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

(Report includes 12 plates)

Prepared for:

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GEOLOGICAL SURVEY

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

CONTENTS

ILLUSTRATIONS

TABLES

INTRODUCTION

Purpose

This text is to be used in conjunction with Coal Resource Occurrence and Coal Development Potential Maps of the Quaker Mountain 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. Published and unpublished public information was used as the data base for this study. No new drilling or field mapping was done as part of this study, nor was any confidential data used.

Location

The Quaker Mountain 7½-minute quadrangle is located in central Routt County in northwestern Colorado, approximately 18 mi (29 km) northwest of Steamboat Springs and 16 mi (26 km) northeast of Craig, Colorado. With the exception of a few ranches, the area within the quadrangle is unpopulated.

Accessibility

U.S. Highway 40 passes approximately 7 mi (11 km) south of the Quaker Mountain quadrangle. The southern half of the quadrangle is accessible along unimproved roads which head northward from U.S. Highway 40. An improved road leaves U.S. Highway 40 at Hayden and runs northward into the southwest portion of the quadrangle. Several unimproved roads and jeep trails provide access to the southwestern, central, and northern portions of the quadrangle.

Railway service for the Quaker Mountain quadrangle is provided by the Denver and Rio Grande Western Railroad from Denver to the railhead at Craig. The route passes some 7 mi (11 km) south of the quadrangle, and serves as the major transportation route for coal shipped east from northwestern Colorado.

Physiography

The Quaker Mountain quadrangle lies on the eastern edge of the Colorado Plateau, approximately 15 mi (24 km) northeast of the Williams Fork Mountains and approximately 20 mi (32 km) southwest of the Park Range, which forms the Continental Divide in northwestern Colorado.

Approximately 2,700 ft (823 m) of relief is present in the Quaker Mountain quadrangle, from an altitude of 9,330 ft (2,844 m) on Quaker Mountain near the center of the quadrangle, to slightly less than 6,600 ft (2,012 m) in the creek valleys in the southwestern corner of the quadrangle.

The landscape within the quadrangle is characterized by hill and valley topography. In the southern and northeastern portions of the quadrangle, gentle slopes and wider stream valleys are dominant, while in the central portion of the quadrangle, the resistant remnants of igneous dikes and sills form the prominent topographic highs of Quaker Mountain and Agner Mountain.

Quaker Mountain and Agner Mountain are dissected by the steep-sided canyon of Elkhead Creek, which, along with its tributaries, serves as the main drainage system for the quadrangle. Elkhead Creek flows southwest into the Yampa River.

Climate and Vegetation

The climate of northwest Colorado is semi-arid. The Sierra Nevada Mountains block much of the Pacific moisture, and moist air from the Gulf of Mexico is blocked by the Rocky Mountains. Clear, sunny days prevail in the Quaker Mountain area, with daily temperatures varying from 0° to 35° F (-18°

to 2° C) in January to 42° to 80° F (6° to 27° C) in July. Annual precipitation in the area averages approximately 15 in. (38 cm), most of which occurs as snowfall during the winter months.

Open to very-dense stands of deciduous trees, often relatively small in size, occur at higher elevations in the Quaker Mountain quadrangle where moisture and soil depth are adequate. At lower elevations and in the northeastern quarter of the quadrangle, the typical mountain shrubbery ranges from 2 to 8 ft (0.6 to 2.4 m) in height.

Land Status

The Quaker Mountain quadrangle lies along the northeastern edge of the Yampa Known Recoverable Coal Resource Area. Most of the quadrangle, except a small area in the southeastern portion, lies outside the KRCRA; of this small area (approximately 10 percent of the quadrangle), approximately 30 percent is open Federal coal land. The coal ownership status is shown on plate 2. No outstanding Federal coal leases, prospecting permits, licenses, or preference right lease applications are located within the quadrangle.

