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COAL RESOURCE OCCURRENCE AND COAL DEVELOPMENT POTENTIAL MAPS OF THE NINEMILE GAP QUADRANGLE, RIO BLANCO AND MOFFAT COUNTIES, COLORADO

[Report includes 58 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 Ninemile Gap quadrangle, Rio Blanco and Moffat Counties, 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 U.S. 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 Published and unpublished public information available through November, 1978, was used as the data base for this study.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 performed as a part of this study, nor was any confidential data used.

Location

The Ninemile Gap quadrangle is located in northwestern Colorado. The southern three fourths of the quadrangle lies in north-central Rio Blanco County and the northern quarter lies in southeastern Moffat County. The quadrangle lies approximately 28 miles (45 km) southwest of the town of Craig, Colorado, via Colorado Highway 13 (also known as Colorado Highway 789) and 7 miles (11 km) northeast of the town of Meeker, also via Colorado Highway 13. With the exception of a few scattered ranches, the quadrangle is unpopulated.

Accessibility

Colorado Highway 13 passes north-south through the center of the quadrangle along Good Spring and Curtis Creeks, connecting Craig and the town of Axial to the northeast with Meeker to the southwest. An improved light-duty road crosses the northwest corner of the quadrangle connecting Wilson Creek Camp to the southwest with Colorado Highway 13 to the northeast. Another improved light-duty road follows Ninemile Draw eastward from Colorado Highway 13 in the south-central part of the quadrangle. The remainder of the quadrangle is accessible along numerous unimproved dirt roads and trails.

Railway service for the Ninemile Gap quadrangle is provided by the Denver and Rio Grande Western Railroad from Denver to the railhead at Craig. This railroad, terminating approximately 22 miles (35 km) northeast of the quadrangle, is the major transportation route for coal shipped east from northwestern Colorado (U.S. Bureau of Land Management, 1977).

Physiography

The Ninemile Gap quadrangle lies at the western edge of the Southern Rocky Mountain physiographic province as defined by Howard and Williams (1972). The quadrangle lies approximately 18 miles (29 km) southwest of the Williams Fork Mountains and 61 miles (98 km) west-southwest of the Continental Divide. The Danforth Hills cross the southern part of the quadrangle.

The landscape throughout the quadrangle is characterized by moderate slopes cut by numerous gulches and narrow valleys. Altitudes range from 8,718 feet (2,657 m) in the southeastern part of the quadrangle to less than 6,640 feet (2,024 m) along Good Springs Creek on the northern edge of the quadrangle.

Good Spring Creek, Wilson Creek and their tributaries drain the northern three fourths of the quadrangle and flow northward into Milk Creek, a tributary of the Yampa River approximately 13 miles (21 km) to the north of the quadrangle. Curtis Creek and its tributaries drain the southern quarter of the quadrangle. Curtis Creek joins the White River approximately 6.5 miles (10 km) south of the quadrangle. The streams in the quadrangle, with the exception of Wilson Creek and Good Spring Creek, 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 Ninemile Gap quadrangle area, with daily temperatures typically varying from 5° to 36°F (-15° to 2°C) in January and from 43° to 84° F (6° to 29° C) in July. Annual precipitation in the area averages 18 inches (46 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 are generally from the west, averaging approximately 3 miles per hour (5 km per hour), but wind directions and velocities tend to vary greatly depending on the local terrain (U.S. Bureau of Land Management, 1977).

The dominant vegetation in the quadrangle is mountain shrub, which includes serviceberry, Gambel Oak, and rabbitbrush. Aspen occur at the higher elevations along the east- and west-central edges of the quadrangle and pinyon, Utah juniper, and Rocky Mountain juniper grow along Wilson Creek in the northwestern part of the quadrangle. Sagebrush grows in the northeastern and northwestern parts of the quadrangle (U.S. Bureau of Land Management, 1977).

Land Status

The Ninemile Gap quadrangle lies in the eastern part of the Danforth Hills Known Recoverable Coal Resource Area (KRCRA). All of the quadrangle lies within the KRCRA boundary. The Federal government owns the coal rights for approximately 92 percent of this area. Seven active coal leases and two Preference Right Lease Application (PRLA) areas are located in the southern part of the quadrangle as shown on plate 2.

GENERAL GEOLOGY

Previous Work

The first geologic description of the general area in which the Ninemile Gap quadrangle is located was included 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). Hancock (1925) mapped the geology and coal resources in the quadrangles to the north of the Ninemile Gap quadrangle, and Hancock and Eby (1930) mapped the geology and reported on coal occurrences in the Meeker 15-minute quadrangle which includes this quadrangle. (Tweto (1976) compiled a generalized regional map which included this quadrangle. Results from drilling by the U.S. Geological Survey in the Ninemile Gap quadrangle during 1975, 1976, 1977, and 1978 are reported by Muller (1976), Reheis (1976 and 1978), Reheis and Peterson (1977), and Nutt (1978). Detailed geologic mapping in this quadrangle by Nutt of the U.S. Geological Survey is in progress.

Stratigraphy

The rock formations which crop out in the Ninemile Gap quadrangle are Late Cretaceous in age and include the coal-bearing Iles and the Williams Fork Formations of the Mesaverde Group.

The Mancos Shale of Late Cretaceous age does not crop out within the quadrangle, but occurs in the subsurface. The formation is composed of gray to dark-gray marine shale with ledge-forming thin-bedded sandstone occurring locally in the upper part of the formation (Hancock and Eby, 1930). The Mancos Shale ranges in thickness from approximately 4,970 to 5,300 feet (1,515 to 1,615 m) where measured in the oil and gas wells drilled in the quadrangle.

