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COAL RESOURCE OCCURRENCE AND COAL DEVELOPMENT POTENTIAL MAPS OF THE RATTLESNAKE BUTTE QUADRANGLE, ROUTT COUNTY, COLORADO

[Report includes 23 plates]

Prepared for

UNITED STATES DEPARTMENT OF THE INTERIOR

GEOLOGICAL SURVEY

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INTRODUCTION

Purpose

This text is to be used in conjunction with Coal Resource Occurrence and Coal Development Potential Maps of the Rattlesnake Butte quadrangle, Routt County, Colorado. This report was compiled to support the land-planning work of the Bureau of Land Management (BLM) and 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 United States Geological Survey under contract number 14-08-0001-15789. 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 Published and unpublished public information available through December, 1978, was used as the data base for this study. No new drilling or field mapping was done as part of this study.

Location

The Rattlesnake Butte quadrangle is located in central Routt County in northwestern Colorado, approximately 12 airline miles (19 km) southwest of the town of Steamboat Springs and 24 airline miles (39 km) southeast of the town of Craig. A small area in the southwestern corner of the quadrangle is included within the boundary of the Routt National Forest. With the exception of several ranches and two school sites, the quadrangle is unpopulated. There are no major highways within the quadrangle.

Accessibility

A paved medium-duty road, crossing from the east-central part of the quadrangle to the northwestern corner, connects Colorado Highway 131 at the town of Oak Creek (approximately 3 miles (5 km) east of the quadrangle) with the town of Hayden (approximately 14 miles (23 km) northwest of the quadrangle). U.S. Highway 40, crossing east-west approximately 8 miles (13 km) north of the quadrangle, connects Steamboat Springs, Hayden, and Craig. The remainder of the quadrangle is accessible by several light-duty roads, unimproved dirt roads, and trails.

Railway service for the Rattlesnake Butte quadrangle is provided by the Denver & Rio Grande Western Railroad from Denver to the railhead at Craig. A spur of the rail line serves the Energy Fuels Corporation mine in the north-central part of the quadrangle, approaching the mine from the north. The Denver & Rio Grande Western Railroad is the major transportation route for coal shipped east from northwestern Colorado (U.S. Bureau of Land Management, 1977).

Physiography

The Rattlesnake Butte quadrangle lies in the southern part of the Wyoming Basin physiographic province, as defined by Howard and Williams (1972). The quadrangle is approximately 2 miles (3 km) southeast of the Williams Fork Mountains and 21 miles (34 km) southwest of the Continental Divide at its closest point.

The landscape in the northwestern half of the Rattlesnake Butte quadrangle is dominated by broad, gentle slopes, low rounded hills, and wide stream valleys, while the relief is more pronounced in the southeastern half of the quadrangle.

Approximately 2,250 feet (686 m) of relief is present in the Rattlesnake Butte quadrangle. Altitudes range from approximately 9,~~000~~ feet (2,743 m) in the southeastern part of the quadrangle, to approximately 6,750 feet (2,057 m) along the Fish Creek valley in the northwestern part of the quadrangle. Rattlesnake Butte, in the east-central part of the quadrangle, rises approximately 760 feet (232 m) above the Trout Creek valley.

Trout Creek and its tributaries (Fish Creek, Foidel Creek, Middle Creek, Little Middle Creek, and Little Trout Creek) flow ~~toward the~~ northeast across the Rattlesnake Butte quadrangle. Trout Creek joins the Yampa River approximately 7 miles (11 km) north of the quadrangle.

Climate and Vegetation

The climate of northwestern Colorado is semiarid. Clear, sunny days prevail in the Rattlesnake Butte quadrangle, and daily temperatures typically vary from 0° to 35° F (-18° to 2° C) in January and from 42° to 80° F (6° to 27° C) in July. Annual precipitation in the area averages approximately 16 inches (41 cm). Snowfall during the winter months accounts for the major part of the precipitation, although rainfall from thundershowers during the summer months also contributes to the total. Winds, averaging approximately 3 miles per hour (5 km per hour), are generally from the west, but wind directions and velocities vary greatly depending on the local terrain (U.S. Bureau of Land Management, 1977).

Open to very dense stands of deciduous trees, often relatively small in size, occur at higher altitudes in the Rattlesnake Butte quadrangle where moisture and soil depth are adequate. These areas predominate in the southern part of the quadrangle in the Routt National Forest, and along Trout Creek and Little Middle Creek, at higher elevations. In the southeastern part of the quadrangle, the typical vegetation is mountain shrub, including serviceberry, Gambel oak and rabbitbrush, which ranges from 2 to 8 feet (0.6 to 2.4 m) in height. The lower, flatter areas in the northwestern part of the quadrangle are primarily vegetated with sagebrush. The north-central part of the quadrangle is used as agricultural land (U.S. Bureau of Land Management, 1977).

Land Status

The Rattlesnake Butte quadrangle lies on the southern boundary of the Yampa Known Recoverable Coal Resource Area (KRCRA). Approximately 75 to 80 percent of the quadrangle lies within the KRCRA boundary, and the Federal government owns the coal rights for approximately three-fourths of this area as shown on plate 2. Eight active coal leases comprise approximately 20 percent of the area within the KRCRA boundary in the quadrangle.

