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COAL RESOURCE OCCURRENCE AND COAL DEVELOPMENT POTENTIAL MAPS OF THE AXIAL QUADRANGLE, MOFFAT COUNTY, COLORADO

[Report includes 68 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 and Coal Development Potential Maps of the Axial quadrangle, Moffat 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 Published and unpublished public information available through November, 1978, was used as the data base for this study.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 Axial quadrangle is located in southeastern Moffat County in northwestern Colorado approximately 23 miles (37 km) southwest of the town of Craig via Colorado Highway 13 (also known as Colorado Highway 789) and 18 miles (29 km) north-northeast of the town of Meeker, also via Colorado Highway 13. The town of Axial is located on Colorado Highway 13 in the southeastern part of the quadrangle. Several ranches lie in the eastern part of the quadrangle while the western half of the quadrangle is unpopulated.

Accessibility

Colorado Highway 13 crosses the southeastern part of the quadrangle connecting Craig to the northeast with Meeker to the south. An improved light-duty road passes east-west across the center of the quadrangle, connecting Colorado Highway 13 with U.S. Highway 40 approximately 21 miles (34 km) northwest of the quadrangle. A second improved light-duty road crosses the quadrangle from north to south. It follows Wilson Creek across the southern part of the quadrangle and connects with the town of Lay approximately 13 miles (21 km) north of the quadrangle. The remainder of the quadrangle is accessed by numerous unimproved dirt roads and trails.

Railway service for the Axial quadrangle is provided by the Denver and Rio Grande Western Railroad from Denver to the railhead at Craig. This railroad, terminating approximately 14 miles (23 km) northeast of the Axial quadrangle, is the major transportation route for coal shipped east from northwestern Colorado (U.S. Bureau of Land Management, 1977a).

Physiography

The Axial quadrangle lies at the western edge of the southern Rocky Mountain physiographic province as defined by Howard and Williams (1972). The quadrangle is approximately 12 miles (19 km) west-southwest of the Williams Fork Mountains and approximately 63 miles (101 km) west of the Continental Divide. The northern part of the quadrangle lies in the northwest-trending Axial Basin (Tweto, 1976).

The landscape in the Axial Basin area in the northern part of the quadrangle is characterized by broad, gentle slopes and low hills. Duffy Mountain and Iles Mountain are located in the northeast corner of the quadrangle. The southern half of the quadrangle is dominated by elongate ridges cut by narrow south and southwest-trending stream valleys and by moderate to steep slopes.

Altitudes range from approximately 7,641 feet (2,329 m) in the southwestern corner of the quadrangle to less than 6,160 feet (1,878 m) along Morgan Gulch in the northwestern part of the quadrangle.

A series of northeast-trending creeks and gulches in the Axial quadrangle are tributaries of the Yampa River, approximately 1 to 2 miles (1.6 to 3.2 km) north of the quadrangle. The major streams include Morgan Gulch, Wilson Creek, Good Spring Creek, and Milk Creek. With the exception of Wilson, Good Spring, and Milk Creeks, the streams and their tributaries are intermittent and flow mainly in response to snowmelt in the spring.

Climate and Vegetation

The climate of northwestern Colorado is semiarid. Clear, sunny days prevail in the Axial quadrangle area, with daily temperatures typically varying from 3° to 34°F (-16° to 1°C) in January and from 45° to 86°F (7° to 30°C) in July. Annual precipitation averages approximately 16 inches (41 cm). Snowfall during the winter months accounts for the major part of the precipitation in the area, but 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, 1977a).

The dominant vegetation in the Axial Basin in the northern half of the quadrangle is sagebrush. Grasslands occur along Morgan Gulch in the northwestern part of the quadrangle, and the broad flat area surrounding Wilson Creek in the northeastern part of the quadrangle is utilized as cropland. The dominant vegetation in the southern half of the quadrangle is mountain shrub, including serviceberry, Gambel oak, and rabbitbrush. Pinyon, Utah juniper and Rocky Mountain juniper occur at higher elevations in the south-central part of the quadrangle and on Duffy Mountain and Iles Mountain in the northeastern corner of the quadrangle (U.S. Bureau of Land Management, 1977a).

