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COAL RESOURCE OCCURRENCE AND COAL DEVELOPMENT POTENTIAL MAPS OF THE BREEZE MOUNTAIN QUADRANGLE, MOFFAT AND ROUTT COUNTIES, COLORADO

[Report includes 38 plates]

Prepared for

UNITED STATES DEPARTMENT OF THE INTERIOR

GEOLOGICAL SURVEY

By

DAMES & MOORE

DENVER, COLORADO

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 Breeze Mountain quadrangle, Moffat and Routt 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 United States Geological Survey under contract number 14-080001-15789. 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 Published and unpublished public information available through April, 1978, was used as the data base for this study. No new drilling or field mapping was done as part of this study, nor was any confidential data used.

Location

The Breeze Mountain quadrangle is located in northwestern Colorado. The western half of the quadrangle lies within eastern Moffat County, while the eastern half is located within western Routt County. The quadrangle is approximately 4 miles (6 km) southeast of the town of Craig via Colorado Highway 394, and approximately 29 airline miles (47 km) west of the town of Steamboat Springs. With the exception of a few ranches and farms, the area within the quadrangle is unpopulated.

Accessibility

U.S. Highway 40 passes through the northeastern corner of the Breeze Mountain quadrangle, and then continues westward passing approximately 1 to 2 miles (1.6 to 3.2 km) north of the quadrangle. It connects the town of Hayden to the east with Craig to the west. Colorado Highway 394, crossing the northern part of the quadrangle, also connects Craig with Hayden. It is a paved medium-duty road in the northwestern corner of the quadrangle and an improved light-duty road across Breeze Basin in the northeastern part of the quadrangle. The quadrangle is also accessible by several light-duty roads and unimproved dirt roads and trails.

Railway service for the Breeze Mountain quadrangle is provided by the Denver & Rio Grande Western Railroad from Denver to the railhead at Craig. The railroad follows U.S. Highway 40, passing within 0.5 mile (0.8 km) of the northeastern corner of the Breeze Mountain quadrangle, and then continues approximately 1 to 2 miles (1.6 to 3.2 km) north of the quadrangle boundary to Craig. The railroad is the major transportation route for coal shipped east from northwestern Colorado (U.S. Bureau of Land Management, 1977).

Physiography

The Breeze Mountain quadrangle lies in the southern part of the Wyoming Basin physiographic province as defined by Howard and Williams (1972), and it is approximately 39 miles (63 km) west of the Continental Divide. The Williams Fork Mountains cross the southern two thirds of the quadrangle. The landscape in the southern half of the quadrangle is dominated by moderate to steep slopes and narrow canyons while the northern half is characterized by less pronounced topography, broader, more gentle slopes and wider canyons.

Approximately 2,000 feet (610 m) of relief is present in the Breeze Mountain quadrangle. Altitudes range from over 8,200 feet (2,499 m) in the southeastern corner of the quadrangle to less than 6,200 feet (1,890 m) in the northwestern corner. Buck Peak rises to an elevation of 7,748 feet (2,362 m) above sea level in the west-central part of the quadrangle. Breeze Mountain rises approximately 400 feet (122 m) above the Breeze Basin valley in the northwestern part of the quadrangle.

Streams in the northeastern half of the Breeze Mountain quadrangle drain into the Yampa River which flows northwestward across the northeastern corner of the quadrangle. The southwestern half of the quadrangle is drained by several southwest-trending intermittent streams which flow into the Williams Fork, a tributary of the Yampa River. The

Williams Fork joins the Yampa River approximately 8 miles (13 km) west of the quadrangle boundary. The intermittent streams in the quadrangle flow mainly in response to snowmelt in the spring. A number of small ponds and lakes occur throughout the quadrangle. Biskup Reservoir, Dresher Reservoir, and Basin Resevoir are located in the northern third of the quadrangle.

Climate and Vegetation

The climate of northwestern Colorado is semiarid. Clear, sunny days prevail in the Breeze Mountain quadrangle area, with daily temperatures typically varying from 0° to 35°F (-18° to 2°) in January and from 42° to 80°F (6° to 27°C) in July. Annual precipitation in the area averages approximately 16 inches (41 cm). Snowfall during the winter months accounts for the major part of the precipitation in the area; however, rainfall from thundershowers during the summer months also contributes to the total. Winds, averaging approximately 3 miles per hour (4.8 km per hour), are generally from the west, but wind directions and velocities vary greatly depending on the local terrain (U.S. Bureau of Land Management, 1977).

The dominant type of vegetation in the southern two thirds of the Breeze Mountain quadrangle is mountain shrub, including serviceberry, Gambel oak and rabbitbrush, which range from 2 to 8 feet (0.6 to 2.4 m) high. Vegetation in the southwestern corner and most of the northern third of the quadrangle is predominately sagebrush. The flatter areas, present in the northwestern corner of the quadrangle and along the Yampa River in the northeastern corner, are utilized as cropland (U.S. Bureau of Land Management, 1977).

Land Status

The Breeze Mountain quadrangle lies in the center of the Yampa Known Recoverable Coal Resource Area (KRCRA). Approximately four fifths of the quadrangle lie within the KRCRA boundary and the Federal government owns the coal rights for about 80 percent of this area. One active coal lease is located in the south-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 Breeze Mountain quadrangle is located was prepared by Emmons (1877) as part of a survey of the Fortieth Parallel. The decision to build a railroad into the region stimulated several investigations of coal between 1886 and 1905, including papers by Hewett (1889), Hills (1893), Storrs (1902), and Parsons and Liddell (1903). Fenneman and Gale (1906) conducted geologic studies of the Yampa coal field and included a description of the geology and coal occurrence in the Breeze Mountain quadrangle in their report. In 1955, Bass and others expanded Fenneman and Gale's work in a report on the geology and mineral fuels of parts of Routt and Moffat Counties, and this is the most comprehensive work on the area. Tweto (1976) compiled a generalized regional map of northwestern Colorado which included this quadrangle. The U.S. Geological Survey (Prost, 1977; Brownfield, 1978) recently conducted reconnaissance drilling in the Yampa coal field.

Stratigraphy

The sedimentary rock formations which crop out in the Breeze Mountain quadrangle are Late Cretaceous in age, and include the coal-bearing Iles and Williams Fork Formations of the Mesaverde Group and the Lance Formation.

The Mancos Shale is present in the subsurface in the Breeze Mountain quadrangle and the upper 1,000 feet (305 m) of the formation consists predominantly of gray to dark-gray marine shale, a number of thin-bedded silty tan sandstone beds, and interbedded sandy shale (Bass and others, 1955).

