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

[Report includes 43 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 Hamilton quadrangle, Moffat County, Colorado. This report was compiled to support the land-planning work of the Bureau of Land Management (BLM) and to provide a systematic coal resource inventory of Federal coal lands in Known Recoverable Coal Resource Areas (KRCRA's) in the western United States. This investigation was undertaken by Dames & Moore, Denver, Colorado, at the request of the United States Geological Survey under contract number 14-08-0001-15789. The resource information gathered for this report is in response to the Federal Coal Leasing Amendments Act of 1975 (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 Published and unpublished public information available through April, 1978, was used as the data base for this study.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 performed as part of this study, nor was any confidential data used.

Location

The Hamilton quadrangle is located in southeastern Moffat County in northwestern Colorado, approximately 14 miles (22 km) south of the town of Craig via Colorado Highway 13 (also known as Colorado Highway 789), and approximately 32 miles (51 km) northeast of town of Meeker via Colorado Highway 13. With the exception of the town of Hamilton in the northwestern part of the quadrangle and several ranches, the quadrangle is unpopulated.

Accessibility

Colorado Highway 13 crosses the northwest corner of the Hamilton quadrangle joining U.S. Highway 40 at Craig. Colorado Highway 317, an improved light-duty road, crosses east-west along the northern edge of the quadrangle connecting Hamilton with the town of Pagoda approximately 5 miles (8 km) to the east. Several other improved light-duty roads serve the Moffat oil field in the northwestern part of the quadrangle, the Waddle Creek oil field in the northeastern part of the quadrangle, and the Deer Creek area in the southwestern part of the quadrangle. The remainder of the quadrangle is accessible along numerous unimproved dirt roads and trails.

A new railroad spur has recently been constructed from the old railhead at Craig to the Colowyo mine near Axial. Access for coal from the Hamilton quadrangle to the new railroad spur could probably be obtained by either of two routes. One route would be toward the north-northwest from the town of Hamilton along the Williams Fork valley. The new spur is about 4.5 miles (7 km) from the northwest corner of the Hamilton quadrangle along this route. The second route would be through the Axial Basin to the west where the spur is approximately 8 miles (13 km) west of the quadrangle (Meyer, written communication). Railway service is provided by the Denver and Rio Grande Western between Craig and Denver, and this railroad is the major transportation route for coal shipped east from northwestern Colorado (U.S. Bureau of Land Management, 1977).

Physiography

The Hamilton quadrangle lies in the southern part of the Wyoming Basin physiographic province as defined by Howard and Williams (1972). The quadrangle is bordered on the north by the southwestern edge of the Williams Fork Mountains, and on the west by the eastern edge of the Axial Basin. The quadrangle is approximately 47 miles (76 km) west of the Continental Divide.

The landscape within the quadrangle is characterized by moderate to steep slopes cut by numerous streams and gulches. The slopes become progressively broader and less pronounced along the Morapos Creek and Waddle Creek valleys in the northwestern and northeastern parts of the quadrangle.

Altitudes range from approximately 8,677 feet (2,645 m) in the southeast corner of the quadrangle, to less than 6,240 feet (1,902 m) along the Williams Fork in the northwest corner of the quadrangle.

The Hamilton quadrangle is drained by the Williams Fork, Morapos Creek, Deer Creek, Waddle Creek, and several smaller tributaries which flow in a northerly direction. The Williams Fork is a tributary of the Yampa River and joins the Yampa River approximately 4.5 miles (7 km) to the northwest of the Hamilton quadrangle.

Climate and Vegetation

The climate of northwestern Colorado is semiarid. Clear, sunny days prevail in the Hamilton quadrangle area with daily temperatures typically varying from 5° to 34° F (-15° to 1° C) in January and from 45° to 84° F (7° to 29° C) in July. Annual precipitation in the area averages 18 inches (46 cm). Snowfall during the winter months accounts for the major part of the precipitation in the area, but rainfall from thundershowers during the summer months also contributes to the total. Winds, 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 characteristic vegetation present at higher altitudes in the southern third of the Hamilton quadrangle is aspen with minor spruce and juniper. Mountain shrub, including serviceberry, Gambel oak, and rabbitbrush, are the predominant vegetative cover across the central part of the quadrangle. Sagebrush grows at lower altitudes, near the Williams Fork in the northern part of the quadrangle (U.S. Bureau of Land Management, 1977).

Land Status

The Hamilton quadrangle lies in the south-central part of the Yampa Known Recoverable Coal Resource Area (KRCRA). Approximately 43 percent of the quadrangle lies within the KRCRA boundary and the Federal government owns the coal rights for approximately 96 percent of this area as shown on plate 2. There are no active coal leases within the KRCRA in this quadrangle.