Land Status

The Axial quadrangle lies at the northeastern edge of the Danforth Hills Known Recoverable Coal Resource Area (KRCRA). The approximate southern third of the quadrangle lies within the KRCRA boundary and the Federal government owns the coal rights for approximately 85 percent of this area. Two active coal leases are located in the southwestern and south-central parts of the quadrangle. These comprise approximately 29 percent of the KRCRA. A Preference Right Lease Application (PRLA) area is located in the west-central part of the quadrangle as shown on plate 2.

GENERAL GEOLOGY

Previous Work

The first geologic description of the general area in which the Axial quadrangle is located was reported 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 1910, including papers by Hewett (1889), Hills (1893), Storrs (1902), and Gale (1907 and 1910). A geologic map and report by Hancock (1925) included the Axial quadrangle. Tweto (1976) compiled a generalized regional map which also included this quadrangle. Drilling by the the U.S. Geological Survey in the quadrangle during 1976, 1977, and 1978 was reported by Reheis (1976 and 1978), Reheis and Peterson (1977), and Nutt (1978). The most comprehensive work on the quadrangle is an unpublished geologic map and coal sections by Nutt (no date).

Stratigraphy

The rock formations which crop out in the Axial quadrangle range in age from Late Cretaceous to Miocene and include the coal-bearing Iles and Williams Fork Formations of the Mesaverde Group.

The Mancos Shale of Late Cretaceous age crops out across approximately the northern half of the quadrangle along the axis of the Axial Basin anticline and is composed of gray to dark-gray marine shale with interbedded tan thin-bedded silty sandstone and sandy shale in the upper 1,000 feet (305 m) of the formation (Hancock, 1925; Bass and others, 1955; Nutt, no date).

The Mesaverde Group of Late Cretaceous age conformably overlies the Mancos Shale and contains two formations, the Iles and the Williams Fork.

The Iles Formation crops out in a narrow band across the central part of the quadrangle and in the northeast corner (Hancock, 1925; Tweto, 1976; Nutt, no date). It consists of fine-grained massive sandstone interbedded with shaly sandstone, sandy shale, black carbonaceous shale, and coal (Hancock, 1925). The Iles Formation ranges in thickness from approximately 1,455 to 1,475 feet (443 to 450 m) where measured in two oil and gas wells drilled in the quadrangle. The "rim rock" sandstone (Hancock, 1925; Konishi, 1959), at the base of the Iles Formation, consists of approximately 40 to 45 feet (12 to 14 m) of light-brown massive sandstone. The Trout Creek Sandstone Member caps the Iles Formation and consists of approximately 60 to 65 feet (18 to 20 m) of massive white sandstone (Hancock, 1925; Bass and others, 1955). Two coal-bearing sequences, the "lower" coal group and Black Diamond coal group, occur in the Iles Formation (Hancock and Eby, 1930).

The Williams Fork Formation crops out in the southern third of the quadrangle (Hancock, 1925; Nutt, no date) and is approximately 1,600 feet (488 m) thick (Hancock, 1925). The formation consists of tan to white massive sandstone interbedded with dark-gray shale, sandy shale, carbonaceous shale, and coal. Generally, the formation is divided into three units, a lower coal-bearing unit, the Twentymile Sandstone Member, and an upper unit (Fenneman and Gale, 1906; Bass and others, 1955). Coals which occur between the base of the formation and the Twentymile Sandstone Member, or its horizon, comprise the Fairfield coal group (Gale, 1910). The Twentymile Sandstone Member crops out in the southeast corner of the Axial quadrangle and was traced west only as far as sec. 27, T. 4 N., R. 93 W., where the sandstone pinches out (Nutt, no date). West of this point the upper and lower units are undifferentiated. The Twentymile Sandstone Member consists of white fine-grained massive sandstone (Hancock, 1925; Bass and others, 1955).

The Browns Park Formation of Miocene age unconformably overlies the Mancos Shale in several small areas along the Axial Basin anticline in the quadrangle (Hancock, 1925; Tweto, 1976). It consists primarily of chalky-white to yellowish-brown fine-grained tuffacous sandstone with conglomerate beds at its base (Hancock, 1925).

Holocene deposits of alluvium cover the valleys of Milk Creek, Good Spring Creek, Taylor Creek, Wilson Creek, and Jubb Creek (Nutt, no date).

The Cretaceous formations cropping out in the quadrangle accumulated close to the western edge of a Late Cretaceous 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 Axial quadrangle area (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 quadrangle area ended with the eastward migration of the shoreline and the subsequent deposition of the Iles Formation (Konishi, 1959; Kucera, 1959).