GENERAL GEOLOGY

Previous Work

The first geologic description of the general area in which the Rattlesnake Butte quadrangle is located was prepared by Emmons (1877) as part of a survey of the Fortieth Parallel. The decision to build a railroad into the region stimulated several investigations of coal between 1886 and 1905, including papers by Hewett (1889), Hills (1893), Storrs (1902), and Parsons and Liddell (1903). Fenneman and Gale (1906) conducted geologic studies of the Yampa coal field and included a description of the geology and coal occurrence in the Rattlesnake Butte quadrangle in their report. In 1955, Bass and others expanded Fenneman and Gale's work in a report on the geology and mineral fuels of parts of Routt and Moffat Counties, and this is the most comprehensive work on the area. Tweto (1976) compiled a generalized regional geologic map which included this quadrangle. Reconnaissance drilling and mapping in the Rattlesnake Butte quadrangle area by the U.S. Geological Survey was reported by Ryer (1977), Schneider (1978), Stevenson (1978), and Brownfield (1978a and 1978b).

Stratigraphy

The rock formations which crop out in the Rattlesnake Butte quadrangle are Late Cretaceous in age. These include the coal-bearing Iles and Williams Fork Formations of the Mesaverde Group, the underlying Mancos Shale, and the overlying Lewis Shale. Only the Iles and Williams Fork Formations are known to contain coal in this quadrangle.

The Mancos Shale is exposed in the southwestern corner of the quadrangle and along Trout and Oak Creeks in the central and southeastern parts of the quadrangle, respectively (Bass and others, 1955). It is composed of gray to dark-gray marine shale interbedded with light-gray to light-brown fine-grained sandstone beds (Bass and others, 1955). According to Ryer (1977), the Mancos Shale is approximately 3,000 feet (914 m) thick in northwestern Colorado, but its total thickness in the Rattlesnake Butte quadrangle is unknown.

The Mesaverde Group conformably overlies the Mancos Shale and consists of two coal-bearing formations, the Iles and the Williams Fork.

The Iles Formation is approximately 1,400 feet (427 m) thick (Ryer, 1977) and crops out over most of the southern half of the quadrangle. The formation consists of the basal Tow Creek Sandstone Member, an overlying sequence of sandstones interbedded with sandy shale, shale, and coal, and at the top of the formation, the Trout Creek Sandstone Member.

The Tow Creek Sandstone Member is a light-brown fine-grained massive ledge-forming sandstone ranging in thickness from 60 to 70 feet (18 to 21 m) where measured in oil and gas test holes drilled in the quadrangle. The member is overlain by light-brown, light-gray, and white massive ledge-forming sandstones interbedded with gray sandy shale, shale, and coal beds. The coal, designated as the Lower Coal Group by Fenneman and Gale (1906), is distributed throughout this sequence beginning about 400 feet (122 m) above the base of the formation and extending up to the base of the the overlying Trout Creek Sandstone Member, a white to light-brown, fine-grained massive cliff-forming sandstone that is approximately 100 feet (30 m) thick (Bass and others, 1955).

The Williams Fork Formation conformably overlies the Iles Formation and is exposed over much of the northern half of the quadrangle. It is approximately 1,300 feet (396 m) thick and is divided into four units by Ryer (1977): a lower coal-bearing member, a marine shale member, the Twentymile Sandstone Member, and an upper member.

The lower coal-bearing member is designated as the Middle Coal Group (Fenneman and Gale, 1906), and contains approximately 300 feet (91 m) of interbedded medium- to dark-gray siltstone, silty sandstone, very fine grained tan to gray sandstone, and coal (Ryer, 1977). Three major coal beds, the Wolf Creek, Wadge, and Lennox, occur in the Middle Coal Group. They are stratigraphically located approximately 50 to 15 m), 210 feet (64 m), and 300 feet (91 m), respectively, above the

Trout Creek Sandstone Member. The overlying marine shale sequence, which is approximately 650 feet (198 m) thick in the Rattlesnake Butte quadrangle, is composed of dark-gray to dark-tan shale, silty shale and tan siltstone which grades upward into the overlying Twentymile Sandstone Member (Ryer, 1977). The Twentymile Sandstone Member, which ranges in thickness from 100 to 120 feet (30 to 37 m) in this quadrangle, is a massive white ledge-forming sandstone (Bass and others, 1955; Ryer, 1977). A well-defined contact separates the Twentymile Sandstone Member and the overlying transitional sequence. This transitional sequence, approximately 200 feet (61 m) thick, is composed of dark-gray to bluish-gray shale interbedded with buff- to tan-colored sandstone and a few local coals. The coal beds in this sequence have been designated as the Upper Coal Group (Fenneman and Gale, 1906). The Fish Creek coal bed is the most extensive of the coal beds in this sequence and is located approximately 150 feet (46 m) stratigraphically above the top of the Twentymile Sandstone Member (Bass and others, 1955).

The Lewis Shale, which conformably overlies the Williams Fork Formation and crops out in the northwestern corner and along the northern edge of the quadrangle, consists of a homogeneous, dark-gray to bluish-gray, marine shale. According to Tweto (1976), the total thickness of the Lewis Shale ranges from 1,500 to 1,900 feet (457 to 579 m) in northwestern Colorado, but the total thickness of the formation in this quadrangle is unknown.

The Cretaceous sedimentary rocks in the Rattlesnake Butte quadrangle accumulated close to the western edge of a Late Cretaceous-age epeirogenic seaway which covered part of the western interior of North America. Several transgressive-regressive cycles caused the deposition of a series of marine, near-shore marine, and non-marine sediments in the Rattlesnake Butte quadrangle area (Masters, 1959; Ryer, 1977).

