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

[Report includes 44 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 Lay SE 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 Published and unpublished public information was used as the data base for this study.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 Lay SE quadrangle is located in east-central Moffat County in northwestern Colorado approximately 11 miles (18 km) west of the town of Craig vis U.S. Highway 40 and approximately 12 miles (19 km) east of the town of Maybell via U.S. Highway 40. The town of Lay is approximately 0.5 miles (0.8 km) west of the quadrangle. With the exception of several ranches, the quadrangle is unpopulated.

Accessibility

U.S. Highway 40 crosses through the southern part of the Lay SE quadrangle connecting Craig to the east with Lay to the west. An improved light-duty road branches northeastward from U.S. Highway 40 in the southeastern part of the quadrangle and follows Big Gulch to the northeast. Another improved light-duty road follows the Lay Creek valley across the northwestern corner of the quadrangle, connecting Lay to the west and the town of Great Divide to the north. The remainder of the quadrangle is accessible along numerous unimproved dirt roads and trails.

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

Physiography

The Lay SE quadrangle lies in the southern part of the Wyoming Basin physiographic province, as defined by Howard and Williams (1972). The quadrangle lies approximately 12 miles (19 km) northwest of the Williams Fork Mountains and 56 miles (90 km) west of the Continental Divide. The landscape throughout the quadrangle is dominated by moderate slopes, gulches, and narrow valleys. Big Gulch, Lay Creek, and North Fork form moderate to wide valleys across the southern, western, and eastern parts of the quadrangle, respectively.

Altitudes range from over 7,040 feet (2,146 m) in the northeastern corner of the quadrangle to less than 6,160 feet (1,878 m) on Lay Creek along the southwestern edge of the quadrangle.

Big Gulch flows westward across the southern half of the quadrangle and joins Lay Creek in the southwestern part of the quadrangle. North Fork, a tributary of Big Gulch, flows to the south along the eastern half of the quadrangle. Lay Creek flows across the northwestern corner of the quadrangle and drains the northern part of the quadrangle. It joins the Yampa River approximately 8 miles (13 km) west of the quadrangle. All 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 SE 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 SE quadrangle is sagebrush, although small areas in the southeastern corner of the quadrangle and along Lay Creek and North Fork near the north-central edge of the quadrangle are utilized as cropland (U.S. Bureau of Land Management, 1977).

Land Status

The Lay SE quadrangle lies in the northwestern part of the Yampa Known Recoverable Coal Resource Area (KRCRA). Approximately 70 percent of the quadrangle lies within the KRCRA boundary and the Federal government owns the coal rights for approximately two fifths of that area as shown on plate 2. There are no active coal leases within the KRCRA in the Lay SE quadrangle.

GENERAL GEOLOGY

Previous Work

The first geologic description of the general area in which the Lay SE 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). Tweto (1976) compiled a generalized regional map which included this quadrangle. Lithologic and geophysical logs of coal test holes drilled by the U.S. Geological Survey during 1975, 1976 and 1977 were described by Muller (1976) and Brownfield (1976 and 1978). Recent work in the area by Brownfield (1979) is the most comprehensive work on the Lay SE quadrangle.

Stratigraphy

The rock formations cropping out in the Lay SE quadrangle range in age from Late Cretaceous to Miocene and include the coal-bearing Williams Fork, Lance, and Fort Union Formations.

The Iles Formation of Late Cretaceous age does not crop out within the quadrangle, but occurs in the subsurface. It is exposed in the southeastern corner of the Lay quadrangle to the west and in the northeastern corner of the Juniper Hot Springs quadrangle to the southwest (Hancock, 1925; Brownfield and Prost, no date). The Iles Formation ranges in thickness from approximately 1,290 to 1,360 feet (393 to 415 m) where measured in the oil and gas wells drilled in the quadrangle. It consists of massive sandstone interbedded with shaly sandstone, sandy shale, and shale. The "rim rock" sandstone, the basal unit of the Iles Formation, is a light-brown massive sandstone (Hancock, 1925; Konishi, 1959) ranging in thickness from 30 to 60 feet (9 to 18 m). Overlying the "rim rock" sandstone is approximately 1,220 to 1,330 feet (372 to 405 m) of light-colored thin-bedded sandstone interbedded with gray sandy shale (Bass and others, 1955). The uppermost unit of the Iles Formation, the Trout Creek Sandstone Member, is a white fine-grained massive sandstone ranging in thickness from 40 to 60 feet (12 to 18 m).

