Text to Accompany

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COAL RESOURCE OCCURRENCE AND COAL DEVELOPMENT POTENTIAL MAPS OF THE SOUTHEAST QUARTER OF THE MT. PENNELL 15-MINUTE QUADRANGLE, GARFIELD COUNTY, UTAH

[Report includes 7 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 text is to be used in conjunction with Coal Resource Occurrence (CRO) and Coal Development Potential (CDP) Maps of the Southeast Quarter of the Mt. Pennell 15-minute quadrangle, Garfield County, 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 Recoverabe 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 Published and unpublished public information available through June, 1979, was used as the data base for this study.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 Southeast Quarter of the Mt. Pennell 15-minute quadrangle is located in the southeast corner of the Henry Mountains coal field in eastern Garfield County, Utah. Hanksville is

39 miles (63 km) north and Lake Powell is 37 miles (60 km) south of the quadrangle's northern and southern borders. Eggnog, Utah is located in the southeast corner of the map area.

Accessibility

Several roads provide access into the quadrangle. An unimproved road to Eggnog parallels Bullfrog Creek along the west side of the map area. Another dirt road from Bullfrog Basin on Lake Powell enters the southeast corner of the quadrangle and trends northward across the Indian Spring benches. A branch of this road reaches a spring near the Stanton Coal Mine in the east central portion of the quadrangle.

Winter weather rarely affects travel in the region.

Physiography

The Southeast Quarter of the Mt. Pennell 15-minute quadrangle is located at the southern end of the Henry Mountains. Typical land forms are rolling hills, benchlands and steep-sloped mesas. Benchlands occupy most of the area.

Principal relief is provided by the pronounced but small Noman's Mesa at the north quadrangle border, Coal Bed Mesa in the central map area and Ant Knoll, a mesa remnant, in the west central part of the quadrangle. The balance of the area consists of low relief hills and benches cut by a moderately incised dendritic drainage system.

Elevations in the quadrangle range from 4,400 feet (134 m) in the southern drainage of Bullfrog Creek to 6,240 feet (1,902 m) on Pennell Creek Bench. Total relief is 1,840 feet (561 m).

All runoff from the quadrangle flows southward to Lake Powell.

Surface water quality and streamflow reflect seasonal climatic changes. Most surface water is saline due to a high evaporation rate during the summer. Perennial drainage is to the south through Bullfrog Creek. The remaining streams in the quadrangle commonly dry up in the late summer months.

Climate and Vegetation

The quadrangle's climate is arid. Average annual precipitation is approximately eight inches (20 cm), but amounts vary from year to year due to the erratic nature of desert rainfall. Most of the moisture comes as localized late-summer thundershowers and light winter snow and rains.

Temperatures in the quadrangle range from over 100°F (38°C) in 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 and precipitation tends to increase with increasing elevation.

Winds generally blow from the west and southwest. The highest seasonal wind velocities occur in the spring and early summer.

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

Land Status

Two tracts of the Henry Mountains Known Recoverable Coal Resource Area, totaling 520 acres, lie in the center of the map area. The Federal government owns the coal rights for most lands in the quadrangle, as shown on plate 2 of the Coal Resource Occurrence Maps. Federal surface ownership extends over 88 percent of the quadrangle. The state of Utah holds 11 percent of the area and 1 percent is privately owned. No Federal coal leases, prospecting permits or licenses are outstanding in the quadrangle.

GENERAL GEOLOGY

Previous Work

John Wesley Powell, one of the first explorers of the region, named the Henry Mountains in 1869 and made some of the first geologic comments on the area (Gilbert, 1877). G. K. Gilbert studied the Henry Mountains in 1875 and 1876. His report is considered one of the classics of geological literature. Gregory and Moore (1931) and later Smith and others (1963) and Davidson (1967) reported on parts of the Waterpocket Fold in the region.

