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COAL RESOURCE OCCURRENCE AND COAL DEVELOPMENT POTENTIAL MAPS OF THE HAYDEN GULCH QUADRANGLE, ROUTT COUNTY, COLORADO

[Report includes 41 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 Hayden Gulch quadrangle, Routt County, Colorado. This report was compiled to support the land-planning work of the Bureau of Land Management (BLM) and to provide a systematic coal resource inventory of Federal coal lands in Known Recoverable Coal Resource Areas (KRCRA's) in the western United States. This investigation was undertaken by Dames & Moore, Denver, Colorado, at the request of the United States Geological Survey under contract number 14-080001-15789. 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 Published and unpublished public information available through August, 1978, was used as the data base for this study.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 Hayden Gulch quadrangle is located in southwestern Routt County in northwestern Colorado, approximately 24 airline miles (39 km) southwest of the town of Steamboat Springs and 14 airline miles (23 km) southeast of the town of Craig. The southeastern and southwestern corners of the quadrangle are included within the boundary of the Routt National Forest. With the exception of several scattered ranches and farms, the quadrangle is unpopulated.

Accessibility

An improved light-duty road connects the town of Pagoda, approximately 3 miles (5 km) to the west of the Hayden Gulch quadrangle, with the town of Oak Creek, approximately 21 miles (34 km) to the east. It crosses east-west through the central part of the quadrangle following the valleys of Willow Creek and the East Fork of Williams Fork. A second improved light-duty road extends south along the East Fork from the junction of the East Fork and Willow Creek valleys in the central part of the quadrangle. A third improved light-duty road extends northeast from the East Fork valley along Hayden Gulch to the town of Hayden, approximately 9 miles (14 km) north of the quadrangle. The remainder of the quadrangle is served by a number of unimproved dirt roads and trails.

Railway service for the Hayden Gulch 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 through Hayden, approximately 9 miles (14 km) north of the quadrangle. It is the major transportation route for coal shipped east from northwestern Colorado (U.S. Bureau of Land Management, 1977).

Physiography

The Hayden Gulch quadrangle lies in the southern part of the Wyoming Basin physiographic province as defined by Howard and Williams (1972). The quadrangle is approximately 34 miles (55 km) west of the Continental Divide. The Williams Fork Mountains cover the northern half of the quadrangle.

The landscape within the northern half of the quadrangle is characterized by the moderate to steep slopes and canyons of the Williams Fork Mountains. The topography to the south becomes less pronounced with broader slopes and wider stream valleys.

Approximately 2,520 feet (768 m) of relief is present in the Hayden Gulch quadrangle. Altitudes range from over 9,200 feet (2,804 m) in the southwestern corner of the quadrangle to less than 6,680 feet (2,036 m) along the East Fork of the Williams Fork on the west-central edge of the quadrangle.

The East Fork of the Williams Fork flows west-northwestward, crossing the quadrangle from the south-central edge to the west-central edge, and joins the Yampa River approximately 17 miles (27 km) northwest of the quadrangle. Many tributaries, some of which are perennial, flow into the East Fork of the Williams Fork in a dendritic pattern. The northeastern corner of the quadrangle is drained by Dry Creek and its tributaries, which also flow into the Yampa River at a point approximately 9 miles (14 km) north of the quadrangle. Numerous small man-made lakes and ponds are located throughout the quadrangle.

Climate and Vegetation

The climate of northwestern Colorado is semiarid. Clear, sunny days prevail in the Hayden Gulch quadrangle and daily temperatures typically vary 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 20 inches (51 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 (5 km per hour), are generally from the west, but wind directions and velocities vary greatly depending on the local terrain (U.S. Bureau of Land Management, 1977).

The predominant vegetative cover in the Hayden Gulch quadrangle is mountain shrub, which ranges from 2 to 8 feet (0.6 to 2.4 m) in height. Sagebrush occurs along the Willow Creek valley in the east-central part of the quadrangle and along the west-central edge of the quadrangle. Open to very dense stands of aspen, often relatively small in size, occur at higher elevations in the northern part of the quadrangle, where moisture and soil depth are adequate (U.S. Bureau of Land Management, 1977).

Land Status

The Hayden Gulch quadrangle lies in the south-central part of the Yampa Known Recoverable Coal Resource Area (KRCRA). Almost all of the northern half of the quadrangle lies within the KRCRA boundary and the Federal government owns the coal rights for approximately 70 percent of this area. Three active coal leases are present within the KRCRA boundary in this quadrangle as shown on plate 2.