GENERAL GEOLOGY

Previous Work

The first geologic description of the general area of the Quaker Mountain quadrangle 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 1886-1905, including papers by Chisholm (1887), Storrs (1902), Hewett (1889), Hills (1893), and Parsons and Liddell (1903). Fenneman and Gale (1906) published a geologic report on the Yampa Coal Field including a description of the geology and occurrence of coal in the Quaker Mountain quadrangle. In 1955, Bass, Eby and Campbell expanded Fenneman and Gale's work in their report on the geology and mineral fuels of parts of Routt and Moffat Counties. This report by Bass, Eby and Campbell remains the most comprehensive work on the area and forms the basis from which this study is taken.

Stratigraphy

The majority of the rocks which crop out in the Quaker Mountain quadrangle, are Upper Cretaceous in age and include the coal-bearing Williams Fork Formation of the Mesaverde Group.

The Upper Cretaceous-age Mesaverde Group, the oldest stratigraphic unit exposed in the Quaker Mountain area, contains two members, the Iles Formation and the overlying Williams Fork Formation. The top of the 1,500-ft-thick (457 m) Iles Formation is inferred to come within 40 ft (12 m) of the surface in the southeast corner of the quadrangle. It consists of sandstone beds interbedded with gray sandy shales. The major sandstone beds of the Iles Formation are, in ascending order, the Tow Creek Sandstone Member, the base of which forms the boundary between the Iles and the Mancos Shale; a recognizable double-ledge-forming sandstone approximately 400 ft (122 m) above the base of the Iles; and the Trout Creek Sandstone Member, which forms the contact between the Iles Formation and the overlying Williams Fork Formation. Coal beds are found beginning approximately 400 ft (122 m) above the base of the Iles and extending up to the Trout Creek Sandstone Member. These coal beds, which are not exposed in the Quaker Mountain quadrangle, make up the Lower Coal Group of the Mesaverde Group (Fenneman and Gale, 1906).

The Williams Fork Formation, which is exposed in the southeast corner of the quadrangle, conformably overlies the Iles Formation. The Williams Fork Formation, which is approximately 900 ft (274 m) thick in the Quaker Mountain quadrangle, is divided into four sequences in the Quaker Mountain area: a lower coal-bearing sequence; a marine shale sequence; the Twentymile Sandstone Member; and an upper marine shaly sandstone sequence (Ryer, 1977). Only the lower coal-bearing sequence and the marine shale sequence of the Williams Fork Formation are exposed in the Quaker Mountain quadrangle.

The lower coal-bearing sequence has been designated by Fenneman and Gale (1906) as the Middle Coal Group of the Mesaverde Group, and contains approximately 300 ft (91 m) if interbedded siltstone, silty sandstone, very fine grained sandstone, and coal. Two major coal beds, the Wolf Creek and the Wadge, are found in the Middle Group; they are stratigraphically located approximately 40 to 50 ft (12 to 15 m) and 200 ft (61 m), respectively, above the top of the Trout Creek Sandstone Member. The marine shale sequence, which is approximately 600 ft (183 m) thick in the Quaker Mountain area, is composed of dark-gray to brown shale and siltstone. The marine shale sequence becomes more sandy toward the top of the unit and eventually grades into the overlying Twentymile Sandstone Member to the south of the quadrangle.

The Upper Cretaceous-age Lewis Shale conformably overlies the Williams Fork Formation in the Quaker Mountain area. It consists of approximately 1,700 ft (518 m) of homogeneous, dark-gray to bluish marine shale, and is not coal-bearing. The Lance Formation, which is also Upper Cretaceous in age, conformably overlies the Lewis Shale in the north central and northwestern portions of the quadrangle. In the Quaker Mountain quadrangle, the Lance Formation consists of approximately 2,000 ft (610 m) of interbedded gray shale, light-buff to tan friable, fine-grained sandstone, and a few local coal beds.

About 600 ft (183 m) of Tertiary-age Wasatch Formation rests unconformably on the Lance Formation in the northwestern portion of the quadrangle. The Wasatch Formation consists of fluvial arkosic sandstone, mudstone, and conglomerate, and does not contain any known coal beds in the quadrangle area.

