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

(Report includes 4 plates)

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INTRODUCTION

Purpose

This text is to be used in conjunction with Coal Resource Occurrence (CRO) Maps of the Pilot Knob quadrangle, Routt County, Colorado. These reports were compiled to support the land planning work of the Bureau of Land Management 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. Published and unpublished public information was used as the data base for this study. No new drilling or field mapping was performed, nor was any confidential data used.

Location

The Pilot Knob 7 1/2-minute quadrangle is located in central Routt County in northwestern Colorado, approximately 18 mi (29 km) northwest of Steamboat Springs and 26 mi (42 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 10 mi (16 km) south of the Pilot Knob quadrangle. The southeast area of the quadrangle is accessible by an improved road which leaves U.S. Highway 40 at Steamboat Springs. The northwest corner is accessible along an unimproved road which connects with U.S. Highway 40 at Hayden. The remainder of the quadrangle can be reached on scattered jeep trails.

Railway service for the Pilot Knob area is provided by the Denver & Rio Grande Western Railroad from Denver to the railhead at Craig. This route passes 10 mi (16 km) south of the Pilot Knob quadrangle and serves as the major transportation route for coal shipped east from northwestern Colorado.

Physiography

The Pilot Knob quadrangle lies on the eastern edge of the Colorado Plateau in a rugged area known as the Elkhead Mountains. This area extends northeastward from the Yampa River valley to the edge of the Park Range, which forms the Continental Divide in northwest Colorado.

Over 3000 ft (914 m) of relief is present in the Pilot Knob quadrangle, from a high of over 10,400 ft (3170 m) on

Sand Mountain on the north edge of the quadrangle, to below 7000 ft (2134 m) on the Deep Creek floodplain in the southeast corner of the quadrangle. Most of the quadrangle is above 8000 ft (2438 m), with the exception of the Deep Creek area.

The landscape is generally rugged, with many high ridges, steep slopes, and deep stream valleys. Four small areas of high relief, Pilot Knob, Rim Rocks, Anthracite Ridge, and Sand Mountain, are the resistant remnants of volcanic dikes and sills.

Deep Creek drains the southern and eastern portions of the quadrangle and flows southeast to the Elk River. First Creek drains the northwest section and flows southwest into Elkhead Creek. Both Elkhead Creek and Elk River empty into the Yampa River south of the quadrangle. Numerous small mountain lakes are present at higher elevations in the southwest area, but no major bodies of water are present within the boundaries of the quadrangle.

Climate and Vegetation

The climate of northwestern 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. This causes an abundance of clear, sunny days with large daily temperature variations in the Pilot Knob area. Annual precipitation in the area averages approximately 20 in (51 cm), most of which occurs as snowfall over the winter months. Average daily temperatures in the Pilot Knob area range from 0° to 35°F (-18° to 2° C) in January, to 42° to 80° F (6° to 27°C) in July.

Vegetation in the Pilot Knob quadrangle includes conifer forests in the higher elevations where moisture and soil depth are adequate, and open-to-very-dense stands of deciduous trees on the edges of the confier forests. River-bottom-type grassland is present along the drainage-ways and at lower elevations.

Land Status

The Pilot Knob quadrangle lies in the northeast corner of the Yampa Known Recoverable Coal Resource Area. Approximately 70 percent of the western half of the quadrangle is within the KRCRA, but the Federal government owns the coal rights for only a small portion of this area, as shown on plate 2 of the Coal Resource Occurrence maps. No outstanding Federal coal leases, prospecting permits, or licenses are present within the quadrangle.

GENERAL GEOLOGY

Previous Work

The first geologic description of the general area of the Pilot Knob quadrangle was published by Emmons (1877) as a part of the Survey of the Fortieth Parallel in 1872. 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 relatively comprehensive geologic report on the Yampa Coal Field which included a description of the geology and occurrence of coal in the Pilot Knob 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. The report by Bass, Eby, and Campbell is the most comprehensive work on the area and is the base for this study.

Stratigraphy

The majority of the rocks which crop out in the Pilot Knob quadrangle are Upper Cretaceous in age, and include the coal-bearing Iles and Williams Fork Formations of the Mesaverde Group.