The Mesaverde Group conformably overlies the Mancos Shale and contains two formations, the Iles and Williams Fork. The Iles Formation ranges from approximately 1,425 to 1,690 feet (434 to 515 m) in thickness where measured in the oil and gas wells drilled in the quadrangle and crops out in the southwestern part of the quadrangle. The basal Tow

Creek Sandstone Member consists of approximately 70 feet (21 m) of light-brown, fine-grained massive cliff-forming sandstone. In some areas it consists of two or more sandstone beds separated by shale and sandy shale. Overlying the Tow Creek Sandstone Member is a unit of light-brown, light-gray and white massive ledge-forming sandstone interbedded with gray sandy shale and coal which is approximately 1,425 feet (434 m) thick. This unit, which contains thick sandstone beds near the base, grades upward to become more silty and shaly. The coal beds contained in this unit have been designated as the Lower Coal Group (Fenneman and Gale, 1906). The overlying Trout Creek Sandstone Member consists of approximately 80 feet (24 m) of white, fine-grained massive cliff-forming sandstone. The top of the Trout Creek Sandstone Member forms the contact between the Iles Formation and the conformably overlying Williams Fork Formation (Bass and others, 1955).

The Williams Fork Formation crops out in the southern three quarters of this quadrangle and ranges in thickness from approximately 1,575 to 1,680 feet (480 to 512 m) where measured in the oil and gas wells drilled in the northern part of the quadrangle. Bass and others (1955) and Prost (1977) indicate that it is probably 1,850 to 2,000 feet (564 to 610 m) thick in the southern part of the quadrangle. The formation is divided by Fenneman and Gale (1906) and Bass and others (1955) into three units: a lower coal-bearing unit, the Twentymile Sandstone Member, and an upper coal-bearing unit.

The lower coal-bearing unit of the Williams Fork Formation extends from the top of the Trout Creek Sandstone Member of the Iles Formation to the base of the Twentymile Sandstone Member. In this quadrangle, it is approximately 950 feet (290 m) thick and consists of dark-gray to black shale, gray siltstone, sandstone, carbonaceous shale, and coal. This unit grades upward from chiefly siltstone, sandstone, shale, and coal in the lower half to shale in the upper half (Bass and others, 1955; Brownfield, 1978). Fenneman and Gale (1906) have designated the coal in this lower unit as the Middle Coal Group.

The Twentymile Sandstone Member, which is approximately 140 feet (43 m) thick in this quadrangle, consists of massive white to gray fine-grained sandstone (Bass and others, 1955; Brownfield, 1978).

The upper coal-bearing unit of the Williams Fork Formation that overlies the Twentymile Sandstone Member is approximately 730 feet (223 m) thick in this quadrangle. The sequence is composed of gray fine-grained sandstone, gray siltstone, gray shale, brown carbonaceous shale, and coal (Bass and others, 1955; Brownfield, 1978). The coal beds in this upper unit, between the top of the Twentymile Sandstone Member and the base of the Lewis Shale, form the Upper Coal Group (Fenneman and Gale, 1906).

The Lewis Shale conformably overlies the Williams Fork Formation and crops out in the northeastern part of the quadrangle. The formation consists of dark-gray to bluish marine shale (Bass and others, 1955). No information is available on the thickness of the Lewis Shale in this quadrangle. However, it ranges from at least 1,700 feet (518 m) to approximately 2,775 feet (846 m) in the quadrangles to the north.

The Lance Formation crops out in the northeastern corner of the quadrangle and conformably overlies the Lewis Shale. The formation is composed of light-buff and light-tan, soft fine-grained sandstone, gray shale, and coal. The thick basal white to gray ledge-forming sandstone of Bass and others (1955) is probably the Fox Hill Sandstone identified by Haun (1961) in the quadrangles to the north. Information is not available on the total thickness of the Lance Formation in this quadrangle, but the combined thickness of the Fox Hills Sandstone and the Lance Formation in the Ralph White Lake quadrangle to the north ranges from approximately 1,100 to 1,430 feet (335 to 436 m).

The Lewis Shale in the northwestern part of the quadrangle has been intruded by Tertiary-age sills and dikes. These igneous rocks, of probable olivine basalt composition, occur at Breeze Mountain (Bass and others, 1955; Tweto, 1976).

Holocene deposits of alluvium cover the stream valley of the Yampa River in the northeastern and northwestern corners of the quadrangle.

The Cretaceous formations in the Breeze Mountain 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 resulted in the deposition of a series of offshore-marine, shallow-marine, and marginal-marine sediments in the Breeze Mountain 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 Mesaverde Group 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 members of the Iles and Williams Fork Formations, including the Tow Creek, Trout Creek and Twentymile Sandstone Members, were deposited in shallow marine and near-shore environments. 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. The major coal beds which have wide areal extent were deposited near the seaward margin of the non-marine environments, probably in large brackish-water lagoons or swamps. The slow migration of this depositional environment is responsible for the wide distribution of some of the coal beds in the Yampa study area (Konishi, 1959; Kucera, 1959).

Deposition of the Lewis Shale marked a landward movement of the sea. The marine sediments of the Lewis Shale were deposited in water depths ranging from a few tens of feet to several hundred feet.

Deposition ended in the area with the regression of the sea (Kucera, 1959).

Following the regression of the Cretaceous sea, broad areas of fluvial, estuarine, marsh, lagoonal, and coastal swamp environments resulted in deposits of sandstone, siltstone, mudstone, carbonaceous shale and coal beds, characteristic of the Lance Formation (O'Boyle, 1955; Weimer, 1961).

Structure

The Yampa KRCRA lies in the southern extension of the Washakie/Sand Wash structural basin of south-central Wyoming. The basin is bordered on the east by the Park Range, approximately 32 miles (51 km) east of the Breeze Mountain quadrangle, and on the southwest by the Axial Basin anticline, approximately 10 miles (16 km) west-southwest of the quadrangle.

The Breeze Mountain quadrangle lies on the southeastern part of the west-northwest-trending Buck Peak anticline. Dips of the coal-bearing strata are quite variable in the quadrangle. In the northern half, north of the Buck Peak anticline, dips range from about 3° to 11° north and northeast. Just south of the Buck Peak anticline axis, a gentle synclinal flexture modifies the southern limb of the Buck Peak anticline. In this area, dips vary from 3° east to 2° south-southeast in the west-central part of the quadrangle to about 3° west-southwest in the central part. South of this flexture, dips on the southern limb of the Buck Peak anticline generally range from approximately 3° north to 9° north-northeast in the southwestern part of the quadrangle and from 4° north-northeast to 10° east-northeast in the southeastern part. Two west-northwest-trending faults offset the Cretaceous rocks in the quadrangle (Bass and others, 1955). One fault, crossing the central part of the quadrangle, cuts the Buck Peak anticline along the axis. A second, smaller fault is located in the extreme southwestern corner of the quadrangle.

The structure contour maps of the isopached coal beds are based on a regional structure map of the top of the Trout Creek Sandstone Member by Bass and others (1955), and it is assumed that the structure of the coal beds duplicates that of the Trout Creek Sandstone Member. Modifications were made where necessary in accordance with outcrop and drill-hole data.

