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

[Report includes 12 plates]

Prepared for

UNITED STATES DEPARTMENT OF THE INTERIOR

GEOLOGICAL SURVEY

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This report has not been edited
for conformity with U.S. Geological
Survey editorial standards or
stratigraphic nomenclature.

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Purpose

This text is to be used in conjunction with Coal Resource Occurrence and Coal Development Potential Maps of the Hayden 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 14-08-0001-15789. The resource information gathered for this report is in response to the Federal Coal Leasing Amendments Act of 1976 (P.L. 94-377). Published and unpublished public information available through April, 1978, was used as the data base for this study.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 Hayden quadrangle is located in southwestern Routt County in northwestern Colorado, approximately 24 miles (39 km) west of the town of Steamboat Springs via U.S. Highway 40 and 11 miles (17.7 km) east-southeast of Craig. With the exception of the town of Hayden, in the northeastern corner of the quadrangle, and a few farms, the area within the quadrangle is unpopulated.

Accessibility

U.S. Highway 40 passes east-west across the northern edge of the Hayden quadrangle. A secondary highway runs along the eastern edge of the quadrangle linking Hayden and the town of Pagoda, which is 10 miles (16 km) southwest of the quadrangle. The remainder of the quadrangle is accessible by several light-duty and unimproved dirt roads.

Railway service for the Hayden quadrangle is provided by the Denver & Rio Grande Western Railroad from Denver to the railhead at Craig. The rail line follows U.S. Highway 40 running along the northern edge of the quadrangle and passing through the town of Hayden. It is the major transportation route for coal shipments to the east from the northwestern Colorado region.

Physiography

The Hayden quadrangle lies in the southern part of the Wyoming Basin physiographic province, as defined by Howard and Williams (1972). The quadrangle is approximately 32 miles (51 km) west of the Continental Divide, and the southern part of the quadrangle lies on the lower slopes of the Williams Fork Mountains.

Approximately 1,500 feet (457 m) of relief is present in the Hayden quadrangle. Altitudes range from approximately 7,800 feet (2,377 m) in the southwestern corner of the quadrangle to approximately 6,300 feet (1,920 m) in the northwestern corner along the Yampa River valley.

The landscape within the quadrangle is characterized by hill and valley topography. Broad gentle slopes and wide stream valleys are dominant over most of the quadrangle, while the topography is more pronounced with steeper slopes and narrower canyons along the southern edge of the quadrangle.

The Hayden area is drained by the Yampa River, which flows westward along the northern border of the quadrangle. Numerous creeks and their tributaries flow northeastwardly into the Yampa River. Most of these streams are intermittent and flow mainly in response to snowmelt in the spring.

Climate and Vegetation

The climate of northwestern Colorado is semiarid. Clear, sunny days prevail in the Hayden area, with daily temperatures varying from 0° to 35° F (-18° to 2° C) in January to 45° to 84° F (7° to 29° 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 spring and summer months also contributes to the total. Winds averaging 3 miles per hour are generally from the west throughout the quadrangle, but in the Yampa valley region winds tend to blow down the valley from the east (U.S. Bureau of Land Management, 1977).

The dominant vegetation in the southern half of the quadrangle is mountain shrubbery, which ranges from 2 to 8 feet (0.6 to 2.4 m) high. Some scattered stands of deciduous trees, often relatively small in size, occur in the southern extremities of the quadrangle at the higher elevations where moisture and soil depth are adequate. Land in the northern half of the quadrangle, along the Yampa River and in some of the flatter areas, is used for agriculture. The remaining land in the northern half is covered by sagebrush and grasses, some of which is used for grazing (U.S. Bureau of Land Management, 1977).

Land Status

The Hayden quadrangle lies in the central part of the Yampa Known Recoverable Coal Resource Area (KRCRA). The southern half, north-central part, and the area along the northwestern edge of the quadrangle lie within the KRCRA boundary. The Federal government owns the coal rights for approximately 60 percent of that area, as shown on plate 2. One active coal lease is located in the extreme southeastern corner of the quadrangle.

