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COAL RESOURCE OCCURRENCE AND COAL DEVELOPMENT POTENTIAL MAPS OF THE RAINBOW POINT QUADRANGLE, KANE COUNTY, UTAH

(Report includes 13 plates)

Prepared for

UNITED STATES DEPARTMENT OF THE INTERIOR

GEOLOGICAL SURVEY

by

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CONTENTS

	Page
Introduction	1
Purpose	1
Location	1
Accessibility	2
Physiography	2
Climate and Vegetation	3
Land Status	4
General geology	5
Previous work	5
Stratigraphy	6
Structure	13
Coal geology	14
General	14
Bald Knoll Coal Zone	15
Smirl Coal Zone	16
Past Production	16
Coal resources	17
Coal development potential	18
Development potential for surface mining method	18
Development potential for subsurface mining methods	20
Selected References	21

ILLUSTRATIONS

Coal resource occurrence maps of the Rainbow Point quadrangle, Kane County, Utah

Plate 1. Coal data map

2. Boundary and coal data map

3. Coal data sheet

4. Isopach map of the Bald Knoll coal zone

5. Structure contour map of the Bald Knoll coal zone

6. Overburden isopach and mining ratio map of the Bald Knoll coal zone

7. Areal distribution and identified resources map of the Bald Knoll coal zone

8. Isopach map of the Smirl coal bed

9. Structure contour map of the Smirl coal bed

10. Overburden isopach and mining ratio map of the Smirl coal bed

11. Areal distribution and identified resources map of the Smirl coal bed

Coal development potential maps of the Rainbow Point quadrangle, Kane County, Utah

Plate 12. Coal development potential for surface mining methods

13. Coal development potential for subsurface mining methods

TABLES

Page

Table 1. Chemical analyses of coals in the Rainbow Point quadrangle, Kane County, Utah --------- 23

Page

Table 2. Coal reserve base data for surface mining methods for Federal coal lands (in short tons) in the Rainbow Point quadrangle, Kane County, Utah ---------- 24

3. Coal reserve base data for subsurface mining methods for Federal coal lands (in short tons) in the Rainbow Point quadrangle, Kane County, Utah ---------- 25

4. Sources of data used on plate 1 ---------- 26

INTRODUCTION

Purpose

This report is to be used with the Coal Resource Occurrence (CRO) and Coal Development Potential (CDP) Maps of the Rainbow Point 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 Rainbow Point 7½-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 Rainbow Point quadrangle is in southwestern Utah in north-central Kane County on the east side of the Alton-Kanab KRCRA. The quadrangle is about 40 miles (64 km) northeast of Kanab, Utah, the nearest town with full services. It is 15 miles (24 km) southwest of Cannonville, Utah and 25 miles (40 km) east of Glendale, Utah.

Accessibility

Access is limited throughout the region and in the Rainbow Point quadrangle. The main paved highway, U.S. 89, runs south from Panguitch through Glendale to Kanab, Utah where it turns east. Although U.S. 89 approaches within 15 miles (24 km) of the quadrangle, it is always at least 35 miles (56 km) away by road. Utah State Road 12 branches east from U.S. 89 seven miles (11 km) south of Panguitch to give access by paved road to Bryce Canyon National Park and Cannonville, Utah. A paved road leads from Utah State Road 12 into the Park. This road is maintained by the U.S. National Park Service and runs along the rim of the Paunsaugunt Plateau. A portion of this road is within the northwest corner of the quadrangle.

The major portion of the quadrangle, which is below the plateau rim, can be reached via a maintained county road from Cannonville, Utah, which crosses the southeast quarter of the quadrangle and connects with Utah State Road 136, 16 miles (26 km) southwest of the quadrangle. Utah 136, which is unpaved, connects with U.S. 89 both northwest and south of its junction with the county road.

All travel within the quadrangle, except for the National Park, is by dirt roads and jeep trails branching from the county road. A few of these roads extend northwest to the coal outcrop. However, large areas, including Horse Mountain to the north, are inaccessible by vehicle.

Physiography

The Rainbow Point quadrangle lies in the High Plateaus section of

the Colorado Plateau physiographic province (Sargent and Hansen, 1976). It is located on the east side of the Paunsaugunt Plateau.

