Text to Accompany

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COAL RESOURCE OCCURRENCE AND COAL DEVELOPMENT POTENTIAL MAPS OF THE NORTHEAST QUARTER OF THE NOTOM 15-MINUTE QUADRANGLE, WAYNE AND GARFIELD COUNTIES, UTAH

[Report includes 9 plates]

Prepared for

UNITED STATES DEPARTMENT OF THE INTERIOR

GEOLOGICAL SURVEY

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

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Purpose

This text is to be used in conjunction with Coal Resource Occurrence (CRO) and Coal Development Potential (CDP) Maps of the Northeast Quarter of the Notom 15-minute quadrangle, Wayne and Garfield Counties, Utah. These maps and report 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 the Henry Mountains Known Recoverable Coal Resource Areas (KRCRA's), Utah. Consequently, only those geologic features relevant to coal occurrences are described herein.

This investigation was undertaken by Dames & Moore, Salt Lake City, Utah at the request of the U.S. Geological Survey under contract number 14-08-0001-17489. The resource information gathered for this report is in response to the Federal Coal Leasing Amendments Act of 1976 (P.L. 94-377). Published and unpublished public information available through June 1979 was used as the data base for this study. Neither drilling nor field mapping was performed; nor were any confidential data used.

Location

The Northeast Quarter of the Notom 15-minute quadrangle lies across the border between Wayne and Garfield Counties and is situated in the south-central and north-central portions of those counties, respectively. The town of Notom, Utah lies in the northwest corner of the area and is about four miles (6.4 km) south of Utah Highway 24. The Capitol Reef National Mounument is 10 miles (16 km) northwest, and Hanksville, Utah is 26 miles (42 km) northeast of the quadrangle.

Accessibility

An unimproved dirt road extends south from Utah Highway 24 to Notom and continues in a south-southeast direction through the map area. Beyond this road, sole established access is by foot and horseback. Winter access is limited by snow and wind during some years.

Physiography

The Northeast Quarter of the Notom 15-minute quadrangle is located on the central west flank of the Henry Mountains structural basin. Although located in a basin, the area is topographically higher than most of the surrounding region. Elevations range from 4,800 feet (1,463 m) in the Sandy Creek channel near the north center to 6,490 feet (1,978 m) near the southwestern corner of the map area.

Thompson and Wildcat Mesas, in the east, rise steeply above finely-dissected, badland topography in the middle portions of the map area. A resistant, coal-bearing sandstone caps both mesas. Badland topography resulting from intermittent stream and flash flood erosion characterizes the west half of the area.

Streams in the quadrangle are part of the Colorado River drainage system. The north flowing perennial Sandy Creek traverses the center of the map area and is the principal collector. Sandy Creek joins with the east flowing Fremont River near Caineville.

Water quality and stream flow reflect seasonal climatic changes. Most surface water is saline due to high evaporation rates during the summer; streams typically dry up in late summer.

Climate and Vegetation

The quadrangle's climate is arid. Average annual rainfall is from 8 to 10 inches (20 to 25 cm). However, precipitation varies from year to year and long-term droughts are common.

Temperatures in the basin range from greater than 100°F (38°C) during the summer months to less than 0°F (-18°C) during the winter. The yearly average for the region is 56°F (13°C) (U.S. Bureau of Land Management, 1978). Temperatures drop slightly and precipitation increases at higher elevations.

Winds generally blow from the west and southwest. Seasonal high wind velocities usually occur during early spring and summer.

Principal types of vegetation in the area include grass, sagebrush, pinon, juniper, saltbrush and greasewood (U.S. Bureau of Land Management, 1978).

Land Status

The extreme northwestern edge of the central portion of the Henry Mountains Known Recoverable Coal Resource Area is located in the southeastern corner of the map area. The Federal government holds coal rights over most of the land, as shown on plate 2 of the Coal Resources occurrence maps. Surface ownership in the Northeast Quarter of the Notom 15-minute quadrangle is as follows: Bureau of Land Management - 66.3 percent, National Park Service - 18.7 percent, the State of Utah - 10.6 percent, and private holdings 4.4 percent. A Preference Right Lease Application (PRLA U6733) is outstanding in section 3 and parts of sections 10, 11 and 12, T. 31 S., R. 8 E., in the map area's southeastern corner.