COAL GEOLOGY

Coal beds have been identified in the Lower, Middle and Upper Coal Groups of the Mesaverde Group and in the Lance Formation in the Breeze Mountain quadrangle. None of the coal beds are formally named, but where coal beds exceed Reserve Base thickness (5.0 feet or 1.5 meters), they have been given bracketed numbers for identification purposes. Coal beds in the Lower Coal Group and in the Lance Formation tend to be thin, lenticular, and of limited areal extent, while the coal beds in the Middle and Upper Coal Groups tend to persist over larger areas. In instances where coal beds exceeding Reserve Base thickness are encountered at one location only, they are treated as isolated data points (see Isolated Data Points section of this report).

Dotted lines shown on some of the derivative maps represent a limit of confidence beyond which isopach, structure contour, overburden isopach, and areal distribution and identified resources maps are not drawn because of insufficient data, even where it is believed that the coal beds may continue to be greater than Reserve Base thickness beyond the dotted lines.

Chemical analyses of coal.--Analyses of the coals in this quadrangle are listed in table 1. In general, chemical analyses indicate that the Lower, Middle, and Upper Coal Group coals are high-volatile C bituminous, and coal in the Lance Formation is subbituminous A in rank on a moist, mineral-matter-free basis according to ASTM Standard Specification D 388-77 (American Society for Testing and Materials, 1977).

Locations of coal samples tested in this quadrangle are listed in table 1 and include those for the Lower Coal Group, zones G and H of the

Middle Coal Group, and zone M, coal bed [33] and an undifferentiated coal bed in the Upper Coal Group. Chemical analyses were not available for each zone in the Lower, Middle, and Upper Coal Groups. However, the analyses shown in the table are believed to be representative of all Lower, Middle, and Upper Group coals. Chemical analyses were also not available for coal in the Lance Formation, but it is believed that the coal is similar in rank to Lance coals mined at the White Mine in the Ralph White Lake quadrangle to the north.

Lower Coal Group

The Lower Coal Group includes all coal beds in the Iles Formation between the Tow Creek and Trout Creek Sandstone Members. Coal beds in this group crop out in the southern part of the quadrangle. Five coal zones within the Lower Coal Group were identified by Bass and others (1955). However, coal zone D is the only zone that contains a coal bed exceeding Reserve Base thickness in this quadrangle.

Coal Zone D

Coal zone D lies approximately 380 feet (116 m) stratigraphically below the top of the Iles Formation (U.S. Geological Survey, 1971; Prost, 1977) and coal beds in the zone have been identified in outcrops in the southwestern part of the quadrangle. Only one of these coal beds, the LGD[1] (i.e., Lower Coal Group, zone D, coal bed [1]) coal bed, is known to exceed Reserve Base thickness in this quadrangle.

The LGD[1] coal bed ranges in thickness from 2.8 to 6.5 feet (0.9 to 2.0 m) where measured along the outcrop and in a drill hole. The coal bed is known to exceed Reserve Base thickness in only two small areas (plate 4); one is in sec. 14, T. 5 N., R. 90 W., and the other is located in sec. 16, T. 5 N., R. 90 W.

Undifferentiated Lower Group Coal Beds

Three Lower Group coal beds exceeding Reserve Base thickness, the LG[2], LG[3], and LG[4] coal beds, were penetrated by an oil and gas test well in SE 1/4 SE 1/4 sec. 23, T. 6 N., R. 90 W., and cannot be located in the stratigraphic section with enough accuracy to place the coal beds within specific zones. Since these coal beds were encountered at only this location, they have been treated as isolated data points.

Middle Coal Group

The Middle Coal Group is located between the top of the Trout Creek Sandstone Member of the Iles Formation and the base of the Twentymile Sandstone Member of the Williams Fork Formation. In quadrangles to the east, Bass and others (1955) indicate that most of the coal beds can be placed in three main zones (F, G, and H) and that two other coal beds (I and J), which may also be zones farther west, overlie the zones in the coal-bearing sequence of strata. All zones except zone I contain coal beds exceeding Reserve Base thickness in this quadrangle.

Coal Zone F

Zone F lies, stratigraphically, at the base of the Williams Fork Formation (Prost, 1977) and crops out in the southwestern part of the quadrangle. Three coal beds, the MGF[7], MGF[8], and MGF[9], were each penetrated by a single drill hole and could not be correlated with other coal beds. Therefore, they have been treated as isolated data points.

Coal Zone G

This zone occurs approximately 130 feet (40 m) stratigraphically above the base of the Williams Fork Formation (U.S. Geological Survey, 1971; Prost, 1977). Seven coal beds in zone G exceed Reserve Base thickness in this quadrangle. However, six of these coal beds, the MGG[4], MGG[48], MGG[50], MGG]51], MGG[12], and MGG[23], the latter two on non-Federal land, were identified at one location only and were treated as isolated data points. The remaining coal bed, the MGG[49] (plate 4) was penetrated in two drill holes in the south-central part of the quadrangle where it ranges in thickness from 5.0 to 7.5 feet (1.5 to 2.3 m), thickening eastward (plate 4).

Coal Zone H

Zone H is approximately 330 feet (101 m) stratigraphically above the base of the Williams Fork Formation (Prost, 1977), and crops out in the southwestern part of the quadrangle. Of the eight coal beds which exceed Reserve Base thickness, only three of these, the MGH[19], MGH[20], and MGH[21], were identified at more than one location and have been isopached. Thw remaining five coal beds, including the MGH]10], MGH[11], MGH[13], MGH[14], and MGH[22], were treated as isolated data points.

The MGH[19] coal bed (plate 7) extends over much of the southern part of the quadrangle where it has been identified in numerous drill holes and outcrops. The coal bed varies from 3.0 to 12.0 feet (0.9 to 3.7 m) in thickness, thinning eastward. At the point of its maximum measured thickness in sec. 11, T. 5 N., R. 90 W., a rock parting of 2.0 feet (0.6 m) thick was reported. Although this coal bed has not been identified in drill holes or outcrops in the adjacent Castor Gulch quadrangle to the west and the Pagoda quadrangle to the south, it is believed that the coal bed projects into those quadrangles based on geologic data along this quadrangle's boundaries.

The MGH[20] coal bed (plate 11) has been penetrated by numerous drill holes in the southern part of the quadrangle, where measured thicknesses range from 1.5 to 13.0 feet (0.5 to 4.0 m), the maximum thickness occurring in sec. 8, T. 5 N., R. 89 W., and in sec. 11, T. 5 N., R. 90 W. Generally, the MGH[20] coal bed is a single coal bed, but it locally contains thin rock partings ranging from 1.5 to 2.0 feet (0.5 to 0.6 m) in thickness.

The MGH[21] coal bed (plate 14) ranges in thickness from 1.5 to 9.0 feet (0.5 to 2.7 m) where penetrated by drill holes in the southern part of the quadrangle. The coal bed commonly contains thin rock partings that vary from 1.0 to 1.8 feet (0.3 to 0.5 m) in thickness.