GENERAL GEOLOGY

Previous Work

The first geologic description of the general area in which the Hamilton quadrangle is located was reported by Emmons (1877) as part of a survey of the Fortieth Parallel. The decision to build a railroad into the region stimulated several investigations of coal between 1886 and 1905, including papers by Hewett (1889), Hills (1893), and Storrs (1902). Fenneman and Gale (1906), in a geologic report on the Yampa Coal Field, including a description of the geology and coal occurrence in the northern part of the Hamilton quadrangle. A geologic map and report by Hancock (1925) included the Hamilton quadrangle. Bass and others (1955) described the geology and coal resources of the quadrangles to the east. Tweto (1976) compiled a generalized regional geologic map which included this quadrangle. Reports by Meyer (1977 and 1978) included geophysical logs of coal test holes drilled by the U.S. Geological Survey in the Hamilton quadrangle during 1976 and 1977. Drill-hole information and outcrop measurements in the Hamilton quadrangle were compiled by Meyer (no date) during the 1977 and 1978 drilling season.

Stratigraphy

The sedimentary rock formations that crop out in the Hamilton quadrangle are Late Cretaceous and Tertiary in age and include the coal-bearing Iles and Williams Fork Formations of the Mesaverde Group.

The Mancos Shale of Late Cretaceous age crops out in the southwest corner of the quadrangle on the northeast flank of the Axial Basin anticline, in the west-central and northwestern parts of the quadrangle on the Hamilton dome, and in the east-central and northeastern parts of the quarangle on the axis of the Beaver Creek anticline (Hancock, 1925). The upper 1,000 feet (305 m) of the formation consists predominately of gray to dark-gray marine shale, a number of thin-bedded silty tan sandstone beds, and interbedded sandy shale (Hancock, 1925; Bass and others, 1955).

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

The Iles Formation, approximately 1,300 to 1,400 feet (396 to 427 m) thick, crops out north of the Williams Fork river, in the north-central part of the quadrangle along the axis of the Badger Creek syncline, and in a narrow to broad arc along the flanks and across the western part of the Hart syncline in the southern half of the quadrangle (Hancock, 1925). The formation consists of the basal Tow Creek Sandstone Member, an overlying sequence of sandstones interbedded with sandy shale, shale, and coal, and at the top of the formation, the Trout Creek Sandstone Member (Bass and others, 1955).

The basal Tow Creek Sandstone Member consists of light-brown, fine-grained massive cliff-forming sandstone, and is probably about 70 to 80 feet (21 to 24 m) thick in this quadrangle 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 that is about 1,200 feet (366 m) thick. This unit, which contains thick sandstone beds near the base, grades upward to become more silty and shaly. The coal beds in this unit have been designated as the Lower Coal Group (Fenneman and Gale, 1906). The overlying Trout Creek Sandstone Member consists of approximately 90 feet (27 m) of white, fine-grained massive cliff-forming sandstone (Hancock, 1925; Bass and others, 1955).

The Williams Fork Formation conformably overlies the Iles Formation and crops out in the central and southern parts of the quadrangle along the axis of the Hart syncline (Hancock, 1925). It is approximately 1,550 feet (472 m) thick in this quadrangle and is divided into three units: a lower coal-bearing unit, the Twentymile Sandstone Member, and an upper coal-bearing unit (Fenneman and Gale, 1906; 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 Twenty-mile Sanstone Member of the Williams Fork Formation. In this quadrangle, it is approximately 880 to 1,050 feet (268 to 320 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 (Hancock, 1925; Bass and others, 1955). Fenneman and Gale (1906) have designated the coal this sequence as the Middle Coal Group.

The Twentymile Sandstone Member, which is probably about 90 feet (27 m) thick in the Hamilton quadrangle, consists of white to gray massive fine-grained sandstone (Hancock, 1925; Bass and others, 1955).

The upper coal-bearing unit of the Williams Fork Formation, overlying the Twentymile Sandstone Member, is composed of gray fine-grained sandstone, gray shale, brown carbonaceous shale, and coal (Bass and others, 1955). It is estimated that only about 500 feet (152 m) of the lower part of the formation is exposed in this quadrangle. Coal beds occurring in the upper member are designated the Upper Coal Group (Fenneman and Gale, 1906).

Basalt flows of Miocene or Pliocene age cap the Mancos Shale and the Iles Formation in several small areas in the east-central and northeastern parts of the quadrangle (Hancock, 1925; Tweto, 1976).

Holocene deposits of alluvium cover the stream valley of the Williams Fork.

The Cretaceous formations in the Hamilton 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, marginal-marine, and non-marine sediments in the Hamilton 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. Most of the lenticular coal beds in the Lower, Middle and Upper Coal Groups were probably deposited in environments associated with fluvial systems, such as back-levee and coastal plain swamps, interchannel basin areas, and abandoned channels. Other coal beds which have wider areal extents were most likely 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 wider distribution of some of the coal beds in the Yampa study area (Konishi, 1959; Kucera, 1959).

Structure

The Yampa KRCRA lies in the southern extension of the Washakie/ Sand Wash structural basin of south-central Wyoming. The basin is bordered on the east by the Park Range, about 46 miles (74 km) northeast of the Hamilton quadrangle, and on the southwest by the Axial Basin anticline, approximately 2 miles (3 km) west of the quadrangle.

The axis of the Hart syncline enters the quadrangle from the west, trending east-northeast to about the center of the quadrangle. There, the axis swings southeastwardly and extends out of the quadrangle. The strata on the northern flank of the syncline are modified by a series of northwest-trending folds which terminate at the Hart syncline. These structural features are, from west to east, the Round Bottom syncline, the Hamilton dome (Williams Fork anticline farther north), the Badger Creek syncline, and the Beaver Creek anticline. Four east-west-striking faults occur in the west-central part of the quadrangle (Hancock, 1925; Meyer, no date) and cut some of the coal beds.