GENERAL GEOLOGY

Previous Work

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

Stratigraphy

Rocks which crop out in the Hayden quadrangle are Late Cretaceous in age, and include the Williams Fork Formation of the Mesaverde Group, the Lewis Shale, and the Lance Formation. Only the Mesaverde Group and the Lance Formations are known to contain coal in the quadrangle.

The Mesaverde Group consists of two formations in the Hayden area, the Iles and the Williams Fork. Although the Iles Formation is not exposed in this quadrangle, the formation is known to be at depths less than 3,000 feet (914 m) below the ground surface and does contain thin coal beds based on geologic data from adjacent and nearby quadrangles. Where exposed in adjacent quadrangles, the Iles Formation consists of approximately 1,400 feet (427 m) of massive ledge-forming beds of light-brown, light-gray, and white sandstone interbedded with gray sandy shale, shale, and thin coal beds (Bass and others, 1955). The Trout Creek Sandstone Member lies at the top of the formation and is a fine-grained, masive, white to buff-colored cliff-forming sandstone approximately 90 feet (27 m) thick. The top of the Trout Creek Sandstone Member marks the contact between the Iles Formation and the overlying Williams Fork Formation. Coal beds contained in the upper part of the Iles Formation below the Trout Creek Sandstone Member have been designated the Lower Coal Group by Fenneman and Gale (1906).

The Williams Fork Formation conformably overlies the Iles Formation and includes all beds between the top of the Trout Creek Sandstone Member and the base of the Lewis Shale. According to Bass and others (1955), the Williams Fork Formation is as much as 1,100 feet (335 m) thick near Mount Harris to the east of this quadrangle, but only approximately 900 feet (274 m) of the upper part of the formation is exposed in the southeastern and southwestern parts of the quadrangle (Tweto, 1976). The formation consists of three units; a lower coal-bearing sequence of sandstone, sandy shale and shale; a middle unit of massive white cliff-forming sandstone, called the Twentymile Sandstone Member; and an upper unit of interbedded sandstone, sandy shale, shale, and coal beds (Bass and others, 1955).

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. This lower unit is approximately 1,000 feet (305 m) thick (Bass and others, 1955); the lower half consists mainly of thin-bedded sandstone, sandy shale, coal beds, and thin beds of shale, while the upper half is chiefly shale with a few sandstone beds and thin coal beds. Fenneman and Gale (1906) designated the coal beds in the lower unit as the Middle Coal Group. Approximately 260 feet (79 m) of the upper part of the lower unit has been penetrated by coal test holes in the Hayden quadrangle (Brownfield, 1978).

The upper unit of the Williams Fork Formation overlying the Twentymile Sandstone Member is approximately 500 feet (152 m) thick in this quadrangle. It is composed of dark-gray shale interbedded with sandstone, siltstone, carbonaceous shale, and thin coal beds (Brownfield, 1978). All of the coal beds in this upper unit, between the top of the Twentymile Sandstone Member and the base of the Lewis Shale, lie within the Upper Coal Group (Fenneman and Gale, 1906).

The Lewis Shale conformably overlies the Williams Fork Formation and crops out over more than half of the quadrangle (Tweto, 1976). It is difficult to determine the maximum thickness of the formation in this quadrangle because the beds have low dips and the outcrops of the basal and top beds are many miles apart (Bass and others, 1955). However, it is estimated that the formation is at least approximately 1,500 feet (457 m) thick in the Hayden quadrangle. The formation chiefly consists of dark-gray homogeneous marine shale, and is not known to contain coal.

Conformably overlying the Lewis Shale, it is estimated that the lower 200 feet (61 m) of the Lance Formation is exposed in the northwest quarter of the quadrangle, and consists of interbedded buff-colored to light tan fine-grained sandstone, gray shale, and a few coal beds (Bass and others, 1955).

Recent deposits of alluvium cover the valley of the Yampa River across the top of the quadrangle.

The rocks exposed in the Hayden 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 marine, near-shore marine, and non-marine sediments in the Hayden area.