GENERAL GEOLOGY

Previous Work

John Wesley Powell named the Henry Mountains in 1869 and made some of the first comments (Gilbert, 1877) on the geology of the area. G. K. Gilbert studied the Henry Mountains during 1875 and 1876. His report (Gilbert, 1877) is considered a classic of geologic literature. Geologic mapping of the quadrangle was completed by Smith and others (1963) as part of their work on the Capitol Reef area for the U.S. Geologic Survey. C. B. Hunt began investigating coal in the Henry Mountains in 1935 and completed field studies in 1939. The results of his effort were published in 1953 as U.S. Geological Survey Professional Paper 228. More recently, coal studies were completed by Doelling (1972) of the Utah Geological and Mineralogical Survey and Law (1977) of the U.S. Geological Survey. The results of these investigations provided most of the data used in this coal resource evaluation. Additional publications which describe geologic features in the region are included in the bibliography.

Stratigraphy

A complete sequence of Jurassic strata, from Navajo Sandstone through the Morrison Formation, underlies the west half of the map area. Jurassic rocks are principally sandstones and shales and are not coaliferous.

The oldest known coal-bearing unit in the Northeast Quarter of the Notom 15-minute quadrangle is the Cretaceous Dakota Sandstone. Overlying this are the Tununk Shale, the Ferron Sandstone, the Blue Gate Shale and the Emery Sandstone members of the Mancos Shale, all of Cretaceous age. A composite columnar section accompanied by lithologic descriptions on CRO plate 3 illustrates the stratigraphic relationships of these units.

The Dakota Sandstone is a westward trangressive littoral sequence and lies uncomformably atop the varicolored Brushy Basin Shale member of the Jurassic Morrison Formation. The Dakota Sandstone weathers to form a thin series of ledges and slopes at the base of broad slopes developed upon the overlying Tununk Shale member of the Mancos Shale (Peterson and Ryder, 1975). It consists principally of sandstone, gray shale and carbonaceous shale with subordinate conglomerate and sandy shale (Hunt, Averitt, and Miller, 1953). The formation averages 60 feet (18 m) in thickness in the map area (Doelling, 1972).

Conglomeratic, cross-bedded sandstones which occur near the base of the Dakota Sandstone in the quadrangle may have been derived by reworking of underlying Morrison Formation strata in a fluvial environment (Hunt, Averitt, and Miller, 1953). Minor interbeds of gray and carbonaceous shale reflect local marsh and lagoonal environments. A diagnostic bed of fossils containing Gryphaea, Exogyra and Inoceramus occurs near the top of the formation. Gryphaea are most abundant and commonly form reefs (Hunt, Averitt, and Miller, 1953).

The Mancos Shale lies conformably over the Dakota Sandstone and fills the sedimentary basin in this part of the Henry Mountains. It is generally divided into five members. However, only four of the five members are present in the map area; the uppermost Masuk Shale member has been completely removed by erosion.

The lowermost, Tununk Shale member of the Mancos Shale is gradational and interfingering with the underlying Dakota Sandstone. It is about 575 ft (175 m) thick in the map area and represents a continuation of the first westward transgression of the late Cretaceous sea in which the Dakota Sandstone was deposited (Peterson and Ryder, 1975).

The Tununk Shale member is a gray fissile shale with subordinate, mostly thin-bedded, medium-grained sandstone and bentonitic shale. The member weathers to a bluish-gray, is generally poorly exposed and forms smooth broad valleys (Peterson and Ryder, 1975). The lowest few feet of the member everywhere contain abundant oysters (Hunt, Averitt, and Miller, 1953). Sandstones in the Tununk Shale member are light gray to brown and become more abundant toward the top of the member, where it is transitional with the overlying Ferron Sandstone member. The top of the Tununk Shale member is placed beneath the first thick-bedded or massive sandstone ledge in the transition zone (Peterson and Ryder, 1975). A regressive sequence, partially the result of deltaic progradation, occurs in the upper part of the Tununk Shale member (Hunt, Averitt, and Miller, 1953).

The first significant coal bearing horizon in the map area, the Ferron Sandstone member of the Mancos Shale, is a regressive unit composed of littoral and coastal plain facies (Doelling, 1972). A lower, littoral unit is characterized by interbedded thin to thick horizons of gray to tan sandstone, siltstone and gray shale. The upper portion of the member is a coastal plain deposit of interbedded tan to yellowish-gray, massive to thick, medium-to coarse-grained sandstone, thin layers of gray carbonaceous and sandy shale and coal. Sandstones become lenticular and lighter in color upward in the section.

