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

[Report includes 23 plates]

Prepared for

UNITED STATES DEPARTMENT OF THE INTERIOR

GEOLOGICAL SURVEY

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CONTENTS

ILLUSTRATIONS

Illustrations--Continued

TABLES

INTRODUCTION

Purpose

This text is to be used in conjunction with Coal Resource Occurrence and Coal Development Potential Maps of the Lay 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 U.S. Geological Survey under contract number 14-08-0001-15789. The resource information gathered for this report is in response to the Federal Coal Leasing Amendments Act of 1976 (P.L. 94-377). Published and unpublished public information available through February, 1979, was used as the data base for this study. No new drilling or field mapping was performed as a part of this study, nor was any confidential data used.

Location

The Lay quadrangle is located in east-central Moffat County in northwestern Colorado, approximately 19 miles (31 km) west of the town of Craig via U.S. Highway 40 and 32 airline miles (51 km) north of the town of Meeker. The town of Lay is located on U.S. Highway 40 near the southeastern edge of the quadrangle. The remainder of the quadrangle is unpopulated.

Accessibility

U.S. Highway 40 crosses east-west through the southern third of the Lay quadrangle, connecting Craig to the east with the town of Maybell approximately 5 miles (8 km) to the west. an improved light-duty road, connecting with U.S. Highway 40 near the town of Lay, follows the Lay Creek valley to the north along the eastern edge of the quadrangle. The road also extends south approximately 4 miles (6 km) to Government Bridge on the Yampa River. A second improved light-duty road connects U.S. Highway 40 with Union Carbide's uranium strip mines in the west-central part of the quadrangle. The remainder of the quadrangle is accessible along numerous unimproved dirt roads and trails.

Railway service for the Lay quadrangle is provided by the Denver and Rio Grande Western Railroad from Denver to the railhead at Craig. The railroad terminates approximately 16 miles (26 km) east of the quadrangle and is the major transportation route for coal shipped east from northwestern Colorado (U.S. Bureau of Land Management, 1977).

Physiography

The Lay quadrangle lies in the southern part of the Wyoming Basin physiographic province, as defined by Howard and Williams (1972). The quadrangle is located approximately 64 miles (103 km) west of the Continental Divide. The landscape throughout the quadrangle is dominated by moderate to steep slopes and numerous gulches. A low prominent east-northeast trending ridge crosses the northern part of the quadrangle. Sugarloaf Basin, a large flat valley, covers approximately 1 square mile (2.6 sq. km) in the south-central part of the quadrangle. Lay Creek flows through a half mile wide (0.8 km) valley in the southern part of the quadrangle.

Altitudes range from over 7,080 feet (2,158 m) along a ridge in the north-central part of the quadrangle to less than 5,960 feet (1,817 m) on Lay Creek in the southwestern corner. Sugarloaf Peak rises to an elevation of 6,642 feet (2,024 m) above sea level in the central part of the quadrangle. Lay Peak rises approximately 500 feet (152 m) above the Lay Creek valley in the southeastern part of the quadrangle.

Lay Creek flows westerly across the southern part of the quadrangle, joining the Yampa River approximately 1.5 miles (2.4 km) to the southwest. The northern part of the quadrangle is drained by Mud Spring Gulch, a tributary of Spring Creek and the Yampa River. The streams in the quadrangle 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 Lay quadrangle area, with daily temperatures typically varying from 1° to 34°F (-17° to 1°C) in January and from 46° to 86°F (8° to 30°C) in July. Annual precipitation averages approximately 12 inches (30 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 dominant vegetation in the Lay quadrangle is sagebrush. Vegetation along the western part of Lay Creek and along the west-central edge of the quadrangle is predominately pinyon, Utah juniper and Rocky Mountain juniper (U.S. Bureau of Land Management, 1977).

Land Status

The Lay quadrangle lies at the western edge of the Yampa Known Recoverable Coal Resource Area (KRCRA). The northern half and southeastern corner of the quadrangle, comprising approximately one half of the quadrangle, lie within the KRCRA boundary, and the Federal government owns the coal rights for approximately 85 percent of this area as shown on plate 2. There are no active coal leases within the KRCRA in the Lay quadrangle.