The Mancos Shale was deposited in an offshore marine environment which existed east of the shifting strand line. Deposition of the Mancos

Shale in the region ended with the eastward migration of the shoreline, and the subsequent deposition of the Iles Formation (Kucera, 1959).

The interbedded sandstone, shale, and coal of the Mesaverde Group were deposited as a result of minor changes in the position of the shoreline. During the deposition of the Iles and Williams Fork Formations, near-shore marine, littoral, brackish tidal, brackish and fresh water supratidal, and fluvial environments existed in northwestern Colorado. The major sandstone members of the Iles and Williams Fork Formations, including the Trout Creek and Twentymile Sandstone Members, were deposited in shallow marine and near-shore marine environments. The major coal beds which have wide areal extent were deposited near the seaward margin of the non-marine environments, probably in large brackish-water lagoons or swamps. The slow migration of this depositional environment is responsible for the wide distribution of the Wolf Creek, Wadge, and Lennox coal beds in the Yampa study area. Coal beds of limited areal extent, including those in the Lower Coal Group, were generally deposited in environments associated with fluvial systems, such as back-levee and coastal plain swamps, interchannel basin areas, and abandoned channels (Konishi, 1959).

Deposition of the Lewis Shale marked a landward movement of the sea. The marine sediments of the Lewis Shale were deposited in water depths ranging from a few tens of feet to several hundred feet. The regional uplift west of the Yampa Basin area caused a regression of the sea and ended the deposition of the Lewis Shale in the quadrangle (Kucera, 1959).

Structure

The Yampa KRCRA lies in the southern extension of the Washakie/ Sand Wash structural basin of south-central Wyoming. The basin is bordered on the east by the Park Range, approximately 14 miles (23 km) northeast of the Rattlesnake Butte quadrangle, and on the southwest by the Axial Basin anticline, approximately 29 miles (47 km) west of the quadrangle.

The northeastern corner of the Rattlesnake Butte quadrangle lies on the southern part of the northwest-trending Twentymile Park syncline. The northwestern corner of the quadrangle lies on the southern tip of the north-northeast-trending Tow Creek anticline. The western edge of the quadrangle borders on the eastern limb of the north-south-trending Fish Creek anticline. Dips in the western section of the quadrangle vary from 6° to 17° to the northwest while dips in the east-central section range from 7° to 11° north to 9° to 27° northeast. Seventeen known northeast-trending faults, all of which display a normal sense of movement, offset Cretaceous rocks in the quadrangle (Bass and others, 1955).

COAL GEOLOGY

Several coal beds in the Lower, Middle, and Upper Coal Groups of the Mesaverde Group have been identified in the Rattlesnake Butte quadrangle. The Lower Coal Group includes all coal beds in the Iles Formation lying below the Trout Creek Sandstone Member. The Middle Coal Group includes the coal beds in the lower coal-bearing zone of the Williams Fork Formation lying between the Trout Creek Sandstone Member of the Iles Formation and the Twentymile Sandstone Member of the Williams Fork Formation. The Upper Coal Group includes the coal beds in the Williams Fork Formation above the Twentymile Sandstone Member extending up to the base of the Lewis Shale. Coals of the Upper and Lower Groups are characteristically lenticular and of limited areal extent while some of the coal beds in the Middle Group persist over a large area.

Isopached coal beds that are not formally named have been given bracketed numbers for identification purposes. In instances where coal bed exceeding Reserve Base thickness (5.0 feet or 1.5 meters) have been encountered at one location only, they are treated as isolated data points (see Isolated Data Points section of this report).

Dotted lines shown on some of the derivative maps represent a limit of confidence beyond which isopach, structure contour, overburden isopach, and areal distribution and identified resources maps are not drawn because of insufficient data, even where it is believed that the

coal beds may continue to be greater than Reserve Base thickness beyond the dotted lines.

Chemical analyses of coals.--Analyses of the coals in this area are listed in table 1 and include coal samples tested in this quadrangle for zones 2 and 3 of the Lower Coal Group and the Wolf Creek and Wadge coal beds of the Middle Coal Group. Chemical analyses were not available in the Rattlesnake Butte quadrangle for coal from zone 1 in the Lower Coal Group, the Lennox coal bed in the Middle Coal Group, or the Fish Creek coal bed in the Upper Coal Group. However, it is believed that these coals are similar in rank to the zone 1, Lennox, and Upper Group coals mined, respectively, at the Old Schuster mine and the Moffat "B" Strip mine in the Oak Creek quadrangle to the east, and the Sleepy Cat mine in the Hayden quadrangle to the northwest.

In general, chemical analyses of coals in the Lower, Middle, and Upper Coal Groups indicate that these coals are high-volatile C bituminous in rank on a moist, mineral-matter-free basis according to ASTM Standard Specification D 388-77 (American Society for Testing and Materials, 1977).

Lower Coal Group

The Lower Coal Group begins approximately 400 feet (122 m) above the base of the Iles Formation and extends up to the base of the Trout Creek Sandstone Member of the Iles Formation. Bass and others (1955) identified three coal zones in the Lower Coal Group (zones 1, 2 and 3). The intervals between the zones are approximately 60 and 100 feet (18 and 30 m), respectively.

Coal Zone 1

Zone 1 averages approximately 75 feet (23 m) thick and begins approximately 400 feet (122 m) above the base of the Iles Formation. Many thin coal beds are present in this zone, but only two, the LG1[1] (i.e., Lower Coal Group, zone 1, coal bed [1]) and LG1[2], exceed Reserve Base thickness. These coal beds were encountered at one location only and have been treated as isolated data points.