Dips of the coal-bearing strata are quite variable owing to the directional change and asymmetric structure of the Hart syncline and to the four faults that nearly parallel the axis of the syncline. In general, dips on the north limb of the syncline range from about 11° to 34° south-southeast in the western part of the quadrangle to a maximum of about 33° in the eastern part. South of the synclinal axis, dips are more consistent, ranging from about 9° to 14° near the surface, lessening to 6° to 10° in the subsurface. Along the axis between the faults the dips are even more variable.

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 Hancock (1925) and a more detailed structure map of the Trout Creek Sandstone Member in the Hart syncline area by Meyer (no date). It is assumed that the structure of the coal beds nearly duplicates that of the Trout Creek Sandstone Member. Modifications were made where necessary in accordance with drill-hole and outcrop data.

COAL GEOLOGY

Numerous coal beds in the Lower, Middle, and Upper Coal Groups have been identified in the Hamilton quadrangle. The Lower Coal Group includes all coal beds in the Iles Formation below the Trout Creek Sandstone Member. The Middle Coal Group includes the coal beds in the lower coal-bearing zone of the Williams Fork Formation between the Trout Creek Sandstone Member of the Iles Formation and the Twentymile Sandstone Member of the Williams Fork Formation. The Upper Coal Group includes the coal beds in the upper Williams Fork Formation above the Twentymile Sandstone Member. None of the coal beds are formally named, but where coal beds exceed Reserve Base thickness they have been given bracketed numbers for identification purposes. In instances where coal beds exceeding Reserve Base thickness (5.0 feet or 1.5 meters) are identified at one location only and cannot be correlated with other coal beds, they are treated as isolated data points (see Isolated Data Points section of this report).

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

Chemical analyses of coal.--Analyses of the coals in this area are listed in table 1 and include samples from the Middle and Upper Coal Groups. In general, chemical analyses indicate that the coals in the Lower and Middle Coal Groups are high-volatile C bituminous 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).

Lower Coal Group

Many coal beds in the Lower Coal Group have been identified in outcrops and drill holes at numerous locations throughout the quadrangle. Six of these coal beds are known to exceed Reserve Base thickness, but only one coal bed was isopached. The remaining five coal beds were identified at one location only and are treated as isolated data points.

Lower Coal Group, Coal Bed [9]

The LG[9] (i.e., Lower Coal Group, coal bed [9]) coal bed (plate 4) has been identified at two locations in the central part of the quadrangle. It ranges in thickness from 6.5 feet (2.0 m) where measured in an outcrop to a maximum known thickness of 7.1 feet (2.2 m) at the Hart mine in sec. 17, T. 4 N., R. 90 W. The coal bed contains rock partings ranging from 0.1 to 1.0 feet (0.03 to 0.3 m) thick.

Middle Coal Group

Thirty-seven coal beds exceeding Reserve thickness in the Middle Coal Group have been identified in the Hamilton quadrangle. Of these, only 11 coal beds were isopached; the remaining 26 coal beds were treated as isolated data points.

All of the isopached coal beds are located in the Hart syncline in the southern part of the quadrangle. In general, the coal beds range in thickness from 2.1 to 25.5 feet (0.6 to 7.8 m) where measured in outcrops and drill holes. Rock partings ranging from 0.6 to 7.0 feet (0.2 to 2.1 m) thick occur locally. Coal beds in the Middle Coal Group that are believed to contain approximately 20.00 million short tons (18.14 million metric tons) of coal or more are described individually in the following paragraphs.

Middle Coal Group, Coal Bed [15]

The MG[15] coal bed (plate 11) ranges in thickness from 7.0 to 12.0 feet (2.1 to 3.7 m) where measured in seven coal test holes in the central to west-central part of the quadrangle. Rock partings 1.0 foot (0.3 m) thick were reported in three of the drill holes. The coal bed is cut by four faults.

Middle Coal Group, Coal Bed [20]

The MG[20] coal bed (plate 15) has been penetrated by six coal test holes in the east-central part of the quadrangle and ranges in thickness from 8.2 to 10.0 feet (2.5 to 3.0 m). The maximum reported thickness is in sec. 13, T. 4 N., R. 91 W. A rock parting 1.0 foot (0.3 m) thick was reported in the drill holes located in the NE 1/4 sec. 24, T. 4 N., R. 91 W.

Middle Coal Group, Zone H, Coal Bed [22]

The MGH[22] coal bed (plate 22) has been identified in outcrops and drill holes throughout much of the southern part of the Hamilton quadrangle and extends into the Pagoda quadrangle to the east. The coal bed has a zone designation because it lies in the stratigraphic interval of zone H (Bass and others, 1955) in quadrangles to the east. In the Hamilton quadrangle the MGH[22] coal bed ranges in thickness from 5.8 to 14.0 feet (1.8 to 4.3 m), attaining its maximum thickness in sec. 32, T. 4 N., R. 90 W. Rock partings occur locally and range from 1.8 to 2.7

feet (0.5 to 0.8 m) in thickness. This coal bed thins to the east and varies from 2.2 to 9.0 feet (0.7 to 2.7 m) where measured in drill holes in the Pagoda quadrangle.