GENERAL GEOLOGY

Previous Work

The first geologic description of the general area in which the Lay 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). Hancock (1925) described the geology and coal resources of the area south of the quadrangle. Tweto (1976) compiled a generalized regional map which included this quadrangle. Brownfield (1978) reported on reconnaissance drilling in the Yampa coal field by the U.S. Geological Survey during 1977. The most comprehensive work on the Lay quadrangle area includes a geologic map and coal sections by Brownfield and Prost (no date).

Stratigraphy

The rock formations cropping out in the quadrangle (Brownfield and Prost, no date) range in age from Late Cretaceous to Miocene and include the coal-bearing Iles and Williams Fork Formations of the Mesaverde Group, and the Lance and Fort Union Formations.

The Iles Formation of Late Cretaceous age crops out in a small area in the southeastern corner of the quadrangle (Brownfield and Prost, no date). It consists of massive sandstone interbedded with shaly sandstone, sandy shale, and shale (Hancock, 1925; Bass and others, 1955). Hancock (1925) indicated that the Iles Formation is approximately 1,350 feet (411 m) thick in the quadrangles to the south, and this thickness is also indicated on the geophysical log of the McMoran No. 15-1 USA oil and gas well drilled in sec. 15, T. 7 N., R. 94 W. The "rim rock" sandstone (Hancock, 1925; Konishi, 1959), the basal unit of the formation, is a massive, light-brown sandstone and is approximately 55 feet (17 m) thick on the geophysical log. The Trout Creek Sandstone Member caps the formation and crops out over a small area in the southeastern corner of the Lay quadrangle (Brownfield and Prost, no date). It consists of a white fine-grained massive sandstone (Hancock, 1925; Bass and others, 1955) and appears to be approximately 40 feet (12 m) thick in the McMoran well.

The Williams Fork Formation also crops out in a small area in the southeastern corner of this quadrangle (Brownfield and Prost, no date). Hancock (1925) estimated the thickness of this formation to be about 1,600 feet (488 m) in the quadrangles to the south. It is approximately 1,450 feet (442 m) thick where measured in the McMoran well. The Williams Fork Formation consists of alternating sandstone, sandy shale, carbonaceous shale, and coal beds (Hancock, 1925).

The Lewis Shale of Late Cretaceous age conformably overlies the Williams Fork Formation but does not crop out in this quadrangle

(Brownfield and Prost, no date). However, it has been identified in the oil and gas wells drilled in the quadrangle. The Lewis Shale consists of dark-gray to bluish, homogeneous marine shale interbedded with a few sandstone units (Hancock, 1925; Bass and others, 1955). Total thickness of the formation is approximately 1,720 feet (524 m) in the U.S. Smelting, Refining, and Mining Company No. 1-31 Federal oil and gas well drilled in sec. 31, T. 8 N., R. 94 W., (Haun, 1961). To the east in the Lay SE quadrangle, the Lewis Shale ranges in thickness from approximately 2,090 to 2,200 feet (637 to 671 m).

The Fox Hills Sandstone of Late Cretaceous age intertongues with the underlying marine Lewis Shale and with the overlying brackish-water and fluviatile sandstone and shale of the Lance Formation (Haun, 1961). It consists of grayish-white to gray, fine-grained massive resistant sandstone interbedded with shaly sandstone, gray sandy shale, and gray papery shale (Dorf, 1942; Bass and others, 1955). It is approximately 70 feet (21 m) thick where measured in the U.S. Smelting, Refining, and Mining Company No. 1-31 Federal well (Haun, 1961). The Fox Hills Sandstone was not mapped by Brownfield and Prost (no date).