Coal Zone 2

Zone 2 is stratigraphically above and separated from zone 1 by approximately 60 feet (18 m) of interbedded sandstone, sandy shale, and shale. It is approximately 65 feet (20 m) thick in the Rattlesnake Butte quadrangle and contains numerous thin coal beds. However, only two of these coal beds, the LG2[4] and LG2[9], are known to exceed Reserve Base thickness in this quadrangle. The LG2[4] coal bed was identified at only one location in the quadrangle and has been treated as an isolated data point.

The LG2[3] coal bed (plate 4) was identified in a single drill hole near the quadrangle boundary in sec. 2, T. 3 N., R. 86 W., where it is reported to be 6.9 feet (2.1 m) in thickness and contains a rock parting 0.1 feet (0.03 m) thick. The LG2[3] coal bed was isopached along the quadrangle boundary north of the drill hole based on outcrop and drill-hole data in the adjacent Oak Creek quadrangle to the east where this coal bed is designated as LG2[9]. In the Oak Creek quadrangle the coal bed ranges in measured thickness from 4.5 to 13.6 feet (1.4 to 4.1 m) and contains local rock partings up to 0.7 feet (0.2 m) thick.

Coal Zone 3

This coal zone is located approximately 100 feet (30 m) straigraphically above the top of zone 2 and ranges up to 80 feet (24 m) in thickness. Because numerous coal beds that are thin, lenticular, and discontinuous occur in this zone and cannot be correlated with accuracy, the coals in the zone have been isopached as a zone (plate 7). Cumulative coal thicknesses in the zone range from 3.5 to 18.3 feet (1.1 to 5.6 m) in the east-central part and along the southeastern edge of the quadrangle. The maximum coal thickness has been reported in sec. 10, T. 4 N., R. 86 W., where the zone includes 63.3 feet (19.3 m) of rock partings. This coal zone extends into the Oak Creek quadrangle to the east and contains two relatively persistent coal beds that were isopached individually in that quadrangle.

Undifferentiated Lower Group Coal Bed

One coal bed exceeding Reserve Base thickness, the LG[3] coal bed, was penetrated by a drill hole in sec. 9, T. 4 N., R. 86 W., and cannot be located in the stratigraphic section with enough accuracy to place the coal bed within a specific zone. Since this coal bed was identified at one location only, it has been treated as an isolated data point.

Middle Coal Group

The Middle Coal Group is located between the top of the Trout Creek Sandstone Member of the Iles Formation and the base of the Twentymile Sandstone Member of the Wiliams Fork Formation. In the Rattlesnake Butte quadrangle, the Middle Coal Group contains three major coal beds, the Wolf Creek, Wadge, and Lennox, which occur, stratigraphically, approximately 45 feet (14 m), 200 feet (61 m), and 285 feet (87 m), respectively, above the base of the Wiliams Fork Formation.

Wolf Creek Bed

The Wolf Creek bed has been identified in outcrops, drill holes, and mine-measured sections throughout most of the northern half of the quadrangle (plate 11). It is located approximately 30 to 45 feet (9 to 14 m) stratigraphically above the base of the Williams Fork Formation and has been mined at the Middle Creek mine located in sec. 10, T. 4 N., R. 86 W. The coal bed ranges in thickness from 4.0 to 21.5 feet (1.2 to 6.6 m) where measured in outcrops and drill holes, attaining the maximum reported thickness in sec. 23, T. 4 N., R. 87 W. Generally, the Wolf Creek coal bed occurs as a single, thick coal bed. However, it locally contains rock partings ranging from 0.2 to 9.0 feet (0.1 to 2.7 m) in thickness. Near the western boundary of the Oak Creek quadrangle to the east, the Wolf Creek coal bed thickens to 11.0 feet (3.4 m) where measured in a drill hole in sec. 14, T. 4 N., R. 86 W. Although the Wolf Creek coal bed has not been identified in the adjacent Dunckley quadrangle to the west, it is believed that the coal bed extends into that quadrangle and may be as much as 20 feet (6.1 m) thick in sec. 23, T. 4 N., R. 87 W.

Wadge Coal Bed

The Wadge coal bed is known to persist over most of the northern half of the quadrangle and has been mined at the Energy Fuel Corporations's Energy No. 1 strip mine and at the Pittsburg and Midway Coal Company's Edna strip mine (plate 15). The coal bed lies about 125 to 180 feet (38 to 55 m) above the top of the Wolf Creek coal bed. Where measured in drill holes, mine-measured sections and outcrops in this quadrangle, the coal bed ranges in thickness from 3 to 13 feet (0.9 to 4.0 m), having its maximum reported thickness in sec. 18, T. 4 N., R. 86 W. Bass and others (1955) indicate that the Wadge coal bed splits locally and contains as much as 9.1 feet (2.8 m) of interburden. In the western part of the quadrangle, only the upper split exceeds Reserve Base thickness; in the north-central part of the quadrangle, only the lower split exceeds Reserve Base thickness. The coal bed then generally becomes a single bed in the central and eastern parts of the quadrangle. Those splits that exceed Reserve Base thickness are isopached as the Wadge coal bed in this quadrangle.