The entire quadrangle is rugged and mountainous with the exception of the southeast quarter, which is characterized by low hills and broad valleys. Elevations range from a high of 9115 feet (2778 m) at Rainbow Point within Bryce Canyon National Park in the northwest, to lows of 6200 feet (1890 m) in Deer Range Canyon in the southeast corner, and 6120 feet (1865 m) along Bull Valley in the northeast.

Climate and Vegetation

The Rainbow Point quadrangle has an arid climate similar to most of southwestern Utah. Precipitation averages about 16 inches (41 cm) per year. It varies from a low of about 10 inches (25 cm) per year in the southeast corner of the quadrangle to a high of about 24 inches (61 cm) per year in the northwest corner on top of the Paunsaugunt Plateau.

Winters are cold, while summers are warm. Annual winter low temperatures average 8^{o} F (-13^{o}C), while average summer highs are 84^{o} F (27^{o} C) at Cannonville, Utah, 15 miles (24 km) to the northeast of the quadrangle. Temperatures on top of the Paunsaugunt Plateau are frequently 10^{o} F - 15^{o} F (5.5^{o}C - 8^{o} C) cooler.

Vegetation shows little variation across the quadrangle. All of the area below the plateau rim has an open Pinyon-Juniper Woodland type vegetation. This is mixed with Ponderosa Pine on the higher slopes below the rim and with small areas of Sagebrush-Grass type vegetation in the lowest elevations and along the larger washes. The plateau surface,

with higher precipitation and cooler temperatures, supports Conifer and Aspen.

Climatalogical and vegetation information is modified from "Department of Interior, 1975, part I p. II-1 to II-4, II-31, to II-35, fig. II-11."

Land Status

The Rainbow Point quadrangle is located on the east side of the Alton-Kanab KRCRA in southwestern Utah. The major land owner is the Federal Government, with 86.2% or about 32,600 acres (13,190 ha) of the land. Slightly less than 4000 acres (1620 ha) of this is within Bryce Canyon National Park. A little less than half of the quadrangle, 17,450 acres (7,062 ha), is underlain by coal. Almost all of the coal is owned by the Federal Government. Virtually all of the coal on private land is reserved to the Federal Government, while the State of Utah owns coal on only about 400 acres (160 ha).

All coal under less than 200 feet (61 m) in the southern portion of the quadrangle is currently under lease. A small area on the east side of the Paunsaugunt Fault and a larger area on Horse Mountain in the north contain unleased coal under less than 200 feet (61 m) of overburden (plates 7 and 11).

GENERAL GEOLOGY

Previous Work

The earliest geologic investigation of the region in which the Rainbow Point quadrangle is located was completed by Gregory and Moore (1931). They pointed out the coal potential of the upper Paria River valley, 12 miles (19 km) to the northeast. Gregory later authored a paper (1951) on the Paunsaugunt Plateau which included the western half of the quadrangle. He concluded that no coal of economic interest was present within the southern and eastern areas of the plateau.

Cashion (1961, 1967) expanded the work of Gregory by concentrating on the coal and adjacent stratigraphy of the western and southern sides of the plateau. His was the first publication dealing primarily with the coal geology. Although he came no further east than Johnson Valley on the Bald Knoll quadrangle 10 miles (16 km) to the southwest, his lithologic descriptions, descriptions of stratigraphic relationships and measurements of coal outcrops have been used by all subsequent authors. Robison (1963, 1964, 1966) extended the known coal-bearing area from Johnson Canyon east into the Tropic area, as well as providing descriptions and measurements of coal outcrops along the east side of the Paunsaugunt Plateau.

The coal geology of the Rainbow Point quadrangle was worked out by the Utah Geological and Mineralogical Survey and reported by Doelling and Graham, (1972). The U.S. Geological survey drilled three holes behind the outcrop to provide subsurface information, as part of an investigation of the Alton-Kanab coal field (Bowers, 1977). W.E. Bowers of the U.S. Geological Survey

has provided a number of unpublished outcrop measurements which have aided materially in the preparation of this report (Bowers, 1979).