The interbedded sandstone, shale, and coal of the Iles and Williams Fork Formations were deposited as a result of minor changes in the position of the shoreline. Near-shore marine, littoral, brackish tidal, brackish and fresh water supratidal, and fluvial environments existed during the deposition of the Iles and Williams Fork Formations. The major sandstone beds in the Iles and Williams Fork Formations were deposited in shallow-marine and near-shore marine environments as the shoreline fluctuated. Coal beds of limited areal extent 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; Kucera, 1959).

The Browns Park Formation was deposited after a long period of non-deposition and erosion. It is a continental deposit consisting mostly of fluvial and eolian deposits, and much of its thickness has been removed as a result of late Cenozoic erosion (Carey, 1955).

Structure

The Danforth Hills KRCRA lies in the northern part of the Piceance structural basin of west-central Colorado. The Danforth Hills area is bordered on the northeast by the Axial Basin anticline and on the west by the Yampa Plateau (Grose, 1972). The Axial Basin anticline passes through the Axial quadrangle, while the Yampa Plateau is approximately 26 miles (42 km) west of the quadrangle.

The Axial Basin anticline, trending southeast across the central part of the quadrangle, is an asymmetric fold, with dips ranging from 20° to 35° on the southern flank and from 7° to 10° on the northern flank. The southeast-trending Collom syncline crosses the southwest corner of the quadrangle. This syncline is also asymmetrical, with the northern limb dipping from 20° to 30° southwest and the southern limb dipping from 5° to 7° northeast. The axis of the southwest-trending Elkhorn syncline crosses the southeast corner of the quadrangle. The syncline dips 10° to the east on its western limb and 6° to the west on its eastern limb (Hancock, 1925; Tweto, 1976). A small east-northeast-striking fault was mapped by Nutt (no date) in the south-central part of the quadrangle.

The structure contour maps of the isopached coal beds in the Axial quadrangle are based on a regional structure map of the top of the Trout Creek Sandstone Member by Nutt (no date), and it is assumed that the structure of the coal beds nearly duplicate that of the Trout Creek Sandstone Member. Minor modifications were made where necessary in accordance with outcrop and drill-hole data. However, the structure maps of the coal beds in the Ninemile Gap quadrangle to the south are based on a less detailed structure contour map of the top of the Trout Creek Sandstone Member by Hancock and Eby (1930). The derivative maps for the Ninemile Gap quadrangle were constructed before the more recent data for the Axial quadrangle were available, and, therefore, the isopach and derivative maps for the quadrangles do not match exactly along the quadrangle boundary.

COAL GEOLOGY

Coal beds in the Iles and Williams Fork Formation have been identified in coal test holes, oil and gas wells, and outcrops in the southern half of the Axial quadrangle. In general, coals in the Iles Formation tend to be thin, lenticular, limited in areal extent, and none are known to exceed Reserve Base thickness (5.0 feet or 1.5 meters) in this quadrangle. In contrast, many coal beds in the Williams Fork Formation (Fairfield coal group) exceed Reserve Base thickness and extend over large areas.

None of the coal beds in this quadrangle are formally named, but coal beds exceeding Reserve Base thickness have been given bracketed numbers for identification purposes. In instances where coal beds have been identified at one location only and cannot be correlated with other coal beds, 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 exceed 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 samples from several undifferentiated coal beds in the Fairfield coal group. In general, the analyses indicate that the coals in the Fairfield coal group are high-volatile C biuminous in rank on a moist, mineral-matter-free basis according to ASTM Standard Specification D 388-77 (American Society for Testing and Materials, 1977).

Fairfield Coal Group

Of the 58 coal beds identified in the Fairfield coal group that exceed Reserve Base thickness in this quadrangle, only 18 of these coal beds and two coal zones were isopached. The remaining 38 coal beds, including 11 located on non-Federal land, were treated as isolated data points (see Isolated Data Points section of this report).

The coal beds in this quadrangle occur in two general areas, in the south-central and southwestern parts of the quadrangle. However, there is no clear-cut distinction between these two areas since many coal beds lap over from one area to the other. Also, quite a few of the coal beds extend into the adjacent Ninemile Gap quadrangle to the south. The coal beds in these two areas lie in the Collom syncline which trends and plunges to the northwest. The southern limb of the syncline dips from approximately 5° to 10° to the northeast, while the northern limb dips from 9° to 32° to the southwest, steepening to the northeast. A general description of the coal beds in each general area is included below, followed by a more detailed discussion of the two coal zones and the coal beds which are believed to contain more than 10.0 million short tons (9.07 million metric tons) of coal.