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 the southeast corner and along the western boundary of the quadrangle (Hancock and Eby, 1930; Nutt, no date). The formation consists of fine-grained, thick-bedded to massive sandstone interbedded with shaly sandstone, sandy shale, black carbonaceous shale, and coal (Hancock and Eby, 1930). The Iles Formation ranges in thickness from approximately 1,440 to 1,650 feet (439 to 503 m) where measured in the oil and gas wells drilled in the quadrangle. The "rim rock" sandstone, the basal unit of the Iles Formation, is a light-brown massive sandstone (Hancock and Eby, 1930; Konishi, 1959) ranging in thickness from approximately 30 to 50 feet (9 to 15 m). The Trout

Creek Sandstone Member caps the formation and consists of approximately 65 to 90 feet (20 to 27 m) of white massive sandstone (Hancock and Eby, 1930). 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 conformably overlies the Iles Formation and crops out over most of the quadrangle (Hancock and Eby, 1930; Nutt, no date). The total thickness of the formation is unknown in this quadrangle. However, the formation ranges in thickness from approximately 4,500 to 5,050 feet (1,372 to 1,539 m) in adjacent quadrangles to the west (Hancock and Eby, 1930), and only about 2,000 feet (610 m) of the formation is preserved in the Thornburgh quadrangle to the west (Reheis, no date).

The Williams Fork Formation is generally divided into three units: a lower coal-bearing unit, the Lion Canyon Sandstone Member, and an upper unit that also contains coal. The lower unit extends from the top of the Trout Creek Sandstone Member of the Iles Formation upward to the base of the Lion Canyon Sandstone Member and is approximately 2,900 feet (884 m) thick. It consists of interbedded sandstone, shale, sandy shale, carbonaceous shale, and coal beds. Two coal groups, the Fairfield and Goff coal groups, occur within this lower unit (Hancock and Eby, 1930).

The Lion Canyon Sandstone Member is exposed only in a small area in the southwest corner of the quadrangle before disappearing near the east side of sec. 19, T. 2 N., R. 93 W. (Hancock and Eby, 1930; Nutt, no date). It consists of light-yellowish-brown thick-bedded sandstone and is approximately 100 feet (30 m) thick to the southwest in the Meeker quadrangle (Hancock and Eby, 1930).

The upper unit of the Williams Fork Formation crops out only in a small area in the southwest corner of the quadrangle (Nutt, no date). In adjacent quadrangles to the east and west this unit is, respectively, about 900 and 2,000 feet (274 and 610 m) thick (Reheis, no date; Hancock and Eby, 1930), but the total thickness of this upper unit is unknown in this quadrangle. It consists of yellowish-brown to white sandstone interbedded with sandy shale, black carbonaceous shale, and coal beds. In the Meeker area, coal beds in this unit have been designated the Lion Canyon coal group (Hancock and Eby, 1930), but coal beds belonging to this group have not been identified in this quadrangle.

Holocene and Pleistocene alluvial deposits cover stream valleys and gulches throughout the quadrangle.

The Cretaceous sedimentary rocks 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 Ninemile Gap 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 in the area. 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).

Structure

The Danforth Hills KRCRA lies in the northern part of the Piceance structural basin of west-central Colorado (Howard and Williams, 1972). 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 Ninemile Gap quadrangle lies at the southwestern edge of the Axial Basin anticline and is approximately 30 miles (48 km) southeast of the Yampa Plateau.

The axis of the Danforth Hills anticline trends east-west across the southern part of the quadrangle. Dips along the southern limb of the anticline range from 7° to 50° to the south, steepening westward. Dips along the northern limb of the syncline range from 5° to 10° north (Hancock and Eby, 1930).

The axis of the Sulphur Creek syncline crosses near the southern edge of the quadrangle and trends approximately east-southeast. Dips range from 5° to 10° to the south on the northern flank and from 4° to 6° to the north on the southern flank of the syncline (Hancock and Eby, 1930).

The Elkhorn syncline trends southwestward from the northeastern corner of the quadrangle, intersecting the Danforth Hills anticline near the center of the quadrangle. The western limb of the syncline dips from 5° to 10° east and the eastern limb dips from 4° to 6° west (Hancock and Eby, 1930).

Large areas of burned and clinkered coal exist in the western half and northeastern part of the quadrangle. It is, therefore, impossible to accurately distinguish between the coal beds which are burned and those which are not, or to accurately plot the clinker/coal boundary traces (Nutt, no date).

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

COAL GEOLOGY

Numerous coal beds in the Iles and Williams Fork Formations have been identified in outcrops, coal test holes, and oil and gas wells in the Ninemile Gap quadrangle. In general, most of the coal beds in these formations tend to be thin, lenticular, and of limited areal extent. Coal beds exceeding Reserve Base thickness (5 feet or 1.5 meters) that are not formally named in this quadrangle have been given bracketed numbers for identification purposes. In instances where coal beds exceeding Reserve Base thickness 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 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 those from the Goff coal group. Analyses were not available for any coal beds in either the "lower", Black Diamond, or Fairfield coal groups. However, analyses from the Hamilton mine in the Hamilton quadrangle, Black Diamond mine in the Meeker quadrangle, and the Wesson and Mount Streeter mines in the Axial quadrangle are believed to be representative of the coals in this quadrangle. In general, the analyses indicate that the coals in the "lower", Black Diamond, Fairfield, and Goff coal groups 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).

Coal Beds in the Iles Formation

In the Meeker area, coal beds in the Iles Formation usually lie within the "lower" or Black Diamond coal groups (Hancock and Eby, 1930). The "lower" coal group generally includes all coal beds within about 250 feet (76 m) above the base of the Iles Formation, and the Black Diamond coal group includes all coal beds within the interval from 150 to 350 feet (46 to 107 m) below the top of the Trout Creek Sandstone Member (Hancock and Eby, 1930).