GENERAL GEOLOGY

Previous Work

The first geologic description of the general area in which the Hayden Gulch 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 northern three quarters of the Hayden Gulch quadrangle in their report. In 1955, Bass and others expanded Fenneman and Gale's work in a report on the geology and mineral fuels of parts of Routt and Moffat Counties, and this is the most comprehensive work on the area. Tweto (1976) compiled a generalized regional geologic map which included this quadrangle. Reconnaissance drilling in the Yampa coal field by the U.S. Geological Survey during 1976 and 1977 was reported by Brownfield (1976 and 1978) and Prost (1977).

Stratigraphy

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

The Mancos Shale of Late Cretaceous age is exposed in the southern half of the quadrangle and is composed of gray to dark-gray marine shale, a number of tan thin-bedded silty sandstone beds, and interbedded sandy shale in the upper 1,000 feet (305 m) of the formation (Bass and others, 1955).

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, approximately 1,450 feet (442 m) thick, crops out along a northwest-trending band through the central part of the quadrangle. The formation consists of the basal Tow Creek Sandstone

Member, an overlying sequence of sandstones interbedded with sandy shale, shale, and coal, and at the top of this formation, the Trout Creek Sandstone Member (Bass and others, 1955).

The Tow Creek Sandstone Member lies at the base of the Iles Formation and consists of approximately 125 feet (38 m) of light-brown, fine-grained massive sandstone. Overlying the Tow Creek Sandstone Member is approximately 1,215 feet (370 m) of light-brown, light-gray and white massive ledge-forming sandstone interbedded with gray sandy shale and coal. The coal, designated as the Lower Coal Group by Fenneman and Gale (1906), is distributed throughout the middle and upper parts of this sequence. This sequence is capped by the Trout Creek Sandstone Member, consisting of approximately 100 to 140 feet (30 to 43 m) of white to gray, fine-grained massive cliff-forming sandstone (Bass and others, 1955; Brownfield, 1978).

The Williams Fork Formation crops out over most of the northern half of the quadrangle and conformably overlies the Iles Formation. It is approximately 1,680 feet (512 m) thick in the Hayden Gulch quadrangle and is generally divided into three units: a lower coal-bearing unit, the Twentymile Sandstone Member, and an upper coal-bearing unit (Bass and others, 1955).

The lower coal-bearing unit extends upward from the top of the Trout Creek Sandstone Member of the Iles Formation to the base of the Twentymile Sandstone Member of the Williams Fork Formation. In this quadrangle it is approximately 1,060 feet (323 m) thick and consists of thin-bedded sandstone, dark-gray to black shale, gray siltstone, carbonaceous shale and coal. The upper half of the unit consists chiefly of shale, although it contains a few beds of sandstone (Bass and others, 1955; Brownfield, 1978). Fenneman and Gale (1906) have designated the coal in this sequence as the Middle Coal Group.

The Twentymile Sandstone Member, which is approximately 110 to 150 feet (34 to 46 m) thick in the Hayden Gulch quadrangle, consists of white to gray massive fine-grained sandstone (Bass and others, 1955; Brownfield, 1978).

A well-defined contact separates the Twentymile Sandstone Member and the overlying upper coal-bearing unit. This sequence, approximately 500 feet (152 m) thick, is composed of gray fine-grained sandstone, gray siltstone, brown and gray carbonaceous shale, gray 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 of Late Cretaceous age conformably overlies the Williams Fork Formation and consists of homogeneous, dark-gray to bluish marine shale (Bass and others, 1955). The total thickness of the Lewis Shale present in this quadrangle is not known, but it is estimated that only the basal 200 to 300 feet (61 to 91 m) of the formation is exposed where it crops out in the northeastern part of the quadrangle.

According to Tweto (1976), a thin layer of Miocene-age Browns Park Formation rests unconformably on the Mancos Shale in the southeastern corner of the quadrangle. The Browns Park Formation generally consists of loosely consolidated eolian tuffaceous sandstone, fluvial siltstone, claystone, and a basal conglomerate (Tweto, 1976). Information is not available on the thickness of the Browns Park Formation in the quadrangle.

A Miocene- or Pliocene-age basalt flow caps the Beaver Flat Tops in the southwestern corner of the Hayden Gulch quadrangle where it unconformably overlies the Cretaceous-age Mancos Shale (Bass and others, 1955; Tweto, 1976).

Holocene deposits of alluvium cover the valley of the East Fork of the Williams Fork in the west-central and southern parts of the quadrangle.

The Cretaceous formations in the Hayden Gulch 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 offshore-marine, shallow-marine, and marginal-marine sediments in the Hayden Gulch 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 marine environments. 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. 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).

Deposition of the Lewis Shale marked a landsward 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 (Kucera, 1959).