In the Oak Creek quadrangle to the east, only the upper split of the Wadge coal bed exceeds Reserve Base thickness and ranges from 2.7 to 8.0 feet (0.8 to 2.4 m) thick, attaining its maximum thickness in secs. 23, 24, 25, and 26, T. 5 N., R. 86 W. To the west in the Dunckley quadrangle, the maximum measured thickness is 11.8 feet (3.6 m) where measured in an outcrop in sec. 11, T. 4 N, R. 87 W.

Lennox Coal Bed

The Lennox coal bed lies about 40 to 80 feet (12 to 24 m) stratigraphically above the Wadge coal bed in the west-central part of the quadrangle. From available drill hole and outcrop measurements, the thickness of the Lennox coal bed appears to range from 0.5 to 5.9 feet (0.2 to 1.8 m). However, the coal bed exceeds Reserve Base thickness in only two small areas (plate 4). One area is located in secs. 8 and 17, T. 4 N., R. 86 W., and the other is in sec. 18, T. 4 N., R. 86 W., and sec. 13, T. 4 N., R. 87 W.

Undifferentiated Middle Group Coal Bed

One coal bed exceeding Reserve Base thickness, the MG[10] coal bed, was penetrated by a single drill hole in the NE 1/4 sec. 7, T. 4 N., R. 86 W., and cannot be correlated with other coal beds in the Middle Coal Group. It has been treated as an isolated data point.

Upper Coal Group

The Upper Coal Group includes all coal beds above the Twentymile Sandstone Member in the upper coal-bearing zone of the Williams Fork Formation. However, only the Fish Creek coal bed has been identified within the Upper Coal Group in the Rattlesnake Butte quadrangle. It ranges in thickness from 2.0 to 6.6 feet (0.6 to 2.0 m) where measured in drill holes and outcrops (plate 19) and exceeds Reserve Base thickness over only a small area in secs. 21 and 28, T. 5 N., R. 86 W.

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 coal 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. Descriptions and Reserve Base tonnages for the isolated data points occurring in this quadrangle are listed in table 5.

COAL RESOURCES

Data from drill holes, mine measured sections, and outcrop measurements were used to construct outcrop, isopach, and structure contour maps of the coal beds in this quadrangle. The source of each indexed data point shown on plate 1 is listed in table 6.

Coal resources for Federal land were calculated using data obtained from the coal isopach maps (plates 4, 7, 11, 15, and 19) and the areal distribution and identified resources maps (plates 6, 10, 14, 18, and 21). The coal-bed acreage (measured by planimeter), multiplied by the average thickness of the coal bed and by a conversion factor of 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 of coal for each isopached coal bed. Coal beds thicker than 5.0 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 stated in U.S. Geological Survey Bulletin 1450-B which call for a minimum thickness of 28 inches (70 cm) and a maximum depth of 1,000 feet (305 m) for bituminous coal.

Reserve Base and Reserve tonnages for the isopached coal beds are shown on plates 6, 10, 14, 18, and 21, 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 the isolated data points. Coal Reserve Base tonnages per Federal section are shown on plate 2 and total approximately 239.79 million short tons (217.54 million metric tons) for the entire quadrangle, including the tonnages for the isolated data points.

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 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 less than 200 feet (61 m) of overburden and 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 5.0 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 area influenced by the isolated data points in this quadrangle contain approximately 2.98 million short tons (2.70 million metric tons) of coal available for surface mining.

The coal development potential for surface mining methods is shown on plate 22. Of those Federal land areas having a known development potential for surface mining, 79 percent are rated high, 9 percent are rated moderate, and 12 percent are rated low. The remaining Federal lands within the KRCRA boundary are classified as having unknown development potential for surface mining methods. Reserve Base tonnages in the various development potential categories for surface mining methods are listed in table 2.

Development Potential for Subsurface and In-Situ Mining Methods

Areas considered to have a development potential for conventional subsurface mining methods include those areas where coal beds of Reserve Base thickness are between 200 and 3,000 feet (61 and 914 m) below the ground surface which 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 conventional subsurface mining are defined as areas underlain by coal beds of Reserve Base thickness 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) below the ground surface, 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 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 6.15 million short tons (5.58 million metric tons) of coal available for conventional subsurface mining.

The coal development potential for conventional subsurface mining methods is shown on plate 23. Of those Federal land areas classified as having known development potential for conventional subsurface mining methods, 98 percent are rated high and 2 percent are rated moderate. The remaining Federal lands within the KRCRA boundary are classified as having unknown development potential for conventional subsurface mining methods. Reserve Base tonnages in the various development potential categories for conventional subsurface mining methods are listed in table 3.

Based on criteria provided by the U.S. Geological Survey, coal beds of Reserve Base thickness dipping between 35° and 90° with a minimum Reserve Base of 50 million short tons (45.4 million metric tons) for bituminous coal and 70 million short tons (63.5 million metric tons) for subbituminous coal have a moderate potential for in-situ development; coal beds dipping from 15° to 35°, regardless of tonnage, and coal beds dipping from 35° to 90° with less than 50 million short tons (45.4 million metric tons) of coal have a low development potential for in-situ mining methods. Coal lying between the 200-foot (61 m) overburden line and the outcrop is not included in the total coal tonnages available as it is needed for cover and containment in the in-situ process.

Areas where faulted coal beds of Reserve Base thickness dip greater than 15° between 200 and 300 feet (61 and 914 m) below the ground surface are classified as having an unknown development potential for in-situ

mining methods. These criteria also apply to those areas influenced by isolated data points where the coal beds dip greater than 15° and are not faulted. The areas influenced by isolated data points in this quadrangle contain approximately 0.67 million short tons (0.61 million metric tons) of coal available for in-situ mining.