Six coal beds in the "lower" and Black Diamond coal groups exceed Reserve Base thickness where penetrated by oil and gas wells in the southeastern part of the quadrangle and have been treated as isolated data points. Another coal bed, the Iles [31], was penetrated by one of the wells and cannot be located in the stratigraphic section with enough accuracy to place the coal bed in either the "lower" or Black Diamond coal group. This coal bed was also treated as an isolated data point.

Coal Beds in the Williams Fork Formation

According to Hancock and Eby (1930), coal beds in the Williams Fork Formation occur in the Fairfield, Goff, and Lion Canyon coal groups. The Fairfield coal group includes the coal beds that occur in the lower 650 feet (198 m) of the Williams Fork Formation in the Ninemile Gap area. The Goff coal group includes the coal beds in the Williams Fork Formation above the Fairfield coal group and below the Lion Canyon Sandstone Member. The Lion Canyon coal group includes the coal beds in the Williams Fork Formation above the Lion Canyon Sandstone Member. However, coal beds in this group have not been specifically identified in this quadrangle.

Fairfield Coal Group

The Fairfield coal group is the most important coal-bearing unit in this quadrangle and numerous coal beds in this group have been identified in drill holes and outcrops throughout the quadrangle. One hundred coal beds and four coal zones greater than Reserve Base thickness have been identified, but only 16 of the coal beds and the coal zones can be correlated with enough accuracy to construct isopach maps of the coal beds and zones. The remaining 84 coal beds, including three located on non-Federal land, were treated as isolated data points. In addition, two coal beds, the Fairfield [216] and [259], that have not been identified in this quadrangle have been projected into the quadrangle based on geologic data in the adjacent Axial quadrangle to the north. In cases where the thickness of a rock parting is greater than one of the coal-bed splits, only the thicker of the splits has been used in constructing the isopach map.

Coal beds in the Fairfield coal group occur in three general areas, in the north, east-central, and west-central parts of the quadrangle. A general description of each area is included below followed by a detailed discussion of only those coal beds which are believed to contain more than 15.00 million short tons (13.61 million metric tons) of coal.

The coal beds in the northern part of the quadrangle lie on the western limb of the Elkhorn syncline and dip to the northeast at approximately 4°. Coal beds in this area generally range in thickness from 10 to 20 feet (3.0 to 6.1 m). Rock partings occur throughout the coal beds and range from 1.0 to 7.0 feet (0.3 to 2.1 m) in thickness. Several of the coal beds extend into the adjacent quadrangles where they have the same designation.

In the east-central part of the quadrangle, the coal beds range in thickness from 5.0 to 26.9 feet (1.5 to 8.2 m), and rock partings ranging from 1.0 to 2.9 feet (0.3 to 0.9 m) thick occur locally. The coal beds lie on the Danforth Hills anticline and generally dip to the west at an average of approximatley 9°.

Two coal beds in the Fairfield coal group have been identified in the west-central part of the quadrangle. These coal beds lie on the east-trending Danforth Hills anticline. The limbs of the anticline dip approximately 6° to the northeast and southeast. These coal beds range in thickness from 5.0 to 21.3 feet (1.5 to 6.5 m) and are not known to contain rock partings.

The Fairfield [209] coal bed (plate 4) extends over a large area in the northwestern part of the quadrangle. It crops out along the western edge of the quadrangle and is burned and clinkered along most of the outcrop. Drill-hole data indicate that the coal bed ranges in thickness from 4.5 to 16.0 feet (1.4 to 4.9 m) in this quadrangle, the maximum reported thickness occurring in the coal test hole drilled in sec. 18, T. 3 N., R. 93 W. Local rock partings range in thickness from 2.5 to 6.0 feet (0.8 to 1.8 m). In the Axial quadrangle to the north, the coal bed has been identified in one drill hole in sec. 7, T. 3 N., R. 93 W., where it is 10.0 feet (3.0 m) thick. The coal bed has not been identified in either the Devils Hole Gulch quadrangle to the west or the Easton Gulch quadrangle to the northwest, but it is inferred to range from 5 to 11 feet (1.5 to 3.4 m) and from 7 to 8 feet (2.1 to 2.4 m) thick, respectively, in those quadrangles based on geologic data in the Ninemile Gap and Axial quadrangles.

The Fairfield [208] coal zone (plate 8) is very thick and extensive in the northern part of the quadrangle. It crops out in the northwestern part of the quadrangle and is burned and clinkered along the outcrop. Drill-hole data indicate that the individual coal beds in this zone thicken, thin, and split over short distances, ranging from 2.0 feet (0.6 m) to as much as 22.5 feet (6.9 m) in thickness. 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) are included in the zone. In the Axial quadrangle, individual coal beds range from 2.0 to 16.0 feet (0.6 to 4.9 m) in thickness. Cumulative coal thicknesses range from 11.6 to 41.0 feet (3.5 to 12.5 m), and thicknesses of the rock partings total from 1.8 to 24.8 feet (0.5 to 7.6 m). Although this coal zone has not been identified in either the Devils Holes Gulch or Easton Gulch quadrangles, it is believed to be about 25 feet (7.6 m) thick in the areas where the zone has been projected into those quadrangles.

