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COAL RESOURCE OCCURRENCE AND COAL DEVELOPMENT POTENTIAL MAPS OF THE PATMOS HEAD QUADRANGLE CARBON COUNTY, UTAH

(Report includes 12 plates)

By

AAA Engineering And Drafting, Inc.

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INTRODUCTION

Purpose

This report was 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. It supplements the land planning requirements of the Federal Coal Leasing Amendments Act of 1976 (Public Law 94-377) sec. (3)(B) which states, in part, that "Each land-use plan prepared by the Secretary [of the Interior] (or in the case of lands within the National Forest System, the Secretary of Agriculture pursuant to subparagraph (A) (i)) shall include an assessment of the amount of coal deposits in such land, identifying the amount of such coal which is recoverable by deep mining operations and the amount of such coal which is recoverable by surface mining operations."

This text is to be used in conjunction with the Coal Resource Occurrence (CRO) Maps (11 plates) and the Coal Development Potential (CDP) Map (1 plate) of the Patmos Head quadrangle, Carbon County, Utah (U.S. Geological Survey Open-File Report 79-492).

Published and unpublished pulic information were used as data sources for this study. No new drilling nor field mapping were done to supplement this study. No confidential nor proprietary data were used.

Location

The Patmos Head 7½-minute quadrangle (1972) covers the same area as the southeast quarter of the old (1913) Sunnyside 15-minute quadrangle and is located in Carbon County in east-central Utah. The towns of Sunnyside, East Carbon City, and Columbia are 1.0 mile (1.6 km) or less west of the Patmos Head quadrangle. The city of Price, the county seat of Carbon County is 23 miles (37 km) west of the quadrangle.

Accessibility

Utah Highway 123 passes through the towns of East Carbon City and Sunnyside and then into the Patmos Head quadrangle for less than half a mile (0.8 km). The road continues northward as a light-duty graveled road up Whitmore Canyon along the west edge of the quadrangle. Because of the rugged mountainous terrain the other roads in the quadrangle are unimproved dirt roads, jeep trails, and pack trails. Most of these are in the main canyons and on some of the high ridges. These roads and trails are mostly used by cattle ranchers and deer hunters. Utah Highway 123 continues westward from Sunnyside for approximately 5 miles (8 km) to its intersection with U.S. Highway 6-50, the main highway along the base of the Book Cliffs.

A branch line of the Denver and Rio Grande Western Railroad passes through East Carbon City and Sunnyside and then into Patmos Head quadrangle a little over half a mile (0.8 km) to the coal loading facilities of the Sunnyside mines. The branch railroad continues west and south from Sunnyside for 7.5 miles (12.1 km) where it joins a main line of the Denver and Rio Grande Western Railroad with connections to Salt Lake City, Utah and Denver, Colorado. The Carbon County Railway runs from East Carbon City southward to the town of Columbia and the Geneva Mine in Horse Canyon. A small 500-ft (152 m) section of railroad crosses into the southwest corner of the Patmos Head quadrangle.

Physiography

Patmos Head quadrangle lies in the central part of the Book Cliffs, a long bold arcuate escarpment of barren sandstone cliffs from 1,000 to

2,000 ft (305 to 610 m) high. A small part of the cliff front lies in the southwest corner of the quadrangle. The rest of the quadrangle area is rugged and mountainous with surface elevations ranging from 6,200 ft (1,890 m) in the southwest corner to over 9,800 ft (2,987 m) at several points along Patmos Ridge which runs through the center of the quadrangle from the south side to the north side.

Patmos Ridge also is the drainage divide between the Range Creek drainage system on the east and Whitmore and other canyon drainages on the west. Range Creek flows southeastward to its confluence with the Green River. The canyons on the west side of Patmos Ridge drain into Price River which also drains into Green River.

Climate

Patmos Head quadrangle is located in the mid-latitude steppe climate with semi-arid conditions prevailing in the lower valley areas on the west side of the quadrangle. The normal annual precipitation in the quadrangle ranges from approximately 11 inches (28 cm) in the southwest corner to 22 inches (56 cm) on the northern part of Patmos Ridge (U.S. Department of Commerce, (1964)).

Temperatures at the lower elevations in Sunnyside and in the southwest corner of the quadrangle range from a summertime high of approximately 100 degrees F (38 degrees C) to a wintertime low of about -10 degrees F (-23 degrees C). Annual maximum and minimum temperatures in the high mountainous areas of the quadrangle are approximately 10 to 15 degrees F (5.6 to 8.3 degrees C) lower than the temperatures at elevations below 7,000 ft (2,134 m).

