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# COAL RESOURCE OCCURRENCE AND COAL DEVELOPMENT POTENTIAL MAPS OF THE NORTHEAST QUARTER OF THE ORDERVILLE 15-MINUTE QUADRANGLE, KANE COUNTY, UTAH

(Report Includes 5 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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# INTRODUCTION

## Purpose

This report is to be used with the Coal Resource Occurrence (CRO) and Coal Development Potential (CDP) Maps of the northeast quarter of the Orderville 15-minute quadrangle, Kane County, Utah. This report was compiled to assist the land planning work of the Bureau of Land Management by providing a systematic coal resource inventory of Federal coal lands for the northeast quarter of the Orderville 15-minute quadrangle of the Alton-Kanab Known Recoverable Coal Resource Area (KRCRA) in southwestern Utah. This investigation was performed by Meiiji Resource Consultants of Layton, Utah for the U.S. Geological Survey under contract number 14-08-0001-17460. Resource information was gathered for this report in response to the Federal Coal Leasing Amendments Act of 1976 (P.L. 94-377). Published and unpublished information was used as the data base for this study. Neither new drilling nor field mapping was done, and confidential data were not used.

## Location

The northeast quarter of the Orderville 15-minute quadrangle is on the west side of the Alton-Kanab Known Recoverable Coal Resource Area (KRCRA) in southwestern Utah. The quadrangle is located in western Kane County.

The southern boundary of the quadrangle is five miles (8 km) north of Glendale, Utah, and the eastern boundary is two miles west of Alton, Utah. Both towns are small with few services. The quadrangle is 28 miles (45 km) by road north of Kanab, Utah, the nearest town with full services.

## Accessibility

U.S. Highway 89, which runs north from Kanab, Utah, crosses the northeast quarter of the Orderville 15-minute quadrangle from southwest to northeast. Utah State Road 136 branches east to Alton, Utah from U.S. 89 midway across the quadrangle. A few dirt roads and jeep trails branching east from U.S. 89 and southwest near Alton, Utah provide access to coal outcrop areas. It is normally possible to drive to within one mile (1.6 km) of the coal outcrops on the quadrangle.

## Physiography

The northeast quarter of the Orderville 15-minute quadrangle lies within the High Plateaus section of the Colorado Plateau physiographic province. The quadrangle covers the east side of the Markagunt Plateau.

The quadrangle is divided into two unequal parts by the Sevier Fault, which trends N. 30° E across the southeast corner of the quadrangle (Doelling and Graham, 1972). The section northwest of the fault includes about 90 percent of the quadrangle. The topography is rugged and mountainous, with a number of deep, steep-walled canyons cut below the general surface. Areas between the canyons are rugged with numerous steep-sided washes and small canyons crossing moderate to steep slopes. About 6700 acres (7080 ha) in the northwest corner is located on top of the Markagunt Plateau.

Relief is low and elevations average about 8000 ft. (2438 m) above sea level, with gentle slopes. Elevations vary from about 6200 feet (1890 m) at the south end of Long Valley to about 8200 ft. (2499 m) in the northwest corner of the quadrangle on top of the plateau.

Topography in The section southeast of the Sevier Fault is more subdued. Some steep valleys or small canyons are located here, but the divides are generally broader and smoother, without as many smaller gullies and canyons. Slopes are gentle to moderate. Elevations range from a low of 6800 feet (2073 m) in Coal Hollow to just over 7760 ft. (2365 m) on Black Mountain.

## Climate and Vegetation

The climate in the quadrangle area is semi-arid. Precipitation varies from 20 inches (51 m) to 30 inches (67 cm) per year, with the lower valleys receiving the least moisture. Temperatures range between average winter lows of about 12$^{\circ}$ F (-11$^{\circ}$ C) to average summer highs of about 84$^{\circ}$ F (29$^{\circ}$ C). There is some variation in temperature with elevation, making the higher mountains a few degrees cooler than the valleys.