Similar to the [208] coal zone, the Fairfield [219] coal zone (plate 12) extends over a large area in the northern part of this quadrangle and the southern part of the Axial quadrangle. Individual coal beds range from 6.0 to 18.0 feet (2.4 to 5.5 m) in thickness where penetrated by five coal test holes. Cumulative coal thicknesses in this zone range from 18.0 to 28.0 feet (5.5 to 8.5 m), and the zone contains rock partings totalling from 3.0 to 9.0 feet (0.9 to 2.7 m) in thickness. In the Axial quadrangle, individual coal beds vary from 1.0 to 10.0 feet (0.3 to 3.0 m) in thickness with cumulative coal thicknesses ranging from 10.0 to 19.0 feet (3.0 to 5.8 m); the zone contains rock partings totalling from 15.0 to 17.3 feet (4.6 to 5.3 m) in thickness.

The Fairfield [244] coal bed (plate 24) was identified in two of the coal test holes drilled in the northern part of the quadrangle and ranges in thickness from 12.0 to 17.0 feet (3.7 to 5.2 m). Rock partings 1.0 feet (0.3 m) thick occur at both locations. The coal bed extends into the Axial quadrangle and is 13.0 and 21.0 feet (4.0 and 6.4 m) thick where penetrated by two drill holes.

The Fairfield [58] coal bed (plate 32) ranges in thickness from 12.0 to 24.0 feet (3.7 to 7.3 m) where penetrated by two drill holes in the northwestern part of the quadrangle and is not known to contain any rock partings.

The Fairfield [269] coal bed (plate 36) extends over a large area in the northern part of the quadrangle and is extensively burned along the crop line. Drill-hole data indicate that the coal bed may be channeled-out or may have developed contemporaneously over separate areas since it is absent between some of the coal test holes. Where the coal bed has been measured in drill holes, it ranges in thickness from 16.0 feet (4.9 m) to a maximum of 28.0 feet (8.5 m) excluding a rock parting 2.0 feet thick. To the north in the Axial quadrangle, the coal bed has been identified in several drill holes and outcrops and ranges in thickness from 9.8 to 18.5 feet (3.0 to 5.6 m).

The Fairfield [83] coal zone (plate 44) is located in the northwestern part of the quadrangle and the rocks are burned and clinkered along the line of the coal bed's projected outcrop. Individual coal beds in the zone range from 2.0 to 9.0 feet (0.6 to 2.7 m) thick where measured in coal test holes. Cumulative coal thicknesses range from 11.0 to 16.0 feet (3.4 to 4.9 m) and the zone contains individual rock partings varying from 1.5 to 16.0 feet (0.5 to 4.9 m) thick. Based on the extrapolation of drill-hole data along the northern edge of the quadrangle, this coal zone has been extended into the southern part of the Axial quadrangle and is inferred to be 5.0 to 10.0 feet (1.5 to 3.0 m) thick within the area of projection.

Goff Coal Group

Coal beds in the Goff coal group have been identified in drill holes, outcrops, and mine-measured sections throughout much of the quadrangle. Fifty-two of these coal beds exceed Reserve Base thickness. Forty-eight of the coal beds, including eight located on non-Federal land, were treated as isolated data points. The remaining four coal beds were isopached, but one of these, the Goff [134] coal bed, is located on non-Federal and leased lands. Therefore, an areal distribution and identified resources map was not constructed for this coal bed.

The Cornrike coal bed (plate 40) has been mined at the Cornrike mine in sec. 10, T. 2 N., R. 93 W., where the total coal thickness is 20.1 feet (6.1 m). The coal bed contains two rock partings totalling 1.5 feet (0.5 m) in thickness at the mine. The coal bed has also been identified in two outcrops more than 2 miles (3.2 km) east of the mine. These outcrops are in the SW 1/4 sec. 6, T. 2 N., R. 92 W., where the coal bed is 17.7 feet (5.4 m) thick, and in the NW 1/4 sec. 12, T. 2 N., R. 93 W., where the coal bed has a cumulative coal thickness of 12.1 feet (3.7 m) and contains rock partings totalling 2.9 feet (0.9 m). The coal bed was not isopached in the area around the mine or between the mine and the two outcrops owing to the insufficient data between these two areas. Also the mine was not treated as an isolated data point because it is located on leased land.

The Goff [127] coal bed (plate 44) has been identified in two outcrops in the east-central part of the quadrangle where measured thicknesses are 5.4 and 9.4 feet (1.6 and 2.9 m). Rock partings were not recorded in either measurement.

The Goff [140] coal bed (plate 32) ranges in thickness from 4.0 to 6.5 feet (1.2 to 2.0 m) in an outcrop and coal test hole in sec. 7, T. 3 N., R. 92 W. Rock partings are not known to occur in this coal bed. In the Thornburgh quadrangle to the east, the coal bed crops out in sec. 7, T. 3 N., R. 92 W., where it is 5.0 feet (1.5 m) thick.

Isolated Data Points

In instances where single or isolated measurements of coal beds thicker than 5.0 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 point maps are included on a separate plate for non-isopached coal beds (plate 56). Because of the extreme lenticularity of the coal beds in this quadrangle, it is assumed that these coal beds maintain their measured thickness for only 1,000 feet (305 m) in all directions from their points of measurement. 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.

COAL RESOURCES

Data from drill holes, mine measured sections, and outcrop measurements (Hancock and Eby, 1930; Muller, 1976; Reheis, 1976, 1978, and no date; Reheis and Peterson, 1977; Nutt, 1978 and no date), as well as data from oil and gas test holes, were used to construct outcrop, isopach, and structure contour maps of the coal beds in the Ninemile Gap quadrangle.

Where coal beds of Reserve Base thickness exist entirely on non-Federal lands or on lands already leased for coal mining, such as the Goff [134] coal bed, areal distribution and identified resources maps are not constructed and Reserve Base tonnages are not calculated. The source of each indexed data point shown on plate 1 is listed in table 4.