Coal development potential for in-situ mining methods is shown on plate 27. All of the Federal land areas classified as having known development potential for in-situ mining methods are rated low. The remaining Federal lands within the KRCRA boundary are classified as having unknown development potential for in-situ mining methods. Reserve Base tonnages in the various development potential categories for subsurface and in-situ mining methods are listed in table 4.

Table 1. -- Chemical analyses of coals in the Rattlesnake Butte quadrangle, Routt 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
S½ sec. 30, T. 4 N., R. 85 W., Old Schuster Mine (Campbell, 1923) from Oak Creek quadrangle	Lower Coal Group Zone 1	A	8.8	36.1	50.2	4.90	1.51	5.69	68.59	1.54	17.77	-	12,160
		B	-	39.6	55.0	5.38	1.66	5.17	75.25	1.69	10.85	-	13,340
		C	-	41.8	58.2	-	1.75	5.46	79.52	1.79	11.48	-	14,100
SW¼ sec. 22, T. 4 N., R. 86 W., Apex Mine (Bass and others, 1955)	Lower Coal Group Zone 2	A	7.7	36.4	50.1	5.8	0.6	5.7	68.7	1.5	17.7	-	12,150
		B	4.4	37.7	51.9	6.0	0.6	5.5	71.2	1.6	15.1	-	12,590
		C	-	39.4	54.4	6.2	0.7	5.2	74.4	1.6	11.9	-	13,160
		D	-	42.0	58.0	-	0.7	5.5	79.4	1.7	12.7	-	14,040
SW¼, NE¼, sec. 23, T. 4 N., R. 86 W., Nicholas Stein Mine (George and others, 1937)	Lower Coal Group Zone 3	A	9.0	36.2	49.4	5.4	0.5	5.6	68.3	1.4	18.8	6,650	11,970
		C	-	39.8	54.2	6.0	0.5	5.0	75.0	1.6	11.9	7,306	13,150
		D	-	42.3	57.7	-	0.6	5.3	79.8	1.6	12.7	7,772	13,990
NW¼ sec. 10, T. 4 N., R. 86 W., Middle Creek Mine (Bass and others, 1955)	Middle Coal Group Wolf Creek	A	7.7	40.9	45.3	6.1	0.6	5.7	67.4	1.5	18.7	-	11,940
		B	5.2	42.0	46.5	6.3	0.6	5.5	69.3	1.5	16.8	-	12,270
		C	-	44.3	49.0	6.7	0.6	5.2	73.1	1.6	12.8	-	12,940
		D	-	47.5	52.5	-	0.7	5.6	78.3	1.7	13.7	-	13,860
NE¼ sec. 32, T. 5 N., R. 86 W., Greenhalgh Prospect (Bass and and others, 1955)	Middle Coal Group Wadge	A	10.1	35.7	48.4	5.8	0.5	-	-	-	-	-	11,670
		B	4.7	37.9	51.3	6.1	0.5	-	-	-	-	-	12,360
		C	-	39.7	53.9	6.4	0.5	-	-	-	-	-	12,970
		D	-	42.5	57.5	-	0.5	-	-	-	-	-	13,860
Sec. 31, T. 5 N., R. 85 W., Moffat "B" Strip Mine (Jones and Murray, 1977) from Oak Creek quadrangle	Middle Coal Group Lennox	A	11.4	42.7	52.3	5.0	0.7	-	-	-	-	-	11,620
NW¼ sec. 16, T. 5 N., R. 88 W., Sleepy Cat Mine (Bass and others, 1955) from Hayden quadrangle	Upper Coal Group Zone L	A	14.4	32.6	48.5	4.5	0.9	6.0	63.2	1.5	23.9	6,134	11,040
		C	-	38.1	56.6	5.3	1.0	5.1	73.8	1.9	13.0	7,172	12,910
		D	-	40.3	59.7	-	1.1	5.4	78.0	1.9	13.6	7,572	13,630

Form of Analysis: A, as received
B, air dried
C, moisture free
D, moisture and ash 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 Rattlesnake Butte quadrangle, Routt County, Colorado.

Coal Bed or Zone	High Development Potential	Moderate Development Potential	Low Development Potential	Unknown Development Potential	Total
Fish Creek	130,000	70,000	290,000	-	490,000
Lennox	680,000	230,000	840,000	-	1,750,000
Wadge	13,000,000	12,540,000	7,240,000	-	32,780,000
Wolf Creek	23,470,000	9,430,000	3,190,000	-	36,090,000
LG 3	2,990,000	2,000,000	1,880,000	-	6,870,000
LG 2 {9}	50,000	40,000	80,000	-	170,000
Isolated Data Points	-	-	-	2,980,000	2,980,000
Totals	40,320,000	24,310,000	13,520,000	2,980,000	81,130,000

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 Rattlesnake Butte quadrangle, Routt County, Colorado.

Coal Bed or Zone	High Development Potential	Moderate Development Potential	Low Development Potential	Unknown Development Potential	Total
Fish Creek	-	-	-	-	-
Lennox	690,000	-	-	-	690,000
Wadge	36,520,000	3,720,000	-	-	40,240,000
Wolf Creek	65,370,000	10,020,000	-	-	75,390,000
LG 3	20,620,000	770,000	-	-	21,390,000
LG 2 {9}	10,000	-	-	-	10,000
Isolated Data Points	-	-	-	6,150,000	6,150,000
Total	123,210,000	14,510,000	-	6,150,000	143,870,000

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

Table 4. -- Coal Reserve Base data for in-situ mining methods for Federal coal lands (in short tons) in the Rattlesnake Butte quadrangle, Routt County, Colorado.