The Miocene-age Browns Park Formation was deposited after a long period of non-deposition and erosion. The coarse, conglomeratic nature of the base of the Browns Park Formation and the fine wind-blown tuffaceous sands of the upper part of the formation suggest that it was deposited during a time when the climate of the region was changing from one of relatively high rainfall to one of semi-aridity such as is found in the region today (Carey, 1955).

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 26 miles (42 km) northeast of the Hayden Gulch quadrangle, and on the southwest by the Axial Basin anticline, which is approximately 16 miles (26 km) west of the quadrangle (Tweto, 1976).

The Pagoda dome is located in the southwestern quarter of the quadrangle and the strata in southeastern corner of the quadrangle lie on the western flank of the Williams Park anticline. Dips of the coal beds in the northern half of the quadrangle are quite variable. In the northwest quarter, dips range from about 4° to 17° north and northeast while in the northeast quarter the dips vary as much as 4° to 14° to the northeast, north, and northwest to 3° east. Beds in the northern two thirds of the quadrangle generally dip northward. There are no faults known to offset the Cretaceous rocks in the Hayden Gulch quadrangle (Bass and others, 1955).

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 and zones duplicates that of the Trout Creek Sandstone Member. Modifications were made where necessary in accordance with outcrop and drill hole data.

COAL GEOLOGY

Numerous coal beds in the Lower, Middle, and Upper Coal Groups of the Mesaverde Group have been identified in the Hayden Gulch 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 in this quadrangle only. Coal beds in the Lower Coal Group tend to be thin, lenticular, and of limited areal extent, while coal beds in the Middle and Upper Coal Groups generally persist over large areas. In instances where coal beds of Reserve Base thickness are encountered at only one location, 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 area are listed in table 1. In general, chemical analyses of coals in the Lower and Middle Coal Groups indicate that these coals are high-volatile C bituminous in rank and the coals in the Upper Coal Group probably range from subbituminous A to 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).

Locations of coal samples tested in this quadrangle are shown in table 1 and include those for zones A, B, and C of the Lower Coal Group, zones G and H of the Middle Coal Group, and coal from an unspecified zone in the Upper Coal Group. Chemical analyses were not available in the Hayden Gulch quadrangle for coals from zones D and E of the Lower Coal Group and specific Upper Group coal zones. However, the analyses listed in the table are believed to be representative of coal beds in the Lower, Middle, and Upper Coal Groups.

Lower Coal Group

The Lower Coal Group includes all coal beds in the Iles Formation between the Tow Creek and Trout Creek Sandstone Members, and coal beds in this group crop out in the northwestern part of the quadrangle. Five coal zones (zones A, B, C, D, and E) within the Lower Coal Group were identified by Bass and others (1955), and coal beds exceeding Reserve Base thickness occur in all five zones in this quadrangle. However, only two coal beds, the LGA[1] (i.e., Lower Coal Group, zone A, coal bed [1]) and the LGB[5], were isopached. All other coal beds in the Lower Coal Group, including the LGA[2], LGA[3], LGC[6], LGC[7], LGD[8], and LGE[10] coal beds, were treated as isolated data points because of insufficient data to enable accurate correlations with coal beds at other locations.

The LGA[1] coal bed (plate 15) ranges from 5.0 to 5.5 feet (1.5 to 1.7 m) in thickness where measured in the two drill holes located in secs. 35 and 36, T. 5 N., R. 89 W. The LGB[5] coal bed (plate 4) was also penetrated by the same two drill holes and lies approximately 115 feet (35 m) above the LGA[1] coal bed. In both drill holes, the LGB[5] coal bed had a measured thickness of 9 feet (2.1 m), and because of the very lenticular nature of coal beds in the Lower Coal Group, this coal bed is inferred to thin rapidly in all directions.

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. Three coal zones (zones F, G, and H) within the Middle Coal Group were identified by Bass and others (1955) in the northwestern part of this quadrangle, but only zones G and H are known to contain coal beds exceeding Reserve Base thickness.

Coal Zone G

This zone lies approximately 120 feet (37 m) above the base of the Williams Fork Formation (Bass and others, 1955; Brownfield, 1978) and crops out along a northwest-trending band in the central part of the quadrangle. Seven coal beds have been identified in coal zone G in this quadrangle. Three coal beds, the MGG[11], MGG[12], and MGG[15], were isopached and the other four coal beds, the MGG[9], MGG[13], MGG[14], and MGG[16], were identified at only one location and were treated as isolated data points.

The MGG[11] coal bed (plate 6) was penetrated by two drill holes in the northwest corner of the quadrangle where measured thicknesses were 5.3 and 7.0 feet (1.6 and 2.1 m). This coal bed extends into the Pagoda quadrangle to the west and ranges in thickness from 4.5 to 9.2 feet (1.4 to 2.8 m) where measured in numerous outcrops and one drill hole. The maximum thickness in that quadrangle was measured in sec. 21, T. 5 N., R. 89 W.