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 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 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 655.12 million short tons (594.32 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 39.01 million short tons (35.39 million metric tons) of coal available for surface mining.

The coal development potential for surface mining methods is shown on plate 57. Of the Federal land areas having a known development potential for surface mining, 82 percent are rated high, 6 percent are rated moderate, and 12 percent are rated low. The remaining Federal lands within the quadrangle are classified as having unknown development potential for surface mining methods.

Development Potential for Subsurface and In-Situ Mining Methods

Areas considered to have a development potential for conventional subsurface mining methods 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 98.64 million short tons (89.49 million metric tons) of coal available for conventional subsurface mining.

The coal development potential for conventional subsurface mining methods is shown on plate 58. All of the Federal land areas having a known development potential for conventional subsurface mining methods are rated high. The remaining Federal lands within the quadrangle are classified as having unknown development potential for conventional subsurface mining methods.

Because the coal beds in this quadrangle have dips less than 15°, all Federal lands within the quadrangle have been rated as having unknown development potential for in-situ mining methods.

Table 1. -- Chemical analyses of coals in the Ninemile Gap quadrangle, Rio Blanco and Moffat Counties, 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 sec. 24, T. 5 N., R. 91 W., Hamilton (Badger Creek) Mine (George and others, 1937) from Hamilton quadrangle	"Lower" coal group	A	12.5	29.7	48.0	9.8	0.8	-	-	-	-	-	10,650
		C	-	33.9	54.9	11.2	1.0	-	-	-	-	-	12,170
SW¼ sec. 15, T. 1 N., R. 94 W., Black Diamond Mine (Hancock, 1925) from Meeker quadrangle	Black Diamond coal group	A	10.8	37.2	44.0	7.98	0.49	-	-	-	-	-	11,220
		B	8.5	38.2	45.1	8.18	0.50	-	-	-	-	-	11,510
		C	-	41.8	49.3	8.95	0.55	-	-	-	-	-	12,580
NE¼ sec. 30, T. 2 N., R. 92 W., Wesson Mine (Gale, 1907) from Rattlesnake Mesa quadrangle	Wesson, Fairfield coal group	A	13.6	36.17	45.57	4.66	0.45	-	-	-	-	-	10,931
SW¼ NE¼ sec. 2, T. 3 N., R. 93 W., Mount Streeter (Joseph Collum) Mine (Hancock and Eby, 1930) from Axial quadrangle	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
SW¼ sec. 10, T. 2 N., R. 93 W., Cornrick Mine (Hancock and Eby, 1930)	Cornrike, Goff coal group	A	13.9	42.0	41.9	2.2	0.28	-	-	-	-	-	11,270
		B	10.6	43.6	43.5	2.3	0.29	-	-	-	-	-	11,700
		C	-	48.8	48.6	2.6	0.33	-	-	-	-	-	13,000
Sec. 15, T. 3 N., R. 93 W., James Mine (George and others, 1937)	Goff (133)	A	12.1	35.8	47.5	4.6	0.5	-	-	-	-	-	11,360
		C	-	40.7	54.0	5.3	0.6	-	-	-	-	-	12,910

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 Ninemile Gap quadrangle, Rio Blanco and Moffat Counties, Colorado.

Coal Bed or Zone	High Development Potential	Moderate Development Potential	Low Development Potential	Unknown Development Potential	Total
Goff {140}	60,000	30,000	190,000	-	280,000
Goff {127}	1,060,000	350,000	400,000	-	1,810,000
Cornrike	1,830,000	170,000	40,000	-	2,040,000
Fairfield {259}	800,000	-	-	-	800,000
Fairfield {101}	20,000	30,000	280,000	-	330,000
Fairfield {97}	330,000	350,000	690,000	-	1,370,000
Fairfield {89}	1,000,000	800,000	2,940,000	-	4,740,000
Fairfield {88}	200,000	330,000	1,010,000	-	1,540,000
Fairfield {83}	3,020,000	1,950,000	4,120,000	-	9,090,000
Fairfield {81}	40,000	-	30,000	-	70,000
Fairfield {80}	-	-	90,000	-	90,000
Fairfield {269}	1,420,000	1,070,000	1,120,000	-	3,610,000
Fairfield {216}	450,000	-	-	-	450,000
Fairfield {68}	3,900,000	-	-	-	3,900,000
Fairfield {58}	-	40,000	400,000	-	440,000
Fairfield {50}	910,000	480,000	330,000	-	1,720,000
Wesson	1,400,000	230,000	80,000	-	1,710,000
Fairfield {244}	50,000	90,000	60,000	-	200,000
Fairfield {37}	2,490,000	1,020,000	-	-	3,510,000
Fairfield {32}	850,000	390,000	550,000	-	1,790,000
Fairfield {219}	560,000	170,000	210,000	-	940,000
Fairfield {21}	1,290,000	610,000	210,000	-	2,110,000

Table 2. -- Continued. (Ninemile Gap)

Coal Bed or Zone	High Development Potential	Moderate Development Potential	Low Development Potential	Unknown Development Potential	Total
Fairfield {12}	2,960,000	360,000	-	-	3,320,000
Fairfield {208}	20,000,000	160,000	100,000	-	20,260,000
Fairfield {209}	500,000	700,000	2,640,000	-	3,840,000
Isolated Data Points	-	-	-	39,010,000	39,010,000
Totals	45,140,000	9,330,000	15,490,000	39,010,000	108,970,000

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 Ninemile Gap quadrangle, Rio Blanco and Moffat Counties, Colorado.