Coal Zone J

Coal zone J crops out in the southern third of the quadrangle and lies approximately 700 feet (213 m) stratigraphically above the base of the Williams Fork Formation (Bass and others, 1955; U.S. Geological Survey, 1971; Prost, 1977). One coal bed, the MGJ[26], has been isopached in the zone and another zone J coal bed, the MGJ[25], was encountered at only one location and was treated as an isolated data point.

The MGJ[26] coal bed (plate 18) has been penetrated by numerous drill holes and identified along the outcrop at many locations in the southern part of the quadrangle. It has been mined at the Jim Dunn mine in secs. 7 and 18, T. 5 N., R. 89 W., and locally at the Searcy Gulch mine in sec. 12, T. 5 N., R. 90 W. A west-northwest-trending fault cuts the MGJ[26] coal bed in the southeastern part of the quadrangle. This coal bed ranges from 1.7 to 18.0 feet (0.5 to 5.5 m) thick, attaining its maximum reported thickness in sec. 13, T. 5 N., R. 90 W. Locally, the coal bed contains thin rock partings ranging from 1.0 to 3.7 feet (0.3 to 1.1 m) in thickness. Based on drill-hole measurements made near the quadrangle's southern boundary, it is believed that this coal bed extends into the adjacent Castor Gulch quadrangle to the west where it may be as much as 9 feet (2.7 m) thick in the southeast quarter of that quadrangle. In the Castor Gulch quadrangle, the MGJ[26] coal bed has been measured in one outcrop having a thickness of 7.0 feet (2.1 m), and it is believed that the coal bed may range from 5 to 11 feet (1.5 to 3.4 m) in thickness based on data projected into that quadrangle from the Breeze Mountain quadrangle.

Undifferentiated Middle Group Coal Beds

Seven coal beds within the Middle Coal Group were identified at one location only and have been treated as isolated data points. Because of incomplete geologic data, the coal beds cannot be placed within a specific zone and are just designated as belonging to the Middle Coal Group. These coal beds include the MG[5], MG[15], MG[17], MG[24], MG[27], MG[28], and the MG[6] which is located on non-Federal land.

Upper Coal Group

The Upper Coal Group extends upward from the top of the Twentymile Sandstone Member to the base of the Lewis Shale and contains numerous relatively thin coal beds. Most of these coal beds can be placed into nine coal zones (zones K, L, M, N, O, P, Q, R, and S), sometimes referred to as beds by Bass and others (1955), and all of these zones except zone P contain coal beds exceeding Reserve Base thickness in this quadrangle.

Coal Zone K

Zone K is approximately 40 feet (12 m) stratigraphically above the Twentymile Sandstone Member (Prost, 1977), and only one coal bed in this zone, the UGK[16], is known to exceed Reserve Base thickness.

The UGK[16] coal bed (plate 22) has been measured in numerous drill holes and in an outcrop in the southern part of the quadrangle where thicknesses range from 1.5 to 7.0 feet (0.5 to 2.1 m). A west-northwest-trending fault cuts this coal bed near the central part of the quadrangle. The coal bed exceeds Reserve Base thickness in three separate areas in this quadrangle and extends into adjacent quadrangles to the east, southeast, and south. In the Hayden quadrangle to the east, the UGK[16] coal bed has a maximum recorded thickness of 9.0 feet (2.7 m) in sec. 14, T. 5 N., R. 89 W.; it ranges from 3.0 to 6.8 feet (0.9 to 2.1 m) thick in the northeastern corner of the Pagoda quadrangle to the south; and in the Hayden Gulch quadrangle to the southeast the maximum measured thickness of the coal bed is 4.5 feet (1.4 m), but it is inferred to be 7 feet (2.1 m) thick in the northwestern corner based on data projected from the Hayden quadrangle.

Coal Zone L

Coal zone L lies approximately 150 feet (46 m) stratigraphically above the top of the Twentymile Sandstone Member (Prost, 1977). The UGL[29] coal bed (plate 25) is the only zone L coal bed known to exceed Reserve Base thickness in this quadrangle and is located near the central part of the quadrangle. It ranges in thickness from 2.5 to 11.3 feet (0.8 to 3.4 m) where measured in drill holes, attaining its maximum reported thickness in sec. 2, T. 5 N., R. 90 W. This coal bed extends into the western part of the Hayden quadrangle to the east, where its thickness ranges from 5.4 to 8.3 feet (1.6 to 2.5 m) in outcrop and drill-hole measurements.

Coal Zone M

Zone M, which is located approximately 210 feet (64 m) stratigraphically above the top of the Twentymile Sandstone Member (Prost, 1977), contains only one coal bed, the UGM[33] that is isopached. Another coal bed, the UGM[32], was encountered at one location only on non-Federal land and is treated as an isolated data point.

The UGM[33] coal bed (plate 29) has been identified in numerous drill holes and outcrops over a large area in the southern half of the quadrangle and is cut by a west-northwest-trending fault near the central part of the quadrangle. The coal bed ranges from 2.0 to 13.8 feet (0.6 to 4.2 m) in thickness where measured in drill holes and contains local rock partings that vary from 1.0 to 4.5 feet (0.3 to 1.4 m) thick. This coal bed extends into the Pagoda quadrangle to the south where it ranges from 2.3 to 7.2 feet (0.7 to 2.2 m) in thickness.

Coal Zone N

This zone crops out in the south-central part of the quadrangle and is located approximately 250 feet (76 m) stratigrapically above the top of the Twentymile Sandstone Member (Prost, 1977). The UGN[34] coal bed (plate 33), identified in drill holes and outcrops, is the only extensive coal bed in zone N that has been identified in the Breeze Mountain quadrangle. This coal bed ranges in thickness from 2.0 to 9.0 feet (0.6 to 2.1 m) where measured in drill holes and outcrops across the central part of the quadrangle. This coal bed is believed to extend into the adjacent Castor Gulch quadrangle where the coal bed is inferred to range from 5 to 9 feet (1.5 to 2.7 m) thick.

Coal Zone O

Zone O begins approximately 330 feet (101 m) stratigraphically above the top of the Twentymile Sandstone Member (Prost, 1977) and crops out in the southeastern corner of the Breeze Mountain quadrangle. Only one coal bed, the UGO[38], has been isopached in the zone. Another coal bed, the UGO[35], was encountered in the zone at just one location and that coal bed is treated as an isolated data point.

The UGO[38] bed (plate 4) varies in thickness from 3.5 to 5.5 feet (1.1 to 1.7 m) where measured along the outcrop and is known to exceed Reserve Base thickness in only the SW 1/4 sec. 9, T. 5 N., R. 89 W. A thin rock parting of 0.1 feet (0.03 m) is noted at the point of maximum thickness.