Vegetation types vary across the quadrangle in response to changes in soil moisture. The soil moisture in turn is dependent on precipitation and evaporation rates which is strongly influenced by elevation. Evaporation rates are temperature-dependent and thus influenced by elevation.

The larger valley floors at lower elevations are covered with Sagebrush-Grass type vegetation. This is the type of vegetation present in Long Valley and the adjacent sections of tributary canyons, such as Winsor

Cove and Lydias Canyon. Mountain Brush type vegetation covers the major portion of the quadrangle southeast of Long Valley. This is particularly characteristic of the large areas underlain by shales of the Tropic Shale.

Ponderosa Pine dominates the mountainous land surface west of Long Valley below the Pink Cliffs. The remaining portions of the quadrangle are host to an open forest of Pinyon-Juniper Woodland vegetation. This vegetation type is especially well developed on top of the Markagunt Plateau in the northwest corner of the quadrangle and at Black Mountain in the southeast corner of the quadrangle.

Climate and vegetation information was modified from Dept. of Interior, 1975, p. II-1 to II-4, II-31 to II-35, fig. II-11.

## Land Status

The southeast quarter of the Orderville 15-minute quadrangle lies at the western edge of the Alton-Kanab KRCRA. Approximately 9.6 percent of the land surface in the quadrangle is included within the KRCRA. (All of the coal outcrop area is on Federal coal land and under lease). The coal-bearing area which is included within the KRCRA is in the southeast corner of the quadrangle. It includes the Sevier Fault zone and the land to the southeast within the quadrangle. The much larger part of the quadrangle northwest of the fault may also be underlain by coal. Private parties and the State of Utah own coal rights for slightly more than a third of that area.

# GENERAL GEOLOGY

## Previous Work

Little definitive geologic work was done prior to 1961. A regional study on coal occurrences was completed by G.B. Richardson (1909), and several papers emphasizing stratigraphy were published by A.E. Gregory and his co-workers (Gregory and Moore, 1931; Gregory, 1950; Gregory, 1951). None of these papers specifically included the northeast quarter of the Orderville 15-minute quadrangle, but they did provide information about the Orderville-Glendale area two to five miles (3 to 8 km) to the south and the Alton area one mile (1.6 km) east of the quadrangle boundary.

Cashion (1961, 1967) completed the first preliminary geologic work in the immediate area. Little work was actually done within the northeast quarter of the Orderville quadrangle, so much of the geology has been projected from the south and east. The earlier information on this and adjacent quadrangles was compiled in a monograph by the Utah Geological and Mineralogical Survey (Doelling and Graham, 1972).

## Stratigraphy

Formations which crop out in the northeast quarter of the Orderville 15-minute quadrangle vary in age from the Cretaceous Dakota Formation to the Eocene Claron Formation. In addition, information projected from adjoining quadrangles indicates the quadrangle is underlain by Jurassic strata to a depth of about 3000 ft. (914 m) below the coal-bearing Dakota Formation.

Mapping completed in the southeast quarter of the Orderville 15-minute quadrangle (Cashion, 1961, 1967), about six miles (10 km) south of this quadrangle, shows the Jurassic Navajo Sandstone approximately 3000 ft. (914 m) below the Dakota Formation. The Navajo Sandstone is fine-grained and light gray to tan, or white. The most conspicuous feature of the Navajo is the sweeping crossbeds characteristic of eolian deposition. Outcrops of this formation characteristically weather to massive cliffs, with thickness in excess of 1000 ft. (305 m).

The Jurassic Carmel Formation overlies the Navajo Sandstone. This formation is easily eroded and commonly forms the surface of benches or terraces underlain by the Navajo Sandstone. The Carmel Formation has four members toward the west end of the Alton-Kanab KRCRA. The following descriptions are based on Cashion's mapping and the terminology of Thompson and Stokes (1970).

The lowest member of the Carmel Formation is the Kolob Limestone. This correlates with the limestone member identified by Cashion (1967). The member is composed of dense gray to tan, silty limestone, with thin, sandy red shale near the base and thin gypsum interbeds near the top. The thickness of this unit in the quadrangle is about 300 ft. (91 m).

