaceous age conformably overlies the Almond Formation and crops out in the eastern half of the 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; Gill, 1974). Measurements from oil and gas wells drilled in the quadrangle indicate that the Lewis Shale is approximately 2,200 to 2,370 feet (671 to 722 m) thick.

The Fox Hills Sandstone of Late Cretaceous age intertongues with the underlying marine Lewis Shale and with the overlying brackish-water and fluviatile sandstone and shale of the Lance Formation (Gill and others, 1970). The Fox Hills Sandstone crops out in the Muddy Mountain area in the northeastern part of the quadrangle where it is composed predominantly of thick units of pale-yellowish-gray to greenish-orange, very fine to fine-grained friable sandstone that contains thin oyster beds and clayey intervals (Barclay, 1979, written communication). This formation ranges in thickness from 130 to 195 feet (40 to 59 m) where penetrated by oil and gas wells in the quadrangle.

The Lance Formation conformably overlies the Fox Hills Sandstone and is exposed in the central part of the quadrangle. It averages approximately 920 feet (280 m) thick where measured in the oil and gas wells drilled in this quadrangle. According to Haun (1961), the formation consists of a non-marine sequence of carbonaceous shale, sandstone, and siltstone, with coal beds occurring immediately above the contact with the Fox Hills Sandstone. Measured thicknesses of Lance Formation coal beds in this quadrangle are not presently known. However, Barclay (1979, written communication) has indicated that locally one or two coal beds 5 to 10 feet (1.5 to 3.0 m) thick occur near the base of the Lance in the northeast quarter of the Baggs 15-minute quadrangle. Logs of some oil and gas test holes, such as Montgomery No. 1 in sec. 18, T. 12 N., R. 90 W., show as many as three coal beds, 2 to 6 feet (0.6 to 1.8 m) thick, in the lower part of the Lance (Barclay, 1979, oral communication).

Unconformably overlying the Lance Formation, the Fort Union Formation of Paleocene age crops out in the southern and western parts of the quadrangle (Hettinger, 1978). Where penetrated by oil and gas wells in this quadrangle, the formation averages 1,330 feet (405 m) in thickness. Barclay and others (1978) describe the Fort Union as consisting of interbedded sandstone, siltstone, and mudstone, carbonaceous shale, and coal. The lowermost 300 to 600 feet (91 to 183 m) of the formation contain thick-bedded to massive, medium- to coarse-grained sandstone overlain by an interbedded sequence of sandstone, siltstone, shale, and coal beds that are up to 40 feet (12.2 m) thick.

The Wasatch Formation of Eocene age conformably overlies the Fort Union Formation and crops out in the southwestern part of the quadrangle (Hettinger, 1978). Geophysical logs from oil and gas wells indicate that at least 1,090 feet (332 m) of the formation is present in the quadrangle. Cronoble (1969) indicates that more than 2,000 feet (610 m) of the Wasatch Formation exists in the South Baggs-West Side Canal gas field of Carbon County, Wyoming, and Moffat County, Colorado. Cronoble describes the formation as consisting of variegated claystones and mudstones with occasional siltstones, sandstones, and conglomerates.

The Browns Park Formation of Miocene age crops out at many places in the quadrangle and unconformably overlies all older formations (Barclay, 1979, written communication). The maximum thickness of the formation in the quadrangle probably underlies the mesa in sec. 28, T. 13 N., R. 90 W., and is about 750 feet (229 m) (Barclay, 1979, written communication). The Browns Park is composed of a basal conglomerate, which is about 80 feet (24 m) thick in the bluffs bordering Cottonwood Creek, and of friable, commonly tuffaceous sandstone (Barclay, 1979, written communication).

Holocene deposits of alluvium cover the stream valleys of Deep Creek, Cottonwood Creek, and their tributaries, as well as the floodplain of the Little Snake River in the southern part of the quadrangle. Several levels of Pleistocene terrace deposits of gravel occur in the bluffs along the Little Snake River.

The Upper Cretaceous formations in the southeast 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, 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. In south-central Wyoming, 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).

Most of the Allen Ridge Formation of south-central Wyoming was deposited in a non-marine fluvial environment, although a marginal-marine, lagoonal sequence of strata generally occurs at the top (Gill and others, 1970). When the Pine Ridge Sandstone, which generally overlies the Allen Ridge, is absent, the marginal-marine beds of the Allen Ridge is included with the Allen Formation and the strata remaining in the Allen Ridge are all non-marine (Barclay and Shoaff, 1978).