Middle Coal Group, Zone H, Coal Bed [24]

The MGH[24] coal bed (plate 26) has been penetrated by drill holes over an extensive area in the central and southeastern parts of the quadrangle. Measured thicknesses range from 13.0 to 25.5 feet (4.0 to 7.8 m), and rock partings 2.2 to 4.0 feet (0.7 to 1.2 m) thick have been reported at several locations. This coal bed is also in the stratigraphic interval of zone H in the Pagoda quadrangle to the east and ranges from 11.2 to 26.1 feet (3.4 to 8.0 m) in thickness where measured along the outcrop and in drill holes in that quadrangle.

Middle Coal Group, Coal Bed [33]

The MG[33] coal bed (plate 30) is located in the west-central part of the quadrangle where it ranges in thickness from 17.5 to 21.5 feet (5.3 to 6.6 m). The maximum thickness is measured in sec. 13, T. 4 N., R. 91 W. The coal bed appears to thin to the southeast and was not identified in the drill hole located near the center of sec. 25, T. 4 N., R. 91 W. A rock parting 6.0 feet (1.8 m) thick was reported in the hole drilled in the NW 1/4 SW 1/4 sec. 22, T. 4 N., R. 91 W.

Middle Coal Group, Coal Bed [35]

The MG[35] coal bed (plate 34) ranges in thickness from 5.5 to 13.0 feet (1.7 to 4.0 m) where penetrated by three coal test holes in the southeastern part of the quadrangle. Rock partings of 3.0 and 7.0 feet (0.9 and 2.1 m) were measured in two of the drill holes. The coal bed thins to the northeast from its area of maximum measured thickness in sec. 28, T. 4 N., R. 90 W. Although the MG[35] coal bed has not been identified in the Pagoda quadrangle, it is believed to extend into that quadrangle and may be as much as 13 feet (4.0 m) thick in the southwestern part.

Middle Coal Group, Coal Bed [48]

The MG[48] coal bed (plate 38) ranges in thickness from 9.5 to

20.5 feet (2.9 to 6.2 m) where measured in outcrops and drill holes in the central part of the quadrangle. Rock partings occur locally and range from 0.1 to 6.0 feet (0.03 to 1.8 m) thick.

Upper Coal Group

Seven coal beds exceeding Reserve Base thickness have been identified in the Upper Coal Group and three of them were isopached. The other four coal beds were identified at one location only and treated as isolated data points.

Upper Coal Group, Coal Bed [51]

The UG[51] coal bed (plate 34) has been penetrated by three drill holes in the central part of the quadrangle where measured thicknesses range from 7.5 to 9.4 feet (2.3 to 2.9 m). Rock partings totalling 3.5 feet (1.1 m) in thickness were reported in the coal test hole drilled in the NE 1/4 NE 1/4 sec. 24, T. 4 N., R. 91 W.

Upper Coal Group, Coal Bed [55]

The UG[55] coal bed (plate 4) is 4.8 and 5.5 feet (1.5 and 1.7 m) thick where measured in two drill holes in the central part of the quadrangle. It is believed to exceed Reserve Base thickness only in small parts of secs. 13 and 24, T. 4 N., R. 91 W.

Upper Coal Group, Coal Bed [56]

The UG[56] coal bed (plate 19) is located on the axis of the Hart syncline in the central part of the quadrangle and ranges in thickness from 14.5 feet (4.4 m) where measured in an outcrop to 15.0 feet (4.6 m) in two drill holes. Rock partings were not reported to be included in the coal bed.

Isolated Data Points

In instances where single or isolated measurements of coal beds thicker than 5 feet (1.5 m) are encountered, the standard criteria for construction of isopach, structure contour, mining ratio, and overburden isopach maps are not available. The lack of data concerning these beds limits the extent to which they can be reasonably projected in any direction and usually precludes correlations with other, better known coal beds. For this reason, isolated data point maps are included on a separate sheet (in U.S. Geological Survey files) for non-isopached coal beds. Descriptions and Reserve Base tonnages for the isolated data points occurring in this quadrangle, and the influences from isolated data points in the adjacent Pagoda quadrangle, are listed in table 5.

COAL RESOURCES

Data from drill holes, mine measured sections, and outcrop measurements (Hancock, 1925; Meyer, 1977, 1978 and no date) were used to construct outcrop, isopach, and structure contour maps of the coal beds in the Hamilton quadrangle. The source of each indexed data point shown on plate 1 is listed in table 6.

Coal resources for Federal land were calculated using data obtained from the coal isopach maps and the areal distribution and identified resources maps. The coal bed acreage (measured by planimeter), multiplied by the average thickness of the coal bed and by a conversion factor of 1,770 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 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 the areal distribution and identified resources maps, and are rounded to the nearest 10,000 short tons (9,072 metric tons). Only Reserve Base tonnages (designated as inferred resources) are calculated for areas influenced by the isolated data points. Coal Reserve Base tonnages per Federal section are shown on plate 2 and total approximately

759.39 million short tons (688.92 million metric tons) for the entire quadrangle, including the tonnages for the isolated data points.