Coal Bed or Zone	Moderate Development Potential	Low Development Potential	Unknown Development Potential	Total
Fish Creek	-	-	-	-
Lennox	-	-	-	-
Wadge	-	3,020,000	-	3,020,000
Wolf Creek	-	9,820,000	-	9,820,000
LG 3	-	1,190,000	-	1,190,000
LG 2 {9}	-	90,000	-	90,000
Isolated Data Points	-	-	670,000	670,000
Totals	-	14,120,000	670,000	14,790,000

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

Table 5.--Descriptions and Reserve Base tonnages (in million short tons) for isolated data points

Coal Bed	Source	Location	Thickness	Reserve Base Tonnages		
				Surface	Subsurface	In-Situ
LG2[4]	Bass and others, 1955	sec. 23, T. 4 N., R. 86 W.	5.5 ft (1.7 m)	0.67	1.42	0.67
LG[3]	Bass, N.W., 1955	sec. 9, T. 4 N., R. 86 W.	7.5 ft (2.3 m)	0.21	3.62	0
MG[10]	Brownfield, M.E., 1978a	sec. 7, T. 4 N., R. 86 W.	8.0 ft (2.4 m)	2.10	1.11	0

Table 6.-- Sources of data used on plate 1

Plate 1 Index Number	Source	Data Base
1	Bass and others, 1955, U.S. Geological Survey Bulletin 1027-D, pl. 22	Measured Section No. 35
2	↓	Measured Section No. 36
3	U.S. Geological Survey, 1963, Inactive Coal Lease No. Colorado 089576, United Electric Coal Co.	Drill hole No. G19
4	↓	Drill hole No. G18
5	↓	Drill hole No. G20
6	↓	Drill hole No. G17
7	Bass and others, 1955, U.S. Geological Survey Bulletin 1027-D, pl. 22	Measured Section No. 44
8	Bass, N.W., 1955, U.S. Geological Survey, unpublished field notes	Core hole No. 5
9	↓	Core hole No. 4
10	Bass and others, 1955, U.S. Geological Survey Bulletin 1027-D, pl. 22	Measured Section No. 46
11	U.S. Geological Survey, 1952, Inactive Coal Lease No. Denver 051669, Middle Creek Mine	Mine-Measured Section No. MC13
12	Bass and others, 1955, U.S. Geological Survey Bulletin 1027-D, pl. 22	Measured Section No. 45
13	↓	Measured Section No. 48
14	↓	Measured Section No. 49
15	↓	Measured Section No. 51
16	↓	Measured Section No. 50

Table 6. -- Continued

Plate 1 Index Number	Source	Data Base
17	Ryer, T.A., 1977, U.S. Geological Survey Open-File Report 77-303, table 2 and fig. 1	Drill hole No. ES23
18	↓	Drill hole No. ES27
19		Drill hole No. ES31
20		Drill hole No. ES19
21		Drill hole No. ES24
22		Drill hole No. ES28
23		Drill hole No. ES32
24		Drill hole No. ES34
25		Drill hole No. ES33
26		Drill hole No. ES25
27		Drill hole No. ES29
28		Drill hole No. ES30
29		Drill hole No. ES26
30	U.S. Geological Survey, 1963b, Inactive Coal Lease No. Colorado 089576, United Electric Coal Co.	Drill hole No. G12
31	Ryer, T.A., 1977, U.S. Geological Survey Open-File Report 77-303, table 2 and fig. 1	Drill hole No. ES18
32	U.S. Geological Survey, 1963b, Inactive Coal Lease No. Colorado 089576, United Electric Coal Co.	Drill hole No. G13
33	↓	Drill hole No. G14

Table 6. -- Continued

Plate 1 Index Number	Source	Data Base
34	Ryer, T.A., 1977, U.S. Geological Survey Open-File Report 77-303, table 2 and fig. 1	Drill hole No. ES9
35	↓	Drill hole No. ES16
36	↓	Drill hole No. ES5
37	↓	Drill hole No. E4
38	↓	Drill hole No. ES7
39	↓	Drill hole No. ES4
40	↓	Drill hole No. ES6
41	U.S. Geological Survey, 1963b, Inactive Coal Lease No. Colorado 089576, United Electric Coal Co.	Drill hole No. G11
42	Ryer, T.A., 1977, U.S. Geological Survey Open-File Report 77-303, table 2 and fig. 1	Drill hole No. ES10
43	↓	Drill hole No. ES13
44	↓	Drill hole No. ES15
45	↓	Drill hole No. ES17
46	↓	Drill hole No. ES20
47	↓	Drill hole No. ES21
48	U.S. Geological Survey, 1963b, Inactive Coal Lease No. Colorado 089576, United Electric Coal Co.	Drill hole No. G9
49	↓	Drill hole No. G10