The coal beds lying mainly in the south-central part of the quadrangle range in thickness from 4.0 to 34.0 feet (1.2 to 10.4 m). However, most of the coal beds are from 7.0 to 12.0 feet (2.1 to 3.7 m) thick. Rock partings range in thickness from 1.5 to 16.0 feet (0.5 to 4.9 m). Several of the coal beds extend into the Ninemile Gap quadrangle to the south where they have the same designation. The coal beds in the south-central part of the quadrangle generally lie on the axis of the northwest-plunging Collum syncline. The Fairfield [83] coal zone has not been identified in this quadrangle, but it is believed to extend into the south-central part based on data in the adjacent Ninemile Gap quadrangle to the south.

The coal beds lying mainly in the southwestern part of the quadrangle range in thickness from 5.0 to 10.0 feet (1.5 to 3.0 m). Rock partings have not been identified in the coal beds in this area. Generally, the coal beds lie on the southern limb of the Collom syncline and dip to the north and northeast.

Fairfield [10] Coal Bed

The Fairfield [10] coal bed (plate 16) has been identified in a coal test hole and in an oil and gas well that were drilled in the south-central part of the quadrangle. The coal bed has measured thicknesses of 15.0 and 18.0 feet (4.6 and 5.5 m) in these drill holes, and the coal bed does not contain rock partings.

Fairfield [20] Coal Bed

The Fairfield [20] coal bed (plate 35) has been identified in three coal test holes drilled in the south-central part of the quadrangle. It ranges in thickness from 6.5 feet (2.0 m) to a maximum of 10.5 feet (3.2 m), excluding rock partings totalling 3 feet (0.9 m) in thickness, in these drill holes in sec. 33, T. 4 N., R. 93 W..

Fairfield [37] Coal Bed

The Fairfield [37] coal bed (plate 55) was penetrated by the same three coal test holes as the Fairfield [20] coal bed. The thickness of the coal bed ranges from 5.0 to 6.5 feet (1.5 to 2.0 m) and does not contain rock partings.

Fairfield Coal Group, Zone [208]

Individual coal beds in the Fairfield [208] coal zone (plate 8) appear to thicken, thin, and split over short distances, ranging from 2.0 feet (0.6 m) to a maximum of 16.0 feet (4.9 m) where measured in three drill holes and an outcrop. The zone contains cumulative coal thicknesses ranging from 11.6 to 41.0 feet (3.5 to 12.5 m) with rock partings totalling from 1.8 to 24.8 feet (0.5 to 7.6 m). This zone extends into the Ninemile Gap quadrangle to the south, and individual coal beds range from 2.0 to 22.5 feet (0.6 to 6.9 m) in thickness where measured in drill holes. Cumulative coal thicknesses range from 13.0 to 41.5 feet (4.0 to 12.6 m) and rock partings totalling from 2.0 to 17.0 feet (0.6 to 5.2 m) thick are included in the zone in that quadrangle. Although this coal zone has not been identified in the adjacent Easton Gulch and Devils Hole Gulch quadrangles, it is believed to extend into those quadrangles and cumulative coal thicknesses are probably about 25 feet (7.6 m) in the areas where the zone has been projected.

Fairfield [216] Coal Bed

The Fairfield [216] coal bed (plate 27) has been identified in four coal test holes drilled in the south-central part of the quadrangle. This coal bed ranges in thickness from 16.0 to 34.0 feet (4.9 to 10.4 m) and contains rock partings from 1.5 to 8.5 feet (0.5 to 2.6 m) thick.

The coal appears to thin to the northeast and the rock partings thicken in the same direction. Although the Fairfield [216] coal bed has not been identified in the Ninemile Gap quadrangle to the south, it is inferred to extend into that quadrangle with a maximum thickness of 25 feet (7.6 m).