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

COAL DEVELOPMENT POTENTIAL

Coal development potential areas are drawn to coincide with the boundaries of the smallest legal land subdivisions shown on plate 2. In sections or parts of sections where no land subdivisions have been surveyed by the BLM, approximate 40-acre (16-ha) parcels have been used to show the limits of the high, moderate, or low development potentials. A constraint imposed by the BLM specifies that the highest development potential affecting any part of a 40-acre (16-ha) lot, tract, or parcel be applied to that entire lot, tract, or parcel. For example, if 5 acres (2 ha) within a parcel meet criteria for a high development potential; 25 acres (10 ha), a moderate development potential; and 10 acres (4 ha), a low development potential; then the entire 40 acres (16 ha) are assigned a high development potential.

Development Potential for Surface Mining Methods

Areas where the coal beds of Reserve Base thickness are overlain by 200 feet (61 m) or less of overburden are considered to have potential for surface mining and were assigned a high, moderate, or low development potential based on the mining ratio (cubic yards of overburden per ton of recoverable coal). The formula used to calculate mining ratios for surface mining of coal is shown 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 21.97 million short tons (19.93 million metric tons) of coal available for surface mining.

The coal development potential for surface mining methods is shown on plate 42. Of the Federal land areas having a known development potential for surface mining, 87 percent are rated high, 1 percent is rated moderate, and 12 percent are rated low. The remaining Federal lands within the KRCRA boundary in this quadrangle are classified as having unknown development potential for surface mining methods. Reserve Base tonnages in the various development potential categories for surface mining methods are listed in table 2.

Development Potential for Subsurface and In-Situ Mining Methods

Areas considered to have a development potential for conventional subsurface mining methods include those areas where coal beds of Reserve Base thickness are between 200 and 3,000 feet (61 and 914 m) below the ground surface which have dips of 15° or less. Unfaulted coal beds lying between 200 and 3,000 feet (61 and 914 m) below the ground surface, dipping greater than 15°, are considered to have development potential for in-situ mining methods.

Areas of high, moderate, and low development potential for conventional subsurface mining are defined as areas underlain by coal beds of Reserve Base thickness at depths ranging from 200 to 1,000 feet (61 to 305 m), 1,000 to 2,000 feet (305 to 610 m), and 2,000 to 3,000 feet (610 to 914 m) below the ground surface, respectively.

Areas where the coal data is absent or extremely limited between 200 and 3,000 feet (61 and 914 m) below the ground surface are assigned unknown development potentials. This applies to areas where coal beds exceeding Reserve Base thickness are not known, but may occur, and to those areas influenced by isolated data points. The areas influenced by isolated data points in this quadrangle contain approximately 8.93 million short tons (8.10 million metric tons) of coal available for conventional subsurface mining.

The coal development potential for conventional subsurface mining methods is shown on plate 43. All of the Federal land areas having a known development potential for conventional subsurface mining methods are rated high. The remaining Federal land within the KRCRA boundary in this quadrangle is classified as having unknown development potential for conventional subsurface mining methods. Reserve Base tonnages in the various development potential categories for conventional subsurface mining methods are listed in table 3.

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

Areas where faulted coal beds of Reserve Base thickness dip greater than 15° between 200 and 3,000 feet (61 and 914 m) below the ground surface are classified as having an unknown development potential for in-situ mining methods. These criteria also apply to those areas influenced by isolated data points where the coal beds are not faulted. The areas influenced by isolated data points in this quadrangle contain approximately 9.00 million short tons (8.16 million metric tons) of coal available for in-situ mining.

Coal development potential for in-situ mining methods is shown on plate 43. All of the Federal land areas classified as having known development potential for in-situ mining methods are rated low. The remaining Federal lands within the KRCRA boundary are classified as having unknown development potential for in-situ mining methods. Reserve Base tonnages in the various development potential categories for in-situ mining methods are listed in table 4.

Table 1. -- Chemical analyses of coals in the Hamilton quadrangle, Moffat County, Colorado.

Location	COAL BED NAME	Form of Analysis	Proximate				Ultimate					Heating Value	
			Moisture	Volatile Matter	Fixed Carbon	Ash	Sulfur	Hydrogen	Carbon	Nitrogen	Oxygen	Calories	Btu/Lb
SW¼ sec. 24, T. 5 N., R. 91. W., Hamilton Mine (Hancock, 1925)	Lower Coal Group coal bed {1}	A	12.5	29.6	48.1	9.79	0.84	-	-	-	-	-	10,650
		B	3.1	32.9	53.2	10.84	0.93	-	-	-	-	-	11,800
		C	-	33.9	54.9	11.19	0.96	-	-	-	-	-	12,170
SW¼ sec 17, T. 4 N., R. 90 W., Hart Mine (Hancock, 1925)	Lower Coal Group coal bed {9}	A	11.9	36.8	45.6	5.72	0.55	-	-	-	-	-	11,230
		B	10.2	37.5	46.5	5.83	0.56	-	-	-	-	-	11,440
		C	-	41.7	51.8	6.49	0.62	-	-	-	-	-	12,750
Sec. 26, T. 4 N., R. 90 W., Roby Mine (Hancock, 1925)	Middle Coal Group coal bed {12}	A	14.2	36.3	45.3	4.18	0.59	-	-	-	-	-	10,980
		B	12.2	37.1	46.4	4.28	0.60	-	-	-	-	-	11,230
		C	-	42.2	52.9	4.87	0.69	-	-	-	-	-	12,790
Sec. 6, T. 5 N., R. 89 W., Carey Mine (George and others, 1937) from Breeze Mountain quadrangle	Upper Coal Group	A	16.85	32.3	45.4	5.4	0.4	-	-	-	-	-	10,360
		C	-	38.8	54.7	6.5	0.5	-	-	-	-	-	12,460