The MGG[12] coal bed (plate 12) was identified in two drill holes in the northwest corner of the quadrangle where measured thicknesses were 6.0 and 7.3 feet (1.8 and 2.2 m). This coal bed is not known to extend into the adjacent Pagoda quadrangle and is inferred to thin rapidly. A rock parting, 2.7 feet (0.8 m) thick, is present where the coal bed attains its maximum reported thickness in the NW 1/4 NW 1/4 sec. 35, T. 5 N., R. 89 W.

The MGG[15] coal bed (plate 19) has been identified in outcrops and drill holes over a large area to the northwest corner of the quadrangle. It ranges in thickness from 3.2 to 10.0 feet (1.0 to 3.0 m) and, locally, contains thin rock partings of 0.3 and 1.6 feet (0.1 and 0.5 m) that were reported in two of the outcrop measurements.

Coal Zone H

Zone H occurs approximately 290 to 320 feet (88 to 98 m) above the base of the Williams Fork Formation (Bass and others, 1955; Brownfield, 1978). Five coal beds in zone H are known to exceed Reserve Base thickness in this quadrangle, and three of these coal beds, the MGH[18], MGH[19], and the MGH[21], were isopached. The MGH[17] and MGH[20] coal beds are each penetrated by only one drill hole and are treated as isolated data points.

The MGH[18] (plate 23) coal bed ranges in thickness from 8.0 to 12.4 feet (2.4 to 3.8 m) where measured in drill holes in the northwest corner of the quadrangle. A rock parting 2.0 feet (0.6 m) thick was reported to be included in the coal bed at one location, but partings were reported in the other drill holes.

The MGH[19] coal bed (plate 27) was identified in two drill holes in the northwestern part of the quadrangle where measured thicknesses were 4.5 and 8.5 feet (1.4 and 2.6 m). Because of the apparent lenticularity of this coal bed, it is inferred to extend over only a relatively small area.

The MGH[21] coal bed has been identified in outcrops and drill holes in the northern part of the quadrangle and ranges in thickness from 5.0 to 13.0 feet (1.5 to 4.0 m). This coal bed exceeds Reserve Base thickness in two areas in the quadrangle as shown on plate 36. The smaller area occurs in the east-central part, where an outcrop measurement of 8.0 feet (2.4 m) was reported in sec. 10, T. 4 N., R. 88 W. A much larger area occurs in the northwestern part where the coal bed ranges in thickness from 5.0 to 13.0 feet (1.5 to 4.0 m) where measured in an outcrop and seven drill holes. Thin rock partings occur locally in the coal bed and thicknesses ranging from 0.2 to 1.5 feet (0.06 to 0.5 m) have been reported. It is believed that the coal bed extends slightly into the northeast corner of the adjacent Pagoda quadrangle even though it has not been identified in that quadrangle.

Upper Coal Group

The Upper Coal Group extends upward from the top of the the Twentymile Sandstone Member to the base of the Lewis Shale and contains numerous relatively thin coal beds that can usually be placed into nine coal zones (zones K through S in ascending order), sometimes referred to as beds by Bass and others (1955), but only zones K through Q appear to be present in this quadrangle.

Coal Zone K

Zone K lies approximately 40 feet (12 m) above the top of the Twentymile Sandstone Member (Bass and others, 1955). Only one zone K coal bed, the UGK[16], is believed to exceed Reserve Base thickness in this quadrangle. This coal bed has been identified in a single outcrop in the northwestern corner of the Hayden Gulch quadrangle where it is 4.5 feet (1.4 m) thick. However, based on data projected into this quadrangle from the Hayden quadrangle to the north, the Breeze Mountain quadrangle to the northwest, and the Pagoda quadrangle to the west, it is believed that the UGK[16] coal bed may be as much as 7 feet (2.1 m) thick in the extreme northwest corner of this quadrangle as shown on plate 30.

Coal Zone L

Zone L lies approximately 140 feet (43 m) above the top of the Twentymile Sandstone Member (Bass and others, 1955), and five coal beds, the UGL[22], UGL[25], UGL[26], UGL[27], and UGL[28], have been identified at about that stratigraphic vicinity in this quadrangle. Although these coal beds have been given different designations on plates 1 and 3, they could be the same coal bed. However, because the accuracy of the correlations is questionable, the coal beds (bed?) have been isopached as a zone (plate 15). Cumulative coal thicknesses in the zone range from 2.5 to 7.6 feet (0.8 to 2.3 m) where measured in outcrops and drill holes.