Coal Zone Q

Zone Q lies approximately 450 feet (137 m) above the Twentymile Sandstone Member (Prost, 1977). Only one zone Q coal bed is known to exceed Reserve Base thickness in the Breeze Mountain quadrangle. This coal bed, the UGQ[36], crops out at the west-central edge of the quadrangle and was mapped as an isolated data point.

Coal Zone R

This zone lies approximately 540 feet (165 m) above the Twentymile Sandstone Member (Prost, 1977) and crops out in the west-central part of the quadrangle. One coal bed, the UGR[39], has been isopached (plate 4) in this zone and it ranges from 2.8 to 6.8 feet (0.9 to 2.1 m) in thickness where measured along the outcrop and in drill holes.

Coal Zone S

Zone S, stratigraphically the uppermost coal zone in the Upper Coal Group, lies approximately 650 feet (198 m) above the top of the Twentymile Sandstone Member (Prost, 1977). Only one coal bed has been identified in this zone(?) in the southeastern part of the quadrangle. This coal bed, the UGS[40] was measured in an outcrop at one location only and was treated as an isolated data point.

Undifferentiated Upper Group Coal Beds

Eight coal beds, the UG[12], UG[30], UG[37], UG[41], UG[42], UG[43], UG[45], and UG[46], penetrated by drill holes or measured in outcrops cannot be located in the stratigraphic section with enough accuracy to place the coal beds within specific zones in the Upper Coal Group. Since each of these coal beds were identified at one location only, they have been treated as isolated data points.

Lance Formation Coal Beds

Coals beds in the Lance Formation are generally thin and contain numerous thin shale partings. Only one coal bed, the La[47], exceeds Reserve Base thickness in this quadrangle and it was identified at only one location. Therefore, the coal bed has been treated as an isolated data point.

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 points are included on a separate sheet (in U.S. Geological Survey files) for non-isopached coal beds. Also, where the inferred limit of influence from the isolated data point is entirely within non-Federal land areas, isolated data point maps are not constructed for the coal bed. Descriptions and Reserve Base tonnages for the isolated data points occurring in this quadrangle, and the influences from isolated data points in adjacent quadrangles, are listed in table 4.

COAL RESOURCES

Data from drill holes, mine measured sections, and outcrop measurements (Bass and others, 1955; U.S. Geological Survey, 1962 and 1963; Prost, 1977; Brownfield, 1978), as well as data from oil and gas wells, were used to construct outcrop, isopach, and structure contour maps of the coal beds in the Breeze Mountain quadrangle.

Coal resources for Federal land were calculated using data obtained from the coal isopach maps (plates 4, 7, 11, 14, 18, 22, 25, 29, and 33) and the areal distribution and identified resources maps (plates 6, 10, 13, 17, 21, 24, 28, 32, and 36). The coal bed acreage (measured by planimeter), multiplied by the average thickness of the coal bed and by a conversion factor of 1,770 short tons of coal per acre-foot (13,018 metric tons per hectare-meter) for subbituminous coal, or 1,800 short tons of coal per acre-foot (13,238 metric tons per hectare-meter) for bituminous coal, yields the coal resources in short tons of coal for each isopached coal bed. Coal beds thicker than 5 feet (1.5 m) that lie less than 3,000 feet (914 m) below the ground surface are included. These criteria differ somewhat from those stated in U.S. Geological Survey Bulletin 1450-B which call for a minimum thickness of 28 inches (70 cm) for bituminous coal and a maximum depth of 1,000 feet (305 m) for both subbituminous and bituminous coal.

Reserve Base and Reserve tonnages for the isopached coal beds are shown on plates 6, 10, 13, 17, 21, 24, 28, 32, and 36, 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 550.72 million short tons (499.61 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. The source of each indexed data point shown on plate 1 is listed in table 5.

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 as follows:

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

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 8.13 million short tons (7.38 millon metric tons) of coal available for surface mining.

The coal development potential for surface mining methods is shown on plate 37. Of those Federal land areas having a known development potential for surface mining, 71 percent are rated high, 10 percent are rated moderate, and 19 percent are rated low. The remaining Federal lands within the KRCRA boundary are classified as having unknown development potential for surface mining methods.

Development Potential for Subsurface and In-Situ Mining Methods

Areas considered to have a development potential for conventional subsurface mining methods 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 those areas influenced by isolated data points and areas where coal beds of Reserve Base thickness are not known, but may occur. The areas influenced by isolated data points in this quadrangle contain approximately 45.47 million short tons (41.25 million metric tons) of coal available for subsurface mining.

The coal development potential for conventional subsurface mining methods is shown on plate 38. All of the Federal land areas classified as having 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.

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

Table 1. -- Chemical analysis of coals in the Breeze Mountain quadrangle, Moffat and Routt 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. 10, T. 5 N., R. 90 W., Corehole No. 403a (Bass and others, 1955)	Lower Coal Group	A	7.6	37.9	38.3	16.2	3.6	-	-	-	-	-	10,630
		B	5.4	38.8	39.2	16.6	3.7	-	-	-	-	-	10,870
		C	-	41.0	41.4	17.6	3.9	-	-	-	-	-	11,490
SW¼ sec. 7, T. 5 N., R. 89 W., Corehole No. 275a (Bass and others, 1955)	Middle Coal Group, zone G	A	8.5	34.2	45.1	12.2	0.6	-	-	-	-	-	10,700
		B	8.2	34.3	45.2	12.3	0.6	-	-	-	-	-	10,730
		C	-	37.4	49.2	13.4	0.6	-	-	-	-	-	11,700
NW¼ sec. 10, T. 5 N., R. 90 W., Corehole No. 387a (Bass and others, 1955)	Middle Coal Group, zone H	A	11.6	36.5	48.0	3.9	0.5	-	-	-	-	-	11,430
		B	10.5	36.9	48.7	3.9	0.4	-	-	-	-	-	11,570
		C	-	41.2	54.4	4.4	0.5	-	-	-	-	-	12,920
Sec. 31, T. 6 N., R. 89 W., Cary Mine (George and others, 1937)	Upper Coal Group, zone M, coal bed {33}	A	13.4	34.0	47.8	4.8	0.6	-	-	-	-	-	10,910
		C	-	39.3	59.2	5.5	0.7	-	-	-	-	-	12,600
Sec. 6, T. 5 N., R. 89 W., Carey Mine (George and others, 1937)	Upper Coal Group	A	16.85	32.25	45.48	5.42	0.39	-	-	-	-	-	10,361
		C	-	38.78	54.70	6.52	0.47	-	-	-	-	-	12,460
NE¼ sec. 4, T. 6 N., R. 89 W., White Mine (Bass and others, 1955) from Ralph White Lake quadrangle	Kimberely	A	20.7	32.4	42.9	4.0	0.5	-	-	-	-	-	9,730
		B	13.1	35.5	47.0	4.4	0.5	-	-	-	-	-	10,600
		C	-	40.9	54.1	5.0	0.6	-	-	-	-	-	12,270

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 Breeze Mountain quadrangle, Moffat and Routt Counties, Colorado.