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 Hamilton quadrangle, Moffat County, Colorado.

Coal Bed or Zone	High Development Potential	Moderate Development Potential	Low Development Potential	Unknown Development Potential	Total
UG {56}	3,670,000	40,000	-	-	3,710,000
UG {55}	70,000	40,000	240,000	-	350,000
UG {51}	850,000	630,000	1,480,000	-	2,960,000
MG {48}	21,660,000	3,460,000	140,000	-	25,260,000
MG {38}	1,110,000	290,000	22,000	-	1,620,000
MG {35}	3,000,000	1,380,000	9,970,000	-	14,350,000
MG {33}	6,250,000	1,620,000	260,000	-	8,130,000
MGH {24}	27,960,000	6,440,000	540,000	-	34,940,000
MGH {22}	9,210,000	6,960,000	5,190,000	-	21,360,000
MG {21}	10,000	10,000	180,000	-	200,000
MG {20}	580,000	490,000	2,540,000	-	3,610,000
MG {15}	2,960,000	1,800,000	1,280,000	-	6,040,000
MG {14}	740,000	500,000	1,820,000	-	3,060,000
MG {10}	10,000	10,000	110,000	-	130,000
LG {9}	330,000	280,000	510,000	-	1,120,000
Isolated Data Points	-	-	-	21,970,000	21,970,000
Totals	78,410,000	23,960,000	24,480,000	21,970,000	148,820,000

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 Hamilton quadrangle, Moffat County, Colorado.

Coal Bed or Zone	High Development Potential	Moderate Development Potential	Low Development Potential	Unknown Development Potential	Total
UG {51}	1,050,000	-	-	-	1,050,000
MG {48}	15,910,000	-	-	-	15,910,000
MG {38}	410,000	-	-	-	410,000
MG {35}	14,560,000	-	-	-	14,560,000
MG {33}	37,440,000	1,600,000	-	-	39,040,000
MGH {24}	181,100,000	2,960,000	-	-	184,060,000
MGH {22}	111,940,000	1,970,000	-	-	113,910,000
MG {21}	2,020,000	-	-	-	2,020,000
MG {20}	67,680,000	540,000	-	-	68,220,000
MG {15}	36,240,000	4,540,000	-	-	40,780,000
MG {14}	11,790,000	1,140,000	-	-	12,930,000
MG {10}	20,000	-	-	-	20,000
LG {9}	3,170,000	-	-	-	3,170,000
Isolated Data Points	-	-	-	8,930,000	8,930,000
Totals	483,330,000	12,750,000	-	8,930,000	505,010,000

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

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

Coal Bed or Zone	Moderate Development Potential	Low Development Potential	Unknown Development Potential	Total
UG {51}	-	750,000	-	750,000
MG {48}	-	15,160,000	-	15,160,000
MG {35}	-	350,000	-	350,000
MG {33}	-	20,910,000	-	20,910,000
MGH {24}	-	25,660,000	-	25,660,000
MGH {22}	-	17,240,000	-	17,240,000
MG {20}	-	7,790,000	-	7,790,000
MG {15}	-	7,360,000	-	7,360,000
MG {14}	-	980,000	-	980,000
LG {9}	-	360,000	-	360,000
Isolated Data Points	-	-	9,000,000	9,000,000
Totals	-	96,560,000	9,000,000	105,560,000

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

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

				Reserve Base Tonnages		
Coal Bed	Source	Location	Thickness	Surface	Subsurface	In-Situ
LG[1]	Hancock (1925)	sec. 23, T. 5 N., R. 91 W.	5.9 ft (1.8 m)	0.15	0	0
LG[2]	Hancock (1925)	sec. 19, T. 5 N., R. 90 W.	5.2 ft (1.6 m)	0.04	0	0
LG[4]	Meyer (1978)	sec. 21, T. 4 N., R. 90 W.	9.5 ft (2.9 m)	0	0.13	1.13
LG[5]	Meyer (1978)	sec. 21, T. 4 N., R. 90 W.	5.5 ft (1.7 m)	0	0.08	0.66
LG[6]	Meyer (1978)	sec. 21, T. 4 N., R. 90 W.	6.5 ft (2.0 m)	0	0.09	0.78
MG[7]	Meyer (no date)	sec. 21, T. 4 N., R. 90 W.	25.0 ft (7.6 m)	1.30	0.05	0
MG[11]	Hancock (1925)	sec. 5, T. 3 N., R. 90 W.	5.6 ft (1.7 m)	0.10	0	0
MG[12]	Hancock (1925)	sec. 26, T. 4 N., R. 91 W.	7.1 ft (2.2 m)	0.45	0	0
MG[13]	Hancock (1925)	sec. 22, T. 4 N., R. 91 W.	10.0+ ft (3.0+ m)	0.66	0	0
MG[16]	Hancock (1925)	sec. 21, T. 4 N., R. 90 W.	41.9 ft (12.8 m)	5.18	0	0.98
MG[17]	Hancock (1925)	sec. 20, T. 4 N., R. 90 W.	16.7 ft (5.1 m)	0.72	0	0.49
MG[18]	Meyer (1978)	sec. 21, T. 4 N., R. 90 W.	13.0 ft (4.0 m)	0.63	0.16	0.94