Coal Bed or Zone	High Development Potential	Moderate Development Potential	Low Development Potential	Unknown Development Potential	Total
Goff {140}	1,420,000	-	-	-	1,420,000
Goff {127}	470,000	-	-	-	470,000
Cornrike	210,000	-	-	-	210,000
Fairfield {101}	3,140,000	-	-	-	3,140,000
Fairfield {97}	30,000	-	-	-	30,000
Fairfield {89}	3,160,000	-	-	-	3,160,000
Fairfield {88}	6,890,000	-	-	-	6,890,000
Fairfield {83}	22,290,000	-	-	-	22,290,000
Fairfield {81}	740,000	-	-	-	740,000
Fairfield {269}	28,040,000	-	-	-	28,040,000
Fairfield {216}	11,270,000	-	-	-	11,270,000
Fairfield {68}	2,020,000	-	-	-	2,020,000
Fairfield {58}	15,420,000	-	-	-	15,420,000
Fairfield {50}	910,000	-	-	-	910,000
Wesson	1,640,000	-	-	-	1,640,000
Fairfield {244}	22,440,000	-	-	-	22,440,000
Fairfield {37}	2,960,000	-	-	-	2,960,000
Fairfield {32}	2,900,000	-	-	-	2,900,000
Fairfield {219}	99,370,000	1,270,000	-	-	100,640,000
Fairfield {21}	4,960,000	-	-	-	4,960,000

Table 3. -- Continued. (Ninemile Gap)

Coal Bed or Zone	High Development Potential	Moderate Development Potential	Low Development Potential	Unknown Development Potential	Total
Fairfield {12}	8,310,000	-	-	-	8,310,000
Fairfield {208}	162,620,000	3,790,000	-	-	166,410,000
Fairfield {209}	36,040,000	5,200,000	-	-	41,240,000
Isolated Data Points	-	-	-	98,640,000	98,640,000
Totals	437,250,000	10,260,000	-	98,640,000	546,150,000

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

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

Plate 1 Index Number	Source	Data Base
1	Hancock and Eby, 1930, U.S. Geological Survey Bulletin 812-C, pl. 30	Measured Section No. 465
2	Cobra Oil and Gas Co.	Oil/gas well No. 1 U.S.A. Pan American-Gov't
3	Hancock and Eby, 1930, U.S. Geological Survey Bulletin 812-C, pl. 30	Measured Section No. 463
4	Pan American Petroleum Corp.	Oil/gas well No. 1 McBride-Gov't
5	Cobra Oil and Gas Corp.	Oil/gas well No. 2 Pan American
6	Reheis, 1976, U.S. Geological Survey Open-File Report No. 76-870	Drill hole No. D-8-NG
7	California Oil Co.	Oil/gas well No. 1 Gov't
8	Hancock and Eby, 1930, U.S. Geological Survey Bulletin 812-C, pl. 30	Measured Section No. 461
9	General Petroleum Corp.	Oil/gas well No. 1-63 Ninemile Unit
10	U.S. Geological Survey, 1959, Inactive Coal Prospecting Permit No. Colorado 15900, Industrial Fuels Corp.	Drill hole No. M-128
11	↓	Drill hole No. M-131
12	Cobra Oil and Gas Corp.	Oil/gas well No. 3 U.S.A. Pan American-Gov't
13	Nutt, (no date), U.S. Geological Survey, unpublished data	Measured Section No.152
14	Hancock and Eby, 1930, U.S. Geological Bulletin 812-C, pl. 30	Measured Section No. 474

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Table 4. -- Continued

Plate 1 Index Number	Source	Data Base
15	Hancock and Eby, 1930, U.S. Geological Bulletin 812-C, pl. 30	Measured Section No. 473
16	↓	Measured Section No. 472
17	Nutt, (no date), U.S. Geological Survey, unpublished data	Measured Section
18	↓	Measured Section No. 17
19	Aztec Oil and Gas Corp.	Oil/gas well No. 1 Bradshaw-Gov't
20	Hancock and Eby, 1930, U.S. Geological Survey Bulletin 812-C, pl. 30	Measured Section No. 470
21	Nutt, (no date), U.S. Geological Survey, unpublished data	Measured Section No. 12
22	↓	Measured Section No. 320
23	Hancock and Eby, 1930, U.S. Geological Survey Bulletin 812-C, pl. 30	Mine-Measured Section No. 469
24	Nutt, (no date), U.S. Geological Survey, unpublished data	Measured Section
25	Stuarco Oil Co.-Bel Oil Corp.	Oil/gas well No. 1 Jensen
26	U.S. Geological Survey, 1959, Inactive Coal Prospecting Permit No. Colorado 15900, Industrial Fuels Corp.	Drill hole No. MC 18
27	Hancock and Eby, 1930, U.S. Geological Survey Bulletin 812-C, pl. 30	Measured Section No. 468
28	Nutt, (no date), U.S. Geological Survey, unpublished data	Measured Section No. 315

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Table 4. -- Continued

Plate 1 Index Number	Source	Data Base
29	Hancock and Eby, 1930, U.S. Geological Survey Bulletin 812-C, pl. 30	Measured Section No. 501
30	Nutt, (no date), U.S. Geological Survey, unpublished data	Measured Section No. 152
31	↓	Measured Section No. 191
32	↓	Measured Section
33	↓	Measured Section No. 168
34	↓	Measured Section
35	↓	Measured Section No. 239
36	Hancock and Eby, 1930, U.S. Geological Survey Bulletin 812-C, pl. 30	Measured Section Nos. 491-493
37	Nutt, (no date), U.S. Geological Survey, unpublished data	Measured Section No. C2
38	Reheis, (no date), U.S. Geological Survey, unpublished data	Measured Section No. 19
39	↓	Measured Section No. 18
40	Muller, 1976, U.S. Geological Survey Open-File Report No. 76-383	Drill hole No. D-1-NG
41	Reheis, 1976, U.S. Geological Survey Open-File Report No. 76-870	Drill hole No. D-4-NG
42	Hancock and Eby, 1930, U.S. Geological Survey Bulletin 812-C, pl. 29	Measured Section No. 398
43	↓	Measured Section No. 406