The first investigation of coal resources in the Henry Mountains was undertaken by C. B. Hunt, who commenced work on the area in 1935, completed field studies in 1939 and published the results in 1953 as U.S. Geological Survey Professional Paper 228. More recently, Henry Mountains coals were studied in detail by Doelling (1972) of the Utah Geological and Mineralogical Survey and Law (1977) of the U.S. Geological Survey. The results of these later 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

The upper, Brushy Basin member of the Jurassic Morrison Formation is exposed in the southwest corner of the quadrangle. Above this is the Dakota Sandstone, the oldest known coal bearing unit in the region. Overlying the Dakota Sandstone are the

Tununk Shale, Ferron Sandstone, Blue Gate Shale and Emery Sandstone members of the Mancos Shale, all of Cretaceous age. A composite columnar section accompanied by lithologic description 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 Morrison Formation. Dakota Sandstone is exposed in the southwest corner of the map area, where it consists of sandstone, carbonaceous shale and minor conglomerate. A few thin coal seams occur locally. The formation is an average 73 ft (22 m) thick in the quadrangle (Doelling, 1972). It 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).

Conglomeritic beds which occur in the Dakota Sandstone in this quadrangle may have been derived by reworking of underlying Morrison Formation strata in a fluvial environment. Minor interbeds of carbonaceous shale reflect local marsh and lagoonal environments. A diagnostic bed of fossils containing Gryphaea, Exogyra and Inoceramus occurs either at the top of the formation or in the lowermost beds of the overlying Tununk Shale member (Hunt, Averitt, and Miller, 1953). Gryphaea are most abundant and commonly form reefs.

The Mancos Shale lies conformably over the Dakota Sandstone and fills the sedimentary basin in this part of the Henry Mountains. Only four of the five members of the Mancos Shale are present in the quadrangle; 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 Dakota Sandstone. It is about 700 ft (213 m) thick in the quadrangle and represents a continuation of the first westward transgression of the Cretaceous sea in which the Dakota Sandstone was deposited (Peterson and Ryder, 1975).

The Tununk Shale member is a dark gray, fissile shale with thin bentonitic shale layers and subordinate, mostly thin-bedded, medium-grained sandstone. Sandstone becomes more abundant toward the top of the member, where it is transitional with the overlying Ferron Sandstone member. The member weathers to a bluish-gray, is generally poorly exposed and forms smooth broad valleys (Peterson and Ryder, 1975).

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 only significant coal bearing horizon in the quadrangle, the Ferron Sandstone member of the Mancos Shale, is a regressive unit composed of littoral and coastal plain facies. A lower, littoral unit is characterized by massive, tan to brown medium-grained sandstone. The middle portion of the member is a coastal plain deposit of gray shale with occasional thin beds of sandstones. An upper unit, again possibly of coastal plain origin, is composed of tan to white, medium-to coarse-grained massive sandstone and coal (Doelling, 1972, Hunt, Averitt, and Miller, 1953). A section of Ferron Sandstone member measured by Doelling (1972) in the quadrangle contained:

Section of Ferron Sandstone member adjacent to Hansen Creek, near the Stanton Coal Mine, center sec. 36, T. 34 S., R. 10 E., measured by Doelling in 1972:

		Feet
1.	Sandstone, light tan to white, medium-to coarse-grained, massive........................	10.5
2.	Coal..	4.0
3.	Sandstone, tan, medium-bedded to massive, cliff former......................................	46.0
4.	Shale, gray, slope former........................	4.0
5.	Shale, gray, interbedded with occasional thin-bedded sandstone, fine-grained....................	31.0
6.	Sandstone, dark tan to brown, medium-grained, single resistant bed.....................	1.0
7.	Shale, gray, like unit 5..........................	24.0
8.	Sandstone, tan, medium-grained, massive cliff former......................................	30.0

Total Ferron Sandstone member.......................... 150.5

Tununk Shale member: gray shale interbedded with subordinate dark gray thin-bedded sandstone.

The Ferron Sandstone member is locally capped by a thin white sandstone bed which probably represents a transgressing beach enivironment. In this quadrangle the Ferron Sandstone member averages 150 ft (46 m) thick.