Stratigraphy

Strata which crop out within the Rainbow Point quadrangle range in age from the Jurassic Navajo Sandstone to the Eocene Claron Formation Formations present in the quadrangle were briefly described by Doelling and Graham (1972), more fully described to the southwest by Goode (1973), and to the northeast by Robison (1966). Doelling and Graham informally divided the Jurassic units on the quadrangle, using occurrence and estimated thickness, from personal observation and descriptions based on a report by Thompson and Stokes (1970) on the San Rafael Group of southern Utah.

The Jurassic Navajo Sandstone underlies the entire quadrangle. It is a massive, cliff-forming sandstone, at least 1000 feet (305 m) thick (Doelling and Graham, 1972). The sandstone is fine-grained, light gray, tan to almost white. The most conspicuous and diagnostic feature is the massive, sweeping crossbeds. The light color and cliff-forming character have led to the informal designation "white cliffs" for the Navajo outcrops in southern Utah. The Navajo Sandstone is exposed within this quadrangle only in the southeast corner, where it occurs in Bullrush Gorge, Tank Canyon and Deer Range Canyon. No more than the upper 300 feet (91 m) is exposed.

The Jurassic Carmel Formation unconformably overlies the Navajo Sandstone. The Carmel Formation is divided into six members, all of which are

reported to be present in the subsurface of the Rainbow Point quadrangle (Doelling and Graham, 1972). The Carmel Formation is a weak, slope-forming unit, which forms the surface of the low area east of the Paunsaugunt Fault, a terrace underlain by the Navajo Sandstone. Doelling and Graham reported the Carmel Formation to be a little over 600 feet (183 m) thick on the Rainbow Point quadrangle, but no attempt has been made to map the individual members within the quadrangle. A general lithologic description of the members, based primarily on Cashion (1967), Thompson and Stokes (1970), and Goode (1973), is as follows:

The lowest member of the Carmel Formation is the Kolob Limestone, which correlates with the limestone member described by Cashion (1967). This member consists of dense gray to tan, silty limestone, with thin, sandy red shale near the base and thin gypsum interbeds near the top.

The Crystal Creek Member conformably overlies the Kolob Limestone Member. This is a gypsiferous siltstone and fine-grained sandstone, with alternating dark-reddish brown and white to light-gray beds which give this member a banded appearance. It contains some minor beds of gypsiferous shale, calcareous shale, and red and green clay-pebble conglomerate. It also contains lenses of gravel, boulders of rhyolite and andesite, plus some lenses of gypsum. This member corresponds to the banded member described by Cashion (1967).

The Thousand Pockets Tongue of the Navajo Sandstone overlies the Crystal Creek Member. It thins to the west (Goode, 1973) and may not extend very far beyond the west boundary of the Rainbow Point quadrangle. The Thousand Pockets Tongue of the Navajo Sandstone is a cross-bedded, white to yellowish-

buff, fine-grained sandstone. It is about 150 feet (46 m) above the base of the Carmel Formation and is 60 to 80 feet (18 to 24 m) thick (Doelling and Graham, 1972).

The Paria River Member of the Carmel Formation overlies the Thousand Pockets Tongue of the Navajo Sandstone. The Paria River corresponds to the gypsiferous member described by Cashion (1967). It is a red, gypsiferous sandstone with some interbedded white sandstone and purplish-red mud and siltstones.

The Winsor Member overlies the Paria River Member. The Winsor Member is predominantly a fine-grained, buff sandstone but ranges in color from white to brown. Thin, red siltstones are interbedded within the sandstones. Goode (1973) reported that the upper contact is marked by a distinctive white sandstone.

The Wiggler Wash Member overlies the Winsor Member and is the youngest member of the Carmel Formation. This member is composed of interbedded limestone, red siltstone, and white and greenish gypsum.

The youngest Jurassic rock unit exposed within this quadrangle is the Entrada Formation, which is divided into two members: a lower reddish, silty sandstone, and an upper massive, earthy-weathering, whitish, fine-grained sandstone. The white upper Entrada contrasts with the darker Cretaceous shales above, greatly aiding in field mapping. The Entrada is 300 feet (91 m) to 400 feet (123 m) thick.

The Cretaceous Dakota Formation unconformably overlies the Jurassic Entrada Formation. The lower contact of the Dakota is distinct in color and lithology from the underlying Jurassic sediments 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). Accordingly, the contact is designated at the top of the highest coal bed in the upper or Smirl coal zone in the Alton-Kanab KRCRA.