The Williams Fork Formation of Late Cretaceous age crops out in the southeastern corner of the quadrangle (Brownfield, 1979). Hancock (1925) estimated that this formation is approximately 1,600 feet (488 m) thick. It ranges in thickness from approximately 1,490 to 1,640 feet (454 to 500 m) where measured in the oil and gas wells drilled in the quadrangle. The Williams Fork Formation consists of alternating brown to white, massive fine-grained sandstone, sandy shale, carbonaceous shale, and coal beds (Hancock, 1925). A prominent sandstone known as the Twentymile Sandstone Member is often present in the Williams Fork Formation. Coal beds below the Twentymile Sandstone Member are included in the Middle Coal Group, while coal beds above the member are in the Upper Coal Group (Fenneman and Gale, 1906). However, the Twentymile Sandstone Member was not identified in the oil and gas wells drilled in this quadrangle and Whitley (1962) indicates that it pinches out east of the quadrangle. Hancock (1925) was unable to trace the member past sec. 36, T. 6 N., R. 93 W., in the Horse Gulch quadrangle to the south, but he did infer it to crop out as far as the northwestern margin of the Horse Gulch quadrangle. Because the exact location of the top of the Middle Coal Group is unknown, the authors have arbitrarily designated the 800 feet

(244 m) of coal-bearing rocks above the base of the Williams Fork Formation as the Middle Coal Group, and the remainder of the formation as the Upper Coal Group.

The Lewis Shale of Late Cretaceous age conformably overlies the Williams Fork Formation and crops out in the south-central part of the Lay SE quadrangle (Brownfield, 1979). It consists of dark-gray to bluish homogeneous marine shale interbedded with a few sandstone units (Hancock, 1925; Bass and others, 1955). The formation ranges in thickness from approximately 2,090 to 2,200 feet (637 to 671 m) where measured in the oil and gas wells drilled in the quadrangle.

The Fox Hills Sandstone of Late Cretaceous age intertongues with the underlying Lewis Shale and 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 130 to 155 feet (40 to 47 m) thick where measured in the oil and gas wells drilled in the quadrangle. The outcrop of the Fox Hills Sandstone was not mapped by Brownfield (1979).

The Lance Formation of Late Cretaceous age conformably overlies the Fox Hills Sandstone and crops out in the south-central and northern third of the quadrangle (Brownfield, 1979). The formation consists of light-buff and light-tan, soft fine-grained sandstone, gray shale, and coal beds (Bass and others, 1955) and is approximately 650 feet (198 m) thick where penetrated by the Pan American Petroleum Corporation No. 1 Rushmore well located in sec. 26, T. 8 N., R. 93 W. (Haun, 1961). In the Iron Springs quadrangle to the north, the Lance formation ranges from approximately 520 to 740 feet (158 to 226 m) thick.

The Fort Union Formation of Paleocene age unconformably overlies the Lance Formation and crops out in the northern part of the quadrangle (Brownfield, 1979). The total thickness of this formation is unknown in this quadrangle, but it ranges from approximately 1,000 to 1,200 feet (305 to 366 m) thick in adjacent quadrangles. It consists of a basal conglomerate and interbedded brown sandstone, gray shale, and coal beds (Bass and others, 1955). Several coal beds in the Fort Union Formation, including the Emerson and Blevins, have been identified in the Lay SE quadrangle.

The Wasatch Formation of Eocene age unconformably overlies the Fort Union Formation and crops out in the northwestern corner of the quadrangle (Brownfield, 1979). Information on the thickness of this formation is not available in this quadrangle, but in the adjacent Lay quadrangle to the west, a hole drilled through the Wasatch Formation in sec. 31, T. 8 N., R. 94 W., penetrated the the Fort Union Formation approximately 1,000 feet (305 m) below the surface. 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, 1979). 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 stream valleys of Lay Creek, North Fork, and Big Gulch (Brownfield, 1979).