Approximately 4000+ ft (1200+ m) of Upper Cretaceous Mancos Shale is exposed in the eastern half of the quadrangle. The Mancos consists of dark-gray marine shale with interbedded sandy shale and thin-bedded, tan, silty sandstone. The number and thickness of the beds of sandy shale and sandstone increase upward (Bass, Eby, and Campbell, 1955). No coal is present in the Mancos Shale.

The Upper Cretaceous Mesaverde Group conformably overlies the Mancos Shale in the Pilot Knob area. The Mesaverde Group consists of two formations, the Iles and overlying Williams Fork. The 1500 ft (457 m) thick Iles Formation crops out in a north-south trend in the east-central part of the quadrangle. It consists of ledge-forming sandstone beds interbedded with gray, sandy shales. The major sandstones, in ascending order, are 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 and Williams Fork Formations. The Lower Coal Group of the Iles Formation includes all coal beds beginning approximately 400 ft (122 m) above the base of the formation and extending upward to the Trout Creek Sandstone Member.

The Williams Fork Formation, which is exposed along the western edge of Pilot Knob quadrangle, conformably overlies the Iles Formation. The Williams Fork is approximately 1300 ft (400 m) thick in the Pilot Knob quadrangle, and is generally divided into four sequences -- a lower coal-bearing sequence, a marine shale sequence, the Twentymile Sandstone Member, and an upper marine, shaley sandstone sequence (Ryer, 1977).

The lower coal-bearing sequence contains approximately 300 ft (91 m) of interbedded siltstone, silty sandstone, very fine-grained sandstone, and coal beds. Two major coal beds, the Wolf Creek and the Wadge, are found in this zone. They are stratigraphically located approximately 90 ft (27 m) and 230 ft (70 m), respectively, above the Trout Creek Sandstone Member. The marine shale sequence, which is approximately 600 ft (183 m) thick, 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. The Twentymile Sandstone Member, which ranges from 150 to 200 ft (45 to 60 m) in thickness, is a massive, white, ledge-forming sandstone interbedded with silty and sandy shale near the base. A well-defined contact is found between the Twentymile Sandstone Member and the overlying marine sequence. The 200 ft (60 m) thick marine sequence is composed of sandstone, sandy shale, and dark-gray shale. No coal has been reported in this zone in the Pilot Knob quadrangle.

The Williams Fork Formation is conformably overlain by the Lewis Shale, a homogeneous dark-gray to bluish marine shale. In the Pilot Knob area, the shale is approximately 1900 ft (579 m) thick.

The Tertiary-age Browns Park Formation rests unconformably on the Mancos Shale along the eastern and northeastern edge of the Pilot Knob quadrangle (Tweto, 1976). Small patches of this unit of tuffaceous sandstone, claystone, and conglomerate are also present at higher elevations in the Pilot Knob and Anthracite Ridge areas, unconformably overlying the Lewis Shale, Williams Fork and Iles Formations.

The rocks exposed in the Pilot Knob quadrangle accumulated close to the western edge of a Late Cretaceous epeiric seaway which covered part of the Western Interior of North America. Several regressive-transgressive cycles caused the deposition of a series of marine, near-shore marine, and non-marine sediments in the Pilot Knob quadrangle. The Mancos Shale was deposited in an offshore marine environment which existed east of the shifting strand line. Deposition of the Mancos Shale in the quadrangle area ended with the eastward movement of the shoreline, and the subsequent deposition of the littoral marine Tow Creek Sandstone Member of the Iles Formation. 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 during deposition of the Iles and Williams Fork were near-shore marine, littoral, brackish and fresh water, and fluvial systems.

The major 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 and Twentymile Sandstone Members, 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 Pilot Knob area.

Intrusive Rocks

Several areas in the Pilot Knob quadrangle have been intruded by Upper Tertiary olivine basalt and latite-trachyte plugs, sills and dikes. Pilot Knob (section 13, T. 8 N., R. 87 W.) and Sand Mountain (section 9, T. 9 N., R. 86 W.) are large dikes or plugs. Rim Rocks (sections 29 and 32, T. 9 N., R. 86 W.; and sections 5 and 8, T. 8 N., R. 86 W.) is a sill approximately 75 ft (23 m) thick (Fenneman and Gale, 1906). This sill has intruded the rocks just below and within the Lower Coal Group, causing local metamorphism which has increased the rank of some of the adjacent coal beds.