The Crystal Creek Member, a gypsiferous siltstone and fine-grained sandstone, conformably overlies the Kolob Limestone Member. Alternating dark reddish-brown and white to light-gray beds give this member a banded appearance. It contains some minor beds of gypsiferous shale, calcareous shale, and red and green clay-pebble conglomerate. The thickness of this rock unit is estimated to be about 180 ft. (55 m) in the area. This member corresponds to the banded member described by Cashion (1967).

The Paria River Member overlies the Crystal Creek Member and corresponds to the gypsiferous member described by Cashion (1967). This unit consists of 55 ft. (17 m) to 95 ft. (29 m) of interbedded gypsum, sandstone, limestone, siltstone, and shale. The color is light gray with some reddish beds.

The youngest member of the Carmel Formation in this quadrangle is the Winsor Member. This member is fine to very fine-grained sandstone, gray to light brown in color, interbedded in the lower quarter with thin red siltstone or mudstone beds. The upper portion of the member has been truncated by an unconformity, and the lower portion is unexposed. Thickness is reported to be about 180 ft. (55 m) by Cashion (1967).

The Cretaceous Dakota Formation unconformably overlies the Jurassic Carmel Formation. The lower contact is distinct in color and lithology and is easily located, but the upper contact is gradational with the overlying Tropic Shale. As a result, the contact of the Dakota with the overlying Tropic has been drawn at widely varying stratigraphic levels by different authors (Gregory and Moore, 1931; Cashion, 1961; Van DeGraff, 1963; Lawrence, 1965; Doelling and Graham, 1972). The division followed here is the same as that advocated by Lawrence (1965) and modified by Utah Geological and Mineralogical Survey practice (Doelling and Graham, 1972) which places the contact at the top of the highest coal bed in the upper or Smirl coal zone in the Alton-Kanab KRCRA.

Mapping by Cashion (1967) shows the Dakota Formation cropping out only in the deeper canyons in the southeast corner of the northeast quarter of the Orderville 15-minute quadrangle. The formation is best exposed in Frankie and Coal Hollows. Probably only the upper half of the Dakota Formation is exposed in the quadrangle.

The Dakota Formation consists of gray to dark-gray shale, alternating with yellow-gray to brown, fine to medium-grained sandstone. Bentonite, carbonaceous shale and coal are interbedded with the shale and sandstone. Coal seams five ft. (11.5 m) or more in thickness occur in two zones named the lower and upper coal zones by Cashion (1961). These lower and upper coal zones were later renamed the Bald Knoll and Smirl coal zones by Doelling and Graham (1972). Both zones are composed of gray to dark-gray shale, carbonaceous shale and coal. The Bald Knoll coal zone is within the lower 50 ft. (15 m) of the Dakota Formation, while the Smirl coal zone is within the upper 50 ft. (15 m). The total thickness of the Dakota Formation on this quadrangle is about 400 ft. (122 m), as projected from the adjoining quadrangles.

The Dakota Formation was deposited over an Upper Jurassic-Lower Cretaceous erosion surface of low relief during a Lower to Upper Cretaceous marine transgression. Deposition occurred in a complex environment ranging from fluvial to marine. The basal beds are generally of fluvial or near-shore origin, overlain by a complex interfingering of paludal, lagoonal, near-shore, and marine sediments. The marine advance was generally continuous but was marked by numerous local, or occasionally regional, retreats followed by renewed transgression.

There is a gradual change from coarse sandstone, in places conglomeratic, at the base of the Dakota Formation upward through the section to fine-grained sandstone and shale. All lithologies are lenticular and discontinuous. The formation is predominantly shale (Doelling and Graham, 1972) with minor interbedded lenticular, discontinuous beds of sandstone, carbonaceous shale and coal. The sandstones form prominent ledges and low cliffs, in contrast to the weathered shale and mudstone of the overlying Tropic Shale.