The Cretaceous formations cropping out in the Lay SE 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 SE 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 sandstones of the Iles and Williams Fork Formations were deposited in shallow-marine and near-shore marine environments as the shoreline fluctuated. Coal beds of limited areal extent, such as those in the Middle and Upper Coal Groups, were generally deposited in environments associated with fluvial systems, such as back-levee and coastal plain swamps, interchannel basin areas, and abandoned channels (Konishi, 1959; Kucera, 1959).

Deposition of the Lewis Shale marked a 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 until a regional uplift west of the Yampa Basin area caused a regression of the sea and ended the deposition of the Lewis Shale in the 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 estuarine, marsh, lagoonal, and coastal swamp environment resulted in deposits of carbonaceous shales, mudstones, 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 coals that 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 57 miles (92 km) east of the Lay SE quadrangle, and on the southwest by the Axial Basin anticline, approximately 10 miles (16 km) south of the quadrangle (Tweto, 1976).

Dips of the coal beds in this quadrangle are quite variable, ranging from approximately 5° to 11° north-northwest in the northern part of the quadrangle to about 5° northeast and 3° southwest in the central part of the quadrangle. In the extreme southwest corner of the quadrangle, dips range from 14° to 18° to the east-southeast.

The west-northwest-trending Lay syncline crosses the center of the quadrangle and the Lay Creek anticline generally parallels the syncline slightly to the south. A northwest-trending fault cuts across the axis of the anticline in the center of the quadrangle (Bergin, 1959). The northern part of the northwest-trending Round Bottom syncline extends into the southeastern part of the quadrangle (Sears, 1924). A fault, north of the syncline runs parallel to the axis (Brownfield, 1979; Bergin, 1959; and Tweto, 1976). Three other faults have been mapped in the southwest corner of the quadrangle (Tweto, 1976; Brownfield, 1979). These generally trend east-west. The northern block of the southwesternmost of these faults is apparently downthrown, which has exposed the Williams Fork Formation and the coal beds associated with it. Bergin (1959) inferred a northwest-trending fault at the southwestern edge of the quadrangle.

The structure contour maps of the isopached coal beds in the northern part of the quadrangle are based on a regional structure map of the Lance-Fort Union contact by Brownfield (1979), while those in the southern part of the quadrangle are based on a regional structure map of the top of the Trout Creek Sandstone Member by Hancock (1925). It is assumed that the structure of the coal beds duplicates these structures. 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 the Lay SE quadrangle. The coal beds are generally thin, lenticular, and limited in areal extent, although several beds in the Fort Union Formation tend to persist over large areas and extend into adjacent quadrangles. Coal beds exceeding Reserve Base thickness (5.0 feet or 1.5 meters) that are not formally named have been given with bracketed numbers for identification purposes. In instances where coal beds greater than 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 exceed 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 Fort Union [20] and Blevins coal beds. Chemical analyses were not available for any Williams Fork or Lance Formation coals. However, the analyses shown in the table are believed to be representative of all of these coals. In general, chemical analyses indicate that the coals in the Middle and Upper Coal Groups 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 Specificiation D 388-77 (American Society for Testing and Materials, 1977).

Coal Beds of the Williams Fork Formation

Coal beds in the Williams Fork Formation are divided into the Middle and Upper Coal Groups (Fenneman and Gale, 1906). The Middle Coal Group includes coal beds in the lower 800 feet (244 m) of the Williams Fork Formation, while the Upper Coal Group includes coal beds in the upper coal-bearing zone in the formation. Coal beds in these two groups have been identified in oil and gas test wells drilled in the central part of the quadrangle. Two northwest-trending faults cut the coal beds in this area.

Middle Coal Group

The Middle Coal Group contains many relatively thin coal beds and only four of them can be correlated between the oil and gas test wells with enough accuracy to enable the construction of isopach maps for the individual coal beds in this coal group. Numerous other coal beds that appear to be thin, lenticular, discontinuous, and cannot be correlated with accuracy, have been placed into two zones and the cumulative thickness of the coals in each zone have been isopached. An additional five coal beds, the MG[8] (i.e., Middle Coal Group, coal bed [8]), MG[11], NG[12], MG[14], and MG[15], that could not be correlated with isopached coal beds and zones, were each identified at one location only and were treated as isolated data points.