The Lance Formation of Late Cretaceous age overlies the Fox Hills Sandstone and part of the formation crops out in a narrow band in the central part of the quadrangle. Haun (1961) indicates the Lance Formation is approximately 110 feet (34 m) thick in the U.S. Smelting, Refining, and Mining Company No. 1-31 Federal well, and about 350 feet (107 m) thick in the U.S. Smelting No. 1 Government McIntyre well drilled in sec. 3, T. 7 N., R. 94 W. However, a measured section by Brownfield and Prost (no date) indicates that about 1,000 feet (305 m) of the Lance Formation may be present in sec. 7, T. 7 N., R. 93 W. The formation consists of a non-marine sequence of sandstone, siltstone, carbonaceous shale, and occasional coal beds (Haun, 1961).

Unconformably overlying the Lance Formation, the Fort Union Formation of Paleocene age crops out in the northern part of the quadrangle (Brownfield and Prost, no date). The Fort Union Formation ranges from 1,000 to 1,200 feet (305 to 366 m) thick in adjacent quadrangles, and Haun (1961) indicates the Fort Union Formation is approximately 1,120 feet (341 m) thick in the U.S. Smelting, Refining, and Mining Company No. 1-31 Federal well. The Fort Union Formation consists of a basal conglomerate and interbedded sandstone, gray shale, and coal beds (Bass and others, 1955). Several Fort Union Formation coal beds, including the Emerson and Blevins, occur in the Lay quadrangle.

The Wasatch Formation of Eocene age unconformably overlies the Fort Union Formation and crops out in the northern part of the quadrangle. Haun (1961) indicates the Wasatch Formation is at least 1,000 feet (305 m) thick in the U.S. Smelting, Refining, and Mining Company No. 1-31 Federal well. The basal 1,000 feet (305 m) of the formation consists of coarse brown sandstone interbedded with gray and red clay shale (Bass and others, 1955).

The Browns Park Formation of Miocene age unconformably overlies older formations over most of the quadrangle (Brownfield and Prost, no date). According to Sears (1924), the Browns Park is at least 1,200 feet (366 m) thick in northwestern Colorado, but its total thickness in this quadrangle is unknown. It consists primarily of fluvial siltstone, claystone, and loosely consolidated eolian tuffaceous sandstone with conglomerate beds at its base (Hancock, 1925; Tweto, 1976).

Holocene deposits of alluvium cover the bottoms of the stream valleys, the Sugarloaf Basin, and most of the gulches in this quadrangle (Brownfield and Prost, no date).

The Cretaceous formations cropping out in the Lay 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, marginal-marine, and non-marine sediments in the Lay quadrangle area (Ryer, 1977).

The interbedded sandstone, shale, and coal of the Iles and Williams Fork Formations were deposited as a result of minor changes in the position of the shoreline. Near-shore marine, littoral, brackish-tidal, brackish and fresh-water supratidal, and fluvial environments existed during the deposition of the Iles and Williams Fork Formations. The major sandstones of the Iles and Williams Fork Formations, were deposited in shallow marine and near-shore marine environments as the shoreline fluctuated (Konishi, 1959; Kucera, 1959).

Deposition of the Lewis Shale marked a landward movement of the sea. The marine sediments of the Lewis Shale were deposited in water depths ranging from a few tens of feet to several hundred feet. Deposition of the Lewis Shale ended in the quadrangle with the regression of the sea caused by a regional uplift west of the Yampa Basin area (Kucera, 1959).

As the sea retreated to the northeast, the Fox Hills Sandstone was deposited over the Lewis Shale in a littoral and near-shore environment. Following the regression of the Cretaceous sea, broad areas of fluvial, estuarine, marsh lagoonal, and coastal swamp environment resulted in deposits of sandstone, mudstones, carbonaceous shales, and thin coal beds, characteristic of the Lance Formation (O'Boyle, 1955; Weimer, 1959 and 1961).

After the final withdrawal of the Cretaceous sea, thick sections of detrital material, eroded from older deposits, were deposited as the Fort Union Formation. The conglomerates, sandstones, shales, and coals were deposited in braided-stream, flood-plain and backswamp environments (Beaumont, 1979). The coal beds, which have 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 the Fort Union [20], Emerson and Blevins 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 (Konishi, 1959; Kucera, 1959).

The coarse sediments at the base of the Wasatch Formation were deposited in a fluvial environment and the upper sediments were deposited in alternating swamp, lake and stream environments (Beaumont, 1979).