The Ferron Sandstone member is locally capped by a thin sandstone bed which probably represents a transgressive beach deposit (Hunt, Averitt, and Miller, 1953). In the Northeast Quarter of the Notom 15-minute quadrangle the Ferron Sandstone member averages 310 ft (95 m) thick and often forms a ridge or cliff.

The Ferron Sandstone member is unconformably overlain by the Blue Gate Shale member. The contact between the Ferron Sandstone and the Blue Gate Shale members is generally sharp. Detailed correlation of sandstone beds in the Ferron Sandstone member suggests that 50 to 100 feet (15 to 30 m) or more of the top of the Ferron Sandstone member have been removed by erosion at the unconformity in the region (Peterson and Ryder, 1975).

Above the hiatus is the Blue Gate Shale member of the Mancos Shale which, like the Tununk Shale member, is a transgressive sequence of marine shales. It is composed of blue-gray, finely laminated shale with thin beds of shaly sandstone and shaly limestone in the upper one-third of the unit (Hunt, Averitt, and Miller, 1953). The member weathers easily to form smooth valleys or broad benches. The lower part is concealed by alluvium in many places, but the upper part is generally well exposed in cliffs that are capped by Emery Sandstone (Peterson and Ryder, 1975).

The average thickness of the Blue Gate Shale member in the map area is 1,400 ft (427 m). The upper contact between the Blue Gate Shale member and the overlying Emery Sandstone member is interfingering and gradational.

The Emery Sandstone member of the Mancos Shale, like the Ferron Sandstone member, is a regressive sequence (Peterson and Ryder, 1975) and is the most important coal bearer in the Northeast Quarter of the Notom 15-minute quadrangle. It can also be divided into two units.

The lowermost unit represents littoral deposition and consists of gray to tan, massive and thick-bedded, medium-to coarse-grained sandstone with a few thin gray shale interbeds (Doelling, 1972). Gypsum seamlets are present in the sandstone. The upper coal-bearing portion of the member consists of interbedded gray shale, coal, tan sandy shale and tan to brown medium-grained massive to thick-bedded, locally resistant sandstone. The upper unit is thought by some investigators to be of nearshore fluvial origin.

The average remaining thickness of the Emery Sandstone member in the map area is 435 ft (15.8 m). It caps Thompson and Wildcat Mesas and is both stratigraphically and topographically the highest unit in the area.

Structure

Structure in the Northeast Quarter of the Notom 15-minute quadrangle is dominated by eastward dipping monoclinal beds on the east flank of the Waterpocket Fold. The monocline formed by the east flank of the fold parallels and separates the Henry Mountains structural basin to the east from the Circle Cliffs upwarp to the west. Jurassic and Cretaceous strata in the monocline exhibit dips ranging from 6 to 12 degrees in the west half of the map area, becoming more gentle eastward. The eastern half of the map area lies within the Henry Mountains structural basin. In this area, flat-lying resistant sandstone and conglomerate of the Emery Sandstone member of the Mancos Shale cap and are responsible for Wildcat and Thompson Mesas. Wide, alluvial filled stream beds and small benches flank the mesas on the west. No faults have been mapped in the area.

Geologic History

Most pre-Cretaceous Mesozoic rocks in this part of the Colorado Plateau are continental in origin. Permian through the Jurassic continental deposition was along coastal plains adjacent to principal seaways. The major types of depositional environments that existed during this period were eolian, intertidal mudflats, lacustrine, fluvial and flood plains (Hunt, Averitt, and Miller, 1953).

The Cretaceous history of the Henry Mountains coal field is similar to that of coal fields in central Utah and throughout the Colorado Plateau in general. The region is one in which classic transgressive and regressive sedimentation provided an environment for coal deposition.

During the early Cretaceous, the Henry Mountains region lay on a lowland plain over which neither subsidence nor uplift were occurring. However, sufficient erosion took place to remove lower Cretaceous strata and plane off the top of the Jurassic Morrison Formation.

Subsidence then resumed in the region and a sheet of fluvial sand and clay was deposited to form the Dakota Sandstone. Broad flood plains with swamps and lakes provided an environment in which vegetation flourished. Resulting accumulations of carbonaceous material formed local, thin coal seams elsewhere in the region.