The four isopached coal beds, the MG[3], MG[5], MG[6], and MG[9], range in measured thicknesses from 3.0 to 11.0 feet (0.9 to 3.4 m) and are not known contain rock partings. Isopach maps of these coal beds are shown on plates 4, 8, 12, and 16, respectively.

Individual coal beds in the Middle Coal Group zones [10] and [13] thicken, thin, and split over short distances, ranging in thickness from less than 5.0 feet (1.5 m) to more than 20 feet (6.1 m). Cumulative coal thicknesses in these zones range from 10.0 to 29.0 feet (3.0 to 8.8 m) and contain rock partings totalling from 5.0 to 15.0 feet (1.5 to 4.6 m) in thickness as shown on plates 20 and 24.

Another coal bed that occurs within the Middle Coal Group, the Peacock coal bed (plate 4), has not been identified in the Lay SE quadrangle, but is believed to extend into the southeast corner of this quadrangle based on the projection of coal-bed measurements from the Lay quadrangle to the west, the Horse Gulch quadrangle to the south, and the Juniper Hot Springs quadrangle to the southwest. Where the Peacock coal bed has been projected into this quadrangle, it is inferred to range from at least 11 to 16 feet (3.4 to 4.9 m) in thickness. In the Lay quadrangle, the coal bed ranges from 11.5 to 14.0 feet (3.5 to 4.3 m) where measured along the outcrop; in the Horse Gulch quadrangle, the coal bed ranges in thickness from 2.5 to 16.0 feet (0.8 to 4.9 m), thinning to the southwest; and the coal bed is 11.7 to 17.0 feet (3.6 to 5.2 m) thick where measured in outcrops and a drill hole in the Juniper Hot Springs quadrangle.

Upper Coal Group

Similar to the coal beds in the Middle Coal Group, the coal beds in the Upper Coal Group are numerous, relatively thin, and appear to be lenticular and of limited areal extent. Only three of the coal beds, the UG[16], UG[18] and UG[19], could be correlated between the oil and gas test wells drilled in the central part of the quadrangle and have been isopached. Another coal bed, the UG[17], could not be correlated with other coal beds and has been treated as an isolated data points.

Two of the coal beds, the UG[18] and UG[19], are of limited areal extent and range in measured thicknesses from 3.0 to 7.0 feet (0.9 to 2.1 m) as shown on plates 32 and 36, respectively. The UG[16] coal bed (plate 28) is more extensive and ranges in thickness from 2.0 to 13.0 feet (0.6 to 4.0 m), attaining its maximum measured thickness in sec. 21, T. 7 N., R. 93 W. Rock partings occur locally in the UG[16] coal bed and range from 4.0 to 7.0 feet (1.2 to 2.1 m) thick.

Undifferentiated Williams Fork Coal Beds

Four coal beds within the Williams Fork Formation, the Williams Fork [3], [4], [5], and [6] coal beds, could not be located in the stratigraphic section with enough accuracy to place the coal beds within a specific coal group. Each of all four coal beds was identified at only one location and is treated as an isolated data point. Also, the Williams Fork [3] and [4] coal beds occur on non-Federal land.

Coal Beds of the Lance Formation

Outcrops of several coal beds in the Lance Formation have been identified near the central part of the quadrangle, but none of the outcrop measurements exceed Reserve Base thickness. One Lance coal bed greater than Reserve Base thicknes, the Lance [37], was penetrated by an oil and gas test well drilled in the NW 1/4 SE 1/4 sec. 26, T. 8 N., R. 93 W., and has been treated as an isolated data point.