Land Status

Approximately 12,800 acres in the west half of Patmos Head quadrangle lies in the Book Cliffs Known Recoverable Coal Resource Area (KRCRA). The

KRCRA land within the quadrangle consists of nearly 12,000 acres of non-Federal land and 800 acres of unleased Federal land (see plate 2).

GENERAL GEOLOGY

Previous Work

Clark (1928) mapped the geology and coal outcrops in the western part of the Book Cliffs coal field from the Standardville 7½-minute quadrangle on the west to Patmos Head quadrangle on the east. Fisher (1936) mapped the eastern part of the coal field. The geology and coal deposits in the area have also been described by Abbot and Liscomb (1956), Fisher, Erdmann, and Reeside (1960), Hayes and others (1977), Brodsky (1960), and Young (1955, 1957, and 1966). Osterwald (1962) has made a detailed study of the structural features in the area of the Sunnyside No. 1 mine. Doelling (1972) has summarized the geology and coal data reported in earlier writings.

Stratigraphy

The coal beds of economic importance in the Book Cliffs coal field are Upper Cretaceous in age, and are confined to the Blackhawk Formation of the Mesaverde Group. The Mesaverde consists of three formations which are, in ascending order, the Blackhawk Formation, Castlegate Sandstone, and the Price River Formation. The Upper Cretaceous Mancos Shale underlies and intertongues with the Blackhawk Formation. The Mancos shale was deposited in an offshore marine environment and the Blackhawk Formation in a mixed marine and continental environment. The Castlegate Sandstone and the Price River Formation were formed in a continental environment.

The bluish-gray shale of the Mancos Shale crops out in a small area in the southwest corner of the quadrangle along the base of the Book Cliffs. Sandstone beds of the Blackhawk Formation occur in steep and precipitous cliffs and ledges above the Mancos Shale.

The lowest bed of the Blackhawk Formation is the Kenilworth Sandstone Member. The lower section of this cliff-forming unit is thin-bedded and divided by shale partings, but the major part is a massive sandstone body some 130 ft (40 m) thick. The coal-bearing part of the Blackhawk Formation lies above the Kenilworth Sandstone and has been divided roughly into three members recognized by Fisher (1936). The lower division consists of alternating sandstone, shaly sandstone, shale, and coal. It contains the Kenilworth coal bed. The middle division is dominated by massive cliff-forming sandstone but near the top has lagoonal deposits which include the Upper and Lower Sunnyside coal beds. The upper division is a sequence of shaly sandstone, shale, and coal. The entire Blackhawk Formation is about 700 ft (214 m) thick.

The cliff-forming Castlegate Sandstone overlies the Blackhawk Formation. It is about 180 ft (55 m) thick and is composed mainly of fine- to medium-grained light-gray sandstone.

The Price River Formation overlies the Castlegate and is about 500 ft (153 m) thick. It consists of interbedded sandstone and shale. The sandstone is light colored, slightly calcareous to argilaceous, and is thin-bedded to massive. The shale is medium to dark gray, carbonaceous, and contains minor beds of bony coal.

The strata successively overlying the Price River Formation include the North Horn Formation (Upper Cretaceous and Paleocene), the Colton and Wasatch Formations (Eocene) which may be partially equivalent or intertonguing (Doelling, 1972; Gross, 1961), and the Green River Formation (Eocene). The North Horn Formation consists of interbedded yellowish-gray sandstone, light yellow to greenish-gray shale and limestone, and conglomeratic sandstone at the base of the formation. The Colton Formation is composed of interbedded sandstone, siltstone, and shale. The Green River

Formation is the youngest formation in the quadrangle and is exposed over the eastern two-thirds of that area. The formation consists mainly of greenish-gray and white claystone and shale. Between 2,500 and 3,000 ft (763 to 915 m) of the formation are exposed in the quadrangle.

Structure

The general structure in the quadrangle is a gently-dipping homocline with an eastward dip in the south half of the area and a northeastward dip in the north part. Inclinations of the beds range from 5 to 8 degrees. Several northwest-trending faults occur in the southwest part of the quadrangle where detailed mapping has been done. The occurrence of faults in other parts of the quadrangle is unknown. The displacements of the known faults are generally under 100 ft (30 m) but may exceed this. Some of the faults have produced shear zones. The effect of these faults on mining coal in this area is unknown.