The Almond Formation in this quadrangle, as in other parts of south-central Wyoming (Gill and others, 1970), is believed to consist of marginal-marine, shore-face to coastal -plain paludal deposits (Barclay, 1979, written communication).

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 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 conglomerates, sandstones, shales, and coals were deposited in braided-stream, flood-plain and backswamp environments (Beaumont, 1979).

Sediments of the Wasatch Formation were deposited in alternating lake, swamp, and stream environments. To the north, the base of the Wasatch Formation grades into thick arkose beds which have been assigned to the Battle Springs Formation (Masursky, 1962).

The conglomerate at the base of the Browns Park Formation contains pebble- to boulder-sized clasts derived from the Sierra Madre Range (Barclay, 1979, written communication). The sandstone beds in the remainder of the formation are of fluvial and eolian origins. Minor post-Browns Park uplift and subsequent erosion has significantly reduced the amount of area originally covered by the formation (Barclay, 1979, written communication).

Structure

The southeast quarter of the Baggs 15-minute quadrangle is located at the eastern end of the Cherokee Ridge arch which separates the Washakie Basin and the Sand Wash Basin (Cronoble, 1969). The arch is a faulted anticline that plunges east and west, extending into the southwestern corner of the quadrangle.

Barclay (1979) identified several faults along the eastern edge of the quadrangle, all of which trend southeast into the Savery quadrangle.

COAL GEOLOGY

The Almond, Lance, and Fort Union Formations are known to be coal-bearing, and the Allen Ridge Formation is believed to be coal-bearing in this quadrangle. In this quadrangle, three coal beds in the Almond Formation and 11 coal beds in the Fort Union Formation have been isopached. To the north, in the northeast quarter of the Baggs 15-minute quadrangle, a measured section in the Lance Formation indicates that coal beds of significant thickness occur at the base of the formation. No surface measurements of the Lance Formation in this quadrangle were available to verify the presence of any Lance coals and subsurface measurements of coal are too deep and/or too thin to use even for isolated data points (see Isolated Data Points section of this report). Measurements of probable coal in the Allen Ridge Formation are also too deep and too thin for isolated data points (Barclay, 1979, written communication).

Coal beds that are equal to or greater than Reserve Base thickness in this quadrangle are not formally named and have been given bracketed numbers for identification purposes in this quadrangle only. The same coal bed in another quadrangle may have a different designation.

Chemical analyses of coal.--Chemical analyses were not available for coals in the Fort Union, Lance, and Almond 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 Almond Formation rank subbituminous A, and coals of the Lance and Fort Union Formations rank subbituminous B, on a moist, mineral-matter-free basis according to ASTM Standard Specification D 388-77 (American Society for Testing and Materials, 1977).

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 line.

Coal Beds of the Almond Formation

Coal beds in the Almond Formation crop out in the northeastern part of the quadrangle and have been penetrated by two drill holes. Three coal beds, the Almond [1], [2] and [3], correlate with coal beds in the adjacent Savery quadrangle to the east where they have the same designation. A fourth coal bed, the Almond [4], was encountered in one drill hole only and has been treated as an isolated data point.

Almond [1] Coal Bed

The Almond [1] coal bed is, stratigraphically, the lowest isopached coal bed in this quadrangle. Where encountered in drill holes, this coal bed measures 10 and 15 feet (3.0 and 4.6 m) in thickness, thinning to the east (plate 4). In the Savery quadrangle, the coal bed was penetrated in a single drill hole, measuring 4 feet (1.2 m) in thickness.

Almond [2] Coal Bed

The Almond [2] coal bed lies approximately 100 feet (30 m) stratigraphically above the Almond [1] coal bed. In this quadrangle, the Almond [2] coal bed measures 4 and 7 feet (1.2 and 2.1 m) thick where identified in two drill holes (plate 7). In the adjacent Savery quadrangle to the northeast, the Almond [2] coal bed is 6 feet (1.8 m) in thickness where measured in a single drill hole.

Almond [3] Coal Bed

The Almond [3] coal bed occurs approximately 10 feet (3.0 m) stratigraphically above the Almond [2] coal bed. As shown on plate 11, this coal bed measures 9 and 11 feet (2.7 and 3.4 m) thick where identified in two drill holes in the northeastern part of the quadrangle. In the Savery quadrangle, the Almond [3] coal bed is somewhat thinner, measuring only 4.5 feet (1.4 m) thick in a single drill hole.