Coal Beds of the Fort Union Formation

Numerous coal beds in the Fort Union Formation have been identified in outcrops and drill holes throughout the northern part of the quadrangle. Although the Fort Union [20], Emerson, and Blevins coal beds are known to be thick and persist over large areas, the other eight Fort Union coal beds that have been isopached tend to be thin, lenticular, and of limited areal extent as shown on plates 8, 12, 16, 20, 24, and 28. These minor coal beds range in thickness from 1.0 to 9.8 feet (0.3 to 3.0 m) where measured in outcrops and drill holes. Some of the coal beds contain local rock partings that range in thickness from 0.3 to 0.7 feet (0.1 to 0.2 m). Two small coal beds, Fort Union [19] and [40], extend into the Lay quadrangle to the west. Also, four other coal beds, the FU[24], FU[28], FU[30], and FU[42], were each identified at one location only and have been treated as isolated data points.

Fort Union [20] Coal Bed

The Fort Union [20] coal bed (plate 40) has been identified at many locations along the outcrop and in drill holes in the northwestern corner of the quadrangle where measured thicknesses range from 4.5 to 17.8 feet (1.4 to 5.4 m). The maximum reported thickness occurs in sec. 31, T. 8 N., R. 93 W., and the coal bed contains a rock parting of 5.2 feet (1.6 m) at this location. The coal bed extends into the Lay quadrangle to the west and is 6.0 feet (1.8 m) thick where penetrated by a single drill hole in sec. 25, T. 8 N., R. 94 W. To the north in the Iron Springs quadrangle, the coal bed was identified in one drill hole and was reported to be 7.0 feet (2.1 m) thick at that location.

Emerson Coal Bed

The Emerson coal bed (Brownfield, 1979) extends over a wide area in the northern part of the quadrangle as shown on plate 32. It has also been identified in numerous outcrops and drill holes where measured thicknesses range from 3.3 to 28.9 feet (1.0 to 8.8 m), the maximum reported thickness occurring in sec. 31, T. 8 N., R. 93 W. Rock partings ranging from 0.3 to 6.0 feet (0.1 to 1.8 m) have been reported at several locations. This coal bed extends into the adjacent quadrangles to the west and north. In the Lay quadrangle to the west, the coal bed ranges from 4.0 to 26.0 feet (1.2 to 7.9 m) thick where measured along the outcrop and in drill holes. Its maximum thickness was recorded in a drill hole in sec. 25, T. 8 N., R. 94 W. Drill hole data in the Iron Springs quadrangle indicate that the coal bed ranges in thickness from 5.0 to 22.0 feet (1.5 to 6.7 m) in that quadrangle.

Blevins Coal Bed

The Blevins coal bed (plate 36) ranges from 6.6 to 17.2 feet (2.0 to 5.2 m) in thickness where measured along the outcrop and in coal test holes in the northwestern part of the quadrangle. Rock partings occur locally and range from 0.3 to 1.0 feet (0.1 to 0.9 m) in thickness. In the Lay quadrangle to the west, the Blevins coal bed ranges from 2.0 to

15.5 feet (0.6 to 4.7 m) thick, the maximum thickness being recorded in a drill hole that penetrated the coal bed in sec. 25, T. 8 N., R. 94 W. In the Iron Springs quadrangle to the north, drill-hole data indicate that the coal bed ranges in thickness from 2.0 to at least 12.0 feet (0.6 to 3.7 m), the maximum reported thickness occurring in sec. 12, T. 8 N., R. 93 W.

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. 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 are listed in table 4.

COAL RESOURCES

Data from drill holes, mine measured sections, and outcrop measurements (Brownfield, 1976, 1978 and 1979; Muller, 1976; U.S. Bureau of Reclamation, no date), as well as data from oil and gas wells were used to construct outcrop, isopach, and structure contour maps of the coal beds in the Lay SE quadrangle. The source of each indexed data point shown on plate 1 is listed in table 5.

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 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 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 364.93 million short tons (331.06 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 43. Of the Federal land areas having a known development potential for surface mining, 86 percent are rated high, 5 percent are rated moderate, and 9 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 12.14 million short tons (11.01 million metric tons) of coal available for subsurface mining.

The coal development potential for conventional subsurface mining methods is shown on plate 44. Of the Federal land areas having a known development potential for conventional subsurface mining methods, 59 percent are rated high, 33 percent are rated moderate, and 8 percent are rated low. The remaining Federal land within the KRCRA boundary is classified as having unknown development potential for conventional subsurface mining methods.