Coal Zone M

This zone, which is located approximately 200 feet (61 m) stratigraphically above the Twentymile Sandstone Member (Bass and others, 1955), contains coal beds, the UGM[23], UGM[24], and UGM[30] that have been identified at only one location and are treated as isolated data points.

Coal Zone N

Zone N begins approximately 250 feet (76 m) stratigraphically above the top of the Twentymile Sandstone Member (Bass and others, 1955). The UGN [34] coal bed is the only extensive coal bed that has been isopached in the Hayden Gulch quadrangle. Four other coal beds, the UGN[29], UGN[31], UGN[32], and UGN[36], were each identified at only location and are treated as isolated data points. The UGN[34] coal bed (plate 8) ranges in thickness from 5.0 to 11.0 feet (1.5 to 3.4 m) where measured in drill holes in the north-central part of the quadrangle.

Coal Zone O

This zone lies approximately 320 feet (98 m) above the top of the Twentymile Sandstone Member (Bass and others, 1955) and crops out in the northwest part of the quadrangle. Only one coal bed, the UGO[35], has been isopached in the zone. Three other coal beds in the zone, the UGO[37], the UGO[41], and the UGO[42] which occurs on non-Federal land, were identified in widely-spaced outcrops and were treated as isolated data points. The UGO[35] coal bed (plate 32) ranges in thickness from 5.0 to 6.0 feet (1.5 to 1.8 m) whre measured in drill holes in secs. 25 and 26, T. 5 N., R. 89 W.

Coal Zone P

Zone P occurs approximately 390 feet (119 m) above the Twentymile Sandstone Member (Bass and others, 1955). The UGP[43] coal bed is the only coal bed that has been identified within the zone in this quadrangle, and because it has been measured at just one location along its outcrop in the northeastern partof the quadrangle, it has been treated as an isolated data point.

Coal Zone Q

According to Bass and others (1955), zone Q occurs approximately 440 feet (134 m) above the Twentymile Sandstone Member. Only one zone Q coal bed is known to exceed Reserve Base thickness in the Hayden Gulch quadrangle. This coal bed, the UGQ[33], crops out near the north-central part of the quarangle and 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, the 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 of 1,000 feet (305 m) from the isolated data point is entirely within non-Federal land areas, an isolated data point map is not constructed for the coal bed. Descriptions and Reserve Base tonnages for the isolated data points occurring in this quadrangle and the influences from isolated data points in an adjacent quadrangle are listed in table 4.

COAL RESOURCES

Data from drill holes, mine measured sections, and outcrop measurements (Bass and others, 1955; Prost, 1977; Brownfield, 1978) were used to construct outcrop, isopach, and structure contour maps of the coal beds in the Hayden Gulch quadrangle. Where coal beds of Reserve Base thickness exist entirely on non-Federal lands or on lands already leased for coal mining, areal distribution and identified resources (ADIR) maps are not constructed and Reserve Base tonnages are not calculated.

Coal resources for Federal land were calculated using data obtained from the coal isopach maps (plates 4, 6, 8, 12, 15, 19, 23, 27, 30, 32, and 36) and the ADIR maps (plates 11, 18, 22, 26, 35, and 39). 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]ons of coal for each coal bed. Coal beds exceeding Reserve Base thickness (5 feet or 1.5 meters) that lie less than 3,000 feet (914 m) below the ground surface are included. These criteria differ somewhat from those stated in U.S. Geological Survey Bulletin 1450-B which call for a minimum thickness of 28 inches (70 cm) 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 11, 18, 22, 26, 35, and 39, 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 169.43 million short tons (153.71 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 4.

Dames & Moore has not made any determination of economic recoverability for any of the coal beds described in this report.

COAL DEVELOPMENT POTENTIAL

Coal development potential areas are drawn 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 on the following page:

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

where MR = mining ratio

t_o = thickness of overburden in feet

t_c = thickness of coal in feet

rf = recovery factor (85 percent for this quadrangle)

cf = conversion factor to yield MR value in terms of cubic yards of overburden per short tons of recoverable coal:
0.911 for subbituminous coal
0.896 for bituminous coal

Note: To convert mining ratio to cubic meters of overburden per metric ton of recoverable coal, multiply MR by 0.8428.

Areas of high, moderate, and low development potential for surface mining methods are defined as areas underlain by coal beds having respective mining-ratio values of 0 to 10, 10 to 15, and greater than 15. These mining ratio values for each development potential category are based on economic and technological criteria and were provided by the U.S. Geological Survey.

Areas where the coal data is absent or extremely limited between the 200-foot (61-m) overburden line and the outcrop are assigned unknown development potential for surface mining methods. This applies to areas where coal beds 5 feet (1.5 m) or more thick are not known, but may occur, and to those areas influenced by isolated data points. Limited knowledge pertaining to the areal distribution, thickness, depth, and attitude of the coal beds prevents accurate evaluation of development potential in the high, moderate, and low categories. The areas influenced by isolated data points in this quadrangle total approximately 6.08 million short tons (5.52 millon metric tons) of coal available for surface mining.