The contact between the Cretaceous Tropic Formation and the underlying Dakota Formation is gradational. A number of authors have described this unit (Gregory and Moore, 1931; Van DeGraff, 1963). This slope-forming unit consists predominantly of light to medium-gray shale and claystone with minor carbonaceous shale and an occasional thin, lenticular coal bed. Some thin brown sandstone and thicker yellow-gray sandstone beds of near shore origin are also present. The sandstones are concentrated toward the lower and upper contacts, which are gradational with the underlying Dakota Formation and overlying Straight Cliffs Sandstone.

The Tropic Shale is predominantly marine shale. To the west, the Tropic Shale interfingers with the Straight Cliffs Sandstone (Cashion, 1961; Lawrence, 1965; Doelling and Graham, 1972) while to the east it is correlated with the Tununk Member of the Mancos Shale of eastern and central Utah. The close proximity of the time-equivalent, near-shore Straight Cliffs Sandstone to the west and interbedded sandstones and coal beds within this area suggest the Tropic Shale was deposited in a shallow marine environment.

The Tropic Shale crops out only within and to the southeast of the Sevier Fault zone (Cashion, 1967). The soft shales of this formation crop out over approximately 80 percent of this restricted area. The Tropic Shale is believed to underlie at depth the major portion of the quadrangle northeast of the Sevier Fault zone. Total thickness of the Tropic Shale on this quadrangle was estimated at about 1000 ft. (305 m) by Doelling and Graham (1972).

The Cretaceous Straight Cliffs Sandstone conformably overlies the Tropic Shale. Cashion (1961) describes this formation as one massive, cliff-forming sandstone bed about 80 ft. (24 m) thick in this area. The Straight Cliffs Sandstone thickens both to the west, where it reaches 600 ft. (182 m) in thickness (Cashion, 1961), and to the east, where it averages 1000 ft. (305 m) in thickness (Gregory and Moore, 1931). The thickness changes over a distance of about 10 miles (16 km).

The Straight Cliffs Sandstone consists of massive, cliff-forming, tan or buff, fine-grained marine sandstone with some thin beds of shale or siltstone. An occasional thin coal bed is present toward the middle of the formation in the central and eastern parts of the Alton-Kanab KRCRA. The sandstones were deposited in a near-shore environment as the Cretaceous sea retreated to the east (Van DeGraff, 1963).

The Wahweap Sandstone conformably overlies the Straight Cliffs Sandstone and is very similar to it. The Wahweap Sandstone is a fine to very fine-grained sandstone, slightly feldspathic and silty, with some interbeds of blue-gray, green, and tan shale, as well as some lenses and cross-beds of fine pebbles. The Wahweap Sandstone weathers to a topography dominated by ledges and low cliffs, which contrasts with the underlying, more massive, cliff-forming Straight Cliffs Sandstone.

The Kaiparowits Formation is the youngest Cretaceous formation. It is a weak, friable sandstone, poorly cemented by calcite. The weathering style is more typical of a shale than a sandstone. The Kaiparowits Formation is dark-gray to gray-green, fine to medium-grained sandstone, with thin conglomerate beds.

The total thickness of the uppermost Cretaceous formations within the quadrangle is estimated to be about 1600 ft. (488 m) (Cashion, 1961). The Wahweap and Kaiparowits Formations crop out in only two areas within the quadrangle. One area of less than 1 square mile (2.6 sq. km) is located between two major faults within the northern part of the Sevier Fault zone. The other is in the southwest quarter of the quadrangle, along Long Valley.

The Tertiary Claron Formation is the youngest consolidated sedimentary formation present in the quadrangle. It unconformably overlies the Cretaceous Kaiparowits Formation. The Claron Formation is predominantly pink to red, sandy limestone with some gray limestone and sandstone beds. The lower part is characterized by abundant calcareous conglomerate and sandstone. There is a general gradation upward from sandy and conglomeratic beds at the base to finer-grained material higher in the section. The total thickness of the formation may reach 1300 ft. (396 m) (Doelling and Graham, 1972). The Claron Formation crops out in a few fault blocks within the Sevier Fault zone, and it also is found in most of the quadrangle northwest of the fault zone.