The Browns Park Formation was deposited after a long period of non-deposition and erosion. It is a continental deposit consisting mostly of fluvial and eolian deposits and much of its thickness has been removed as a result of late Cenozoic erosion (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 Park Range, approximately 63 miles (101 km) east of the Lay quadrangle, and on the southwest by the Axial Basin anticline, approximately 9 miles (14 km) south of the quadrangle (Tweto, 1976).

Coal beds in the northern part of the quadrangle dip north to north-northwest from 5° to about 15° along the outcrop and become slightly less in the subsurface; dips of the coal beds in the southeast corner range from approximately 9° to 12° east. Numerous faults have been identified in the southern half of the quadrangle (Brownfield and Prost, no date). Only one of these faults is known to affect coal-bearing sediments. It strikes east-west in the southeastern corner of the quadrangle (Brownfield and Prost, no date; Tweto, 1976).

The structure contour maps of the isopached coal beds are based on a regional structure map of the Lance-Fort Union contact by Brownfield and Prost (no date), and it is assumed that the structure of the coal beds nearly duplicates that of the mapped structure. Modifications were made where necessary in accordance with outcrop and drill-hole data.

COAL GEOLOGY

Coal beds in the Williams Fork, Lance, and Fort Union Formations have been identified in outcrops, coal test holes, and oil and gas wells in the Lay quadrangle. In general, coals in the Williams Fork and Lance Formations tend to be thin, lenticular and of limited areal extent, whereas coal beds in the Fort Union Formation exceed Reserve Base thickness (5.0 feet or 1.5 meters) over large areas. Coal beds greater than Reserve Base thickness that are not formally named have been given bracketed numbers for identification purposes. In instances where coal beds exceeding Reserve Base thickness are measured at one location only, they are treated as isolated data points (see Isolated Data Points section of this report).

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

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

Locations of coal samples tested in this quadrangle are listed in table 1 and include those for an undifferentiated Williams Fork Formation coal bed. Chemical analyses were not available for coals in the Fort Union or Lance Formations, but representative analyses from nearby areas are listed in table 1.

Coal Beds of the Williams Fork Formation

Coal beds in the Williams Fork Formation have been identified in outcrop in the southeast corner and in an oil and gas test well drilled in the central part of the quadrangle. Of the five coal beds known to exceed Reserve Base thickness in this quadrangle, only the Peacock coal bed has been ispached. The other four coal beds, the Williams Fork [1], [2], [3], and [4], were each identified at one location only and they have been treated as isolated data points. Also, the Williams Fork [1] and [2] coal beds occur on non-Federal land.

The Peacock coal bed (plate 4) has been identified at three locations along the outcrop in the southeast corner of the quadrangle where measured thicknesses range from 11.5 to 14.0 feet (3.5 to 4.3 m. Rock partings 0.5 feet (0.2 m) thick were reported at two locations. The coal bed is cut by an east-striking fault approximately 1 miles (1.6 km) north of the southern quadrangle boundary. Based on the coal-bed measurements in this quadrangle, the coal bed is believed to extend into the Lay SE quadrangle to the west where it is inferred to range from 11 to 16 feet (3.4 to 4.9 m) in thickness. In the Horse Gulch quadrangle to the southeast, the Peacock coal bed ranges in thickness from 2.7 feet (0.8 m), where measured along the outcrop, to a reported maximum of 16.0 feet (4.9 m) where penetrated by a drill hole in sec. 18, T. 6 N., R. 93 W. In the Juniper Hot Springs quadrangle to the south, the coal bed is 11.7 feet (3.6 m) thick where measured in an outcrop and is reported to be 17.0 feet (5.2 m) thick in a coal test hole drilled in sec. 6, T. 6 N., R. 93 W.

Coal Beds of the Lance Formation

Several coal beds in the Lance Formation have been identified in two drill holes and a measured section that are located in the northern half of the quadrangle. Three of these coal beds, the Lance [23], [24], and [25], were each identified at one location only and have been treated as isolated data points.