The coal development potential for surface mining methods is shown on plate 40. Of those Federal land areas having a known development potential for surface mining, 80 are rated high, 5 percent are rated moderate, and 15 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 and have dips of 15° or less. Unfaulted coal beds lying between 200 and 3,000 feet (61 and 914 m) below the ground surface, dipping greater than 15°, are considered to have 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 the areas influenced by isolated data points and to those areas where coal beds of Reserve Base thickness are not known, but may occur. The areas influenced by isolated data points in this quadrangle contain approximately 8.55 million short tons (7.76 million metric tons) of coal available for conventional subsurface mining.

The coal development potential for conventional subsurface mining methods is shown on plate 41. Of the Federal land areas having a known development potential for conventional subsurface mining methods, 98 percent are rated high and 2 percent are rated moderate. The remaining Federal land within the KRCRA boundary is classified as having unknown development potential for conventional subsurface mining methods.

All of the Federal lands where the dip of the MGG[15] coal bed exceeds 15° are rated low for in-situ development potential because only approximately 0.31 million short tons (0.28 million metric tons) of coal distributed through two areas about 2 miles (3.2 km) apart are believed to be available for in-situ mining. The remaining Federal lands within the KRCRA boundary are classified as having unknown development potential for in-situ mining methods.

Table 1. -- Chemical analyses of coals in the Hayden Gulch quadrangle, Routt County, Colorado.

Location	COAL BED NAME	Form of Analysis	Proximate				Ultimate					Heating Value	
			Moisture	Volatile Matter	Fixed Carbon	Ash	Sulfur	Hydrogen	Carbon	Nitrogen	Oxygen	Calories	Btu/Lb
Sec. 12, T. 4 N., R. 89 W., Sun Mine (Jones and Murray, 1977)	Lower Coal Group, Zone A	A	11.4	38.3	55.6	6.1	0.5	-	-	-	-	-	11,440
NE¼ sec. 34, T. 5 N., R. 89 W., Corehole (Bass and others, 1955)	Lower Coal Group, Zone B	A	10.1	35.2	49.4	5.3	0.6	-	-	-	-	-	11,750
		B	8.9	35.7	50.0	5.4	0.6	-	-	-	-	-	11,900
		C	-	39.1	55.0	5.9	0.7	-	-	-	-	-	13,060
NE¼ sec. 12, T. 4 N., R. 89 W., Rice Mine (Bass and others, 1955)	Lower Coal Group, Zone C	A	11.8	34.4	50.2	3.6	0.5	-	-	-	-	-	11,650
		B	5.9	36.7	53.6	3.8	0.6	-	-	-	-	-	12,420
		C	-	39.0	56.9	4.1	0.6	-	-	-	-	-	13,200
NE¼ sec. 34, T. 5 N., R. 89 W., Corehole (Bass and others, 1955)	Middle Coal Group, Zone G	A	10.5	31.2	45.0	13.3	0.8	-	-	-	-	-	10,140
		B	7.1	32.4	46.6	13.9	0.9	-	-	-	-	-	10,530
		C	-	34.9	50.2	14.9	0.9	-	-	-	-	-	11,330
NE¼ sec. 34, T. 5 N., R. 89 W., Corehole (Bass and others, 1955)	Middle Coal Group, Zone H	A	11.9	35.5	45.4	7.2	0.7	-	-	-	-	-	10,790
		B	10.3	36.1	46.2	7.4	0.7	-	-	-	-	-	10,990
		C	-	40.3	51.5	8.2	0.8	-	-	-	-	-	12,250
Secs. 30 and 31, T. 5 N., R. 88 W., Hayden Gulch Strip Mine (Dawson and Murray, 1978)	Upper Coal Group	A	17.0	-	-	6.0	0.4	-	-	-	-	-	10,000

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 Hayden Gulch quadrangle, Routt County, Colorado.

Coal Bed or Zone	High Development Potential	Moderate Development Potential	Low Development Potential	Unknown Development Potential	Total
UGO {35}	3,490,000	390,000	840,000	-	4,720,000
UGO {34}	6,720,000	2,610,000	50,000	-	9,380,000
UGL	420,000	940,000	1,420,000	-	2,780,000
UGK {16}	60,000	60,000	160,000	-	280,000
MGH {21}	850,000	990,000	3,840,000	-	5,680,000
MGH {19}	40,000	70,000	240,000	-	350,000
MGH {18}	930,000	2,790,000	3,430,000	-	7,150,000
MGG {15}	1,190,000	900,000	4,200,000	-	6,290,000
MGG {12}	-	10,000	140,000	-	150,000
MGG {11}	-	-	20,000	-	20,000
LGB {5}	-	-	210,000	-	210,000
Isolated Data Points	-	-	-	6,080,000	6,080,000
Totals	13,700,000	8,760,000	14,550,000	6,080,000	43,090,000

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 Hayden Gulch quadrangle, Routt County, Colorado.