Olivine basalt flows cover the area just north of the south border of the quadrangle. Minor, small olivine phenocrysts are distributed in an aphanitic groundmass of plagioclase, augite, olivine, and minor iron-titanium oxides. These flows are unusual in that they emanated from fissure vents just west of Flax Lakes. Basalt flows are most commonly related to cinder cones in southwestern Utah (Gregory, 1950).

## STRUCTURE

### Folds

The northeast quarter of the Orderville 15-minute quadrangle lies between the Paunsaugunt Plateau to the east and the Markagunt Plateau to the west. It is within the High Plateaus section of the Colorado Plateau physiographic province. The regional structure is characterized by broad, open folds and an occasional north-trending normal fault. The structure of the quadrangle is typical of the Colorado Plateau Province.

The northeast quarter of the Orderville 15-minute quadrangle lies on the west side of the Paunsaugunt Syncline. The Paunsaugunt Syncline is a broad, gentle fold which underlies the Paunsaugunt Plateau (Doelling and Graham, 1972). The structure plunges north, and dips do not exceed $3^{o}$ on either limb. Dips at the outcrop in this quadrangle are east to northeast at about $2^{o}$. Much steeper dips are found where bedding has been disturbed near faults within the Sevier Fault zone.

## Faults

The Sevier Fault zone runs N. $30^{o}$ E. across the southeast corner of the quadrangle. The zone is approximately a mile wide and is composed of numerous subparallel, en echelon, and cross-faults. Total displacement across the fault zone has been 1000 ft. (305 m) to 2000 ft. (610 m) with the west side downthrown. Grose, Hileman and Ward (1967) found, while investigating the coal beds and mines, that the Sevier Fault generally had only a moderate effect on the coal beds and then only within 100 ft. (31 m) to 500 ft. (152 m) of a major fault branch.

overburden is currently under lease.

## Past Production

There is no known production.

## Coal Resources

Coal reserves are calculated by multiplying the total tons of coal in place (the reserve base) by a recovery factor, which takes into account losses experienced under similar circumstances in other areas, to arrive at an assumed recoverable coal tonnage (the reserve). The recovery factors used, 0.85 for surface mining and 0.50 for subsurface mining, were provided by the U.S. Geological Survey and are based on economic and technical criteria.

Coal reserves for Federal land were calculated using data obtained from the coal isopach maps and the areal distribution and identified resource maps. The coal zone acreage (measured by planimeter), multiplied by the average thickness of the coal zone and by a conversion factor of 1770 short tons of coal per acre-foot (13,017 metric tons per-hectare meter) for sub-bituminous coal, yields the coal resources in short tons of coal for each coal zone. Coal beds thicker than five ft. (1.5 m) which are overlain by less than 3000 ft. (914 m) of overburden are included. These criteria were provided by the U.S. Geological Survey.

No public information on coal thickness or quality is available for this quadrangle. Consequently, no coal reserve figures could be calculated. No attempt has been made by Meiiji Resource Consultants to determine the economic recoverability of coal described in this report.

## Coal Development Potential

Coal development potential maps are prepared using the boundaries

# COAL GEOLOGY

## General

Coal deposition occured near the beginning and end of deposition of the Dakota Formation with some minor deposition in between. The coal was deposited over broad areas as thin to moderately thick, discontinuous, and sometimes overlapping beds. Localized areas of greater than normal deposition are found within some coal beds, possibly the result of deposition in parts of an oxbow lake, swamp or lagoon.