Structure

The Yampa KRCRA lies in the southern extension of the Washakie/Sand Wash structural basin of south-central Wyoming. The basin is bordered on the east by the Park Range, some 14 mi (22 km) east of the Pilot Knob quadrangle, and on the southwest by the Axial Basin anticline, approximately 25 mi (40 km) southwest of the quadrangle. The Iles and Williams Fork Formations dip to the west, varying from 6° to 10° in the southern part of the quadrangle, to 10° to 23° in the northern part.

Two major structural features have been mapped in the Pilot Knob quadrangle. Bass, Eby, and Campbell (1955) mapped a sequence of small folds in sections 7, 8, 17, and 18 in T. 8 N., R. 86 W., near the Iles/Mancos contact; and Tweto (1976) mapped a fault which displaces the Mancos Shale and the Browns Park Formation. The fault extends from the southeast corner of the quadrangle northward to just east of Sand

Mountain. Both of these structural features lie east of the Yampa KRCRA and do not affect coal-bearing strata of the Iles and Williams Fork Formations.

COAL GEOLOGY

Several coal beds from the Middle and Lower Coal Groups of the Mesaverde Group have been identified from outcrop data obtained in the quadrangle (CRO plate 1). The Lower Coal Group includes the coal beds beginning approximately 400 ft (122 m) above the base of the Iles Formation and extending to the Trout Creek Sandstone Member. The Middle Coal Group includes the coal beds between the Trout Creek and Twentymile Sandstone Members in the lower coal-bearing zone of the Williams Fork Formation.

Coals of the Lower Group are characteristically lenticular and of limited areal extent, while the coal beds in the Middle Group persist over a large area.

Lower Group Coals

The coals in the Lower Coal Group have not been formally named, but for this report, the coal beds have been numbered with bracketed numbers for identification purposes in this quadrangle only (CRO plates 1 and 3).

Coal Bed {1}. Lower Group coal {1} is known from a single outcrop 5 ft (1.5 m) thick in section 20, T. 9 N., R. 87 W. This coal bed is approximately 850 ft (260 m) below the top of the Trout Creek Sandstone and dips to the west at approximately 16°. No known chemical analyses of this coal bed have been made; the quality of the coal is assumed to be similar to other coal beds of the lower group of the Mesaverde, probably high-volatile bituminous C.

Coal Bed {2}. Two Lower Group coal beds have been mined at the Block mines in the NE 1/4 of section 24, T. 8 N., R. 87 W. Bed {2}, the lower of the two, is approximately 600 ft (182 m) below the top of the Trout Creek Sandstone Member.

Bed {2} is 8.8 ft (2.7 m) thick at the Block No. 1 mine, but is split by 4 ft (1.2 m) of rock into a 5.5 ft (1.7 m) and a 4.0 ft (1.2 m) thick seam at the Block No. 2 mine, less than 1000 ft (300 m) away. The areal extent of this coal is unknown, but it is inferred to exist for 1/2 mile down-dip to the west. A chemical analysis of the bed {2} coal is given in Table 1. This bed is noncoking, high-volatile bituminous C in rank.

<u>Coal Bed {3}</u>. Bed {3} lies 55 to 71 ft (17 to 22 m) above Bed {2} near the Block mines, and extends from the Block mines southwest to the Keitel mine (CRO plate 1). The bed thickens from 4.9 ft (1.5 m) at the Keitel mine, to 5.1 ft (1.6 m) at the Block mines, where it contains a 0.4 ft (12 cm) split at the Block No. 2 mine. Bed {3} dips approximately 6° to the west, parallel to bed {2}. The areal extent of this coal is unknown, but it is inferred to exist for 1/2 mile down the dip.

Bed {3} is similar in quality to bed {2}. It is noncoking, high-volatile bituminous C in rank.