COAL GEOLOGY

The coal in the quadrangle crops out along a southwestward-facing escarpment in the southwest part of the quadrangle. In the northeast part of the quadrangle the coal beds are deep and no non-proprietary drilling data was available for use in this report.

Kenilworth Coal Bed

In the southwest area of the quadrangle where a limited number of coal outcrops have been measured the Kenilworth coal bed ranges in thickness up to 2.5 ft (0.8 m). The coal bed rests directly on the massive Kenilworth Sandstone Member of the Blackhawk Formation or is separated from it by a few feet of shale.

Lower Sunnyside Coal Bed

The Lower Sunnyside coal bed occurs approximately 220 ft (67 km) above the Kenilworth coal bed and ranges from 4.1 to 17.5 ft (1.2 to 5.3 m) or more in thickness in the southwest part of the quadrangle. The bed includes splits and sub-beds in most of the drill holes shown on plates 1 and 3. This coal bed has been extensively mined in the southwest part of the quadrangle area.

The Lower Sunnyside coal is brittle, tough, and hard to pick. It has a metallic ring when struck with a hammer (Clark, 1928). It is a bright coal lacking definite fracture lines and breaks into large irregular lumps (Thiessen and Sprunk, 1937). Doelling (1972) summarized the coal's description as "a uniform attrital-anthraxylous bright coal largely derived from small plant material such as small stems, twigs, roots and leaves." Clark (1928) reports that the Upper and Lower Sunnyside coal beds contain the best coking coal known in the Book Cliffs coal field in Utah and that "the coal weathers very slowly on exposure to the air and therefore makes a good stocking fuel. . ."

The Lower Sunnyside coal bed thickens and thins erratically in the isopached area shown on plate 8. Without additional information, the coal isopach map indicates a northeastward thinning of the coal bed.

Upper Sunnyside Coal Bed

The Upper Sunnyside coal bed is perhaps better developed in this quadrangle than in any other part of the Book Cliffs coal field. The bed ranges in thickness from 0.6 to 6.2 ft (0.2 to 1.9 m) in areas where it has an outcrop or was encountered in drill holes. A problem with the bed is its close proximity to the Lower Sunnyside coal bed. The noncoal interval between the Upper Sunnyside bed and the uppermost sub-bed of the Lower Sunnyside coals ranges from only 2 or 3 ft (0.6 or 0.9 m) to 39 ft (12 m) in the Sunnyside No. 1 mine (Doelling, 1972).

Clark (1928) describes the physical characteristics of the Upper Sunnyside coal and the Lower Sunnyside coal together as though both coals were the same. The description of the Lower Sunnyside coal in the preceeding section also applies to the Upper Sunnyside coal.

A thickening of the Upper Sunnyside bed shown in the northwest part of the quadrangle as shown on the coal isopach map, plate 4, is based on measurements of the coal bed in holes drilled in the adjoining Sunnyside quadrangle to the west.

Intervals reported as "bony coal," "bone," "shaly coal," or other similar terms in the data sources are shown as "rock" intervals in this report on plates 1 and 3. These intervals were not included in the coal thicknesses used to construct the coal isopach maps.

Chemical Analyses of the Coal

Doelling (1972) reports 61 analyses of coal samples collected from the Lower and Upper Sunnyside beds in the Sunnyside and Columbia mines. The ranges and averages of the proximate analyses are shown in table 1.

Table 1. Average proximate analysis of Lower and Upper Sunnyside coals, Patmos Head quadrangle, Carbon County, Utah*

	No. Analyses	Percent	
		Average	Range
Moisture	61	5.1	3.1-15.2
Volatile Matter	56	38.1	33.9-42.9
Fixed Carbon	56	50.6	44.8-54.2
Ash	61	6.3	4.2-11.9
Sulfur	60	1.02	0.5-3.0
Btu/lb**	51	12,906	9,530-13,660

*Doelling, 1972, p. 379
**To convert Btu/lb to Kj/kg multiply by 2.326

Based on the ASTM system of classification (American Society of Testing and Materials, 1977) coal with the average analysis shown in table 1 above is classified as high volatile B bituminous. The coal in the Sunnyside and Patmos Head quadrangle area is a coking coal, but must be blended with 15 to 20 percent of low- or medium-volatile coals from other sources to achieve metallurgical grade (Doelling, 1972).