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 a sharp erosional surface. Detailed correlation of sandstone beds in the Ferron Sandstone member suggests that 50 to 100 ft (15 to 30 m) or more of the top of the Ferron Sandstone member have been removed at the unconformity in the region (Peterson and Ryder, 1975). Above the hiatus, the Blue Gate Shale member of the Mancos Shale, like the Tununk Shale member, represents a transgressive period of marine deposition. It is composed of bluish-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 this quadrangle is 1,295 ft (295 m). The upper contact between the Blue Gate Shale and the overlying Emery Sandstone members is interfingering and gradational in nature.

The Emery Sandstone member of the Mancos Shale, like the Ferron Sandstone member, represents a regressive period of marine deposition. Elsewhere in the region the member is composed of littoral and coastal plain facies divisible into three units. However, only a few scattered remnants of the lower two units of the member occur in this quadrangle. These are a basal, medium-grained, gray to brown sandstone with shale partings and an upper gray shale with some thin, lenticular sandstone interbeds (Doelling, 1972). The average thickness of the Emery Sandstone member in the Southeast Quarter of the Mt. Pennell 15-minute quadrangle is 255 ft (78 m). The upper shaly portion of the member is coal bearing elsewhere in the Henry Mountains but has been removed from this area by erosion.

Structure

The Southeast Quarter of the Mt. Pennell 15-minute quadrangle is at the south end of the Henry Mountains structural basin and on the east limb of the Henry Mountains syncline. Bedding in the quadrangle is horizontal to gently west-dipping, toward the syncline axis. Westward dips in the northeast corner of the map area have been slightly exaggerated by doming around Mt. Pennell and Mt. Hiller.

A single, relatively continuous fault cuts through the west central portion of the Southeast Quarter of the Mt. Pennell 15-minute quadrangle. Measured displacement on the structure is about 30 ft (9 m). The fault is down dropped on the west and horizontally offsets the trace of the flat-lying Ferron coal zone in the area by approximately 1,500 ft (457 m).

Geologic History

Most pre-Cretaceous Mesozoic rocks in this part of the Colorado Plateau are continental in origin. Permian through 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 deposition 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). 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 Henry Mountains structural basin was formed between the close of Cretaceous time and the Eocene epoch. Eocene deposits occur elsewhere in the basin.

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

COAL GEOLOGY

Measurable coal in the quadrangle appears only in the Ferron Sandstone member of the Mancos Shale. The Dakota Sandstone contains only local thin coal seams in the map area. The upper, coaliferous portion of the Emery Sandstone member of the Mancos Shale does not occur extensively in the quadrangle. Erosional remnants of upper Emery Sandstone member exist at scattered locations and coal beds have been noted in their vicinity. However, no measurements have been recorded.

Coal near the upper contact of the Ferron Sandstone member is exposed almost continuously along benches across the center of the quadrangle. Near the east border of the map area in the vicinity of the Stanton Coal Mine, a single seam or two seams with a thin rock parting occupy the Ferron coal zone. The average cumulative coal thickness through this area is 3.2 ft (1.0 m). The maximum is 6.2 ft (1.9 m) of coal (Fe-2) with 0.2 foot (6 cm) of rock partings in section 25 T. 34 S., R. 10 E. Six feet (1.8 m) of coal (Fe-1) intercepted at a depth of roughly 259 ft (79 m) in a drill hole in section 26, T. 34 S., R. 10 E., one-half mile (800 m) to the northwest may or may not correlate with the Fe-2 bed.

Two coal beds separated by roughly three feet (91 cm) of rock occupy the Ferron coal zone in the east-central map area. The beds individually maintain an average thickness of 2.1 ft (64 cm) and contain no known single bed more than 4.5 ft

(1.4 m) thick. Only a single coal seam averaging 2.4 ft (70 cm) thick occurs in the Ferron Sandstone member in the west part of the quadrangle, except for the westernmost coal exposure, where three thin beds occur.

Chemical Analyses of Ferron Zone Coal

One composite channel sample 5.1 ft (1.6 m) thick was taken about 35 feet (10.7 m) back from the portal of the Stanton Mine in the east central map area. Analytical results are shown in table 1. The analyses indicates the coal to be high-volatile C bituminous in rank (ASTM, 1966).