Coal beds of Reserve Base thickness dipping in excess of 15° are not known to occur on Federal lands within the KRCRA boundary in this quadrangle. Therefore, all of the Federal land areas have been rated as having unknown development potential for in-situ mining methods.

Table 1. -- Chemical analyses of coals in the Lay SE 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 SW¼ sec. 31, T. 6 N., R. 91 W., Ratcliff Mine (George and others, 1937) from Round Bottom quadrangle	Middle Coal Group undifferentiated	A	13.5	35.5	47.8	3.5	0.3	-	-	-	-	-	11,010
		C	-	41.0	55.3	3.7	0.4	-	-	-	-	-	12,720
NW¼ SW¼ sec. 29, T. 6 N., R. 91 W., Haubrich Mine (George and others, 1937) from Round Bottom quadrangle	Upper Coal Group undifferentiated	A	17.8	30.4	48.0	3.8	0.5	-	-	-	-	-	10,340
		C	-	37.0	58.4	4.6	0.6	-	-	-	-	-	12,570
Sec. 32, T. 7 N., R. 90 W., Kimberley Mine (George and others, 1937) from Craig quadrangle	Lance Formation Kimberley	A	22.1	31.6	42.0	4.3	0.7	-	-	-	-	-	9,300
		C	-	40.6	53.8	5.6	0.8	-	-	-	-	-	11,930
Sec. 31, T. 7 N., R. 93 W., Grassie Mine (George and others, 1937)	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
Sec. 28, T. 8 N., R. 93 W., Blevins Mine (Fieldner and others, (1918)	Blevins	A	18.94	30.41	44.36	6.29	0.64	-	-	-	-	-	9,722
		C	-	40.68	59.32	-	0.86	-	-	-	-	-	13,001

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

Coal Bed or Zone	High Development Potential	Moderate Development Potential	Low Development Potential	Unknown Development Potential	Total
Blevins	13,680,000	2,850,000	3,110,000	-	19,640,000
Emerson	21,700,000	2,850,000	1,900,000	-	26,450,000
Fort Union {43}	100,000	40,000	260,000	-	400,000
Fort Union {40}	10,000	10,000	30,000	-	50,000
Fort Union {38}	50,000	10,000	-	-	60,000
Fort Union {29}	410,000	140,000	1,950,000	-	2,500,000
Fort Union {27}	70,000	40,000	200,000	-	310,000
Fort Union {26}	90,000	60,000	490,000	-	640,000
Fort Union {25}	160,000	70,000	400,000	-	630,000
Fort Union {20}	2,170,000	820,000	1,240,000	-	4,230,000
Fort Union {19}	20,000	10,000	20,000	-	50,000
Isolated Data Points	-	-	-	1,300,000	1,300,000
Totals	38,460,000	6,900,000	9,600,000	1,300,000	56,260,000

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 SE quadrangle, Moffat County, Colorado.

Coal Bed or Zone	High Development Potential	Moderate Development Potential	Low Development Potential	Unknown Development Potential	Total
Blevins	6,760,000	-	-	-	6,760,000
Emerson	85,250,000	370,000	-	-	85,620,000
Fort Union {43}	130,000	-	-	-	130,000
Fort Union {29}	330,000	-	-	-	330,000
Fort Union {27}	20,000	-	-	-	20,000
Fort Union {25}	510,000	-	-	-	510,000
Fort Union {20}	15,270,000	-	-	-	15,270,000
UG {19}	830,000	1,120,000	-	-	1,950,000
UG {18}	30,000	2,820,000	370,000	-	3,220,000
UG {16}	-	49,650,000	11,850,000	-	61,500,000
Peacock	30,000	-	-	-	30,000
MG {13}	-	50,070,000	36,060,000	-	86,130,000
MG {10}	-	12,120,000	13,310,000	-	25,430,000
MG {9}	-	400,000	5,610,000	-	6,010,000
MG {6}	-	-	370,000	-	370,000
MG {5}	-	-	2,450,000	-	2,450,000
MG {3}	-	-	800,000	-	800,000
Isolated Data Points	-	-	-	12,140,000	12,140,000
Totals	109,160,000	116,550,000	70,820,000	12,140,000	308,670,000