Mining Operations

The portals of the Sunnyside group of mines owned by Kaiser Steel Corporation are all located near the mouth of Whitmore Canyon in the Patmos Head quadrangle. Each of the mines has a large mined-out area. At this writing (1979) the No. 1 and No. 3 mines were operating and the No. 2 mine was inactive. The mining area of the Sunnyside No. 1 mine lies in the Sunnyside quadrangle (Southwest Quarter of the Sunnyside 15-minute quadrangle). The mining area of the No. 3 mine is directly east of its portal, and the mining area of the No. 2 mine is to the south. All three mines were active in 1969.

The inactive Columbia mine in the south part of the quadrangle is owned by U.S. Steel Corporation. The mine was opened in 1923 and closed in May 1967 because of poor working conditions in deep coal served by a mile long rock tunnel. Approximately 17.3 million short tons (15.7 million metric tons) were mined from the Lower Sunnyside coal bed in this mine.

Doelling (1972) reported that as of December 31, 1969 the Sunnyside mines produced a total of 44.885 million short tons (40.720 million metric tons) with a recoverability of 44.5 percent, and that the Columbia mine produced a total of 39.155 million short tons (35.521 million metric tons) with a recovery rate of 38.6 percent.

COAL RESOURCES

The principal sources of data used in the construction of the coal isopach maps, structure contour maps, and the coal data maps were Doelling (1972), Clark (1928), and Brodsky (1960). Nearly all recent drilling in the area is classified as proprietary information and was not available to present authors.

Coal resource tonnages were calculated for measured, indicated, and inferred categories in unleased areas of Federal coal land within the KRCRA boundary. Data obtained from the coal isopach maps (plates 4 and 8) were used to calculate the Reserve Base values. The coal-bed acreage (measured by planimeter) multiplied by the average isopached thickness of the coal bed times a conversion factor of 1,800 short tons of coal per acre-foot of bituminous coal yields the coal resources in short tons of coal for each isopached coal bed. Reserve Base and Reserve values for the Upper Sunnyside and Lower Sunnyside beds are shown on plates 7 and 11 and are rounded to the nearest tenth of a million short tons. The Reserve values are based on a subsurface mining recoverability factor of 50 percent.

"Measured resources are computed from dimensions revealed in outcrops, trenches, mine workings, and drill holes. The points of observation and measurement are so closely spaced and the thickness and extent of coal are so well defined that the tonnage is judged to be accurate within 20 percent of true tonnage. Although the spacing of the points of observation necessary to demonstrate continuity of the coal differs from region to region according to the character of the coal beds, the points of observation are no greater than ½ mile (0.8 km) apart. Measured coal is projected to extend as a ¼ mile (0.4 km) wide belt from the outcrop or points of observation or measurement.

"Indicated resources are computed partly from specified measurements and partly from projection of visible data for a reasonable distance on the basis of geologic evidence. The points of observation are 1/2 (0.8 km) to 1 1/2 miles (2.4 km) apart. Indicated coal is projected to extend as a 1/2-mile (0.8 km) wide belt that lies more than 1/4 mile (0.4 km) from the outcrop or points of observation or measurement.

"Inferred quantitative estimates are based largely on broad knowledge of the geologic character of the bed or region and where few measurements of bed thickness are available. The estimates are based primarily on an assumed continuation from Demonstrated coal for which there is geologic evidence. The points of observation are 1 1/2 (2.4 km) to 6 miles (9.6 km) apart. Inferred coal is projected to extend as a 2 1/4-mile (3.6 km) wide belt that lies more than 3/4 mile (1.2 km) from the outcrop or points of observation or measurement." (U.S. Bureau of Mines and U.S. Geological Survey, 1976).

Coal Reserve Base tonnages per Federal section are shown on plate 2 and total approximately 1.81 million short tons (1.64 million metric tons) for the unleased Federal coal lands within the KRCRA boundary in the Patmos Head quadrangle.

Table 2. Coal Reserve Base data for subsurface mining methods for Federal coal lands (in short tons) in the Patmos Head quadrangle, Carbon County, Utah.

(To convert short tons to metric tons, multiply by 0.9072)

Coal Bed Name	High development potential	Moderate development potential	Low development potential	Total
Upper Sunnyside	210,000	1,000,000	-0-	1,210,000
Lower Sunnyside	600,000	-0-	-0-	600,000
Total	810,000	1,000,000	-0-	1,810,000

AAA Engineering and Drafting, Inc. has not made any determination of economic mineability for any of the coal beds described in this report.