Coal Beds of the Fort Union Formation

Coal beds of the Fort Union Formation crop out in the western half of the quadrangle. Data from oil and gas wells in the southwestern part of the quadrangle and data from a single uranium test hole (drilled by Urangesellschaft, U.S.A., Inc.) provided the only subsurface data in the northwestern corner of the quadrangle. Water wells were logged by the U.S. Geological Survey (Barclay and Shoaff, 1978) around the town of

Dixon and the geophysical logs from these wells provided subsurface data in that area. Limited outcrop data (Strong, no date; Barclay, 1979) was available in the northwestern and southeastern parts of the quadrangle. Because of the widely-spaced nature of the data for the coal beds in the Fort Union Formation in this quadrangle, extensive correlations were not possible. It should be noted that some of the coal beds identified with different bracketed numbers may actually be equivalent and may, therefore, be much more extensive than what has been represented in this report.

Twenty-one coal beds in the Fort Union Formation that are equal to or greater than Reserve Base thickness have been identified in this quadrangle. Derivative maps for eleven of these coal beds are shown on the plates accompanying this report. Nine coal beds have been identified at one location only and have been treated as isolated data points, only six of which occur on Federal land. One coal bed, the Fort Union [4], is less than Reserve Base thickness in this quadrangle, but is greater than 5.0 feet (1.5 m) thick in the northeast quarter of the Baggs 15-minute quadrangle to the north. In addition, the Fort Union [8] coal bed is equal to Reserve Base thickness at two isolated locations and has not been mapped in this quadrangle.

Fort Union [1] Coal Bed

The Fort Union [1] coal bed was identified in a drill hole in the northwestern corner of the quadrangle and in a drill hole in the adjacent northeast quarter of the Baggs 15-minute quadrangle. As shown on plate 13, this coal bed attains a mmaximum measured thickness of 17 feet (5.2 m) in this quadrangle and tends to thin to the north.

Fort Union [2] Coal Bed

The Fort Union [2] coal bed lies 9 feet (2.7 m) stratigraphically above the Fort Union [1] coal bed. The coal bed is 16 feet (4.9 m) thick where measured in the northwestern corner of the quadrangle (plate 16). In the northeast quarter of the Baggs 15-minute quadrangle, this coal bed has a measured thickness of 7.5 feet (2.3 m) where identifed in one drill hole.

Fort Union [3] Coal Bed

The Fort Union [3] coal bed is 3 feet (0.6 m) stratigraphically above the Fort Union [2] coal bed and is 11 feet (3.4 m) thick where measured in the northwestern corner of the quadrangle, as shown on plate 7. To the north in the northeast quarter of the Baggs 15-minute quadrangle, the coal bed is 9 feet (2.7 m) thick where measured in a single drill hole.

Fort Union [5] Coal Bed

The Fort Union [5] coal bed occurs approximately 49 feet (15 m) stratigraphically above the Fort Union [3] coal bed. This coal bed is 9 feet (2.7 m) thick where measured in a drill hole in the northwestern corner of the quadrangle and 18 feet (5.5 m) thick in a measured section approximately 1 1/2 miles to the south of that drill hole. In the northeast quarter of the Baggs 15-minute quadrangle, the coal bed is 5 feet (1.5 m) in thickness and contains a rock parting 1 foot (0.3 m) thick where measured in a drill hole in sec. 34, T. 14 N., R. 91 W.

Fort Union [6] Coal Bed

The Fort Union [6] coal bed was identified in a measured section (Strong, no date) where it had a thickness of 12 feet (3.7 m) as shown on plate 4. The coal bed extends into the adjacent quadrangle to the north, where thicknesses of 10.5 and 13 feet (3.2 and 4.0 m) were measured in two drill holes.

Fort Union [7] Coal Bed

The Fort Union [7] coal bed is, stratigraphically, the lowest coal bed exceeding Reserve Base thickness in the southwestern part of the quadrangle. This coal bed ranges in thickness from 5 to 9 feet (1.5 to 2.7 m) and can be traced into adjacent quadrangles to the west and south, as indicated on plate 10.

Fort Union [10] Coal Bed

The Fort Union [10] coal bed occurs approximately 12 to 35 feet (3.7 to 10.7 m) stratigraphically above the Fort Union [7] coal bed and ranges from 3 to 7 feet (0.9 to 2.1 m) thick (plate 7) where measured in the oil and gas wells drilled in the southwestern part of the quadrangle.