In the meantime, as subsidence increased, a sea in which the Mancos Shale was to be deposited began its encroachment from the east. The sea eventually covered all the Henry Mountains region and extended westward to the present-day Wasatch Plateau area. The shoreline remained there throughout Mancos Shale depostion except for two dramatic regressions which deposited the Ferron and Emery Sandstone members. Orogenic pulses to the west supplied clastics for these sandstone members faster than the area could subside (Doelling, 1972). Marine shale deposition changed to nearshore sand and finally to lagoonal and fluvial sand and shale. Forests flourished, dead vegetation accumulated and, in places, coal was produced. All of the thick coal seams in the Henry Mountains Basin were deposited during these two events.

After deposition of the Mancos Shale the Cretaceous sea retreated permanently eastward. Although sedimentation undoubtedly continued in the Henry Mountains region, continental rather than marine beds were deposited and these were later removed by erosion.

According to Hunt and others (1953) the Waterpocket Fold and presumably the Henry Mountains structural basin were formed between the close of Cretaceous time and the Eocene epoch. Eocene deposits cover the fold at places in the region.

Emplacement of the Henry Mountains intrusives east of the Notom quadrangle may have occurred anytime after early to mid-Tertiary. Thereafter the Colorado Plateau began its uplift and erosion instead of deposition dominated. This activity has continued to the present day.

COAL GEOLOGY

No Dakota coal zones have been mapped in the area. Dakota Sandstone is described as locally coal bearing (Doelling, 1972), but occurrences are highly lenticular and the beds are less than one foot (30 cm) thick.

Ferron Sandstone member coal outcrops follow a north-south trend through the map area, broken only by alluvial cover. The coals lie within 150 feet (46 m) of the top of the member, below a resistant sandstone ledge, and correlate with coals in the lower of two Ferron coal zones which occur further north. The upper Ferron coal zone is present only as a carbonaceous horizon in this area, poorly exposed and usually covered by Blue Gate Shale member float. Coal seams in the lower Ferron coal zone average 1.3 ft (40 cm) in thickness.

Significant coal beds appear in the Emery Sandstone member along the eastern border of the Northeast Quarter of the Notom 15-minute quadrangle. Remnants of coal in the member appear on Thompson Mesa and Wildcat Mesa, near the northeast and southeast corners of the map area, respectively. On Thompson Mesa coal beds exhibit an average thickness of 1.7 ft (50 cm). Single beds appear thicker to the south on Wildcat Mesa, where the average is 2.1 ft (64 cm). The maximum individual seam is 7.2 ft (2.2 m) thick and occurs in section 3, T. 31 S., R. 8 E.

Chemical Analyses of Emery Zone Coal

No analyses for coal in the Northeast Quarter of the Notom 15-minute quadrangle are available. However, nine analyses of Emery coal from the Southwest Quarter of the Mt. Ellen quadrangle, adjoining the map area at its southeast corner, were published by Doelling (1972). The average of these analyses shown in table 1, yields an ash content of 10.6 percent, 0.9 percent sulfur and a heat value of 11,300 Btu/lb, indicating that the coal is subbituminous A in rank (ASTM, 1966). Doelling (1972) states that the validity of the analyses is questionable.

COAL RESOURCES

Data from 23 measured surface sections and surface mapping by Doelling (1979) of the Utah Geological and Mineralogical Survey and Law (1979) of the U.S. Geological Survey were used to construct outcrop, isopach and structure contour maps of coal zones and beds in the map area, (CRO plates 1 through 7).

Coal resources were calculated using data obtained from the coal isopach maps (CRO plates 4 and 7). The coal-bed acreage (measured by planimeter) multiplied by the average isopached thickness of the coal bed times a conversion factor of 1,770 short tons of coal per acre-foot for subbituminous coal yielded the coal resources in short tons of coal for each isopached coal bed. Reserve Base for the Em-1 coal bed is shown on CRO plate 6 and is rounded to the nearest tenth of a million short tons.