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Table 4. -- Continued

Plate 1 Index Number	Source	Data Base
44	Reheis and Peterson, 1977, U.S. Geological Survey Open-File Report No. 77-42	Drill hole No. D-31-NG
45	↓	Drill hole No. D-29-NG
46	Hancock and Eby, 1930, U.S. Geological Survey Bulletin 812-C, pl. 29	Measured Section No. 426
47	Reheis and Peterson, 1977. U.S. Geological Survey Open-File Report No. 77-42	Drill hole No. D-27-NG
48	Reheis, 1976, U.S. Geological Survey Open-File Report No. 76-870	Drill hole No. D-12-NG
49	Nutt, (no date), U.S. Geological Survey, unpublished data	Measured Section No. 310
50	Reheis, 1976, U.S. Geological Survey Open-File Report No. 76-870	Drill hole No. D-6-NG
51	Reheis and Peterson, 1977, U.S. Geological Survey Open-File Report No. 77-42	Drill hole No. D-34-NG
52	Nutt, (no date), U.S. Geological Survey, unpublished data	Measured Section No. Cl
53	↓	Measured Section No. 305
54	↓	Measured Section No. 2
55	↓	Measured Section No. C3
56	Hancock and Eby, 1930, U.S. Geological Survey Bulletin 812-C, pl. 29	Measured Section No. 378

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Table 4. -- Continued

Plate 1 Index Number	Source	Data Base
57	Reheis, 1976, U.S. Geological Survey Open-File Report No. 76-870	Drill hole No. D-7-NG
58	Reheis and Peterson, 1977, U.S. Geological Survey Open-File Report No. 77-42	Drill hole No. D-18-NG
59	Nutt, (no date), U.S. Geological Survey, unpublished data	Measured Section No. 203
60	Reheis, 1976, U.S. Geological Survey Open-File Report No. 76-870	Drill hole No. D-2-NG
61	Reheis and Peterson, 1977, U.S. Geological Survey Open-File Report No. 77-42	Drill hole No. D-20-NG
62	↓	Drill hole No. D-19-NG
63	Sun Oil Co.	Oil/gas well No. 1 Gossard-Gov't
64	Reheis and Peterson, 1977, U.S. Geological Survey Open-File Report No. 77-42	Drill hole No. D-25-NG
65	↓	Drill hole No. D-35-NG
66	↓	Drill hole No. D-28-NG
67	↓	Drill hole No. D-24-NG
68	↓	Drill hole No. D-33-NG
69	↓	Drill hole No. D-23-NG
70	The Texas Co. and California Oil Co.	Oil/gas well No. 44 Wilson Creek Unit
71	Nutt, (no date), U.S. Geological Survey, unpublished data	Measured Section No. 9

Table 4. -- Continued

Plate 1 Index Number	Source	Data Base
72	Reheis, 1978, U.S. Geological Survey Open-File Report No. 78-1031	Drill hole No. D-48-NG
73	Reheis, 1976, U.S. Geological Survey Open-File Report No. 76-870	Drill hole No. D-10-NG
74	Reheis and Peterson, 1977, U.S. Geological Survey Open-File Report No. 77-42	Drill hole No. D-22-NG
75	↓	Drill hole No. D-21-NG
76	↓	Drill hole No. D-17-NG
77	↓	Drill hole No. D-16-NG
78	Nutt, (no date), U.S. Geological Survey, unpublished data	Measured Section No. 193
79	↓	Measured Section No. C4
80	Reheis and Peterson, 1977, U.S. Geological Survey Open-File Report No. 77-42	Drill hole No. D-32-NG
81	Reheis, 1976, U.S. Geological Survey Open-File Report No. 76-870	Drill hole No. D-5-NG
82	Hancock and Eby, 1930, U.S. Geological Survey Bulletin 812-C, pl. 29	Measured Section Nos. 399-402
83	W.C. McBride, Inc.	Oil/gas well No. 1 Gov't-Little Creek
84	Reheis and Peterson, 1977, U.S. Geological Survey Open-File Report No. 77-42	Drill hole No. D-13-NG
85	Nutt, 1978, U.S. Geological Survey Open-File Report 78-273	Drill hole No. D-62-NG

Table 4. -- Continued

Plate 1 Index Number	Source	Data Base
86	Nutt, 1978, U.S. Geological Survey Open-File Report No. 78-273	Drill hole No. D-61-NG
87	↓	Drill hole No. D-60-NG
88	Reheis and Peterson, 1977, U.S. Geological Survey Open-File Report No. 77-42	Drill hole No. D-14-NG
89	Nutt, 1978, U.S. Geological Survey Open-File Report No. 78-273	Drill hole No. D-58-NG
90	Nutt, (no date), U.S. Geological Survey, unpublished data	Measured Section No. 188
91	↓	Measured Section No. 11
92	Hancock and Eby, 1930, U.S. Geological Survey Bulletin 812-C, pl. 29	Measured Section No. 404
93	Fuel Resources Co.	Oil/gas well No. 2-1 Jensen-Federal
94	Cobra Oil and Gas Corp.	Oil/gas well No. 2 McBride-USA

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REFERENCES

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

Bass, N. W., Eby, J. B., and Campbell, M. R., 1955, Geology and mineral fuels of parts of Routt and Moffat Counties, Colorado: U.S. Geological Survey Bulletin 1027-D, p. 143-250.