Coal Bed or Zone	High Development Potential	Moderate Development Potential	Low Development Potential	Unknown Development Potential	Total
UGL	880,000	-	-	-	880,000
UGK {16}	870,000	-	-	-	870,000
MGH {21}	19,130,000	640,000	-	-	19,770,000
MGH {19}	5,410,000	90,000	-	-	5,500,000
MGH {18}	33,380,000	9,440,000	-	-	42,820,000
MGG {15}	26,370,000	1,600,000	-	310,000*	28,280,000
MGG {12}	6,100,000	360,000	-	-	6,470,000
MGG {11}	8,280,000	1,210,000	-	-	9,490,000
LGB {5}	2,490,000	-	-	-	2,490,000
LGA {1}	1,210,000	10,000	-	-	1,220,000
Isolated Data Points	-	-	-	8,550,000	8,550,000
Totals	104,130,000	13,350,000	-	8,860,000	126,340,000

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

*Tonnages for coal beds dipping greater than 15°.

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

				Reserve Base Tonnages	
Coal Bed	Source	Location	Thickness	Surface	Subsurface
LGA[2]	Bass and others (1955)	sec. 7, T. 4 N., R. 88 W.	6.0 ft (1.8 m)	0.39	0.18
LGA[3]	Bass and others (1955)	Sun mine sec. 12, T. 4 N., R. 89 W.	7.5 ft (2.3 m)	0.07	0
LGC[6]	Prost (1977)	sec. 35, T. 5 N., R. 89 W.	8.0 ft (2.4 m)	0.42	0.48
LGC[7]	Bass and others (1955)	Rice mine sec. 12, T. 4 N., R. 89 W.	9.8 ft (3.0 m)	0.39	0.13
LGD[8]	Bass and others (1955)	sec. 34, T. 5 N., R. 89 W.	5.8 ft (1.8 m)	0.18	0.28
LGE[10]	Bass and others (1955)	sec. 34, T. 5 N., R. 89 W.	6.8 ft (2.1 m)	0.20	0.26
MGG[9]	Bass and others (1955)	sec. 23, T. 5 N., R. 89 W.	6.0 ft (1.8 m)	0	0.77
MGG[13]	Bass and others (1955)	sec. 23, T. 5 N., R. 89 W.	6.0 ft (1.8 m)	0	0.77
MGG[14]	Brownfield (1978)	sec. 35, T. 5 N., R. 89 W.	10.0 ft (3.0 m)	0.44	0.95
MGG[16]	Brownfield (1978)	sec. 35, T. 5 N., R. 89 W.	7.0 ft (2.1 m)	0.55	0.35
MGH[17]	Brownfield (1978)	sec. 27, T. 5 N., R. 89 W.	13.8 ft (4.2 m)	0	1.76

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

Table 4.--Continued

Coal Bed	Source	Location	Thickness	Reserve Base Tonnages Surface	Reserve Base Tonnages Subsurface
MGH[20]	Bass and others (1955)	sec. 23, T. 5 N., R. 89 W.	6.0 ft (1.8 m)	0	0.77
UGM[23]	Brownfield (1978)	sec. 25, T. 5 N., R. 89 W.	6.5 ft (2.0 m)	0.09	0.73
UGM[24]	Brownfield (1978)	sec. 25, T. 5 N., R. 89 W.	6.0 ft (1.8 m)	0.21	0.52
UGM[30]	Bass and others (1955)	sec. 22, T. 5 N., R. 89 W.	8.5 ft (2.6 m)	0.44	0
UGN[29]	Brownfield (1978)	sec. 25 T. 5 N., R. 89 W.	6.0 ft (1.8 m)	0.90	0.60
UGN[31]	Bass and others (1955)	sec. 25, T. 5 N., R. 89 W.	6.5 ft (2.0 m)	0.42	0
UGN[32]	Bass and others (1955)	sec. 26, T. 5 N., R. 89 W.	5.6 ft (1.7 m)	0.19	0
UGN[36]	Bass and others (1955)	sec. 23, T. 5 N., R. 89 W.	6.0 ft (1.8 m)	0.36	0
UGO[37]	Bass and others (1955)	sec. 25, T. 5 N., R. 89 W.	5.3 ft (1.6 m)	0.22	0
UGO[41]	Bass and others (1955)	sec. 22, T. 5 N., R. 89 W.	8.2 ft (2.5 m)	0.07	0
UGP[43]	Bass and others (1955)	sec. 29, T. 5 N., R. 88 W.	5.8 ft (1.8 m)	0.01	0
UGQ[33]	Bass and others (1955)	sec. 25, T. 5 N., R. 89 W.	6.0 ft (1.8 m)	0.02	0