The Dakota Formation crops out in the southwest corner of the quadrangle and in a narrow band, adjacent to the Paunsaugunt Plateau, through the center of the quadrangle. Horse Mountain in the north is also underlain by this formation.

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 beds five feet (11.5 m) or more in thickness are confined to 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 feet (15 m) of the Dakota Formation, while the Smirl coal zone is within the upper 50 feet (15 m).

The Bald Knoll coal bed, within the coal zone, was mapped by Bowers (1979) two feet (0.6 m) above the base of the Dakota Formation (see data

point 20, plates 1 and 3). This supports Goode's (1973) statement that the first coal bed was found six to ten feet (1.8 to 3.0 m) above the base of the Dakota Formation on the Skutumpah Creek quadrangle, southeast of the Rainbow Point quadrangle.

The central section of the Dakota Formation is interbedded gray shale beds and yellow-gray ledge-forming sandstones. Some of the shales are carbonaceous with an occasional interbedded thin coal bed. This section, the largest portion of the formation, weathers to low cliffs and ledgy slopes, even though shale comprises over half of the interval.

The upper section, the Smirl coal zone, is very similar to the Bald Knoll coal zone. The Smirl coal zone has three beds which appear continuous throughout the coal bearing area. A coquina bed about three feet (1 m) thick is found a short distance below the upper coal bed.

The Dakota ranges from 150 to 250 feet (46 to 76 m) thick on the quadrangle. It 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 usually of fluvial or near-shore origin, overlain by a complex interfingering of paludal, lagoonal, near-shore, and minor marine sediments. The marine advance was generally continuous but was marked by numerous local, occasionally regional, retreats followed by renewed transgression.

There is a gradual fining upward from coarse sandstone, in places conglomeratic, at the base of the Dakota Formation 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 Shale and the Dakota Formation is gradational. A number of authors have described the Tropic Shale (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 sandstones beds of near-shore origin are also present. The sandstones are concentrated toward the lower and upper contacts with the underlying Dakota Formation and overlying Straight Cliffs Sandstone.

The Tropic Formation crops out in a band extending from the southwest corner of the Rainbow Point quadrangle, along the west side of the Paunsaugunt Fault. The mesa top of Horse Mountain is underlain by this formation. Most of the gravel-covered bench in the southwestern portion of the quadrangle is also underlain by the non-resistant Tropic shales.

Upper Cretaceous formations present in the Rainbow Point quadrangle have not received extensive study. These formations crop out in the western part of the quadrangle, from south of the middle of the western boundary to near the middle of the northern boundary. They form a mountainous topography characterized by moderate to steep slopes, dominated by cliffs and ledges below the plateau rim.

The Straight Cliffs and Wahweap Sandstones are very similar and mapped

together on this quadrangle (Doelling and Graham, 1972). The sandstones are fine-to medium-grained, tan to yellow-gray, and thin to thick-bedded. Occasional thin coal beds are present and concentrated toward the center of the section. The sandstones were deposited in a near-shore environment as the Cretaceous sea retreated to the east (Van DeGraff, 1963).

The Kaiparowits Formation is the youngest Cretaceous formation. It is a weak, friable sandstone, poorly cemented by calcite, with a weathering style more typical of shale than a sandstone. The Kaiparowits Formation is dark gray to gray-green, fine-to medium-grained sandstone. Some thin conglomerate beds are also present. The total thickness of the Upper Cretaceous formations on the Rainbow Point quadrangle is estimated to be about 1400 feet (427 m) (Doelling and Graham, 1972).

The youngest consolidated formation is the Eocene Claron Formation. This formation forms the surface and rimrock of the Paunsaugunt Plateau. It crops out only within Bryce Canyon National Park in this quadrangle and forms the spectacular "Pink Cliffs" of Bryce Canyon. Robison (1966) reported an estimated thickness of 1600 feet (488 m), 20 miles (32 km) to the east on the Kaiparowits Plateau. However, Doelling and Graham (1972) estimate that only about 500 feet (152 m) of the Claron is present on the Paunsaugunt Plateau.