Coal Bed or Zone	High Development Potential	Moderate Development Potential	Low Development Potential	Unknown Development Potential	Total
UGR {39}	200,000	140,000	1,000,000	-	1,340,000
UGN {34}	1,970,000	1,520,000	12,560,000	-	16,050,000
UGM {33}	8,540,000	12,310,000	24,320,000	-	45,170,000
UGL {29}	5,000,000	4,610,000	12,130,000	-	21,740,000
UGK {16}	3,650,000	3,690,000	8,620,000	-	15,690,000
MGJ {26}	8,190,000	4,630,000	7,580,000	-	20,400,000
MGH {21}	90,000	90,000	640,000	-	820,000
MGH {20}	440,000	640,000	1,040,000	-	2,120,000
MGH {19}	2,090,000	1,990,000	3,510,000	-	7,590,000
MGG {49}	20,000	20,000	80,000	-	120,000
LGD {1}	160,000	160,000	970,000	-	1,290,000
Isolated Data Points	-	-	-	8,130,000	8,130,000
Totals	30,340,000	29,800,000	72,450,000	8,130,000	140,730,000

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

Table 3. -- Coal Reserve Base data for subsurface mining methods for Federal coal lands (in short tons) in the Breeze Mountain quadrangle, Moffat and Routt Counties, Colorado.

Coal Bed or Zone	High Development Potential	Moderate Development Potential	Low Development Potential	Unknown Development Potential	Total
UGN {34}	10,680,000	-	-	-	10,680,000
UGM {33}	34,270,000	-	-	-	34,270,000
UGL {29}	39,910,000	-	-	-	39,910,000
UGK {16}	21,730,000	-	-	-	21,730,000
MGJ {26}	102,270,000	-	-	-	102,270,000
MGH {21}	16,630,000	50,000	-	-	16,680,000
MGH {20}	54,170,000	940,000	-	-	55,110,000
MGH {19}	71,330,000	8,550,000	-	-	79,880,000
MGG {49}	3,200,000	-	-	-	3,200,000
LGD {1}	790,000	-	-	-	790,000
Isolated Data Points	-	-	-	45,470,000	45,470,000
Totals	354,980,000	9,540,000	-	45,470,000	409,990,000

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

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

Coal Bed	Source	Location	Thickness	Reserve Base Tonnages Surface	Reserve Base Tonnages Subsurface
LG[2]	Malco Refineries, #1 Federal-Deakins	sec. 23, T. 6 N., R. 90 W.	7.0 ft (2.1 m)	0	0.84
LG[3]	Malco Refineries, #1 Federal-Deakins	sec. 23, T. 6 N., R. 90 W.	8.0 ft (2.4 m)	0	0.97
LG[4]	Malco Refineries, #1 Federal-Deakins	sec. 23, T. 6 N., R. 90 W.	7.0 ft (2.1 m)	0	0.84
MGF[7]	Atlantic Refining Co. #2 Voloshin	sec. 25, T. 6 N., R. 90 W.	7.0 ft (2.1 m)	0	0.75
MGF[8]	Brownfield (1978)	sec. 17, T. 5 N., R. 90 W.	9.0 ft (2.7 m)	0	1.82
MGF[9]	Mesa Petroleum, #1-17 Dill Gulch-Federal	sec. 17, T. 5 N., R. 90 W.	6.0 ft (1.8 m)	0	1.37
MGG[44]	Prost (1977)	sec. 9, T. 5 N., R. 90 W.	9.5 ft (2.9 m)	0	1.29
MGG[48]	Prost, (1977)	sec. 10, T. 5 N., R 90 W.	5.5 ft (1.7 m)	0	0.70
MGG[50]	Bass and others (1955)	sec. 10, T. 5 N., R. 90 W.	5.9 ft (1.8 m)	0.15	0.61
MGG[51]	Prost (1977)	sec. 10, T. 5 N., R. 90 W.	11.0 ft (3.4 m)	0	1.39
MGH[10]	Mesa Petroleum, #1-17 Dill Gulch-Federal	sec. 17, T. 5 N., R. 89 W.	7.0 ft (2.1 m)	0	1.59
MGH[11]	Atlantic Refining Co. #2 Voloshin	sec. 25, T. 6 N., R. 90 W.	8.0 ft (2.4 m)	0	0.86

Table 4.--Continued

Coal Bed	Source	Location	Thickness	Reserve Base Tonnages Surface	Reserve Base Tonnages Subsurface
MGH[13]	Prost (1977)	sec. 9, T. 5 N., R. 90 W.	6.0 ft (1.8 m)	0.26	1.12
MGH[14]	Prost (1977)	sec. 9, T. 5 N., R. 90 W.	8.0 ft (2.4 m)	0.24	1.14
MGH[22]	Prost (1977)	sec. 13, T. 5 N., R. 90 W.	8.0 ft (2.4 m)	0.06	1.60
MGJ[25]	U.S. Geological Survey (1962)	sec. 13, T. 5 N., R. 90 W.	5.5 ft (1.7 m)	0.51	0.02
MG[5]	Brownfield (1978)	sec. 11, T. 5 N., R. 90 W.	6.5 ft (2.0 m)	0	1.29
MG[15]	McCulloch Oil, #1 Skeeter	sec. 8, T. 5 N., R. 89 W.	6.0 ft (1.8 m)	0	1.28
MG[17]	Bass and others (1955)	sec. 7, T. 5 N., R. 89 W.	9.8 ft (3.0 m)	0	0.64
MG[24]	Brownfield (1978)	sec. 6, T. 5 N., R. 89 W.	6.0 ft (1.8 m)	0	0.59
MG[27]	Malco Refineries, #1 Federal-Deakins	sec. 23, T. 6 N., R. 90 W.	8.0 ft (2.4 m)	0	0.97
MG[28]	Malco Refineries, #1 Federal-Deakins	sec. 23, T. 6 N., R. 90 W.	22.0 ft (6.7 m)	0	20.01
UGO[35]	Brownfield (1978)	sec. 1, T. 5 N., R. 90 W.	7.0 ft (2.1 m)	1.03	0
UGQ[36]	Bass and others (1955)	sec. 4, T. 5 N., R. 90 W.	7.4 ft (2.3 m)	0.51	0