No information on coal thickness or quality is available. The only publicly available mapping was completed by W.B. Cashion (1967). According to Cashion's work, only the Smirl coal zone crops out within the quadrangle. The Smirl coal zone crops out in both Frankie Hollow and Coal Hollow in the southeast corner of the quadrangle. The Bald Knoll coal zone was mapped on the adjacent Alton, Bald Knoll, and southeast quarter of the Orderville 15-minute quadrangle within a mile (1.6 m) of the northeast quarter of the Orderville 15-minute quadrangle boundary. Presumably, the Bald Knoll coal zone extends across the quadrangle at depth.

The only near-surface coal is confined to the area southeast of the Sevier Fault zone. Coal northeast of the fault zone is in the downdropped block, which has caused the coal to be deeply buried, probably in excess of 3000 ft. (914 m) over most of the block.

Information projected from the adjoining quadrangles suggests the Smirl coal zone is continuous and has a thickness of seven to nine ft. (2.1 to 2.7 m) in the KRCRA (see U.S.G.S. Open-File Reports 79-1423, 79-1424, 79-1425). The Bald Knoll coal zone varies in thickness on the adjoining quadrangles and may be less than five ft. (1.5 m) thick over most of the KRCRA within this quadrangle. All coal overlain by less than 200 ft. (61 m) of of the smallest legal land divisions, shown on plate 2, as boundaries for the coal development potential area. These divisions contain 40 acres (16 ha) or approximately 40 acres (16 ha) each. In portions of Federally owned sections containing no surveyed divisions, parcels of approximately 40 acres (16 ha) have been constructed and used as the development potential area boundaries. When a number of development potential areas are present in the same 40-acre (16 ha) parcel, the highest development potential is assigned to the entire 40-acre (16 ha) parcel, in accordance with Bureau of Land Management guidelines.

## Development Potential for Surface Mining Methods

Areas between the coal outcrop and 200 ft. (61 m) of overburden are included as surface mining areas. The divisions between high, moderate, and low development potential areas for surface mining methods are based on a calculated mining ratio. This ratio is defined as the cubic yardage of overburden overlying each ton of recoverable coal, assuming an 85 percent recovery. The formula used to calculate mining ratios for surface mining of coal is shown below:

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

where MR = mining ratio

$t_o$ = thickness of overburden in feet

$t_c$ = thickness of coal in feet

rf = recovery factor (85 percent for this quadrangle)

cf = conversion factor to yield MR value in terms of cubic yards of overburden per short tons of recoverable coal: 0.911 for sub-bituminous coal

Note: To convert mining ratio to cubic meters of overburden per metric ton of recoverable coal, multiply MR by 0.8428.

A high development potential ranking is applied to those areas between the coal outcrop and a line representing a mining ratio value of 10. A moderate development potential is applied to areas which have mining ratio values between 10 and 15. A low development potential ranking is assigned to areas with mining ratio values over 15, but under less than 200 ft. (61 m) of overburden. 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. An unknown development potential is assigned to areas where coal data is absent or very limited between the outcrop and 200 ft. (61 m) depth. The surface development potential for this quadrangle is shown on plate 4.

No information on coal thickness is available, and data on outcrop location are limited. As a result, the unleased area is designated as having an unknown development potential for surface mining methods.

## Development Potential for Subsurface Mining Methods

Areas where coal is overlain by more than 200 ft. (61 m) but less than 3000 ft. (914.4 m) of overburden are considered potentially minable by conventional subsurface mining methods. Coal with 200 ft. (61 m) to 1000 ft. (304.8 m) of overburden is rated as having a high potential. Coal with

1000 ft. (304.8 m) to 2000 ft. (609.6 m) of overburden is rated as moderate, while that under more than 2000 ft. (609.6 m) of overburden is rated low.

An unknown development potential is assigned to areas under less than 3000 ft. (914.4 m) of overburden, where coal data are absent or very limited. Where coal is beneath 3000 ft. (914.4 m) or more of overburden, a ranking of no development potential is assigned. The subsurface development potential for this quadrangle is shown on plate 4.

No information on coal thickness is available,and data on outcrop locations are limited. As a result, the unleased area is designated as having an unknown development potential for both surface and subsurface mining methods.

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