COAL DEVELOPMENT POTENTIAL

Development Potential for Surface Mining Methods

No development potential for surface mining methods exists in the area of this quadrangle because of the rugged topography, steep-sided canyons, extreme relief, and thick overburden. There may be very small areas where some rim stripping could be done, but in general the area is not conducive to surface mining methods.

Development Potential for Subsurface Mining and In Situ Gasification

The coal development potential for the underground mining of coal is shown on plate 12. In this quadrangle the areas where coal beds 5 ft (1.5 m) or more in thickness are overlain by less than 1,000 ft (305 m) of overburden are considered to have a high development potential for subsurface mining.

Areas where such beds are overlain by 1,000 to 2,000 ft (305 to 610 m) and 2,000 to 3,000 ft (610 to 914 m) of overburden are rated as having a moderate and a low development potential respectively. Areas that contain no known coal in beds 5 ft (1.5 m) or more thick, but coal-bearing units are present at depths of less than 3,000 ft (914 m) are classified as areas of unknown coal development potential. Areas where no coal beds are known to occur or where coal beds are present at depths greater than 3,000 ft (914 m) have no coal development potential.

The designation of a coal development potential classification is based on the occurrence of the highest-rated coal-bearing area that may occur within any fractional part of a 40-acre BLM land grid area or lot area of unleased Federal coal land. For example, a certain 40-acre area is totally underlain by a coal bed with a "moderate" development potential. If a small corner or the same 40-acre area is also underlain by another coal bed with a "high" development potential, the entire 40-acre area is given a "high" development potential rating even though most of the area is rated "moderate" by the lower coal bed. Another possibility is a 40-acre area devoid of any coal except a small corner where a 5-ft (1.5 m) coal bed crops out. In this case the 40-acre area will have a "high" development potential rating.

In the Patmos Head quadrangle approximately 320 acres of unleased Federal land have a high development potential, 360 acres have a moderate development potential, and 80 acres have an unknown development potential.

The in situ coal gasification methods of development potential classification are based on the dip and depth of coal beds having a minimum thickness of 5 ft (1.5 m). There are only two development potential classifications--moderate and low. The criteria for in situ classification include coal bed dips of 15 to 90 degrees and coal bed depth of 200 to 3,000 ft (61 to 914 m).

Inasmuch as the coal beds dip less than 15 degrees in the Patmos Head quadrangle, the in situ coal gasification methods of development potential classification do not apply.

Table 3. Sources of data used on plate 1.

Source	Plate 1 Index Number	Data Base Measured Section No.	Data Base Page or Plate No.
Doelling, 1972	1	15	378
	2	25	378
Clark, 1928	3	342	pl. 11
	4	343 and 366	pl. 5
	5	344 and 367	pl. 11
	6	334	pl. 2
	7	335 and 345	pl. 2, p. 73
	8	346 and 368	pl. 5
	9	369	pl. 11
	10	347 and 370	pl. 11
	11	348	pl. 11
	12	349	73
	13	350	73
	14	351	73
	15	352 and 371	pl. 5
	16	353 and 372	pl. 11, p. 73
	17	354	73
	18	356 and 374	pl. 11
	19	338 and 357 and 376	pl. 11
	20	339 and 358 and 376	pl. 5
	21	377 and 359	pl. 5
	22	360	73
	23	361	pl. 11
	24	340 and 362	pl. 11, p. 73
	25	363 and 378	pl. 11
	26	364	73
Brodsky, 1960	27	28	pl. 2
	28	30	pl. 2
	29	31	pl. 2
	30	32	pl. 2
	31	33	pl. 2
	32	36	pl. 2
	33	39	pl. 2
	34	38	pl. 2
	35	41	pl. 2
	36	40	pl. 2
	37	43	pl. 2
	38	355 and 373	pl. 11, p. 75
Doelling, 1972	39	50	379
Brodsky, 1960	40	135	pl. 2

Source	Plate 1 Index Number	Data Base Measured Section No.	Page or Plate No.
Brodsky, 1960	41	37	pl. 2
Doelling, 1972	42	51	379
Brodsky, 1960	43	42	pl. 2
Doelling, 1972	44	52	fig. 35 and 379
	45	53	fig. 35 and 379
Brodsky, 1960	46	48	pl. 2
	47	50	pl. 2

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