The interbedded sandstones, shales, and coals of the Mesaverde Group were deposited as a result of minor changes in the position of the shoreline. During the deposition of the Iles and Williams Fork Formations, near-shore marine, littoral, brackish, tidal, brackish and freshwater supratidal, and fluvial environments existed in the Yampa study area. The major sandstones of the Iles and Williams Fork Formations, including the Trout Creek and Twentymile Sandstone Members, were deposited in shallow marine and near-shore marine environments.

The major coal beds with relatively wide areal extent were deposited near the seaward margins 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 coal beds in the Yampa study area. Coals 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.

A large rise in sea level caused a landward movement of the shoreline, which resulted in the end of the deposition of the near-shore and continental sediments of the Mesaverde Group. After this rise in sea level, the marine Lewis Shale was deposited in the Hayden area. Following this period of marine deposition, the sea retreated from the area for the last time and the essentially non-marine sediments of the Lance Formation were deposited.

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) east of the Hayden quadrangle, and on the southwest by the Axial Basin Anticline, approximately 16 miles (26 km) west-southwest of the quadrangle. The dips of the beds in the Hayden quadrangle are influenced by the Sage Creek Anticline in the adjacent Mount Harris and Dunckley quadrangles to the east and southeast, respectively, and by the Buck Peak Anticline in the Breeze Mountain quadrangle to the west.

The structure contour maps of the isopached coal beds are based on a regional structure contour map of the top of the Trout Creek Sandstone Member by Bass and others (1955). It is assumed that the structure of the coal beds within the quadrangle duplicate that of the Trout Creek Sandstone Member. Minor modifications were made where necessary to accomodate outcrop and drill hole data.

COAL GEOLOGY

Coal beds in the Middle and Upper Coal Groups of the Mesaverde Group (Williams Fork Formation) and in the Lance Formation have been identified in the Hayden quadrangle. The Middle Coal Group includes all coal beds between the top of the Trout Creek Sandstone Member of the Iles Formation and the base of the Twentymile Sandstone Member, and the Upper Coal Group includes all coal beds between the top of the Twentymile Sandstone Member and the base of the Lewis Shale. The coal beds in the Middle and Upper Coal Groups tend to be thin, lenticular and of limited areal extent although a few coal beds can be traced for several miles.

Chemical analyses of coals.--Analyses of the coals in this area are listed in table 1. In general, chemical analyses of the coals in the Williams Fork and Lance Formations indicate that these coals are high-volatile C bituminous and subbituminous B in rank, respectively, on a moist, mineral-matter-free bases 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 the Upper Coal Group. Chemical analyses were not available in the Hayden quadrangle for coals from the Middle Coal Group or the Lance Formation. However, it is believed that these coals are similar to the Middle Coal Group and Lance coals mined, respectively, at the Lindholm mine in the Dunckley quadrangle to the southeast and the Rose mine in sec. 18, T. 6 N., R. 88 W.

Middle Coal Group

Only one formally named coal bed in the Middle Coal Group, coal bed J (Bass and others, 1955), has been identified in two drill holes in this quadrangle. This coal bed lies approximately 140 to 190 feet (32 to 58 m) stratigraphically below the base of the Twentymile Sandstone Member and is less than Reserve Base thickness (5.0 feet or 1.5 meters) in this quadrangle. It ranges in thickness from 2 feet (0.6 m), with a parting 5 feet (1.5 m) thick, to 2.5 feet (0.8 m) without a parting. Coal bed J is extensive and much thicker in the adjacent Breeze Mountain quadrangle to the west. It was reported to be 12.0 feet (3.7 m) thick at the Jim Dunn mine in the NW 1/4 sec. 18, T. 5 N., R. 89 W., and the maximum measured thickness was reported to be 17.3 feet (5.3 m) in a coal test hole in the SW 1/4 sec. 12, T. 5 N., R. 90 W.

Four drill holes penetrated what may be one or more coal beds that are approximately 100 feet (30 m) above coal bed J. The bed, or beds, ranges in thickness from 1.5 to 3.2 feet (0.5 to 1.0 m).