The Claron unconformably overlies the Cretaceous Kaiparowits Formation. This formation is predominantly pink to red arenaceous limestone with some gray limestone and sandstone beds. The lower portion is characterized by abundant calcareous conglomerates and sandstones.

Pediment gravels are common in this area. They are often found on the

outcrop of the easily-eroded Tropic Formation and less commonly on weak members of the Carmel Formation.

STRUCTURE

Folds

Regional structure in the Rainbow Point quadrangle area is characterized by broad open folds and an occasional north-trending normal fault, frequently with large displacement. The structure of the Rainbow Point quadrangle is typical of the Colorado Plateau province as a whole.

The Rainbow Point quadrangle is located on the east side of the Paunsaugunt Syncline (Doelling and Graham, 1972). The sturcture plunges north, and dips do not exceed 3^{0} on either limb. Dips at the outcrop on the Rainbow Point quadrangle are west at 1^{0} to 3^{0}.

Faults

The Paunsaugunt Fault is the only major fault in the quadrangle. It is the easternmost of three north-south trending faults which separate major tectonic blocks in southern Utah. The others, in order from east to west, are the Sevier Fault and the Hurricane Fault.

The Paunsaugunt Fault comprises a fault zone which separates the Paunsaugunt Plateau to the west from the Kaiparowits Plateau to the east. It is a normal fault with dips of 70^{0} to 90^{0} to the west, with movement across the fault zone which varies from 200 feet (61 m) in the south to

more than
500 feet (152 m) in the north (Doelling and Graham, 1972). Robison (1966) reports greater movement north of the quadrangle at Tropic Canyon, where displacement of more than 1500 feet (457 m) was recognized. Dips are steepened locally to the west, near the main faults within the fault zone. Grose, Hileman, and Ward (1967) reported that major deformation was confined within 100 feet (30 m) to 500 feet (152 m) of the major fault branches. Doelling and Graham (1972) described a badly disturbed area along the fault zone in the central portion of the quadrangle.

COAL GEOLOGY

General

Coal deposition occurred near the beginning and end of deposition of the Dakota Formation, with some minor deposition in between. The coal was laid down 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 deeper parts of an oxbow lake, swamp or lagoon.

Thirty-six measured sections and three drill holes are available for use in evaluating the coal resources within the Rainbow Point quadrangle. Fourteen measured sections and one drill hole give information on the Bald Knoll coal zone, while twenty-two measured sections and three drill holes are located within the Smirl coal zone. Five coal analyses provide information on the quality of the coal.

The western half of the quadrangle, west of the Paunsaugunt Fault, is

underlain by both the Bald Knoll and Smirl coal zones. The coal zones are nearly horizontal and dip at about 2^{o} to the northwest (plates 5 and 9). Both are presumed to extend beneath the edge of the plateau at depth. This is not shown on plates 6 and 10, as it was not considered justified to project known coal occurrence information so far from the outcrops. Coal has been removed from east of the fault by erosion, with the exception of the coal located on Horse Mountain and a few small areas adjacent to the fault.

Bald Knoll Coal Zone

The Bald Knoll coal zone is present throughout the coal-bearing area. Coal thickness is near six feet (1.8 m) over most of the coal area west of the fault. This thickness decreases to less than five feet (1.5 m) at the south end of the coal area (plate 4). A local area of coal as thick as 10 feet (3 m) underlies Horse Mountain to the north. A majority of the thicker coal bed is under less than 200 feet (61 m) of overburden and may also extend into the Bryce Point quadrangle to the north.

Two coal analyses are available for the Bald Knoll coal zone, although one of the Bald Knoll samples may be contaminated and therefore is of doubtful value. The remaining sample from the Bald Knoll coal zone indicates a rank of sub-bituminous "C". Sulfur and ash are both low at 0.5 percent and 9.9 percent, respectively. The Bald Knoll coal zone contains the major portion of the reserves in this quadrangle.

Smirl Coal Zone

The Smirl coal zone is divided into three continuous beds, the upper, middle, and lower Smirl coal beds, and a number of thin, discontinuous coal beds in the Rainbow Point quadrangle. Both the upper and middle Smirl coal beds are thin, usually less than three feet (0.9 m). The lower Smirl coal bed is also thin where it has been measured along the outcrop. Only two of these measurements (data points 16 and 21, plate 1) reach five feet (1.5 m). Both measurements are at the south end of the coal-bearing area.