Table 4.--Continued

Coal Bed	Source	Location	Thickness	Reserve Base Tonnages Surface	Reserve Base Tonnages Subsurface
UGS[40]	Bass and others (1955)	sec. 9, T. 5 N., R. 89 W.	6.8 ft (2.1 m)	0.34	0
UG[12]	Prost (1977)	sec. 5, T. 5 N., R. 89 W.	7.0 ft (2.1 m)	0	1.60
UG[30]	Brownfield (1978)	sec. 4, T. 5 N., R. 90 W.	5.5 ft (1.7 m)	0.01	0.50
UG[37]	Brownfield (1978)	sec. 21, T. 5 N., R. 89 W.	5.5 ft (1.7 m)	0.27	0
UG[41]	Malco Refineries #1 Federal-Deakins	sec. 23, T. 6 N., R. 90 W.	7.0 ft (2.1 m)	1.23	0.06
UG[42]	Malco Refineries #1 Federal-Deakins	sec. 23, T. 6 N., R. 90 W.	11.0 ft (3.4 m)	0.98	0.51
UG[43]	Prost (1977)	sec. 5, T. 5 N., R. 89 W.	7.0 ft (2.1 m)	0.90	0.63
UG[45]	Brownfield (1978)	sec. 9 T. 5 N., R. 89 W.	6.0 ft (1.8 m)	0.56	0
UG[46]	Bass and others (1955)	sec. 5, T. 5 N., R. 89 W.	8.8 ft (2.7 m)	0.54	0.48
La[47]	Bass and others (1955)	sec. 7, T. 6 N., R. 89 W.	6.0 ft (1.8 m)	0.22	0
		From Hayden Quadrangle			
UGM[11]	Brownfield (1976)	sec. 21, T. 5 N., R. 89 W.	6.0 ft (1.8 m)	0.14	0
UGN[12]	Brownfield (1976)	sec. 21, T. 5 N., R. 89 W.	8.0 ft (2.4 m)	0.18	0

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

Plate 1 Index Number	Source	Data Base
1	Prost, 1977, U.S. Geological Survey Open-File Report No. 77-155	Drill hole No. BM-3
2	↓	Drill hole No. BM-27
3		Drill hole No. BM-2
4		Drill hole No. BM-26
5		Drill hole No. BM-28
6		Drill hole No. BM-4
7		Drill hole No. BM-11
8		Drill hole No. BM-5
9	Brownfield, 1978, U.S. Geological Survey Open-File Report No. 78-365	Drill hole No. BM-30
10	Prost, 1977, U.S. Geological Survey Open-File Report No. 77-155	Drill hole No. BM-12
11	↓	Drill hole No. BM-10
12		Drill hole No. BM-7
13	Bass and others, 1955, U.S. Geological Survey Bulletin 1027-D, pl. 23	Drill hole No. 275a
14	Prost, 1977, U.S. Geological Survey Open-File Report No. 77-155	Drill hole No. BM-6
15	McCulloch Oil Co.	Oil/gas well No. 1 Skeeter
16	Brownfield, 1978, U.S. Geological Survey Open-File Report No. 78-365	Drill hole No. BM-43
17	Prost, 1977, U.S. Geological Survey Open-File Report No. 77-155	Drill hole No. BM-25

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Table 5. -- Continued

Plate 1 Index Number	Source	Data Base
18	Brownfield, 1978, U.S. Geological Survey Open-File Report No. 78-365	Drill hole No. BM-40
19	Mesa Petroleum Co.	Oil/gas well No. 1-17 Dill Gulch-Federal
20	Prost, 1977, U.S. Geological Survey Open-File Report No. 77-155	Drill hole No. BM-23
21	↓	Drill hole No. BM-9
22	↓	Drill hole No. BM-8
23	↓	Drill hole No. BM-22
24	Brownfield, 1978, U.S. Geological Survey Open-File Report No. 78-365	Drill hole No. BM-24
25	↓	Drill hole No. BM-42
26	↓	Drill hole No. BM-38
27	Prost, 1977, U.S. Geological Survey Open-File Report No. 77-155	Drill hole No. BM-13
28	Brownfield, 1978, U.S. Geological Survey Open-File Report No. 78-365	Drill hole No. BM-31
29	Bass and others, 1955, U.S. Geological Survey Bulletin 1027-D, pl. 25	Measured Section No. 377
30	↓	Measured Section No. 376
31	Brownfield, 1978, U.S. Geological Survey Open-File Report No. 78-365	Drill hole No. BM-37
32	↓	Drill hole No. BM-36
33	Bass and others, 1955, U.S. Geological Survey Bulletin 1027-D, pl. 25	Measured Section No. 379
34	↓	Measured Section No. 380

Table 5. -- Continued

Plate 1 Index Number	Source	Data Base
35	Prost, 1977, U.S. Geological Survey Open-File Report No. 77-155	Drill hole No. BM-20
36	Bass and others, 1955, U.S. Geological Survey Bulletin 1026-D, pl. 25	Measured Section No. 385
37	Prost, 1977, U.S. Geological Survey Open-File Report No. 77-155	Drill hole No. BM-19
38	Bass and others, 1955, U.S. Geological Survey Bulletin 1027-D, pl. 25	Drill hole No. 387b
39	Prost, 1977, U.S. Geological Survey Open-File Report No. 77-155	Drill hole No. BM-18
40	Bass and others, 1955, U.S. Geological Survey Bulletin 1027-D, pl. 25	Measured Section No. 387
41	U.S. Geological Survey, 1962, Inactive Coal Lease File No. Colorado-019556, Pittsburgh and Midway Coal Co.	Drill hole No. 6M
42	↓	Drill hole No. 5M
43	Bass and others, 1955, U.S. Geological Survey Bulletin 1027-D, pl. 25	Drill hole No. 387a
44	U.S. Geological Survey, 1962, Inactive Coal Lease File No. Colorado-019556, Pittsburgh and Midway Coal Co.	Drill hole No. 12M
45	↓	Drill hole No. 3M
46	Prost, 1977, U.S. Geological Survey Open-File Report No. 77-155	Drill hole No. BM-17
47	U.S. Geological Survey, 1962, Inactive Coal Lease File No. Colorado-019556, Pittsburgh and Midway Coal Co.	Drill hole No. 1M

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Table 5. -- Continued

Plate 1 Index Number	Source	Data Base
48	U.S. Geological Survey, 1962, Inactive Coal Lease File No. Colorado-019556, Pittsburgh and Midway Coal Co.	Drill hole No. 2M
49	↓	Drill hole No. 8M
50	↓	Drill hole No. 9M
51	Bass and others, 1955, U.S. Geological Survey Bulletin 1027-D, pl. 25	Drill hole No. 403a
52	Brownfield, 1978, U.S. Geological Survey Open-File Report No. 78-365	Drill hole No. BM-39
53	U.S. Geological Survey, 1962, Inactive Coal Lease File No. Colorado-019556, Pittsburgh and Midway Coal Co.	Drill hole No. 84M
54	U.S. Geological Survey, 1963, Inactive Coal Lease File No. Colorado-076691, United Electric Coal Co.	Drill hole No. 3
55	U.S. Geological Survey, 1962, Inactive Coal Lease File No. Colorado-019556, Pittsburgh and Midway Coal Co.	Drill hole No. 85M
56	↓	Drill hole No. 86M
57	↓	Drill hole No. 83M
58	↓	Drill hole No. 75M
59	Prost, 1977, U.S. Geological Survey Open-File Report No. 77-155	Drill hole No. BM-16
60	Bass and others, 1955, U.S. Geological Survey Bulletin 1027-D, pl. 25	Measured Section No. 388