Three major coal beds, the Wolf Creek, Wadge and Lennox, are commonly found in the lower 250 feet (76 m) of the Middle Coal Group in quadrangles to the east, but test holes have not been drilled deep enough in this quadrangle to verifiy whether they are present in the subsurface or not.

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 six coal zones (zones K, L, M, N, O, and P), sometimes referred to as beds by Bass and others (1955), and all zones except zone O contain coal beds exceeding Reserve Base thickness. None of the coal beds within the zones are formally named, but where the coal beds exceed Reserve Base thickness they have been given bracketed numbers for identification purposes in this quadrangle only.

In general, coal beds in the Upper Coal Group tend to be thin, lenticular and of limited areal extent. Only a few of the coal beds exceeding Reserve Base thickness can be correlated between drill holes and/or outcrops. Where coal beds greater than Reserve Base thickness are identified at only one location, they are treated as isolated data points (see Isolated Data Points section of this report).

Coal Zone K

Zone K averages approximately 50 feet (15 m) thick and lies immediately above the Twentymile Sandstone Member. Many thin coal beds are present in this zone, but only two, the UGK[1] and UGK[16], have sufficient thickness and lateral extend to warrant preparation of derivative maps. One other coal bed of Reserve Base thickness, the UGK[2], was identified at only one location and has been treated as an isolated data point (plate 10).

The UGK[1] coal bed was penetrated in two drill holes in the southwestern part of the quadrangle (plate 4) where measured thicknesses were 6.4 and 6.5 feet (2.0 m). Rock partings were not reported at these locations. Since the UGK[1] coal bed was not identified in any other drill holes or outcrops, the areal extent of the coal bed has been limited by an inferred 5-foot (1.5 m) isopach. The dip of the coal bed averages approximately 6° from the north-northwest to the northeast as calculated from the structure map.

Measured thicknesses of the UGK[16] coal bed in an outcrop and in drill holes range from 4.0 feet (1.2 m), without a rock parting, to 9.0 feet (2.7 m) with a rock parting 0.1 feet (0.03 m) thick. This coal bed is located in the southwestern corner of the quadrangle (plate 7) and extends into the adjacent Breeze Mountain, Hayden Gulch, and Pagoda quadrangles. Dips of the coal bed, as derived from the structure map, vary from a minimum of approximately 5° to the north-northwest to a maximum of approximately 9° to the north-northwest.

Coal Zone L

Coal zone L begins approximately 20 to 35 feet (6 to 11 m) stratigraphically above the top of zone K and ranges in thickness from approximately 45 to 60 feet (14 to 18 m). This coal zone contains numerous thin coal beds, but only the UGL[29] coal bed is mapped (plate 4) near the southwestern corner of the quadrangle. Two other coal beds, the UGL[6] and UGL[8], are treated as isolated data points and are shown on plate 10.

The UGL[29] coal bed has been identified in an outcrop and in a drill hole where its thickness was measured to be 8.3 and 5.4 feet (2.5 and 1.6 m), respectively. A parting, 0.1 feet (0.03 m thick, was measured at the outcrop, but partings were not recorded in the drill hole. This coal bed extends to the west over a large part of the southern third of the Breeze Mountain quadrangle, thickening to 11.3 feet (3.4 m) as recorded in a drill hole in sec. 2, T. 5 N., R. 90 W. The coal bed dips in a general northeast direction from approximately 4° to 10°, as calculated from the structure map.

Coal Zones M and N

Coal beds in zone M begin approximately 60 to 70 feet (18 to 21 m) above the top of zone L, and the zone averages approximately 25 feet (8 m) in thickness. Zone N is located between approximately 12 and 40 feet (4 and 12 m) stratigraphically above the uppermost coal beds in zone M, and ranges in thickness from approximately 35 to 75 feet (11 to 23 m).

The coal beds in these two zones are typically thin and lenticular, and any correlations between drill holes would be very questionable. Therefore, the six coal beds exceeding Reserve Base thickness that have been penetrated only once by drill holes have been treated as isolated data points. These beds include the UGM[11], UGN[3], [12], [13], [14], and [15] coal beds and are shown on plate 10. Although the UGM[10] coal bed was identified in a drill hole and a nearby outcrop, its lateral extent is unknown and this coal bed has also been treated as an isolated data point.