The coal-bearing rocks exposed in the Quaker Mountain 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 marine, near-shore marine, and non-marine sediments in the Quaker Mountain area. The interbedded sandstones, shales, and coals of the Iles and Williams Fork Formations were deposited as a result of minor changes in position of the shoreline. The major environments present in the Yampa KRCRA during deposition of the Iles and Williams Fork Formations were near-shore marine, littoral, brackish and fresh water, and fluvial systems.

The coals with wide areal extent were deposited near the seaward margins of non-marine environments, probably in large brackish water lagoons or swamps. The slow migration of this depositional environment is responsible for the wide areal extent of the Wadge and Wolf Creek 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. The major sandstones of the Iles and Williams Fork Formations, such as the Trout Creek Sandstone Member, were deposited in shallow marine and near-shore environments. Subsequent deposition of the marine Lewis Shale marked a large landward movement of the sea, and the end of near-shore and continental sedimentation of the Mesaverde Group in the Quaker Mountain area.

Intrusive Rocks

All of the sedimentary formations in the Quaker Mountain quadrangle have been intruded by Upper Tertiary sills and dikes of intermediate and basaltic composition. Quaker Mountain and Agner Mountain contain thick sills of latite-trachite and olivine basalt, respectively, which have intruded the Lance Formation (Bass, Eby, and Campbell, 1955). Two other igneous features of considerable extent have been mapped in the quadrangle by Tweto (1976). A dike extends from the Dry Fork of Elkhead Creek in the southwest quarter of section 19, T. 8 N., R. 87 W., northeastward to Quaker Mountain, and a large sill runs along Elkhead Creek northwest of Quaker Mountain.

Structure

The Quaker Mountain quadrangle lies on the northwestern edge of the southern extension of the Washakie/Sand Wash Basin of south-central Wyoming. The axis of the basin passes approximately 13 mi (21 km) southwest of the Quaker Mountain quadrangle. The Cretaceous strata in the quadrangle dip 10° to 20° toward the west, while the Tertiary-age Wasatch Formation is inferred to display only a slight westward dip as a result of its unconformable deposition on the already-tilted Cretaceous-age sedimentary rocks, and as a result of the continuing subsidence of the Washakie/Sand Wash Basin.

Structure contour maps of the Wadge and Wolf Creek coal beds (plates 5 and 9, respectively) are based on a structure contour map drawn on the top of the Trout Creek Sandstone Member by Bass, Eby, and Campbell (1955), which has been modified to reflect coal bed elevations derived from the information presented on plates 1 and 3. Drill holes from which respective coal bed altitude could not be determined are not shown on the structure maps or on their derivative maps.

COAL GEOLOGY

The Lance Formation contains thin coal beds in the quadrangle. These coals are outside of the KRCRA and are of no economic importance. Two major coal beds, the Wadge and Wolf

Creek beds, which are both members of the Middle Coal Group of the Mesaverde Group, have been identified in the quadrangle (plate 1). The Middle Coal Group includes the thick, persistent coal beds of the lower coal-bearing zone of the Williams Fork Formation. These two Middle Group coal beds are found over a large area in the Yampa KRCRA. Additionally, several thin, lenticular Middle Group coal beds occur locally, but they are of no economic importance.

Wadge Coal Bed

The Wadge coal bed has been identified in drill holes and mine measured sections in the southeast corner of the Quaker Mountain quadrangle where the bed varies from 6.0 to 7.8 ft (1.8 to 2.4 m) in thickness.

No chemical analyses have been made of the Wadge bed in the Quaker Mountain quadrangle, but the coal is assumed to be of the same quality in the Quaker Mountain quadrangle as it is in adjoining quadrangles, where it has been analyzed. In adjoining quadrangles, the Wadge coal bed is non-coking, high volatile bituminous B or C in rank (Bass, Eby, and Campbell, 1955).