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	Subsurface
MG[8]	Tesoro Petroleum Corp. #2-21 Culverwell	sec. 21, T. 7 N., R. 93 W.	7.0 ft (2.1 m)	0	0.37
MG[11]	Tesoro Petroleum Corp., #2-21 Culverwell	sec. 21, T. 7 N., R. 93 W.	6.0 ft (1.8 m)	0	0.32
MG[12]	Intex Oil. Co. #1-15 Gamma	sec. 15, T. 7 N., R. 93 W.	6.0 ft (1.8 m)	0	0.64
MG[14]	Fuelco-Berry Holding Co., #1 Big Gulch Unit	sec. 11, T. 7 N., R. 93 W.	7.0 ft (2.1 m)	0	1.52
MG[15]	Tesoro Petroleum Corp., #2-22 Beta State	sec. 22, T. 7 N., R. 93 W.	6.0 ft (1.8 m)	0	0.15
UG[17]	Intex Oil Co. #1-15 Gamma	sec. 15, T. 7 N., R. 93 W.	6.0 ft (1.8 m)	0	0.64
Williams Fork [5]	Muller (1976)	sec. 32, T. 7 N., R. 93 W.	8.0 ft (2.4 m)	0	0.86
Williams Fork [6]	Muller (1976)	sec. 32, T. 7 N., R. 93 W.	8.0 ft (2.4 m)	0.06	0.80
Lance [37]	Pan American Corp. #1-Rushmore USA	sec. 26, T. 8 N., R. 93 W.	8.0 ft (2.4 m)	0	1.95
Fort Union [24]	Brownfield (1979)	sec. 32, T. 8 N., R. 93 W.	6.0 ft (1.8 m)	0.53	0

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

Table 4.--Continued

Coal Bed	Source	Location	Thickness	Reserve Base Tonnages Surface	Subsurface
Fort Union [28]	Muller (1976)	sec. 26, T. 8 N., R. 93 W.	9.0 ft (2.7 m)	0	2.11
Fort Union [30]	Brownfield (1979)	sec. 31, T. 8 N., R. 92 W.	5.7 ft (1.7 m)	0.71	0
Fort Union [42]	Brownfield (1978)	sec. 25, T. 8 N., R. 93 W.	11.8 ft (3.6 m)	0	2.78

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

Plate 1 Index Number	Source	Data Base
1	Pan American Petroleum Corp.	Oil/gas well No. 1 Roland McLean
2	Brownfield, 1979, U.S. Geological Survey Open-File Report 79-1680	Measured Section No. 45
3		Measured Section No. 44
4	Carter Oil Corp.	Oil/gas well No. 1 Annie P. Olson
5	Fuelco-Berry Holding Co.	Oil/gas well No. 1 Big Gulch Unit
6	Intex Oil Co.	Oil/gas well No. 1-15 Gamma
7	Tesoro Petroleum Corp.	Oil/gas well No. 2-15 Big Gulch-State
8	Intex Oil Co.	Oil/gas well No. 1-15 Culverwell
9	↓	Oil/gas well No. 2-16 Alpha-State
10	↓	Oil/gas well No. 1-16 Alpha-State
11	Tesoro Petroleum Corp.	Oil/gas well No. 2-21 Culverwell
12	Intex Oil Co.	Oil/gas well No. 1-22 Beta-State
13	Tesoro Petroleum Corp.	Oil/gas well No. 2-22 Beta-State
14	Intex Oil Co.	Oil/gas well No. 1-22 Culverwell