These thicknesses correlate with those on the Skutumpah Creek quadrangle immediately to the southwest, where the Smirl coal zone thins toward the northeast boundary of the quadrangle and thickens northwest of the outcrop. The same pattern may exist on the Rainbow Point quadrangle. Three drill holes behind the outcrop show the Lower Smirl coal bed thickening in the subsurface. Six feet (1.8 m) is an average thickness for the coal bed between the five foot (1.5 m) isopach and the Limit of Data line (plate 8).

The one coal analysis of the lower Smirl coal bed reported by Doelling and Graham (1972) shows a spot coal rank of sub-bituminous "C". Affolter and Hatch have reported an analysis of core from the upper and lower Smirl coal beds in drill hole AK-2RP (Bowers, 1977). The lower Smirl coal bed has a rank of sub-bituminous "C".

Past Production

No production has been reported from the Rainbow Point quadrangle.

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 factor 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. Reserve base and reserve tonnages are listed in tables 2 and 3.

Data from outcrop and drill hole measurements were used to construct outcrop, coal isopach and structure contour maps for both the Smirl coal zone and the Bald Knoll coal zone. The source of each indexed data point shown on plate 1 is shown on table 4.

Coal reserves for Federal land were calculated using data obtained from the coal isopach maps (plates 4 and 8) and the areal distribution and identified resources maps (plates 7 and 11). 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 feet (1.5 m) which lie less than 3,000 feet (914 m) below the ground surface are included. These criteria were provided by the U.S. Geological Survey.

Reserve base and reserve tonnages for the isopached coal zones are shown on plates 7 and 11 and are rounded to the nearest 10,000 short tons (9,072 metric tons). Coal reserve base tonnages for each Federally owned section are shown on plate 2 and total approximately 82,190,000 short tons

(74,560,000 metric tons) for the entire quadrangle.

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 drawn, at the request of the BLM, using the boundaries of the smallest legal land division shown on plate 2 as boundaries for the coal development potential areas. These divisions contain 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 BLM guidelines.

Development Potential for Surface Mining Methods

Areas between the coal outcrop and 200 ft. (61 m) of overburden are designated 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

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 beteen 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 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. The surface development potential for this quadrangle is shown on plate 12 and table 2. Twenty-three percent of the coal tonnage is rated high, 28 percent is rated moderate, and 49 percent is rated low. The total surface development potential for this quadrangle is 11,970,000 short tons of coal.

Most of the potential surface mining areas are currently under lease. Only two additional areas are available. One, an elongate area of about 250 acres (101 ha), lies along the east side of the coal outcrop area adjacent to the Paunsaugunt Fault. The other covers about 900 acres (364 ha) at the north end of the quadrangle on Horse Mountain. The Horse Mountain

coal beds contain approximately 90 percent of the 11,970,000 short tons (10,860,000 metric tons) of coal available for surface mining.

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 13 and table 3.

Little data is available for coal beyond the stripping limit. Accordingly, over half of the KRCRA is given an unknown development potential rating. The remaining portion is rated high and contains 70,220,000 short tons (63,700,000 metric tons) of coal.

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Table 1. Chemical analyses of coals in the Rainbow Point quadrangle, Kane County Utah.

LOCATION	COAL BED NAME OR ZONE	Form of Analysis	Proximate				Ultimate					Heating Value	
			Moisture	Volatile Matter	Fixed Carbon	Ash	Sulfur	Hydrogen	Carbon	Nitrogen	Oxygen	Calories	Btu/Lb
SE¼ Sec. 23, T38S, R4W	Bald Knoll	A	8.4	26.5	33.2	31.9	-	-	-	-	-	-	-
		C	-	28.9	36.3	34.8	0.59	-	-	-	-	-	6,40
NW.SE.SE. Sec. 13, T39S, R4W	Lower Smirl	A	14:6	34.8	39.8	10.8	-	-	-	-	-	-	-
		C	-	40.7	46.7	12.6	0.61	-	-	-	-	-	8,58
NE¼ Sec. 25, T39S, R4W	Bald Knoll	A	15.3	34.9	41.4	8.4	-	-	-	-	-	-	-
		C	-	41.2	48.9	9.9	0.46	-	-	-	-	-	9,27
SW¼, SE¼, SE¼, Sec. 14, T39S, R4W	Upper Smirl	A	23.4	28.1	34.6	13.9	3.5	-	-	-	-	-	8,07
		C	-	36.7	45.2	18.1	4.6	-	-	-	-	-	10,53
	Lower Smirl	A	24.3	28.8	38.6	8.4	0.6	-	-	-	-	-	8,99
		C	-	38.0	50.9	11.1	0.8	-	-	-	-	-	11,86