Fort Union [11] Coal Bed

The Fort Union [11] coal bed is up to 12 feet (3.7 m) stratigraphically above the Fort Union [10] coal bed and ranges from 17 to 39 feet (5.2 to 11.9 m) in thickness (plate 4) where measured in oil and gas wells; it has an average thickness of about 26 feet (7.9 m).

Fort Union [12] Coal Bed

The Fort Union [12] coal bed, shown on plate 13, occurs approximately 45 feet stratigraphically above the Fort Union [11] coal bed where identified in two oil and gas wells drilled in the quadrangle. Measurements from geophysical logs made in both drill holes indicated that this coal bed is 6 feet (1.8 m) in thickness.

Fort Union [13] Coal Bed

The Fort Union [13] coal bed lies approximately 30 feet (30.1 m) stratigraphically above the Fort Union [12] coal bed. This coal bed was identified in two oil and gas wells where measured thicknesses of 7 and 12 feet (2.1 and 3.7 m) were obtained from geophysical logs. The isopach map of this coal bed is shown on plate 16.

Fort Union [19] Coal Bed

The Fort Union [19] coal bed was identified in an outcrop measured section by Strong (no date) in the northwestern part of the quadrangle. The thickness of the coal bed at the point of measurement is 14 feet (4.3 m). Because no other measurements of the coal bed are available, the coal bed is assumed to maintain this thickness in the localized area where it has been mapped (plate 10).

Isolated Data Points

In instances where single and 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. The isolated data points mapped 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. Geological Survey (no date)	sec. 8, T. 12 N., R. 90 W.	FU[22]	12 ft (3.7 m)
Barclay (1979)	sec. 15, T. 12 N., R. 90 W.	FU[21]	7 ft (2.1 m)
Strong (no date)	sec. 13, T. 13 N., R. 91 W.	FU[20]	7 ft (2.1 m)
Consolidated Oil and Gas Co.	sec. 15, T. 12 N., R. 91 W.	FU[15]	6 ft (1.8 m)
Kirby Royalties, Inc.	sec. 14, T. 12 N., R. 91 W.	FU[14]	8 ft (2.4 m)
Kirby Royalties, Inc.	sec. 18, T. 12 N., R. 90 W.	FU[9]	7 ft (2.1 m)
Barclay and Shoaff (1978)	sec. 27, T. 13 N., R. 90 W.	Al[4]	10 ft (3.0 m)

COAL RESOURCES

Information from oil and gas wells, coal test holes drilled by the U.S. Geological Survey (Barclay and Shoaff, 1978), and measured sections by Strong (no date) and Barclay (1979) were used to construct outcrop, isopach, and structure contour maps of the coal beds in the southeast quarter of the Baggs 15-minute quadrangle.

Coal resources were calculated using data obtained from the coal isopach maps (plates 4, 7, 10, 13, and 16). 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, 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 maximum depth of 1,000 feet (305 m) for subbituminous coal.

Reserve Base and Reserve tonnages for the isopached beds are shown on plates 6, 9, 12, 15, and 18, 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 227.59 million short tons (206.47 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 of 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 2.31 million short tons (2.10 million metric tons) of coal available for surface mining.

The coal development potential for surface mining methods is shown on plate 19. Of the Federal land areas having a known development potential for surface mining methods, 90 percent are rated high, 5 percent is rated moderate, and 5 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 the areas influenced by isolated data points and to those 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 13.40 million short tons (12.16 million metric tons) of coal available for conventional subsurface mining.

The coal development potential for subsurface mining methods is shown on plate 20. Of the Federal land areas having a known development potential for conventional subsurface mining methods, 58 percent are rated high, 33 percent are rated moderate, and 9 percent are rated low. The remaining Federal land within the proposed KRCRA boundary 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 1.43 million short tons (1.30 million metric tons) of coal distributed through three 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 4. -- Sources of data used on plate 1