Fairfield Coal Group, Zone [219]

Similar to the [208] coal zone, the Fairfield [219] coal zone (plate 12) extends over a large area in the southern part of this quadrangle and the northern part of the Ninemile Gap quadrangle. Individual coal beds range from 1.0 to 10.0 feet (0.3 to 3.0 m) in thickness where penetrated by three coal test holes. Cumulative thicknesses of the coal in this zone range from 10.0 to 19.0 feet (3.0 to 5.8 m), and the zone contains rock partings totalling from 15.0 to 17.3 feet (4.6 to 5.3 m) in thickness. The coal zone thickens to the southwest, and, in the Ninemile Gap quadrangle, cumulative coal thicknesses range from 18.0 to 28.0 feet (5.5 to 8.5 m) and rock partings total from 3.0 to 9.0 feet (0.9 to 2.7 m) thick.

Fairfield [244] Coal Bed

The Fairfield [244] coal bed (plate 20) has been penetrated by a coal test hole and an oil and gas well drilled in the south-central part of the quadrangle. The coal bed is 13.0 (4.0 m) thick in the coal test hole, excluding 3.2 feet (1.0 m) of rock partings. In the oil and gas well, the coal bed is 21.0 feet (6.4 m) thick and rock partings, if any, could not be determined from the geophysical log. This coal bed extends into the Ninemile Gap quadrangle and is 12.0 and 17.0 feet (3.7 and 5.2 m) thick where measured in two drill holes.

Fairfield [269] Coal Bed

The Fairfield [269] coal bed crops out at several locations in the south-central part of the quadrangle and has been penetrated by four drill holes. Along the outcrop, the coal bed ranges in thickness from 9.8 to 18.0 feet (3.0 to 5.5 m) and does not contain rock partings. Measured thicknesses in the drill holes range from 12.0 to 18.5 feet (3.7

to 5.6 m). Rock partings of 6.5 and 16.0 feet (2.0 and 4.9 m) were recorded in two of the drill holes. The coal bed thickens southhward to a maximum measured thickness of 28.0 feet (8.5 m) in sec. 11, T. 3 N., R. 93 W., in the Ninemile Gap quadrangle to the south.

Isolated Data Points

In instances where single or isolated measurements of coal beds thicker than 5 feet (1.5 m) are encountered, the standard criteria for construction of isopach, structure contour, mining ratio, and overburden isopach maps are not available. The lack of data concerning these beds limits the extent to which they can be reasonably projected in any direction and usually precludes correlations with other, better known coal beds. For this reason, isolated data point maps 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, an isolated data point map is not constructed for the coal bed. Descriptions and Reserve Base tonnages for the isolated data points occurring in this quadrangle are listed in table 4.

COAL RESOURCES

Data from coal test holes, mine measured sections, and outcrop measurements (Hancock, 1925; Nutt 1978 and no date; Reheis, 1976 and 1978; Reheis and Peterson, 1977; U.S. Bureau of Land Management, 1975 and 1977b), as well as oil and gas wells, were used to construct outcrop, isopach, and structure contour maps of the coal beds in the Axial quadrangle. The source of each indexed data point shown on plate 1 is listed in table 5.

Coal resources for Federal land were calculated using data obtained from the coal isopach maps and the areal distribution and identified resources maps). 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 coal bed. Coal beds exceeding Reserve Base thickness (5 feet or 1.5 meters) 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 the areal distribution and identified resources maps 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 374.81 million short tons (340.03 million metric tons) for the entire quadrangle, including the tonnages for 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.

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 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 potential 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 prevents accurate evaluation of development potential in the high, moderate, and low categories. The areas influenced by isolated data points in this quadrangle total approximately 6.83 million short tons (6.20 million metric tons) of coal available for surface mining.

The coal development potential for surface mining methods is shown on plate 67. Of those Federal land areas having a known development potential for surface mining, 82 percent are rated high, 7 percent are rated moderate, and 11 percent are rated low. The remaining Federal lands within the KRCRA boundary in this 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 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 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 areas where coal beds of Reserve Base thickness are not known, but may occur, and to those areas influenced by isolated data points. The areas influenced by isolated data points in this quadrangle contain approximately 14.90 million short tons (13.52 million metric tons) of coal available for conventional subsurface mining.