Other Lower Group Coal Beds. Several unnamed Lower Group coal beds are exposed in sections 29 and 32, T. 9 N., R. 87 W., and sections 5 and 6, T. 8 N., R. 87 W., along Rim Rocks. These coals are lenticular in nature and often contain thin partings of rock. Most of these coals are less than 4 ft (1.2 m) thick, but one unnamed coal prospect in section 6, T. 8 N., R. 87 W., contains 7.7 ft (2.3 m) of coal with only a 0.3 ft (9.1 cm) parting.

Several of the coals in the Rim Rocks area have been altered by the intrusion of the basalt sill that forms Rim Rocks, but most of the beds rank as high-volatile bituminous C. This is probably typical of Lower Group coals in this area, with the exception of those very close to the sill. No chemical analysis or resource calculation of coals in the Rim Rocks area is included in this report because the coal is located on non-Federal land.

Middle Group Coals

Wolf Creek Coal Bed. The Wolf Creek coal bed has been identified in this quadrangle in a single outcrop in section 23, T. 8 N., R. 87 W. At this point, the Wolf Creek bed is 4 ft (1.2 m) thick, but is reported to thicken to 12.8 ft (3.9 m) just 4 miles (6.4 km) to the west. The Wolf Creek coal bed is approximately 90 ft (27 m) stratigraphically above the Trout Creek Sandstone Member and dips to the west at 6° to 10°. Although the Wolf Creek is laterally persistent throughout much of the eastern Yampa Coal Field, it is irregular in thickness. No chemical analyses have been made of the Wolf Creek bed in this quadrangle. No resource calculation of the Wolf Creek bed is included in this report because all known occurrences of Reserve Base thickness are located on non-Federal land.

Wadge Coal Bed. The Wadge coal bed, which lies approximately 160 ft (49 m) above the Wolf Creek bed, has not been identified in the Pilot Knob quadrangle, but it crops out to the south and west of the quadrangle. The lateral continuity of this bed in adjacent areas strongly suggests it should be present in the western half of the Pilot Knob quadrangle, but on non-Federal land.

COAL RESOURCES

Coal outcrop measurements and mine measured section data, plate 1, were used to construct outcrop maps and an Areal Distribution and Identified Resource (ADIR) map, plate 4, of the isolated coal beds of 5.0 ft (1.5 m) thickness or greater in the Pilot Knob quadrangle. Sources of information are listed in Table 4.

Coal resources were calculated using data obtained from the ADIR map (CRO plate 4). The coal-bed acreage (measured by planimeter), multiplied by the average thickness of the coal bed times a conversion factor of 1800 short tons of coal per acre-ft for bituminous coal, yields the coal resources in short tons of coal for each isopached coal bed. Reserve Base values for Coal Beds {1}, {2}, and {3} are also shown on CRO plate 4 and are rounded to the nearest 10,000 short tons. Total coal Reserve Base data for all coal beds thicker than 5.0 ft (1.5 m) that lie less than 3000 ft (914 m) below the ground surface are shown on CRO plate 2 and total approximately 7,040,000 short tons. The criteria used in calculating Reserve Base and Reserve data in this report differs from that advocated in U.S. Geological Survey Bulletin 1450-B, a minimum thickness of 28 in (70 cm) for bituminous coal and a maximum depth of 1000 ft (300 m). Because of the lenticular quality of the coals and limited geologic data, any calculations on the Reserve Base must necessarily fall into the Inferred resource category, which totals 1,800,000 short tons for the strippable mining method and 5,240,000 short tons for the underground mining method. In this study, coal lying between the ground surface and a depth of 200 ft (61 m) is considered strippable; coal lying between 200 ft (61 m) and 3000 ft (914 m) can be mined underground.

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

COAL DEVELOPMENT POTENTIAL

The standard criteria for classifying coal resources development potential by strippable and underground mining methods were not applied to the Pilot Knob quadrangle because of the limited areal extent and thickness irregularity of the coal beds. Based on the data available, the Reserve Base of Coal Beds {1}, {2}, and {3} is assigned an unknown development potential for both strippable and underground mining methods.

The development of the Reserve Base of Coal Beds {1}, {2}, and {3} by in-situ (underground) coal gasification methods is assigned a low development potential based on the lenticularity, limited areal extent, and a dip of less than 35° of the coal beds.