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

Table 5.--Continued

Coal Bed	Source	Location	Thickness	Reserve Base Tonnages Surface	 Subsurface	 In-Situ
MG[19]	Hancock (1925)	sec. 22, T. 4 N., R. 91 W.	11.5 ft (3.5 m)	0.54	0	0.08
MG[23]	Meyer (no date)	sec. 22, T. 4 N., R. 91 W.	20.8 ft (6.3 m)	0.47	2.23	0
MG[25]	Meyer (no date)	sec. 17, T. 4 N., R. 90 W.	6.3 ft (1.9 m)	0.16	0	0.28
MG[26]	Meyer (1977)	sec. 22, T. 4 N., R. 91 W.	17.5 ft (5.3 m)	0	1.70	0.84
MG[27]	Meyer (1978)	sec. 25, T. 4 N., R. 91 W.	11.0 ft (3.4 m)	0	1.46	0
MG[28]	Meyer (1977)	sec. 22, T. 4 N., R. 91 W.	6.0 ft (1.8 m)	0	0.53	0.29
MG[30]	Hancock (1925)	sec. 14, T. 4 N., R. 91 W.	5.9 ft (1.8 m)	0.18	0.05	0.11
MG[31]	Meyer (1977)	sec. 30, T. 4 N., R. 90 W.	9.0 ft (2.7 m)	0	1.15	0
MG[32]	Meyer (1977)	sec. 28, T. 4 N., R. 90 W.	28.0 ft (8.5 m)	2.05	0.39	0.24
MG[34]	Hancock (1925)	sec. 22, T. 4 N., R. 91 W.	15.1 ft (4.6 m)	0.35	0	0.04
MG[36]	Hancock (1925)	sec. 22, T. 4 N., R. 91 W.	15.3 ft (4.7 m)	1.06	0	0.55
MG[37]	Meyer (1977)	sec. 32, T. 4 N., R. 90 W.	7.0 ft (2.1 m)	0.69	0	0
MG[41]	Hancock (1925)	sec. 19, T. 4 N., R. 90 W.	11.5+ ft (3.5+ m)	0.53	0	0

Table 5.--Continued

Coal Bed	Source	Location	Thickness	Reserve Base Tonnages Surface	Subsurface	In-Situ
MG[42]	Hancock (1925)	sec. 23, T. 4 N., R. 91 W.	18.6 ft (5.7 m)	2.03	0	0
MG[43]	Hancock (1925)	sec. 19, T. 4 N., R. 90 W.	6.6 ft (2.0 m)	0.30	0	0
MG[44]	Hancock (1925)	sec. 19, T. 4 N., R. 90 W.	14.2 ft (4.3 m)	0.55	0	0
MG[45]	Hancock (1925)	sec. 25, T. 4 N., R. 91 W.	16.0 ft (4.9 m)	1.06	0	0
MG[46]	Hancock (1925)	sec. 25, T. 4 N., R. 91 W.	15.8 ft (4.8 m)	1.12	0	0
MG[47]	Hancock (1925)	sec. 25, T. 4 N., R. 91 W.	8.0 ft (2.4 m)	0.55	0	0
UG[49]	Meyer (1977)	sec. 23, T. 4 N., R. 91 W.	7.0 ft (2.1 m)	0.89	0	0.04
UG[50]	Meyer (no date)	sec. 24, T. 4 N., R. 91 W.	5.9 ft (1.8 m)	0	0	0.79
UG[53]	Meyer (no date)	sec. 24, T. 4 N., R. 91 W.	5.8 ft (1.8 m)	0.06	0	0.69
		From Pagoda quadrangle				
MGG[8]	Meyer (1977)	sec. 4, T. 3 N., R. 90 W.	7.0 ft (2.1 m)	0.04	0.11	0
MGG[13]	Meyer (1977)	sec. 4, T. 3 N., R. 90 W.	13.4 ft (4.1 m)	0.11	0.22	0

Table 5.--Continued

Coal Bed	Source	Location	Thickness	Reserve Base Tonnages Surface	Subsurface	In-Situ
MGH[15]	Meyer (1977)	sec. 4, T. 3 N., R. 90 W.	17.2 ft (5.2 m)	0	0.46	0
MGH[25]	Meyer (1977)	sec. 4, T. 3 N., R. 90 W.	7.3 ft (2.2 m)	0	0.19	0