Coal Beds of the Fort Union Formation

Fort Union coal beds have been identified throughout the northern part of the quadrangle. Sixteen coal beds exceed Reserve Base thickness, but only the Emerson, Blevins, Fort Union [8], [9], [14], [17], [19], [20], [22], and [40] coal beds have been isopached. Of these, the Emerson and Blevins coal beds are the most significant. The other six coal beds, the Fort Union [10], [11], [15], [16], [18], and [21], were identified at one location each and are treated as isolated data points.

The Emerson coal bed (Brownfield, 1979) extends over much of the northeastern part of the quadrangle as shown on plate 17. It ranges in thickness from 5.0 to 26.0 feet (1.5 to 7.9 m) where measured along the outcrop and in drill holes. The coal bed generally occurs as a single bed, but it locally contains thin rock partings ranging from 0.5 to 1.0 feet (0.2 to 0.3 m) thick. The Emerson coal bed extends to the east into the Lay SE quadrangle (Brownfield, 1979) where the coal bed has been identified in numerous outcrops and drill holes. Measured thicknesses in that quadrangle range from 3.3 to 28.9 feet (1.0 to 8.8 m) thick, excluding local rock partings that vary from 0.3 to 6.0 feet (0.1 to 1.8 m) in thickness.

The Blevins coal bed (plate 4) also extends over a large area in the northern part of the quadrangle and ranges in thickness from 2.0 to 15.5 feet (0.6 to 4.7 m) where measured in drill holes and along the outcrop (Brownfield and Prost, no date). Rock partings ranging from 1.0 to 10.0 feet (0.3 to 0.6 m) thick were reported at several locations. In cases where the thickness of the rock parting is greater than one of the coal bed splits, only the larger of the splits has been used on the isopach map. This coal bed extends into the Lay SE quadrangle (Brownfield, 1979) to the east and the coal bed ranges from 6.6 to 17.2 feet (2.0 to 5.2 m) in thickness, the maximum thickness being recorded in an outcrop in sec. 28, T. 8 N., R. 93 W.

The Fort Union [8] coal bed (plate 8) exceeds Reserve Base thickness in a small area in sec. 1, T. 7 N., R. 94 W., where outcrop measurements range from 2.5 to 5.5 feet (0.8 to 1.7 m) in thickness.

The Fort Union [9] coal bed (plate 11) ranges in thickness from 3.0 to 11.5 feet (0.9 to 3.5 m) where measured along the outcrop, attaining its maximum reported thickness in sec. 2, T. 7 N., R. 94 W. Much of the outcrop has burned.

The Fort Union [14] coal bed (plate 8) exceeds Reserve Base thickness in a small area in sec. 1, T. 7 N., R. 94 W., and sec. 36, T. 8 N., R. 94 W. The coal bed had a thickness of 9.0 feet (2.7 m) at both locations where it was measured along the outcrop.

The Fort Union [17] coal bed (plate 11) has been measured at two locations along the outcrop in sec. 31, T. 8 N., R. 93 W., where it ranges in thickness from 5.0 to 6.0 feet (1.5 to 1.8 m).

The Fort Union [19] coal bed (plate 8) ranges in thickness from 1.5 to 6.0 feet (0.5 to 1.8 m) where measured along the outcrop in sec. 31, T. 8 N., R. 93 W. To the east in the Lay SE quadrangle, the Fort Union [19] coal bed was reported to be 5.9 feet (1.8 m) thick at one location along the outcrop.

The Fort Union [20] coal bed (plate 14) has been identified in one drill hole in sec. 25, T. 8 N., R. 94 W., in the northeastern part of the quadrangle where it is 6.0 feet (1.8 m) thick. In the Lay SE quadrangle to the east, the coal bed extends over a large area in the northwesten part of that quadrangle and ranges in thickness from 4.5 to 17.8 feet (1.4 to 5.4 m) where measured in numerous drill holes and outcrop locations. Its maximum reported thickness is along the outcrop in sec. 31, T. 8 N., R. 93 W., and it contains rock a rock parting 5.2 feet (1.6 m) thick at that location.