Coal Zone P

Zone P lies about 400 feet (122 m) above the Twentymile Sandstone Member and is approximately 22 to 35 feet (8 to 11 m) thick. One coal bed in this zone, the UGP[18], has been mined in secs. 4, 7 and 16, T. 5 N., R. 88 W., where the coal bed crops out along Dry Creek. Two other coal beds that exceed Reserve Base thickness, the UGP[17] and [19], are included in zone P and are treated as isolated data points.

The UGP[18] coal bed is named the P bed by Bass and others (1955), who also refer to this bed as the Dry Creek bed, and is located in the southeastern part of the Hayden quadrangle. The thickness of the UGP[18] coal bed ranges from 2.0 to 10.1 feet (0.6 to 3.1 m) where measured in drill holes, outcrops and mine-measured sections (plate 4). A rock parting ranging from 0.2 to 2.2 feet (0.06 to 0.7 m) thick is common in this coal bed where measured in outcrops or mine-measured sections, but it was not reported in the drill holes.

Isolated Data Points

In instances where 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 plate for non-isopached coal beds (plate 10). Coal beds identified by bracketed numbers are not formally named, but are used for identification purposes in this quadrangle only.

COAL RESOURCES

Information from mine measured sections, outcrop measurements and drill holes were used to construct outcrop, isopach, and structure contour maps of the coal beds in this quadrangle. The source of each indexed data point shown on plate 1 is listed in table 4.

Coal resources were calculated using data obtained from the coal isopach maps (plates 4 and 7) and the areal distribution and identified resources (ADIR) maps (plates 6, 9, and 10). The coal bed acreage (measured by planimeter) multiplied by the average isopached 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 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 used in calculating Reserve Base and Reserve tonnages as stated in U.S. Geological Survey Bulletin 1450-B which calls for a minimum thickness of 28 inches (70 cm) for bituminous coal and a maximum depth of 1,000 feet (305 m) for both bituminous and subbituminous coal. Only Reserve Base tonnages (designated as inferred resources) are calculated for areas influenced by the isolated data points in this quadrangle.

Reserve Base and Reserve tonnages for the isopached and non-isopached coal beds are shown on plates 6, 9 and 10, and are rounded to the nearest 10,000 short tons (9,072 metric tons). Coal Reserve Base tonnages per Federal section are shown on plate 2 and total approximately 34.42 million short tons (31.23 million metric tons) for the entire quadrangle, including tonnages from the isolated data points. Reserve Base tonnages in the various development potential categories for surface and subsurface mining methods are shown in tables 2 and 3.

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

COAL DEVELOPMENT POTENTIAL

Coal development potential areas are drawn so as 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 potentials for surface mining methods. This applies to areas where no known coal beds of 5 feet (1.5 m) or more thick occur and to those areas influenced by isolated data points. Limited knowledge pertaining to the areal distribution, thickness, depth, and attitude of the coals in these areas prevents accurate evaluation of the development potential in the high, moderate, or low categories. The areas influenced by isolated data points in this quadrangle contain approximately 6.74 million short tons (6.11 million metric tons) of coal available for surface mining.

The coal development potential for surface mining methods is shown on plate 11. Of the Federal land areas having a known development potential for surface mining methods, 30 percent are rated high, 5 percent are rated moderate, and 65 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 are those areas where the 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. 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 a development potential for in-situ mining methods.

Areas of high, moderate, and low development potential for conventional subsurface mining methods are defined as areas underlain by coal beds 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), 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 to the areas where no known coal beds of Reserve Base thickness occur. The areas influenced by isolated data points in this quadrangle contain approximately 2.79 million short tons (2.53 million metric tons) of coal available for conventional subsurface mining.

The coal development potential for subsurface mining methods is shown on plate 12. All of the Federal land areas classified as having known development potential for conventional subsurface mining methods are rated high. The remaining Federal lands within the KRCRA boundary are classified as having unknown development potential for conventional subsurface mining methods.