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

Plate 1 Index Number	Source	Data Base
1	Hancock, 1925, U.S. Geological Survey Bulletin 757, pl. 13	Measured Section No. 163C
2	↓	Measured Section 181
3	↓	Mine-Measured Section No. 187
4	↓	Measured Section No. 169
5	↓	Measured Section No. 170
6	↓	Measured Section No. 195
7	↓	Measured Section No. 194
8	Meyer, 1977, U.S. Geological Survey Open-File Report No. 77-118	Drill hole No.H-4-P
9	↓	Drill hole No. H-9A-P
10	Hancock, 1925, U.S. Geological Survey Bulletin 757, pl. 13	Measured Section No. 167
11	↓	Measured Section No. 166
12	Meyer, 1977, U.S. Geological Survey Open-File Report No. 77-118	Drill hole No. H-8-P
13	↓	Drill hole No. H-25-P

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Table 6. -- Continued

Plate 1 Index Number	Source	Data Base
14	Hancock, 1925, U.S. Geological Survey Bulletin 757, pl. 13	Measured Section No. 165
15	↓	Measured Section No. 210
16	↓	Measured Section No. No. 209
17	Hancock, 1925, U.S. Geological Survey Bulletin 757, pl. 14	Measured Section No. 233
18	Meyer, 1977, U.S. Geological Survey Open-File Report No. 77-118	Drill hole No. H-22-P
19	↓	Drill hole No. H-14-P
20	Hancock, 1925, U.S. Geological Survey Bulletin 757, pl. 14	Measured Section No. 226
21	↓	Measured Section No. 227
22	↓	Measured Section No. 225
23	↓	Measured Section No 244
24	↓	Measured Section No. 245
25	Meyer, 1977, U.S. Geological Survey Open-File Report No. 77-118	Drill hole No. H-17-P
26	Hancock, 1925, U.S. Geological Survey Bulletin 757, pl. 14	Measured Section No. 223

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Table 6. -- Continued.

Plate 1 Index Number	Source	Data Base
27	Hancock, 1925, U.S. Geological Survey Bulletin 757, pl. 14	Measured Section No. 222
28	↓	Measured Section No. 228
29	Meyer, 1977, U.S. Geological Survey Open-File Report No. 77-118	Drill hole No. H-15-P
30	↓	Drill hole No. H-11-P
31	Hancock, 1925, U.S. Geological Survey Bulletin 757, pl. 14	Measured Section No. 224
32	Meyer, 1977, U.S. Geological Survey Open-File Report 77-118	Drill hole No. H-12-P
33	Hancock, 1925, U.S. Geological Survey Bulletin 757, pl. 14	Measured Section No. 230
34	Meyer, 1977, U.S. Geological Survey Open-File Report No. 77-118	Drill hole No. H-16-P
35	↓	Drill hole No. H-26-P
36	↓	Drill hole No. H-20-P
37	Hancock, 1925, U.S. Geological Survey Bulletin 757, pl. 14	Measured Section No. 171
38	↓	Measured Section No. 172
39	↓	Measured Section No. 173
40	↓	Measured Section No. 219

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Table 6. -- Continued.

Plate 1 Index Number	Source	Data Base
41	Meyer, 1977, U.S. Geological Survey Open-File Report No. 77-118	Drill hole No. H-21-P
42	Hancock, 1925, U.S. Geological Survey Bulletin 757, pl. 14	Measured Section No. 220
43	↓	Measured Section No. 235
44	↓	Measured Section No. 236
45	↓	Measured Section No. 214
46	↓	Measured Section No. 234
47	Hancock, 1925, U.S. Geological Survey Bulletin 757, pl. 12	Measured Section No. 298
48	Hancock, 1925, U.S. Geological Survey Bulletin 757, pl. 11	Mine-Measured Section No. 391
49	Meyer, (no date), U.S. Geological Survey, unpublished data	Drill hole No. H-38-H
50	↓	Drill hole No. H-39-H
51	Meyer, 1978, U.S. Geological Survey Open-File Report No. 78-366	Drill hole No. H-35-H
52	Meyer, (no date), U.S. Geological Survey, unpublished data	Drill hole No. H-36-H
53	↓	Measured Section
54	↓	Drill hole No. H-40-H
55	↓	Measured Section

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Table 6. -- Continued.

Plate 1 Index Number	Source	Data Base
56	Meyer, 1978, U.S. Geological Survey Open-File Report No. 78-366	Drill hole No. H-34-H
57	Meyer, (no date), U.S. Geological Survey, unpublished data	Drill hole No. C-1C-H
58	↓	Drill hole No. C-1-H
59	Meyer, 1978, U.S. Geological Survey Open-File Report No. 78-366	Drill hole No. H-33-H
60	↓	Drill hole No. H-30-H
61	Meyer, (no date), U.S. Geological Survey, unpublished data	Measured Section
62	Meyer, 1978, U.S. Geological Survey Open-File Report No. 78-366	Drill hole No. H-32-H
63	Meyer, (no date), U.S. Geological Survey, unpublished data	Measured Section
64	↓	Measured Section

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