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

	Moisture	Volatile Matter	Fixed Carbon	Ash	Sulfur	Btu/lb
Stanton Mine Ferron Coal Zone	4.50	36.90	40.80	14.60	3.20	12,309

Doelling (1972)

COAL RESOURCES

Data from one U.S. Geological Survey coal test hole and 34 measured surface sections and surface mapping by Doelling (1972) and Law (1979) were used to construct outcrop, isopach and structure contour maps of coal zones and beds in the map area, (CRO plates 1 through 6).

Coal resources were calculated using data obtained from the coal isopach map (CRO plate 4). The coal-bed acreage (measured by planimeter) multiplied by the average isopached thickness of the coal bed times a conversion factor of 1,880 short tons of coal per acre-foot for bituminous coal yielded the coal resources in short tons of coal for each isopached coal bed. Reserve Base for the Fe-2 coal bed is shown on CRO plate 6 and is rounded to the nearest tenth of a million short tons. 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, total about 5,370,000 short tons. Reserve Base (in short tons) in the various development-potential categories for surface and underground mining methods is shown in tables 2 and 3.

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

Isolated Data Points

In instances where isolated measurements of coal beds of Reserve Base thickness or greater are encountered, the standard criteria for construction of isopach, structure contour, mining ratio and overburden isopach maps are not available. The lack of data concerning these coal beds limits the extent to which they can be reasonably projected in any direction and usually precludes correlations with other, better known coal beds. For this reason, the isolated data point is mapped separately and is shown on figure 2. The isolated point mapped in this quadrangle is listed below.

Source	Location	Coal Bed	Millions Short Tons	Thickness
LAW (1979)	Section 26 T.33S., R.10E.	Fe-1	5,379,000	6 ft (1.8 m)

O (21)
C 6(Fe)[1]

DRILL HOLE - Showing thickness of coal, in feet. Index number refers to hole on plate 1 of CRO map. Letters designate name of coal bed as listed below. Bracketed number identifies coal bed named on plates 1 or 3.

Fe - Ferron coal zone

COAL BED SYMBOL AND NAME - Coal bed identified by bracketed number is not formally named, but is numbered for identification purposes in this quadrangle only.

A

BOUNDARY OF IDENTIFIED RESERVE BASE COAL - Drawn along the coal bed outcrop, an arc (A) drawn 2,640 feet from the nearest point of Reserve Base coal bed measurement, the PRLA boundary (P), the quadrangle boundary (Q), and the non-Federal coal ownership boundary (N). Arrow points toward area of identified Reserve Base coal.

RB

— (Measured)
— (Indicated)
4.62 (Inferred)

IDENTIFIED COAL RESOURCES - Showing totals for Reserve Base (RB), in millions of short tons, for each section or part(s) of section of non-leased Federal coal land, either within or beyond the stripping-limit. Dash indicates no resources in that category.

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

To convert feet to meters, multiply feet by 0.3048.

SCALE - 1:24,000 (1 inch = 2,000 feet)

FIGURE 1. - Explanation for FIGURE 2.