Wolf Creek Coal Bed

The Wolf Creek coal bed has been identified in two drill holes, in an underground coal prospect, and along an outcrop in the southeastern corner of the quadrangle (plate 1). The Wolf Creek bed is situated approximately 50 ft (15 m) stratigraphically above the Trout Creek Sandstone Member. The Wolf Creek bed varies considerably in thickness, from less than 8 ft (2.4 m) to greater than 15 ft (4.6 m) in a distance of less than 1/2 mi (0.8 km). The bed generally contains a 0.3- to 0.8-ft (0.1 to 0.3 m) split. Plate 8 is an isopach map of the Wolf Creek coal bed in a portion of the Quaker Mountain quadrangle. Owing to the lack of data, the extent and thickness of the bed is unknown throughout most of the quadrangle.

Several chemical analyses of the Wolf Creek bed in the Quaker Mountain quadrangle are shown in table 1. The typical analysis, on a moist, mineral-matter-free basis, shows the Wolf Creek bed to be non-coking, high volatile bituminous B in rank. Several analyses reported by Gale (1910) and Bass, Eby, and Campbell (1955) show the Wolf Creek bed to rank as high as anthracite, on the basis of fixed carbon content, on a dry, mineral-matter-free basis. These high fixed carbon coals have been upgraded through contact metamorphism by local dikes and sills.

COAL RESOURCES

Data from coal test holes, mine measured sections, and outcrop measurements (plate 1) was used to construct outcrop, isopach, and structure contour maps of the Wadge and Wolf Creek coal beds. The sources of information are listed in table 3. In general, the Quaker Mountain quadrangle structure contour maps are based on contours drawn on top of the Trout Creek Sandstone Member by Bass, Eby, and Campbell (1955).

Coal resources of the Wadge coal bed and Wolf Creek coal bed were calculated using data obtained from the coal isopach maps (plates 4 and 8). The coal-bed acreage (measured by planimeter) multiplied by the average thickness of the coal bed in the planimetered area, times a conversion factor of 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. Reserve Base and Reserve values for the Wadge and Wolf Creek beds are shown on plates 7 and 11, and are rounded to the nearest 10,000 short tons (9,072 metric tons). Toal coal Reserve Base tonnages for the Wadge and Wolf Creek beds, where they are thicker than 5.0 ft (1.5 m) and lie less than 3,000 ft (914 m) below the ground surface total approximately 3,430,000 and 4,870,000 short tons (3,110,000 and 4,420,000 metric tons), respectively.

Conventional subsurface reserves were calculated by multiplying the mineable Reserve Base for conventioanl subsurface mining methods by a recovery factor of 50 percent where the beds dip less than 15°.

The criteria used in calculating Reserve Base tonnages in this report differ from those stated in U.S. Geological Survey Bulletin 1450-B, which calls for a minimum thickness of 28 in. (71 cm) for bituminous coal and a maximum depth of 1,000 ft (305 m).

Reserve Base (in short tons) in the various development potential categories for conventional subsurface and in-situ mining methods are shown in table 2. In this study, coal lying between the ground surface and a depth of 200 (61 m) (200 ft of overburden) is considered strippable; coal lying between 200 ft (61 m) and 3,000 ft (914 m) (3,000 ft of overburden) below the ground surface and having bed dips of less than 15° is considered to be amenable to conventional subsurface mining methods. In areas where the dip is greater than 15°, there is no potential for subsurface mining by conventional methods, but there is a low potential for coal recovery using in-situ mining methods.

Dames & Moore has not made any determination of economic recovery 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 portions 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 portions 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 are assigned 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 are overlain by 200 ft (61 m) or less of overburden are considered to have potential for strip 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 is as follows:

$$MR = \frac{t_o \quad (0.911)}{t_c \quad (rf)}$$

where MR = mining ratio

t_o = thickness of overburden

t_c = thickness of coal

rf = recovery factor.