Table 4.--Continued

From Hayden Quadrangle

Coal Bed	Source	Location	Thickness	Reserve Base Tonnages Surface	Subsurface
MGM[11]	Brownfield (1976)	sec. 21, T. 5 N., R. 89 W.	6.0 ft (1.8 m)	0.19	0
UGN[12]	Brownfield (1976)	sec. 21, T. 5 N., R. 89 W.	8.0 ft (2.4 m)	0.26	0
UGN[15]	Prost (1977)	sec. 23, T. 5 N., R. 89 W.	5.3 ft (1.6 m)	0.06	0

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

Plate 1 Index Number	Source	Data Base
1	Bass and others, 1955, U.S. Geological Survey Bulletin 1027-D, pl. 23	Measured Section No. B 223
2		Measured Section No. B 225
3		Measured Section No. B 224
4		Measured Section No. B 227
5		Mine-Measured Section No. B 264 Sun Mine
6		Mine-Measured Section No. B 263 Rice Mine
7		Measured Section No. B 238
8		Measured Section No. B 239
9		Measured Section No. B 240
10	Brownfield, 1978, U.S. Geological Survey Open-File Report No. 78-365	Drill hole No. HAYG-9
11	Bass and others, 1955, U.S. Geological Survey Bulletin 1027-D, pl. 23	Measured Section No. B 287
12		Measured Section No. B 289
13		Measured Section No. B 291
14		Measured Section No. B 288
15		Measured Section No. B 292
16		Measured Section No. B 295
17		Measured Section No. B 300a
18		Measured Section No. B 300
19		Measured Section No. B 299

Table 5. -- Continued

Plate 1 Index Number	Source	Data Base
20	Prost, 1977, U.S. Geological Survey Open-File Report No. 77-155	Drill hole No. HAYG-7
21	Bass and others, 1955, U.S. Geological Survey Bulletin 1027-D, pl. 23	Measured Section No. B 302
22	↓	Measured Section No. B 303
23	↓	Measured Section No. B 301
24	↓	Measured Section No. B 306
25	↓	Measured Section No. B 307
26	Prost, 1977, U.S. Geological Survey Open-File Report No. 77-155	Drill hole No. HAYG-3
27	Bass and others, 1955, U.S. Geological Survey Bulletin 1027-D, pl. 23	Measured Section No. B 308
28	↓	Measured Section No. B 310
29	Prost, 1977, U.S. Geological Survey Open File Report No. 77-155	Drill hole No. HAYG-6
30	↓	Drill hole No. HAYG-4
31	Bass and others, 1955, U.S. Geological Survey Bulletin 1027-D, pl. 23	Drill hole No. B 310a
32	↓	Measured Section No. B 311
33	Prost, 1977, U.S. Geological Survey Open-File Report No. 77-155	Drill hole No. HAYG-5
34	Brownfield, 1978, U.S. Geological Survey Open-File Report No. 78-365	Drill hole No. HAYG-11
35	Bass and others, 1955, U.S. Geological Bulletin 1027-D, pl. 23	Drill hole No. B 325a

Table 5. -- Continued

Plate 1 Index Number	Source	Data Base
36	Bass and others, 1955, U.S. Geological Survey Bulletin 1027-D, pl. 23	Measured Section No. B 322
37		Measured Section No. B 327
38		Measured Section No. B 324
39		Measured Section No. B 325
40		Measured Section No. B 323
41		Measured Section No. B 329
42		Measured Section No. B 330
43	Brownfield, 1978, U.S. Geological Survey Open-File Report No. 78-365	Drill hole No. HAYG-12
44	Prost, 1977, U.S. Geological Survey Open-File Report No. 77-155	Drill hole No. HAYG-2
45		Drill hole No. HAYG-1
46		Drill hole No. HAYG-8
47	Bass and others, 1955, U.S. Geological Survey Bulletin 1027-D, pl. 23	Measured Section No. B 331
48		Measured Section No. B 332
49	Brownfield, 1978, U.S. Geological Survey Open-File Report No. 78-365	Drill hole No. HAYG-10
50	Bass and others, 1955, U.S. Geological Survey Bulletin 1027-D, pl. 23	Measured Section No. B 296
51		Mine-Measured Section No. B 333

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