The Fort Union [22] coal bed (plate 8) exceeds Reserve Base thickness in sec. 4, T. 7 N., R. 94 W. This coal bed, identified along the outcrop at three locations, ranges from 4.5 to 7.0 feet (1.4 to 2.1 m) in thickness.

The Fort Union [40] coal bed (plate 11) was reported to be 6.0 feet (1.8 m) thick at one location along the outcrop in sec. 31, T. 8 N., R. 93 W., in this quadrangle. Just about 100 feet (305 m) outside of the quadrangle boundary in the Lay SE quadrangle to the east, the coal bed has a measured thickness of 5.9 feet (1.8 m).

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

COAL RESOURCES

Data from oil and gas wells, drill holes, mine measured sections, and outcrop measurements (U.S. Geological Survey, 1971; Muller, 1976; Brownfield, 1978; Brownfield and Prost, no date; and U.S. Bureau of Reclamation, no date) were used to construct outcrop, isopach, and structure contour maps of the coal beds in the Lay quadrangle. The source of each indexed data point shown on plate 1 is listed in table 5. 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 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, 7, 11, 13, and 17) and the areal distribution and identified resources maps (plates 6, 9, 12, 16, and 20). 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 greater than Reserve Base thickness that lie less than 3,000 feet (914 m) below the ground surface are included. These criteria differ somewhat from those stated in U.S. Geological Survey Bulletin 1450-B which call for a minimum thickness of 28 inches (70 cm) for bituminous coal and a maximum depth of 1,000 feet (305 m) for both subbituminous and bituminous coal.

Reserve Base and Reserve tonnages for the isopached coal beds are shown on plates 6, 9, 12, 16, and 20, 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 157.92 million short tons (143.27 million metric tons) for the entire quadrangle, including the tonnages for the isolated data points. Reserve Base tonnages in the various development potential categories for surface and subsurface mining methods are shown in tables 2 and 3.

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

COAL DEVELOPMENT POTENTIAL

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

Development Potential for Surface Mining Methods

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

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

where MR = mining ratio

t_o = thickness of overburden in feet

t_c = thickness of coal in feet

rf = recovery factor (85 percent for this quadrangle)

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

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

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

Areas where the coal data is absent or extremely limited between the 200-foot (61-m) overburden line and the outcrop are assigned unknown development potential for surface mining methods. This applies to areas where coal beds 5 feet (1.5 m) or more thick are not known, but may occur, and to those areas influenced by isolated data points. Limited knowledge pertaining to the areal distribution, thickness, depth, and attitude of the coal beds prevents accurate evaluation of development potential in the high, moderate, and low categories. The areas influenced by isolated data points in this quadrangle total approximately 1.30 million short tons (1.18 million metric tons) of coal available for surface mining.

The coal development potential for surface mining methods is shown on plate 21. Of the Federal land areas having a known development potential for surface mining, 83 percent are rated high, 6 percent are rated moderate, and 11 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.

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 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 6.65 million short tons (6.03 million metric tons) of coal available for subsurface mining.

The coal development potential for conventional subsurface mining methods is shown on plate 22. Of the Federal land areas having a known development potential for conventional subsurface mining methods, 99 percent are rated high and 1 percent is rated low. The remaining Federal land within the KRCRA boundary is classified as having unknown development potential for conventional subsurface mining methods.