Because the coal beds in this quadrangle 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.

Table 1. Chemical analyses of coals in the Hayden 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
NE¼, sec. 4, T. 5 N., R. 88 W., Babson Mine (Jones, D. C., and Murray, D. K., 1977) and (Bass and others, 1955)	Upper Coal Group Dry Creek	A	14.4	37.5	56.0	6.5	0.4	-	-	-	-	-	10,850
		B	13.5	33.7	49.3	3.5	0.4	-	-	-	-	6,245	11,240
		C	-	39.0	57.0	4.0	0.5	-	-	-	-	7,215	12,990
		D	-	40.6	59.4	-	0.5	-	-	-	-	7,520	13,540
NW¼, sec. 16, T. 5 N., R. 88 W. Sleepy Cat Mine (Bass and others, 1955)	Upper Coal Group Zone L	A	14.4	32.6	48.5	4.5	0.9	6.0	63.2	1.5	23.9	6,134	11,040
		C	-	38.1	56.6	5.3	1.0	5.1	73.8	1.9	13.0	7,172	12,910
		D	-	40.3	59.7	-	1.1	5.4	78.0	1.9	13.6	7,572	13,630
Sec. 30, T. 5 N., R. 87 W. Lindholm Mine (Bass and others, 1955) from Dunckley quadrangle	Middle Coal Group	A	12.3	33.6	43.0	11.1	0.4	-	-	-	-	5,690	10,240
		B	9.3	34.8	44.4	11.5	0.4	-	-	-	-	5,885	10,590
		C	-	38.4	48.9	12.7	0.5	-	-	-	-	6,490	11,680
		D	-	44.0	56.0	-	0.5	-	-	-	-	7,435	13,380
NW¼, sec. 18, T. 6 N., R. 88 W. Rose Mine (Bass and others, 1955) from Mount Harris quadrangle	Lance Coal	A	20.1	31.5	44.2	4.2	0.3	-	-	-	-	5,390	9,700
		B	15.2	33.4	47.0	4.4	0.3	-	-	-	-	5,715	10,290
		C	-	39.4	55.4	5.2	0.3	-	-	-	-	6,745	12,140
		D	-	41.5	58.5	-	0.3	-	-	-	-	7,110	12,800

Form of Analysis: A, as received
B, Air dried
C, moisture free
D, moisture and ash 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 quadrangle, Routt County, Colorado.

Coal Bed	High Development Potential	Moderate Development Potential	Low Development Potential	Unknown Development Potential	Total
UGP [18]	110,000	70,000	210,000	-	390,000
UGL [29]	510,000	260,000	1,400,000	-	2,170,000
UGK [16]	690,000	540,000	2,820,000	-	4,050,000
UGK [1]	50,000	50,000	1,770,000	-	1,870,000
Isolated data points	-	-	-	6,740,000	6,740,000
Totals	1,360,000	920,000	6,200,000	6,740,000	15,220,000

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 quadrangle, Routt County, Colorado.

Coal Bed	High Development Potential	Moderate Development Potential	Low Development Potential	Unknown Development Potential	Total
UPG [18]	3,590,000	-	-	-	3,590,000
UGL [29]	920,000	-	-	-	920,000
UGK [16]	7,980,000	-	-	-	7,980,000
UGK [1]	3,920,000	-	-	-	3,920,000
Isolated data points	-	-	-	2,790,000	2,790,000
Totals	16,410,000	-	-	2,790,000	19,200,000