The coal development potential for conventional subsurface mining methods is shown on plate 68. All of the Federal land areas having a known development potential for conventional subsurface mining methods are rated high. The remaining Federal land within the 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 7.49 million short tons (6.79 million metric tons) of coal distributed through eight 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 Axial quadrangle, 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 NE¼ sec. 2, T. 3 N., R. 93 W., Mount Streeter (Joseph Collum) Mine (Hancock and Eby, 1930)	Fairfield coal group	A	11.9	40.6	45.3	2.2	0.32	-	-	-	-	-	11,610
		B	10.0	41.5	46.2	2.3	0.33	-	-	-	-	-	11,860
		C	-	46.1	51.4	2.5	0.36	-	-	-	-	-	13,180
Sec. 2, T. 3 N., R. 93 W., Phelan Mine (George and others, 1937)	Fairfield coal group	A	10.6	40.4	46.0	3.0	0.3	-	-	-	-	-	11,770
		C	-	45.2	51.4	3.4	0.4	-	-	-	-	-	13,160
Sec. 35, T. 4 N., R. 93 W., Smith Mine (George and others, 1937)	Fairfield coal group	A	14.2	34.8	44.4	6.6	0.6	-	-	-	-	-	10,510
		C	-	40.5	51.8	7.7	0.7	-	-	-	-	-	12,250
NE¼ sec. 31, T. 4 N., R. 92 W., Shafer Mine (Hancock, 1925)	Fairfield coal group	A	13.5	38.5	44.1	3.89	0.59	-	-	-	-	-	11,020
		B	9.3	40.4	46.2	4.08	0.62	-	-	-	-	-	11,550
		C	-	44.5	51.0	4.50	0.68	-	-	-	-	-	12,750

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 Axial quadrangle, Moffat County, Colorado.

Coal Bed or Zone	High Development Potential	Moderate Development Potential	Low Development Potential	Unknown Development Potential	Total
Fairfield {259}	1,790,000	880,000	780,000	-	3,450,000
Fairfield {46}	250,000	210,000	470,000	-	930,000
Fairfield {43}	160,000	170,000	580,000	-	910,000
Fairfield {41}	10,000	40,000	160,000	-	210,000
Fairfield {37}	290,000	300,000	2,070,000	-	2,660,000
Fairfield {111}	70,000	90,000	480,000	-	640,000
Fairfield {101}	130,000	150,000	930,000	-	1,210,000
Fairfield {34}	290,000	260,000	520,000	-	1,070,000
Fairfield {30}	100,000	200,000	1,030,000	-	1,330,000
Fairfield {25}	500,000	640,000	670,000	-	1,810,000
Fairfield {83}	-	-	60,000	-	60,000
Fairfield {27}	20,000	-	-	-	20,000
Fairfield {20}	140,000	220,000	1,380,000	-	1,740,000
Fairfield {269}	1,350,000	1,460,000	850,000	-	3,660,000
Fairfield {216}	1,450,000	830,000	320,000	-	2,600,000
Fairfield {244}	70,000	140,000	160,000	-	370,000
Fairfield {208}	270,000	270,000	320,000	-	860,000
Fairfield {209}	30,000	-	-	-	30,000
Isolated Data Points	-	-	-	6,830,000	6,830,000
Totals	6,920,000	5,860,000	10,780,000	6,830,000	30,390,000

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 Axial quadrangle, Moffat County, Colorado.

Coal Bed or Zone	High Development Potential	Moderate Development Potential	Low Development Potential	Unknown Development Potential	Total
Fairfield {259}	1,020,000	-	-	-	1,020,000
Fairfield {46}	70,000	-	-	-	70,000
Fairfield {43}	3,050,000	-	-	-	3,050,000
Fairfield {41}	1,380,000	-	-	-	1,380,000
Fairfield {37}	11,040,000	-	-	-	11,040,000
Fairfield {111}	2,410,000	-	-	-	2,410,000
Fairfield {101}	2,500,000	-	-	-	2,500,000
Fairfield {34}	7,220,000	-	-	80,000*	7,300,000
Fairfield {30}	3,810,000	-	-	70,000*	3,880,000
Fairfield {25}	1,470,000	-	-	120,000*	1,590,000
Fairfield {83}	960,000	-	-	-	960,000
Fairfield {27}	60,000	-	-	-	60,000
Fairfield {20}	16,410,000	-	-	330,000*	16,740,000
Fairfield {269}	48,230,000	-	-	2,920,000*	51,150,000
Fairfield {216}	81,120,000	-	-	2,530,000*	83,650,000
Fairfield {15}	870,000	310,000	-	10,000*	1,190,000
Fairfield {244}	21,710,000	7,940,000	1,000,000	-	30,650,000
Fairfield {10}	-	14,020,000	-	-	14,020,000
Fairfield {219}	12,160,000	17,090,000	-	-	29,250,000
Fairfield {208}	19,450,000	44,750,000	-	1,430,000*	65,630,000
Fairfield {209}	1,670,000	310,000	-	-	1,980,000
Isolated Data Points	-	-	-	14,900,000	14,900,000
Totals	236,610,000	84,420,000	1,000,000	22,390,000	344,420,000

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

*Tonnages for coal beds dipping greater than 15 degrees.