Table 6. -- Continued

Plate 1 Index Number	Source	Data Base
50	Ryer, T.A., 1977, U.S. Geological Survey Open-File Report 77-303, table 2 and fig. 1	Drill hole No. ES22
51	↓	Drill hole No. ES11
52	↓	Drill hole No. ES12
53	U.S. Geological Survey, 1963b, Inactive Coal Lease No. Colorado 089576, United Electric Coal Co.	Drill hole No. G1
54	Ryer, T.A., 1977, U.S. Geological Survey Open-File Report 77-303, table 2 and fig. 1	Drill hole No. E5
55	↓	Drill hole No. ES3
56	↓	Drill hole No. ES2
57	U.S. Geological Survey, 1963a, Inactive Coal Prospecting Permit No. Colorado 093707, Energy Coal Co.	Drill hole No. EC6
58	↓	Drill hole No. EC7
59	Bass and others, 1955, U.S. Geological Survey Bulletin 1027-D, pl. 22	Mine-Measured Section No. 52
60	↓	Measured Section No. 54
61	↓	Mine-Measured Section No. 55
62	↓	Measured Section No. 62
63	↓	Measured Section No. 66

Table 6. -- Continued

Plate 1 Index Number	Source	Data Base
64	U.S. Geological Survey, 1963b, Inactive Coal Lease No. Colorado 089576, United Electric Coal Co.	Drill hole No. G16
65	↓	Drill hole No. G15
66	↓	Drill hole No. G8
67	Ryer, T.A., 1977, U.S. Geological Survey Open-File Report 77-303, table 2 and fig. 1	Drill hole No. E3
68	U.S. Geological Survey, 1963b, Inactive Coal Lease No. Colorado 089576, United Electric Coal Co.	Drill hole No. G7
69	Bass and others, 1955, U.S. Geological Survey Bulletin 1027-D, pl. 22	Measured Section No. 53
70	U.S. Geological Survey, 1963b, Inactive Coal Lease No. Colorado 089576, United Electric Coal Co.	Drill hole No. G5
71	Ryer, T.A., 1977, U.S. Geological Survey Open-File Report 77-303, table 2 and fig. 1	Drill hole No. E1
72	↓	Drill hole No. E2
73	U.S. Geological Survey, 1963a, Inactive Coal Prospecting Permit No. Colorado 093707, Energy Coal Co.	Drill hole No. EC9
74	↓	Drill hole No. EC8
75	Bass, N.W., 1955, U.S. Geological Survey, unpublished field notes	Core hole No. 15
76	↓	Core hole No. 6

Table 6. -- Continued

Plate 1 Index Number	Source	Data Base
77	Ryer, T.A., 1977, U.S. Geological Survey Open-File Report 77-303, table 2 and fig. 1	Drill hole No. ES36
78	↓	Drill hole No. ES35
79	Bass, and others, 1955, U.S. Geological Survey Bulletin 1027-D, pl. 23	Measured Section No. 95
80	Bass, N.W., 1955, U.S. Geological Survey, unpublished field notes	Drill hole No. 1 Thomas P. Greehalgh Prospect Hole
81	Bass and others, 1955, U.S. Geological Survey Bulletin 1027-D, pl. 23	Measured Section No. 97
82	↓	Measured Section No. 105
83	↓	Measured Section No. 104
84	Ryer, T.A., 1977, U.S. Geological Survey Open-File Report 77-303, table 2 and fig. 1	Drill hole No. ES39
85	Bass and others, 1955, U.S. Geological Survey Bulletin 1027-D, pl. 23	Measured Section No. 106
86	↓	Measured Section No. 111
87	↓	Measured Section No. 158b
88	Bass and others, 1955, U.S. Geological Survey Bulletin 1027-D, pl. 22	Measured Section No. 56
89	↓	Measured Section No. 65
90	↓	Measured Section No. 64

Table 6. -- Continued

Plate 1 Index Number	Source	Data Base
91	Bass and others, 1955, U.S. Geological Survey Bulletin 1027-D, pl. 22	Measured Section No. 69
92	↓	Measured Section No. 70
93	↓	Measured Section No. 73
94	↓	Measured Section No. 71
95	Stevenson, A.E., U.S. Geological Survey Open-File Report 78-1048	Drill hole No. RB-18
96	↓	Drill hole No. RB-19
97	↓	Drill hole No. RB-20
98	↓	Drill hole No. RB-22
99	Brownfield, M.E., 1978b, U.S. Geological Survey Open-File Report 78-365	Drill hole No. RB-12
100	↓	Drill hole No. RB-13
101	↓	Drill hole No. RB-15
102	↓	Drill hole No. RB-14
103	Brownfield, M.E., 1978a, U.S. Geological Survey Open-File Report 78-364	Drill hole No. RB-2
104	↓	Drill hole No. RB-4
105	↓	Drill hole No. RB-6
106	↓	Drill hole No. RB-7
107	↓	Drill hole No. RB-8
108	↓	Drill hole No. RB-9

Table 6. -- Continued

Plate 1 Index Number	Source	Data Base
109	Schneider, G. B., U.S. Geological Survey Open-File Report 78-848	Drill hole No. 2
110	↓	Drill hole No. 3
111	Bass and others, 1955, U.S. Geological Survey Bulletin 1027-D, pl. 23	Drill hole No. 96
112	↓	Drill hole No. 100
113	↓	Drill hole No. 99
114	↓	Mine-Measured Section No. 99a
115	↓	Mine-Measured Section No. 99b
116	↓	Drill hole No. 98
117	↓	Drill hole No. 101
118	↓	Drill hole No. 102
119	↓	Drill hole No. 103
120	↓	Drill hole No. 107
121	Brownfield, M.E., 1979, U.S. Geological Survey, personal communication	Measured Section
122	↓	Measured Section
123	↓	Measured Section

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