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 are here defined as areas underlain by coal beds having respective mining-ratio values of 0 to 10, 10 to 15, and greater than 15, as shown on plates 6 and 10. These mining-ratio values for each development-potential category are applicable only to this quadrangle, and were derived in consultation with the U.S. Geological Survey. In the Quaker Mountain quadrangle, there were no areas of Federally-owned land within the KRCRA boundary which met these surface mining criteria.

Development Potential for Subsurface Mining Methods

The coal development potential for conventional subsurface and in-situ mining of coal is shown on plate 12. In the Quaker Mountain quadrangle, the Wolf Creek and Wadge coal beds are classified as having high, moderate, or low development potential for conventional subsurface mining where they are of Reserve Base thickness, the dip is less than 15°, and where they are found between 200 ft (61 m) and 1,000 ft (305 m), 1,000 and 2,000 ft (610 m), and 2,000 and 3,000 ft (914 m) below the ground surface, respectively.

Areas are considered to have a low development potential for in-situ recovery methods where the coal beds dip between 15^{o} and 35^{o}, are of Reserve Base thickness, and occur between 200 ft (61 m) and 3,000 ft (914 m) below the ground surface. Areas are considered to have moderate development potential for in-situ methods where the coal beds dip greater than 35^{o} and meet the thickness and depth criteria listed above.

The development potential by in-situ underground coal gasification methods for the coal Reserve Base of the Quaker Mountain quadrangle is considered low because the beds dip less than 35^{o}.

An unknown development potential has been used to categorize those areas, shown on plate 12, where coal-bearing strata may occur within 3,000 ft (914 m) of the ground surface, but which cannot otherwise be categorized due to a lack of information regarding the thickness, extent, or bedding attitude of the coal beds.

TABLE 1

CHEMICAL ANALYSES OF COALS ON AN AS-RECEIVED BASIS

QUAKER MOUNTAIN QUADRANGLE, ROUTT COUNTY, COLORADO

LOCATION	COAL BED NAME	Source	Proximate				Ultimate					Heating value	
			Moisture	Volatile matter	Fixed carbon	Ash	Sulfur	Hydrogen	Carbon	Nitrogen	Oxygen	Calories	Btu***
T. 8 N., R. 87 W., sec 27, Moffat Coal Company Prospect, Crawford tract	Wolf Creek	1*	6.1	27.4	55.7	10.8	0.6	--	--	--	--	6720	12,160
		1**	7.3	5.6	75.4	11.7	0.7	3.2	74.1	1.3	9.0	6755	12,160
		1	7.0	6.3	72.2	14.5	0.6	--	--	--	--	6415	11,550
		1	12.4	11.7	62.3	13.6	0.5	--	--	--	--	5550	9,990
		2	6.9	3.4	75.7	14.1	0.6	--	--	--	--	6810	12,260

1. Bass, Eby, and Campbell, 1955
2. Gale, 1910

*Composite of 3 samples

**Composite of 4 samples near dike

***To convert Btu/lb to kJ/kg, multiply by 2.326

TABLE 2

COAL RESERVE BASE DATA FOR SUBSURFACE MINING METHODS
FOR FEDERAL COAL LANDS (IN SHORT TONS)
QUAKER MOUNTAIN QUADRANGLE, ROUTT COUNTY, COLORADO

	Conventional Underground			In-Situ	
Coal Bed Name	High Development Potential	Moderate Development Potential	Low Development Potential	Low Development Potential	Total
Wadge	330,000	1,070,000	450,000	1,580,000	3,430,000
Wolf Creek	80,000	1,160,000	1,400,000	2,230,000	4,870,000
Total	410,000	2,230,000	1,850,000	3,810,000	8,300,000

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

TABLE 3

SOURCES OF DATA USED ON PLATE 1 (CRO MAP)

Plate 1 Index No.	Source	Data Base
1	Bass, et al, 1955	U.S. Geological Survey Bulletin 1027D, plate 24, section 203
2	↓	Same as above, section 201
3	↓	Same as above, section 215
4	↓	Same as above, section 211
5	↓	Same as above, section 212
6	↓	Same as above, section 214
7	↓	Same as above, section 210

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