Table 5. -- Continued

Plate 1 Index Number	Source	Data Base
15	Brownfield, 1979, U.S. Geological Survey Open-File Report 79-1680	Measured Section No. 48
16	↓	Measured Section No. 47
17	Muller, 1976, U.S. Geological Survey Open-File Report No. 76-383	Drill hole No. Y-5
18	Brownfield, 1979, U.S. Geological Survey Open-File Report 79-1680	Measured Section No. 42
19	↓	Measured Section No. 41
20	↓	Measured Section No. 40
21	Brownfield, 1978, U.S. Geological Survey Open-File Report No. 78-365	Drill hole No. LSE-5
22	↓	Drill hole No. LSE-9
23	Brownfield, 1979, U.S. Geological Survey Open-File Report 79-1680	Measured Section No. 38
24	Brownfield, 1976, U.S. Geological Survey Open-File Report No. 76-817	Drill hole No. Y-27-LS
25	Brownfield, 1979, U.S. Geological Survey Open-File Report 79-1680	Measured Section No. 36
26	↓	Measured Section No. 39
27	↓	Measured Section No. 37
28	U.S. Bureau of Reclamation, (no date), unpublished data	Drill hole No. 1
29	Muller, 1976, U.S. Geological Survey Open-File Report No. 76-383	Drill hole No. Y-6

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Table 5. -- Continued

Plate 1 Index Number	Source	Data Base
30	Pan American Petroleum Corp.	Oil/gas well No. 1 Rushmore USA
31	Brownfield, 1979, U.S. Geological Survey Open-File Report 79-1680	Measured Section No. 28
32	↓	Measured Section No. 27
33	↓	Measured Section No. 26
34	↓	Measured Section No. 30
35	↓	Measured Section No. 29
36	↓	Measured Section No. 31
37	↓	Measured Section No. 17
38	↓	Measured Section No. 16
39	↓	Measured Section No. 18
40	U.S. Bureau of Reclamation, (no date), unpublished data	Drill hole No. 2
41	Brownfield, 1979, U.S. Geological Survey Open-File Report 79-1680	Measured Section No. 21
42	↓	Measured Section No. 23
43	Brownfield, 1976, U.S. Geological Survey Open-File Report No. 76-817	Drill hole No. Y-8-LS
44	Brownfield, 1979, U.S. Geological Survey Open-File Report 79-1680	Measured Section No. 24
45	↓	Measured Section No. 25
46	↓	Measured Section No. 22
47	↓	Measured Section No. 20

Table 5. -- Continued

Plate 1 Index Number	Source	Data Base
48	Brownfield, 1979, U.S. Geological Survey Open-File Report 79-1680	Measured Section No. 19
49	Brownfield, 1978, U.S. Geological Survey Open-File Report No. 78-365	Drill hole No. LSE-4
50	U.S. Bureau of Reclamation (no date), unpublished data	Drill hole No. 3
51	Brownfield, 1979, U.S. Geological Survey Open-File Report 79-1680	Mine-Measured Section No. 13 (Blivin Mine)
52	↓	Measured Section No. 12
53	↓	Measured Section No. 15
54	↓	Measured Section No. 14
55	Brownfield, 1976, U.S. Geological Survey Open-File Report No. 76-817	Drill hole No. Y-7-LS
56	Brownfield, 1979, U.S. Geological Survey Open-File Report 79-1680	Measured Section No. 11
57	Brownfield, 1978, U.S. Geological Survey Open-File Report No. 78-365	Drill hole No. LSE-3
58	↓	Drill hole No. LSE-2
59	Brownfield, 1979, U.S. Geological Survey Open-File Report 79-1680	Measured Section No. 8
60	↓	Measured Section No. 10
61	Brownfield, 1978, U.S. Geological Survey Open-File Report No. 78-365	Drill hole No. LSE-1
62	↓	Drill hole No. LSE-12
63	Brownfield, 1976, U.S. Geological Survey Open-File Report No. 76-817	Drill hole No. Y-11-LS

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Table 5. -- Continued

Plate 1 Index Number	Source	Data Base
64	Brownfield, 1979, U.S. Geological Survey Open-File Report 79-1680	Measured Section No. 4
65	〃	Measured Section No. 1
66	〃	Measured Section No. 3
67	〃	Measured Section No. 2
68	〃	Measured Section No. 9
69	〃	Measured Section No. 7
70	〃	Measured Section No. 6
71	〃	Measured Section No. 5
72	〃	Measured Section No. 32
73	〃	Measured Section No. 34
74	〃	Measured Section No. 31
75	〃	Measured Section No. 33

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