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

Table 1. -- Chemical analyses of coals in the Lay 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
Sec. 6, T. 6 N., R. 93 W., and sec. 31, T. 7 N., R. 93 W., Wisconsin Mine (Lord, 1913)	Williams Fork Formation, undifferentiated	A	14.65	34.73	44.48	6.14	0.99	-	-	-	-	-	10,564
		C	-	40.69	52.12	7.19	1.16	-	-	-	-	-	12,377
		D	-	43.85	56.15	-	1.25	-	-	-	-	-	13,338
Sec. 28, T. 8 N., R. 93 W., Blevins Mine (Fieldner and others, 1918) from Lay SE quadrangle	Blevins	A	18.94	30.41	44.36	6.29	0.64	-	-	-	-	-	9,722
		C	-	37.52	54.72	7.76	0.79	-	-	-	-	-	11,993
		D	-	40.68	59.32	-	0.86	-	-	-	-	-	13,001
Sec. 31, T. 7 N., R. 93 W., Grassie Mine (George and others, 1937) from Lay SE quadrangle	Fort Union (20)	A	15.9	32.5	46.6	5.0	0.5	-	-	-	-	-	10,140
		C	-	38.6	55.5	5.9	0.6	-	-	-	-	-	12,060
		D	-	41.0	59.0	-	0.6	-	-	-	-	-	12,820
SW¼ sec. 33, T. 7 N., R. 90 W., Hindman Mine (George and others, 1937) from Craig quadrangle	Kimberley	A	20.1	30.4	45.0	4.5	0.6	-	-	-	-	-	9,720
		C	-	38.0	46.4	5.6	0.8	-	-	-	-	-	12,150

Form of Analysis: A, as received
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 Lay quadrangle, Moffat County, Colorado.

Coal Bed or Zone	High Development Potential	Moderate Development Potential	Low Development Potential	Unknown Development Potential	Total
Fort Union {22}	150,000	90,000	50,000	-	290,000
Blevins	14,030,000	4,800,000	2,910,000	-	21,740,000
Fort Union {19}	70,000	20,000	10,000	-	100,000
Fort Union {17}	10,000	20,000	90,000	-	120,000
Fort Union {14}	40,000	10,000	-	-	50,000
Emerson	9,540,000	870,000	370,000	-	10,780,000
Fort Union {40}	10,000	20,000	60,000	-	90,000
Fort Union {20}	250,000	80,000	110,000	-	440,000
Fort Union {9}	310,000	120,000	150,000	-	580,000
Fort Union {8}	30,000	20,000	90,000	-	140,000
Isolated Data Points	-	-	-	1,300,000	1,300,000
Totals	24,440,000	6,050,000	3,840,000	1,300,000	35,630,000

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 Lay quadrangle, Moffat County, Colorado.

Coal Bed or Zone	High Development Potential	Moderate Development Potential	Low Development Potential	Unknown Development Potential	Total
Blevins	46,690,000	460,000	-	-	47,150,000
Fort Union {17}	50,000	-	-	-	50,000
Emerson	59,960,000	1,140,000	-	-	61,110,000
Fort Union {20}	7,150,000	-	-	-	7,150,000
Fort Union {9}	190,000	-	-	-	190,000
Isolated Data Points	-	-	-	6,650,000	6,650,000
Totals	114,040,000	1,600,000	-	6,650,000	122,290,000

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

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

Coal Bed	Source	Location	Thickness	Reserve Base Tonnages Surface	Reserve Base Tonnages Subsurface
WF[3]	McMoran Exploration #15-1 U.S.A.	sec. 15, T. 7 N., R. 94 W.	7.0 ft (2.1 m)	0	0.83
WF[4]	McMoran Exploration #15-1 U.S.A.	sec. 15, T. 7 N., R. 94 W.	7.0 ft (2.1 m)	0	0.83
La[23]	U.S. Smelting, Refining, & Mining Co. #2 McIntyre-Gov't	sec. 3, T. 7 N., R. 94 W.	6.0 ft (1.8 m)	0	0.78
FU[24]	U.S. Smelting, Refining, & Mining Co. #1-31 Federal 8-94	sec. 31, T. 8 N., R. 94 W.	7.0 ft (2.1 m)	0	0.78
FU[25]	U.S. Smelting, Refining, & Mining Co. #1-31 Federal 8-94	sec. 31, T. 8 N., R. 94 W.	6.0 ft (1.8 m)	0	0.67
FU[10]	Brownfield and Prost (no date)	sec. 2, T. 7 N., R. 94 W.	8.0 ft (2.4 m)	0.42	0.19
FU[11]	Brownfield (1978)	sec. 34, T. 8 N., R. 94 W	7.5 ft (2.3 m)	0	0.74
FU[15]	Brownfield and Prost (no date)	sec. 3, T. 7 N., R. 94 W.	9.5 ft (2.9 m)	0.65	0.20
FU]16]	Brownfield (1978)	sec. 35, T. 8 N., R. 94 W.	6.0 ft (1.8 m)	0	0.78
FU[18]	Brownfield and Prost (no date)	sec. 36, T. 8 N., R. 94 W.	15.5 ft (4.7 m)	0.23	0
FU[21]	Brownfield (1978)	sec. 33, T. 8 N., R. 94 W.	6.0 ft (1.8 m)	0	0.85