Table 4.--Descriptions and Reserve Base tonnages (in million short tons) for isolated data points

Coal Bed	Source	Location	Thickness	Reserve Base Tonnages	
				Surface	Subsurface
Fairfield [1]	Nutt (no date)	sec. 28, T. 4 N., R. 93 W.	5.1 ft (1.6 m)	0.16	0.15
Fairfield [2]	Nutt (no date)	sec. 21, T. 4 N., R. 93 W.	5.6 ft (1.7 m)	0.14	0.21
Fairfield [4]	Nutt (no date)	sec. 36, T. 4 N., R. 93 W.	5.2 ft (1.6 m)	0.02	0.04
Fairfield [5]	Reheis (1978)	sec. 33, T. 4 N., R. 93 W.	6.0 ft (1.8 m)	0	0.83
Fairfield [6]	Nutt (no date)	sec. 31, T. 4 N., R. 92 W.	7.0 ft (2.1 m)	0.16	0.32
Fairfield [7]	Nutt (no date)	sec. 20, T. 4 N., R. 93 W.	9.2 ft (2.8 m)	0.31	0.31
Fairfield [8]	Nutt (no date)	sec. 31, T. 4 N., R. 92 W.	10.6 ft (3.2 m)	0.52	0.38
Fairfield [9]	Nutt (no date)	sec. 31, T. 4 N., R. 92 W.	29.4 ft (9.0 m)	1.36	1.08
Fairfield [11]	Nutt (no date)	sec. 31, T. 4 N., R. 92 W.	18.0 ft (5.5 m)	0.53	0.63
Fairfield [12]	Reheis (1976)	sec. 5, T. 3 N., R. 93 W.	10.0 ft (3.0 m)	0	1.33
Fairfield [13]	Reheis (1976)	sec. 7, T. 3 N., R. 93 W.	7.0 ft (2.1 m)	0	0.32
Fairfield [14]	Nutt (no date)	sec. 35, T. 4 N., R. 93 W.	14.8 ft (4.5 m)	0.71	0

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

Table 4.--Continued

Coal Bed	Source	Location	Thickness	Reserve Base Tonnages Surface	Subsurface
Fairfield [19]	Nutt (no date)	sec. 5, T. 3 N., R. 93 W.	7.2 ft (2.2 m)	0.07	0
Fairfield [21]	Reheis (1976)	sec. 5, T. 3 N., R. 93 W.	8.0 ft (2.4 m)	0.02	1.02
Fairfield [24]	Nutt (1978)	sec. 34, T. 4 N., R. 93 W.	9.0 ft (2.7 m)	0	1.23
Fairfield [28]	Reheis (1978)	sec. 28, T. 4 N., R. 93 W.	6.5 ft (2.0 m)	0.10	0.76
Fairfield [29]	Reheis (1978)	sec. 28, T. 4 N., R. 93 W.	13.0 ft (4.0 m)	0.70	1.48
Fairfield [31]	Nutt (1978)	sec. 34, T. 4 N., R. 93 W.	13.0 ft (4.0 m)	0	1.77
Fairfield [32]	Nutt (no date)	sec. 33, T. 4 N., R. 93 W.	6.5 ft (2.0 m)	0	0.90
Fairfield [36]	Nutt (1978)	sec. 34, T. 4 N., R. 93 W.	5.5 ft (1.7 m)	0	0.74
Fairfield [40]	Reheis (1976)	sec. 7, T. 3 N., R. 93 W.	12.0 ft (3.7 m)	0.52	0
Fairfield [45]	Nutt (no date)	sec. 28, T. 4 N., R. 93 W.	5.2 ft (1.6 m)	0.25	0.09
Fairfield [47]	Reheis (1978)	sec. 33, T. 4 N., R. 93 W.	6.5 ft (2.0 m)	0.07	0.81
Fairfield [48]	Reheis (1976)	sec. 5, T. 3 N., R. 93 W.	7.0 ft (2.1 m)	0.40	0
Fairfield [49]	Nutt (no date)	sec. 27, T. 4 N., R. 93 W.	6.7 ft (2.0 m)	0.31	0.15