Emmons, S. F., 1877, Valleys of the Upper Yampa and Little Snake Rivers, Section VIII, _in_ Report of the geological exploration of the Fortieth Parallel, Vol. II, Descriptive geology: U.S. Army Engineer Department Professional Paper No. 18, p. 181-189.

Gale, H. S., 1907, Coal fields of the Danforth Hills and Grand Hogback in northwestern Colorado, _in_ Campbell, M. R., Coal, lignite, and peat, contributions to economic geology, 1906, Part II: U.S. Geological Survey Bulletin 316, p. 264-301.

______1910, Coal fields of northwestern Colorado and northeastern Utah: U.S. Geological Survey Bulletin 415, 265 p.

George, R. D., Denny, E. H., Young, W. H., Snyder, N. H., Fieldner, A. C., Cooper, H. M., and Abernethy, R. F., 1937, Analyses of Colorado coals: U.S. Bureau of Mines Technical Paper 574, 327 p.

Grose, L. T., 1972, Tectonics, _in_ Mallory, W. W., ed., Geologic atlas of the Rocky Mountain region: Rocky Mountain Association of Geologists, p. 37.

Hancock, E. T., 1925, Geology and coal resources of the Axial and Monument Butte quadrangles, Moffat County, Colorado: U.S. Geological Survey Bulletin 757, p. 47.

Hancock, E. T., and Eby, J. B., 1930, Geology and coal resources of the Meeker quadrangle, Moffat and Rio Blanco Counties, Colorado: U.S. Geological Survey Bulletin 812-C, p. 191-242.

Hewett, G. C., 1889, The northwestern Colorado coal region: American Institute of Mining and Metallurgical Engineers Transactions, v. 17, p. 375-380.

Hills, R. C., 1893, Coal fields of Colorado, _in_ Coal: U.S. Geological Survey, Mineral resources of the United States, calendar year 1892, p. 319-365.

References--Continued

Howard, A. D., and Williams, J. W., 1972, Physiography, in Mallory, W. W., ed., Geologic atlas of the Rocky Mountain region: Rocky Mountain Association of Geologists, p. 30.

Konishi, Kenji, 1959, Upper Cretaceous surface stratigraphy, Axial Basin and Williams Fork area, Moffat and Routt Counties, Colorado, in Washakie, Sand Wash, and Piceance Basins, Symposium on Cretaceous rocks of Colorado and adjacent areas, Rocky Mountain Association of Geologists Guidebook, 11th Annual Field Conference, 1959: p. 67-73.

Kucera, R. E., 1959, Cretaceous stratigraphy of the Yampa district, northwest Colorado, in Washakie, Sand Wash, and Piceance Basins, Symposium on Cretaceous rocks of Colorado and adjacent areas, Rocky Mountain Association of Geologists Guidebook, 11th Annual Field Conference, 1959: p. 37-45.

Muller, S. C., 1976, Lithologic and geophysical logs of seven holes drilled in 1975 in Yampa and Danforth Hills coal fields, northwestern Colorado: U.S. Geological Survey Open-File Report 76-383, 180 p.

Nutt, C. J., 1978, Drilling during 1977 in the Danforth Hills coal field, Axial and Ninemile Gap quadrangles, Moffat and Rio Blanco Counties, Colorado: U.S. Geological Survey Open-File Report 78-273, 17 p.

_______(no date), Coal sections and map: U.S. Geological Survey, unpublished field notes.

Reheis, M. J., 1976, Reconnaissance drilling in the Danforth Hills coal field, Moffat and Rio Blanco counties, Colorado, August-September 1976: U.S. Geological Survey Open-File Report 76-870, 74 p.

______1978, Drilling during 1978 in the Danforth Hills coal field, Easton Gulch, Devils Hole Gulch, Axial, and Ninemile Gap quadrangles, Moffat and Rio Blanco Counties, Colorado: U.S. Geological Survey Open-File Report 78-1031, 38 p.

______(no date), Geologic map of the Thornburgh quadrangle, Moffat and Rio Blanco Counties, Colorado: U.S. Geological Survey, scale 1:24,000, in preparation.

Reheis, M. J., and Peterson, J. E., 1977, Reconnaissance drilling in the Danforth Hills coal field, Moffat and Rio Counties, Colorado, September-October 1976: U.S. Geological Survey Open-File Report 77-42, 67 p.

References--Continued

Ryer, T. A., 1977, Geology and coal resources of the Foidel Creek EMRIA site and surrounding area, Routt County, Colorado: U.S. Geological Survey Open-File Report 77-303, 31 p.

Sears, J. D., 1924, Geology and oil and gas prospects of part of Moffat County, Colorado, and southern Sweetwater County, Wyoming: U.S. Geological Survey Bulletin 751-G, p. 269-319 [1925].

Storrs, L. S., 1902, The Rocky Mountain coal field: U.S. Geological Survey, 22nd Annual Report, pt. III, j, p. 415-471.

Tweto, Ogden, compiler, 1976, Geologic map of the Craig 1° x 2° quadrangle, northwest Colorado: U.S. Geological Survey Miscellaneous Investigations Series Map I-972, scale 1:250,000.

U.S. Bureau of Land Management, 1977, Description of the environment, chapter II, in Final environmental statement, northwest Colorado coal: v. 1, Regional analysis, p. II-1-II-125, and appendix B, foldout 9.

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

U.S. Geological Survey, 1959, Inactive Coal Prospecting Permit No. Colorado 15900, Industrial Fuels Corporation.