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

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

Plate 1 Index Number	Source	Data Base
1	Brownfield and Prost, no date, U.S. Geological Survey, in preparation	Measured Section No. 25
2		Measured Section No. 26
3		Measured Section No. 27
4		Measured Section No. 28
5		Mine-Measured Section No. 29 (Waliham Mine)
6	U.S. Geological Survey, 1971, Inactive Coal Prospecting Permit No. Colorado 12705, Ark Land Co.	Measured Section No. 313
7	Brownfield and Prost, no date, U.S. Geological Survey, in preparation	Measured Section
8		Measured Section
9		Measured Section
10		Measured Section No. 14
11		Measured Section
12		Measured Section
13		Measured Section No. 6
14		Measured Section No. 8
15		Measured Section No. 10

Page 1 of 4

Table 5. -- Continued

Plate 1 Index Number	Source	Data Base
16	Brownfield and Prost, no date, U.S. Geological Survey, in preparation	Measured Section No. 11
17	↓	Measured Section
18	↓	Measured Section No. 12
19	↓	Measured Section No. 13
20	↓	Measured Section
21	↓	Measured Section No. 9
22	↓	Measured Section No. 5
23	↓	Measured Section
24	↓	Measured Section
25	↓	Measured Section No. 3
26	↓	Measured Section
27	↓	Measured Section No. 4
28	U.S. Smelting, Refining, & Mining Co.	Oil/gas well No. 1 Federal-McIntyre
29	Brownfield and Prost, no date, U.S. Geological Survey, in preparation	Measured Section
30	↓	Measured Section

Page 2 of 4

Table 5. -- Continued

Plate 1 Index Number	Source	Data Base
31	Brownfield and Prost, no date, U.S. Geological Survey, in preparation	Measured Section
32	U.S. Smelting, Refining, & Mining Co.	Oil/gas well No. 2 McIntyre-Government
33	Brownfield and Prost, no date, U.S. Geological Survey, in preparation	Measured Section
34	↓	Measured Section No. 2
35	↓	Measured Section No. 1
36	↓	Measured Section
37	↓	Measured Section
38	↓	Measured Section
39	↓	Measured Section
40	↓	Measured Section
41	↓	Measured Section
42	McMoran Exploration Co.	Oil/gas well No. 15-1 U.S.A.
43	Brownfield and Prost, no date, U.S. Geological Survey, in preparation	Measured Section
44	↓	Measured Section No. 20
45	↓	Measured Section No. 23
46	↓	Measured Section No. 21

Table 5. -- Continued

Plate 1 Index Number	Source	Data Base
47	Brownfield and Prost, no date, U.S. Geological Survey, in preparation	Measured Section No. 22
48	↓	Measured Section No. 19
49	Muller, 1976, U.S. Geological Survey Open-File Report No. 76-383	Drill hole No. Y-1A
50	Brownfield, 1978, U.S. Geological Survey Open-File Report 78-365	Drill hole No. Lay 2
51	U.S. Smelting, Refining, & Mining Co.	Oil/gas well No. 1-31 Federal 8-94
52	Brownfield, 1978, U.S. Geological Survey Open-File Report 78-365	Drill hole No. Lay 6
53	↓	Drill hole No. Lay 5
54	↓	Drill hole No. Lay 4
55	↓	Drill hole No. Lay 3
56	Brownfield and Prost, no date, U.S. Geological Survey, in preparation	Measured Section No. 18
57	↓	Measured Section No. 15
58	↓	Measured Section No. 16
59	↓	Measured Section No. 17
60	U.S. Bureau of Reclamation, no date, unpublished data	Drill hole No. 4

Page 4 of 4

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