Table 1 -- Average proximate analyses of coal samples in percent

	Moisture	Volatile Matter	Fixed Carbon	Ash	Sulfur	Btu/lb
1. Outcrop Emery Coal Zone T.32S., R.9E.	10.5	38.2	48.5	10.8	0.8	9,590
2. Outcrop Emery Coal Zone Sec. 36, T.31S., R.8E.	13.5	37.08	43.23	20.28	0.71	9,015
3. Outcrop Emery Coal Zone Sec. 36, T.31S., R.8E.	13.9	39.89	47.97	11.27	0.58	10,204
4. Respect Pit South Creek Emery Coal Zone Sec. 27, T.31S., R.9E	7.4	40.0	51.8	6.1	0.7	11,130
5. Prospect Pit Sweet Water Creek Emery Coal Zone Sec. 30 T.31S., R.9E.	10.1	39.8	50.0	7.0	0.9	10,900
6. Outcrop Sweet Water Creek Emery Coal Zone Composite Sec. 30, T.31S., R.9E	7.70	38.50	40.80	11.50	1.50	12,491
7. Outcrop Sweet Water Creek Same as No. 6, upper 4 ft.	7.40	36.70	44.90	10.00	1.20	12,808
8. Outcrop Sweet Water Creek same as No. 6, 4 to 6 1/2 ft.	5.70	36.70	45.50	10.40	1.70	12,954
9. Outcrop Sweet Water Creek same as No. 6, lower 4 ft.	6.00	37.10	43.00	12.70	1.20	12,607
Average Total	9.2	38.7	47.7	10.6	0.9	11,300

Doelling (1972)

The Reserve Base for the Em-2 coal bed is under PRLA and thus is not calculated. Only that coal equal to or thicker than the 5.0 ft (1.5 m) minimum advocated in U.S. Geological Survey Bulletin 1450-B is included in the Reserve Base. Thinner beds presently being mined or for which there is evidence that they could be mined commercially at this time are not included in the Reserve Base calculation. Total coal Reserve Base for all coal beds thicker than 5.0 ft (1.5 m), as shown on CRO plate 2, is about 50,000 short tons. Reserve Base (in short tons) in the various development-potential categories for surface mining methods is shown in table 2.

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 so as 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 100 ft (30 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 as follows:

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

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

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 are absent or extremely limited between the 100-foot (30-m) overburden line and the outcrop are assigned unknown development potentials for surface mining methods. This applies to those areas where no known coal beds 5 feet (1.5 m) or more thick occur or where coal exceeds 5 feet (1.5 m) but data is insufficient to properly evaluate Coal Development Potential. Limited knowledge pertaining to the areal distribution, thickness, depth, and attitude of the coal beds prevents accurate evaluation of the development potential in the high, moderate, or low categories.

The coal development potential for surface mining methods is shown on plate 9. Of the Federal land areas having a known development potential for surface mining methods, 100 percent are rated high. The remaining Federal lands within the KRCRA boundary are classified as having unknown development potential for surface mining methods.

Development Potential for Subsurface Mining Methods

Areas considered to have a development potential for conventional subsurface mining methods include those areas where the coal beds of Reserve Base thickness are between 100 and 3,000 feet (30 and 914 m) below the ground surface and have dips of 15° or less. Coal beds lying between 100 and 3,000 feet (30 and 914 m) below the ground surface, dipping greater than 15°, are considered to have a development potential for in-situ mining methods.

Areas of high, moderate and low development potential for subsurface mining methods are defined as areas underlain by coal beds at depths ranging from 100 to 1,000 feet (30 to 305 m), 1,000 to 2,000 feet (305 to 610 m), and 2,000 to 3,000 feet (610 to 914 m), respectively.

Areas where the coal data are absent or extremely limited between 100 and 3,000 feet (30 and 914 m) below the ground surface are assigned unknown development potentials. This applies to those areas influenced by isolated data points and the areas where no known coal beds of Reserve Base thickness occur. Limited knowledge pertaining to the areal distribution, thickness, depth, and attitude of the coals in these areas prevents accurate evaluation of the development potential in the high, moderate or low categories.

No coal reserves are known to occur below the stripping limit within the map area thus excluding the compilation of coal development potential for conventional subsurface mining methods. All Federal lands within the KRCRA boundary are therefore classified as having unknown development potential for subsurface mining methods.

Table 2 -- Coal Reserve Base Data for surface mining methods for Federal coal lands (in short tons) in the Northeast Quarter of the Notom 15-minute quadrangle, Wayne and Garfield Counties, Utah

[Development potentials are based on mining ratios (cubic yards of overburden/ton of underlying coal). To convert short tons to metric tons, multiply by 0.9072; to convert mining ratios in yd^3/ton coal to m^3/t, multiply by 0.842]

Coal bed	High development potential (0-10 mining ratio)	Moderate development potential (10 - 15 mining ratio)	Low development potential (>15 mining ratio)	Total
Em-1	50,000	0	---	50,000
Em-2	---	---	---	---
Total	50,000	0	---	50,000

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