Table 4.--Continued

Coal Bed	Source	Location	Thickness	Reserve Base Tonnages Surface	Reserve Base Tonnages Subsurface
Fairfield [50]	Nutt (no date)	sec. 27, T. 4 N., R. 93 W.	7.0 ft (2.1 m)	0.28	0.20
Fairfield [53]	Nutt (no date)	sec. 27, T. 4 N., R. 93 W.	6.3 ft (1.9 m)	0.21	0.14

Table 5. -- Sources of data used on plate 1

Plate 1 Index Number	Source	Data Base
1	Nutt, (no date), U.S. Geological unpublished data	Measured Section No. 10
2		Measured Section No. 9
3		Measured Section
4		Measured Section No. 7
5		Measured Section No. 6
6	U.S. Bureau of Land Management, 1977b, vol. 2, p. GII-5, figure GII-3	Composite Section
7	U.S. Bureau of Land Management, 1975, EMRIA Report No. 3-1975, p. 22	Drill hole No. BR 102
8	W.S. Kilroy, San Jacinto Petroleum Corp., Jack J. Grynberg	Oil/gas well No. 1 Gossard Inc.
9	U.S. Bureau of Land Management, 1975, EMRIA Report No. 3-1975, p. 18-20	Drill hole No. BR 101
10	Nutt, (no date), U.S. Geological Survey, unpublished data	Measured Section No. 27
11	Reheis and Peterson, 1977, U.S. Geological Survey Open-File Report No. 77-42	Drill hole No. D-26-A
12	Texaco, Inc.	Oil/gas well No. 1-A Klaenhammer-Gov't
13	Reheis, 1976, U.S. Geological Survey Open-File Report No. 76-870	Drill hole No. D-11-A

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Table 5. -- Continued

Plate 1 Index Number	Source	Data Base
14	Reheis, 1976, U.S. Geological Survey Open-File Report No. 76-870	Drill hole No. D-3-A
15	Hancock, 1925, U.S. Geological Survey Bulletin 757, pl. 15	Measured Section No. 257
16	↓	Measured Section No. 258
17	Nutt, (no date), U.S. Geological Survey, unpublished data	Measured Section No. 1
18	Hancock, 1925, U.S. Geological Survey Bulletin 757, pl. 15	Measured Section No. 250
19	Nutt, (no date), U.S. Geological Survey, unpublished data	Measured Section No. 33
20	↓	Measured Section No. 35
21	↓	Measured Section No. 28
22	↓	Measured Section No. 19
23	↓	Measured Section No. 34
24	↓	Measured Section No. 38
25	↓	Measured Section
26	↓	Measured Section No. 14
27	↓	Measured Section
28	↓	Measured Section
29	↓	Measured Section No. 16
30	↓	Measured Section No. 17

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Table 5. -- Continued

Plate 1 Index Number	Source	Data Base
31	Nutt, (no date), U.S. Geological Survey, unpublished data	Measured Section No. 18
32	↓	Measured Section No. 21
33	Reheis, 1978, U.S. Geological Survey Open-File Report No. 78-1031	Drill hole No. D-47-A
34	Nutt, (no date), U.S. Geological Survey, unpublished data	Measured Section No. 22
35	↓	Measured Section No. 23
36	↓	Measured Section No. 31
37	↓	Measured Section No. 29
38	↓	Measured Section No. 24
39	↓	Measured Section No. 25
40	↓	Measured Section No. 26
41	Reheis, 1978, U.S. Geological Survey Open-File Report No. 78-1031	Drill hole No. D-47-A1
42	Nutt, (no date), U.S. Geological Survey, unpublished data	Measured Section No. 15
43	Nutt, 1978, U.S. Geological Survey Open-File Report No. 78-273	Drill hole No. D-56-A
44	Nutt, (no date), U.S. Geological Survey, unpublished data	Measured Section No. 4
45	↓	Measured Section
46	↓	Measured Section
47	↓	Measured Section No. 3

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