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

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

Plate 1 Index Number	Source	Data Base
1	Bass and others, 1955, U.S. Geological Survey Bulletin 1027-D, pl. 23	Measured Section No. 231
2	Brownfield, 1976, U.S. Geological Survey Open-File Report No. 76-817	Drill hole No. Y-25-H
3	Prost, 1977, U.S. Geological Survey Open-File Report No. 77-155	Drill hole No. HAY-6B
4	↓	Drill hole No. HAY-4
5	↓	Drill hole No. HAY-3
6	↓	Drill hole No. HAY-5
7	↓	Drill hole No. HAY-6A
8	↓	Drill hole No. HAY-2
9	Bass and others, 1955, U.S. Geological Survey Bulletin 1027-D, pl. 23	Measured Section No. 270
10	Brownfield, 1976, U.S. Geological Survey Open-File Report No. 76-817	Drill hole No. HAY-8
11	Prost, 1977, U.S. Geological Survey Open-File Report No. 77-155	Drill hole No. HAY-1
12	Brownfield, 1976, U.S. Geological Survey Open-File Report No. 76-817	Drill hole No. HAY-22-H
13	Bass and others, 1955, U.S. Geological Survey Bulletin 1027-D, pl. 23	Measured Section No. 334-A
14	↓	Measured Section No. 244
15	↓	Measured Section No. 243
16	↓	Measured Section No. 229

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Table 4. -- Continued

Plate 1 Index Number	Source	Data Base
17	Bass and others, 1955, U.S. Geological Survey Bulletin 1027-D, pl. 23	Measured Section No. 230
18	↓	Measured Section No. 232A
19	↓	Measured Section No. 236
20	↓	Measured Section No. 271
21	↓	Measured Section No. 296
22	↓	Measured Section No. 273
23	↓	Measured Section No. 242
24	Brownfield, 1978, U.S. Geological Survey Open-File Report No. 78-365	Drill hole No. HAY-9
25	↓	Drill hole No. HAY-7

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SELECTED 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. C., 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.

Campbell, M. R., 1923, The Twentymile Park district of the Yampa coal field, Routt County, Colorado: U.S. Geological Survey Bulletin 748, p. 72-73.

Emmons, S. F., 1877, Valleys of the Upper Yampa and Little Snake Rivers, in Hague, Arnold and Emmons, S. F., Descriptive Geology: U.S. Geological Exploration of the Fortieth Parallel, Section IX, 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.

Gale, H. S., 1910, Coal fields of northwestern Colorado and northeastern Utah: U.S. Geological Survey Bulletin 415, 265 p.

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

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

Hornbaker, A. L., Holt, R. D., and Murray, K. D., 1975, Summary of coal resources in Colorado: Colorado Geological Survey Special Publication No. 9, 17 p.

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

Selected References--Continued

Jones, D. C. and Murray, D. K., 1977, First annual report - Evaluation of coking-coal deposits in Colorado: Colorado Geological Survey, 225 p.

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

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

Masters, C. D., 1959, Correlation of the post-Mancos Upper Cretaceous sediments of the Sand Wash and Piceance Basins, 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. 78-80.

______ 1967, Use of sedimentary structures in determination of depositional environments, Mesaverde Formation, Williams Fork Mountains, Colorado: American Association of Petroleum Geologists Bulletin, v. 51, no. 10, p. 2033-2046.

McGookey, D. P., (Compiler), 1972, Cretaceous systems, in Geologic Atlas of the Rocky Mountain region (W. W. Mallory, ed.): Rocky Mountain Association of Geologists, p. 190-228.

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.

Reeside, J. B., Jr., 1957, Paleoecology of the Cretaceous seas of the western interior: Geological Society of America Memoir 67, v. 2, p. 505-542.

Ritzma, H. R., 1955, Early Cenozoic history of the Sand Wash Basin, northwest Colorado, in Guidebook to the geology of northwest Colorado, Intermountain Association of Petroleum Geologists and Rocky Mountain Association of Geologists Guidebook, 10th Annual Field Conference, 1955: p. 36-40.

Selected References--Continued

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

Storrs, L. S., 1902, The Rocky Mountain coal field: U.S. Geological Survey Annual Report 22, pt. 3, p. 415-471.

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

U.S. Bureau of Land Management, 1977, Description of the environment, chapter II, in Final environmental statement on northwest Colorado coal: p. 1-125, 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.

Weimer, R. J., 1959, Upper Cretaceous stratigraphy, 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. 9-16.

Zapp, A. D., and Cobban, W. A., 1960, Some Late Cretaceous strand lines in northwestern Colorado and northeastern Utah: U.S. Geological Survey Professional Paper 400-B, p. 246-249.