Plate 1 Index Number	Source	Data Base
1	Barclay and Shoaff, 1978, U.S. Geological Survey Open-File Report 78-660	Drill hole No. Dixon-A
2	Barclay and others, 1978, U.S. Geological Survey, unpublished report	Drill hole, Dillon Water Well
3	Barclay and Shoaff, 1978, U. S. Geological Survey Open-File Report 78-660	Drill hole No. Dixon-B
4	Barclay, 1979, U.S. Geological Survey open-file report, in preparation	Measured Section
5	Kirby Royalties, Inc.	Oil/gas well No. 1 Montgomery
6	Consolidated Oil and Gas, Inc.	Oil/gas well No. 1 Sheehan
7	Eason Oil Co.	Oil/gas well No. 1 M.E. Russel
8	Kirby Royalties, Inc.	Oil/gas well No. 1 Mary Blair
9	Consolidated Oil and Gas, Inc.	Oil/gas well No. 1 Consolidated LSR Federal
10	Argo Oil-Cosden Petroleum	Oil/gas well No. 1 Gov't-Fleetwood

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Table 4. -- Continued

Plate 1 Index Number	Source	Data Base
11	Barclay and Shoaff, 1978, U.S. Geological Survey Open-File Report 78-660	Drill hole No. B-D25
12	↓	Drill hole No. B-D24
13	↓	Drill hole No. Dixon-C
14	↓	Drill hole No. B-D23
15	Urangesellschaft U.S.A., Inc., 1978, unpublished data	Drill hole No. WH 3-1
16	Caulkins Oil Co.-Alpine Oil Co.	Oil/gas well No. 1 Wren
17	Strong, (no date), Master's thesis, in preparation	Measured Section
18	↓	Measured Section
19	↓	Measured Section
20	↓	Measured Section

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Table 1. -- Chemical analyses for coals in the southeast quarter of the Baggs 15-minute quadrangle, Carbon County, Wyoming and Moffat County, Colorado.

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 C	22.7 0.0	30.4 39.3	42.1 54.5	4.8 6.2	0.2 0.3	- -	- -	- -	- -	- -	9,206 11,902
NE¼, NW¼, sec. 33, T. 18 N., R. 91 W., (RMEC, CB-77)	Muddy Creek	A C	22.9 0.0	30.1 39.0	41.7 54.0	5.4 6.9	0.3 0.4	- -	- -	- -	- -	- -	9,043 11,726
NE¼, NE¼, sec. 5, T. 17 N., R. 91 W., (RMEC, CB-86)	Separation Creek	A C	22.3 0.0	0.0 0.0	0.0 0.0	10.1 13.0	0.8 1.1	- -	- -	- -	- -	- -	8,699 11,193
NE¼, SE¼, sec. 33, T. 18 N., R. 91 W., (RMEC, CB-81)	Red Rim	A C	24.3 0.0	29.7 39.2	33.5 50.8	7.6 10.1	0.7 0.9	- -	- -	- -	- -	- -	8,646 11,416
NE¼, SW¼, sec. 6, T. 20 N., R. 88 W., Old Nebraska Mine (Ball, 1909)	Lance-Fox Hills Formation, undifferentiated	A B	19.20 17.30	36.46 37.32	40.56 41.51	3.78 3.87	0.34 0.35	5.74 5.61	58.88 60.27	1.34 1.37	29.92 28.53	5,401 5,528	9,722 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

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 Baggs quadrangle, Carbon County, Wyoming and Moffat County, Colorado.

Coal Bed	High Development Potential	Moderate Development Potential	Low Development Potential	Unknown Development Potential	Total
Fort Union [19]	2,140,000	330,000	130,000	-0-	2,600,000
Fort Union [13]	-0-	-0-	-0-	-0-	-0-
Fort Union [12]	-0-	-0-	-0-	-0-	-0-
Fort Union [11]	-0-	-0-	-0-	-0-	-0-
Fort Union [10]	-0-	-0-	-0-	-0-	-0-
Fort Union [7]	-0-	-0-	-0-	-0-	-0-
Fort Union [6]	3,890,000	1,390,000	1,630,000	-0-	6,910,000
Fort Union [5]	9,900,000	2,580,000	1,118,000	-0-	13,660,000
Fort Union [3]	1,430,000	770,000	790,000	-0-	2,990,000
Fort Union [2]	2,000,000	1,110,000	220,000	-0-	3,330,000
Fort Union [1]	2,100,000	1,180,000	40,000	-0-	3,320,000
Almond [3]	-0-	-0-	-0-	-0-	-0-
Almond [2]	-0-	-0-	-0-	-0-	-0-
Almond [1]	-0-	-0-	-0-	-0-	-0-
Isolated Data Points	-0-	-0-	-0-	2,310,000	2,310,000
Totals	21,460,000	7,360,000	3,990,000	2,310,000	35,120,000

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