Table 5. -- Continued

Plate 1 Index Number	Source	Data Base
61	U.S. Geological Survey, 1962, Inactive Coal Lease File No. Colorado-019556, Pittsburgh and Midway Coal Co.	Drill hole No. 50M
62	↓	Drill hole No. 70M
63	↓	Drill hole No. 74M
64	↓	Drill hole No. 78M
65	↓	Drill hole No. 71M
66	↓	Drill hole No. 52M
67	Brownfield, 1978, U.S. Geological Survey Open-File Report No. 78-365	Drill hole No. BM-41
68	Prost, 1977, U.S. Geological Survey Open-File Report No. 77-155	Drill hole No. BM-14
69	U.S. Geological Survey, 1962, Inactive Coal Lease File No. Colorado-019556, Pittsburgh and Midway Coal Co.	Drill hole No. 18M
70	↓	Drill hole No. 17M
71	↓	Drill hole No. 23M
72	↓	Drill hole No. 43M
73	↓	Drill hole No. 55M
74	↓	Drill hole No. 37M
75	↓	Drill hole No. 54M
76	↓	Drill hole No. 38M
77	↓	Drill hole No. 53M
78	↓	Drill hole No. 57M

Table 5. -- Continued

Plate 1 Index Number	Source	Data Base
79	U.S. Geological Survey, 1962, Inactive Coal Lease File No. Colorado-019556, Pittsburgh and Midway Coal Co.	Drill hole No. 59M
80	↓	Drill hole No. 35M
81	↓	Drill hole No. 63M
82	Prost, Gary, 1977, U.S. Geological Survey Open-File Report No. 77-155	Drill hole No. BM-15
83	U.S. Geological Survey, 1962, Inactive Coal Lease File No. Colorado-019556, Pittsburgh and Midway Coal Co.	Drill hole No. 60M
84	Bass and others, 1955, U.S. Geological Survey Bulletin 1027-D, pl. 25	Drill hole No. 390a
85	Prost, Gary, 1977, U.S. Geological Survey Open-File Report No. 77-155	Drill hole No. BM-21
86	U.S. Geological Survey, 1962, Inactive Coal Lease File No. Colorado-019556, Pittsburgh and Midway Coal Co.	Drill hole No. 68M
87	↓	Drill hole No. 69M
88	↓	Drill hole No. 66M
89	↓	Drill hole No. 72M
90	↓	Drill hole No. 73M
91	U.S. Geological Survey, 1963, Inactive Coal Lease File No. Colorado-076691, United Electric Coal Co.	Drill hole No. 4
92	Bass and others, 1955, U.S. Geological Survey Bulletin 1027-D, pl. 25	Measured Section No. 394

Table 5. -- Continued

Plate 1 Index Number	Source	Data Base
93	Bass and others, 1955, U.S. Geological Survey Bulletin 1027-D, pl. 25	Measured Section No. 395
94	↓	Measured Section No. 400
95	↓	Measured Section No. 399
96	↓	Measured Section No. 397a
97	↓	Measured Section No. 403
98	↓	Measured Section No. 402
99	↓	Measured Section No. 405
100	↓	Measured Section No. 406
101	Brownfield, 1978, U.S. Geological Survey Open-File Report No. 78-365	Drill hole No. BM-29
102	Prost, 1977, U.S. Geological Survey Open-File Report No. 77-155	Drill hole No. BM-1
103	Malco Refineries	Oil/gas well No. 1 Federal-Deakins
104	Bass and others, 1955, U.S. Geological Survey Bulletin 1027-D, pl. 24	Measured Section No. 409
105	↓	Measured Section No. 410

Table 5. -- Continued

Plate 1 Index Number	Source	Data Base
106	Atlantic Refining Co.	Oil/gas well No. 2 Voloshin
107	Brownfield, 1978, U.S. Geological Survey Open-File Report No. 78-365	Drill hole No. BM-44
108	↓	Drill hole No. BM-34
109	↓	Drill hole No. BM-33
110	Bass and others, 1955, U.S. Geological Survey Bulletin 1027-D, pl. 23	Measured Section No. 265
111	Bass and others, 1955, U.S. Geological Survey Bulletin, 1027-D, pl. 24	Mine-Measured Section No. 407a
112	Pan American Petroleum Corp.	Oil/gas well No. 1-0 State
113	Bass and others, 1955, U.S. Geological Survey Bulletin 1027-D, pl. 23	Measured Section No. 266
114	Bass and others, 1955, U.S. Geological Survey Bulletin 1027-D, pl. 24	Measured Section No. 335
115	Bass and others, 1955, U.S. Geological Survey Bulletin 1027-D, pl. 23	Measured Section No. 267

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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.

Brownfield, M. E., 1976, Geophysical logs of seventeen holes drilled in 1976 in the Yampa coal field, northwestern Colorado: U.S. Geological Survey Open-File Report 76-817, 4 p.

______1978, Reconnaissance drilling during 1977 in the Yampa coal field, Moffat and Routt Counties, Colorado: U.S. Geological Survey Open-File Report 78-365, 135 p.

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.

Fenneman, N. M., and Gale, H. S., 1906, The Yampa coal field, Routt County, Colorado: U.S. Geological Survey Bulletin 297, 96 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.

Haun, J. D., 1961, Stratigraphy of post-Mesaverde Cretaceous rocks, Sand Wash Basin and vicinity, Colorado and Wyoming, *in* Symposium on the Late Cretaceous rocks of Wyoming and adjacent areas, Wyoming Geological Assocation Guidebook, 16th Annual Field Conference, 1961: p. 116-124.

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.

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.

References--Continued

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.

O'Boyle, C. C., 1955, The Cretaceous rocks of northwest Colorado, in Guidebook to the geology of northwest Colorado, Intermountain Association of Petroleum Geologists and Rocky Mountain Association of Geologists, 6th Annual Field Conference, 1955: p. 32-35.

Parsons, H. F. and Liddell, C. A., 1903, Coal and mineral resources of Routt County: Colorado School of Mines Bulletin 1, no. 4, p. 47-59.

Prost, Gary, 1977, Reconnaissance drilling in the Yampa coal field, Hayden-Williams Fork Mountains area (Yampa No. 3), Moffat and Routt Counties, Colorado, during 1976: U.S. Geological Survey Open-File Report 77-155, 7 p.

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.

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

Tweto, Ogden, 1976, compiler, 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: 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, 1962, Inactive Coal Lease File, No. Colorado-019556, Pittsburgh and Midway Coal Company.

______ 1963, Inactive Coal Lease File, No. Colorado-076691, United Electric Coal Company.

Weimer, R. J., 1961, Uppermost Cretaceous rocks in central and southern Wyoming, and northwest Colorado, in Symposium on the Late Cretaceous rocks in Wyoming and adjacent areas, Wyoming Geological Association Guidebook, 16th Annual Field Conference, 1961: p. 17-28.