Form of Analysis: A, as received
C, moisture-free

NOTE: To convert Btu/pound to kilojoules/kilogram, multiply by 2.326

Table 2. Coal Reserve Base Data for Surface Mining Methods for Federal Coal Lands (in Short Tons) in the Rainbow Point Quadrangle, Kane and Garfield Counties, Utah.

Coal Bed or Zone	High Development Potential	Moderate Development Potential	Low Development Potential	Total
Bald Knoll Zone	2,390,000	3,370,000	5,660,000	11,420,000
Lower Smirl Bed	320,000	30,000	200,000	550,000
Total	2,710,000	3,400,000	5,860,000	11,970,000

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

Table 3. Coal Reserve Base Data for Subsurface Mining Methods for Federal Coal Lands (in Short Tons) in the Rainbow Point Quadrangle, Kane and Garfield Counties, Utah.

Coal Bed or Zone	High Development Potential	Moderate Development Potential	Low Development Potential	Total
Bald Knoll Zone	46,490,000	-	-	46,490,000
Lower Smirl Bed	23,730,000	-	-	23,730,000
Total	70,220,000	-	-	70,220,000

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

Table 4. Sources of data used on plate 1.

Plate 1 Index Number	Source	Data Base
1	Doelling and Graham, 1972, Utah Geological and Mineralogical Survey, Monograph Series No. 1	Measured Section
2	"	"
3	Bowers, 1979, U.S.G.S., Unpublished field notes	"
4	"	"
5	Doelling and Graham, 1972, U.G. & M.S., Monograph Series No. 1	"
6	"	"
7	Bowers, 1979, U.S.G.S., Unpublished field notes	"
8	"	"
9	Doelling and Graham, 1972, U.G. & M.S., Monograph Series No. 1	"
10	"	"
11	"	"
12	Bowers, 1979, U.S.G.S., Unpublished field notes	"
13	"	"
14	"	"
15	Doelling and Graham, 1972, U.G. & M.S., Monograph Series No. 1	"
16	Bowers, 1979, U.S.G.S., Unpublished field notes	"

Table 4 - Continued

Plate 1 Index Number	Source	Data Base
17	Doelling and Graham, 1972, U.G. & M.S., Monograph Series No. 1	Measured Section
18	Bowers, 1977, U.S.G.S., Open File Report 77-43	Coal Drill Hole No. AK-3RP
19	"	Coal Drill Hole No. AK-2RP
20	Bowers, 1979, U.S.G.S., Unpublished field notes	Measured Section
21	"	"
22	Doelling and Graham, 1972, U.G. & M.S., Monograph Series No. 1	"
23	"	"
24	"	"
25	Bowers, 1977, U.S.G.S., Open File Report 77-43	Coal Drill Hole No. AK-4RP
26	Doelling and Graham, 1972, U.G. & M.S., Monograph Series No. 1	Measured Section
27	Bowers, 1979, U.S.G.S., Unpublished field notes	"
28	Doelling and Graham, 1972, U.G. & M.S., Monograph Series No. 1	"
29	Bowers, 1979, U.S.G.S., Unpublished field notes	"
30	Doelling and Graham, 1972, U.G. & M.S., Monograph Series No. 1	"
31	"	"
32	Bowers, 1979, U.S.G.S., Unpublished field notes	"
33	"	"

Table 4 - Continued

Plate 1 Index Number	Source	Data Base
34	Doelling and Graham, 1972, U.G. & M.S., Monograph Series No. 1	Measured Section
35	"	"
36	"	"
37	"	"
38	"	"
39	Bowers, 1979, U.S.G.S., Unpublished field notes	"
40	Doelling and Graham, 1972, U.G. & M.S., Monograph Series No. 1	"