TABLE 1

CHEMICAL ANALYSES OF COALS IN THE PILOT KNOB QUADRANGLE,

ROUTT COUNTY, COLORADO

LOCATION	COAL BED NAME	Form of analalysis	Proximate				Ultimate					Heating value	
			Moisture	Volatile matter	Fixed carbon	Ash	Sulfur	Hydrogen	Carbon	Nitrogen	Oxygen	Calories	Btu
T.8N., R.87W., sec. 24, NE¼ (Block Mine 1)	Composite sample of Coal Beds {2} and {3} (Assumed)	A	11.4	33.4	52.4	2.8	.6	6.0	67.0	1.4	22.2	6,572	11,830
		B	7.3	34.9	54.9	2.9	.6	5.7	70.0	1.4	19.4	6,872	12,370
		C	....	37.6	59.2	3.2	.7	5.3	75.0	1.5	13.8	7,417	13,350
		D	....	38.9	61.1	...	.7	5.5	78.0	1.6	14.2	7,661	13,790
T.8N., R.87W., sec. 24, NE¼ (Block Mine 2)	Composite sample of Coal Beds {2} and {3} (Assumed)	A	12.0	34.4	50.7	2.9	.9	...	....	...	....	6,485	11,670
		B	6.5	36.6	53.8	3.1	1.0	...	....	...	....	6,895	12,410
		C	....	39.1	57.6	3.3	1.0	...	....	...	....	7,365	13,260
		D	....	40.4	59.6	...	1.1	...	....	...	....	7,615	13,710
T.8N., R.87W., sec. 24, SW¼ (Keitel Mine)	Coal Bed {3}	A	10.8	34.3	49.4	5.5	.6	...	....	...	....	.....	......
		B	5.4	36.4	52.4	5.8	.6	...	....	...	....	.....	......
		C	....	38.5	55.4	6.1	.7	...	....	...	....	.....	......
		D	....	41.0	59.0	...	.7	...	....	...	....	.....	......

(After Bass, Eby, and Campbell, 1955)

Form of Analysis:
A, as received
B, air dried
C, moisture free
D, moisture and ash free

TABLE 2

STRIPPABLE COAL RESERVE BASE DATA FOR FEDERAL COAL LANDS (IN SHORT TONS)

PILOT KNOB QUADRANGLE, ROUTT COUNTY, COLORADO

Coal Bed	High Development Potential	Moderate Development Potential	Low Development Potential	Unknown Development Potential
Bed {1}	0	0	0	590,000
Bed {2}	0	0	0	780,000
Bed {3}	0	0	0	430,000
Total				1,800,000

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

TABLE 3

COAL RESERVE BASE DATA FOR UNDERGROUND MINING METHODS

FOR FEDERAL COAL LANDS (IN SHORT TONS)

PILOT KNOB QUADRANGLE, ROUTT COUNTY, COLORADO

Coal Bed	High Development Potential	Moderate Development Potential	Low Development Potential	Unknown Development Potential
Bed {1}	0	0	0	1,680,000
Bed {2}	0	0	0	2,600,000
Bed {3}	0	0	0	960,000
Total				5,240,000

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

TABLE 4

SOURCES OF DATA USED ON PLATE 1 (CRO MAP)

Plate 1 Index No.	Source	Data Base
1	Bass, et al, 1955	USGS Bull. 1027-D, plate 24, Section 142
2		Same as above, Section 146
3		Same as above, Section 143
4		Same as above, Section 144
5		Same as above, Section 145
6		Same as above, Section 147
7		Same as above, Section 204
8		Same as above, Section 205
9	U.S. Geol. Survey	Inactive Coal Prospecting Permit No. Denver 054104, Irene Gould
10	Bass, et al, 1955	USGS Bull. 1027-D, plate 24, Section 206
11		Same as above, Section 207
12		Same as above, Section 148
13		Same as above, Section 149
14		Same as above, Section 150
15		Same as above, Section 151
16		Same as above, Section 152
17		Same as above, Section 153
18		Same as above, Section 154
19		Same as above, Section 155

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