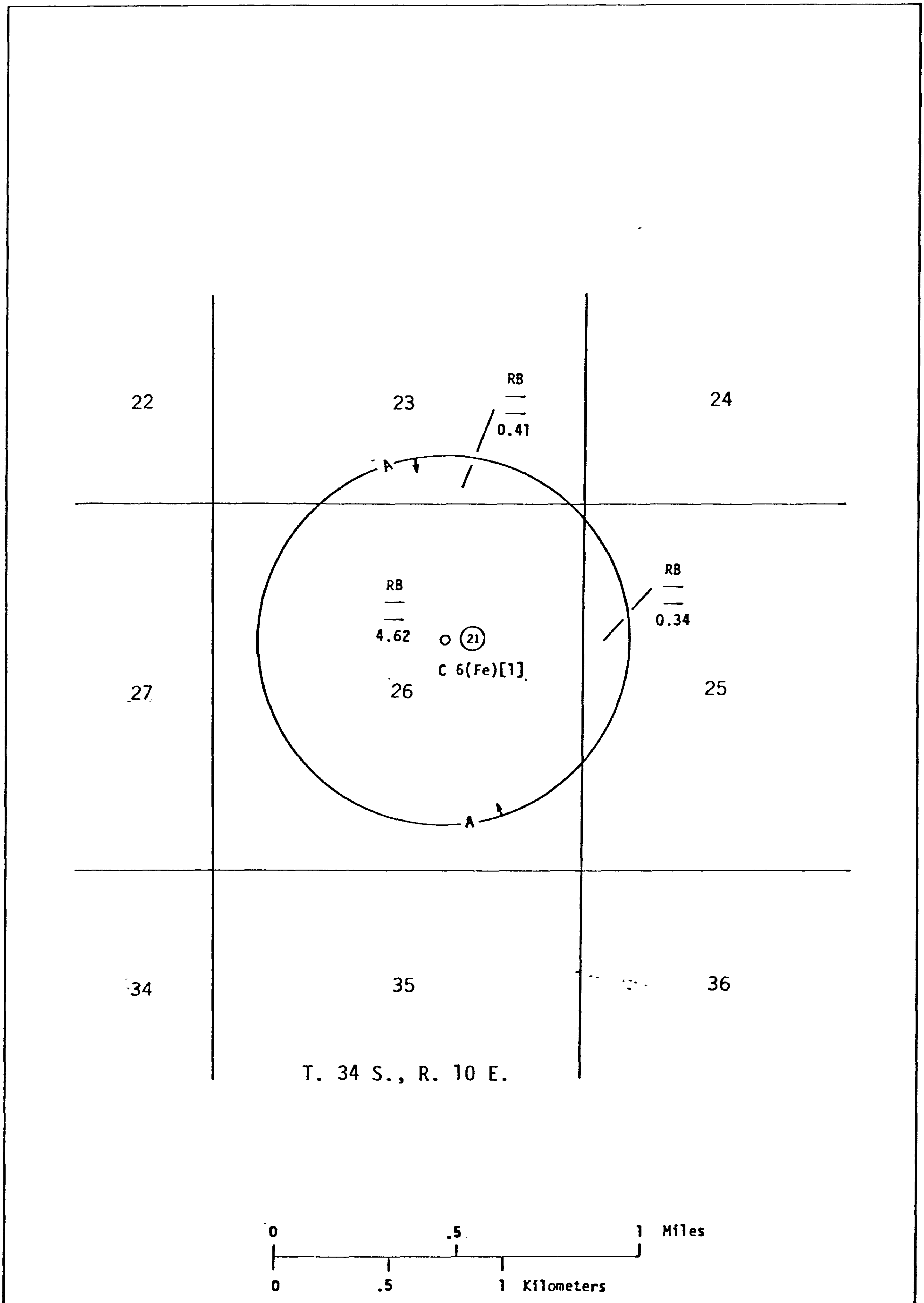

FIGURE 2. - Isolated data point map of the Ferron [1] coal bed.

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 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 upon the mining ratio (cubic yards of overburden per ton of recoverable coal). The formula used to calculate mining ratios 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 ton~~s~~ of recoverable coal:

0.896 for bituminous 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 here defined as areas underlain by coal beds having respective mining ratio values of 0 to 10, 10 to 15, and greater than 15 as shown on CRO plate 7. These mining ratio values for each development potential category are based on economic and technological criteria. They are applicable only to this quadrangle and were derived in consultation with J. Moffit, Area Mining Supervisor, 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 7. Of the Federal land assigned a development potential for surface mining methods, 55 percent are rated high 24 percent are rated moderate and 21 percent are rated low.

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. Even though these areas may contain coal thicker than 5 feet (1.5 m), 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. Coal greater than 5 feet (1.5 m) thick associated with the Fe-1 coal bed in the Southeast Quarter of the Mt. Pennell 15-minute quadrangle is therefore assigned an unknown development potential.

Table 2 -- Coal Reserve Base Data for surface mining methods for Federal coal lands (in short tons) in the Southeast Quarter of the Mt. Pennell 15-minute quadrangle, Garfield County, 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
Fe-1	---	---	---	---
Fe-2	160,000	70,000	60,000	290,000
Total	160,000	70,000	60,000	290,000

Table 3 -- Coal Reserve Base Data for subsurface mining methods for Federal coal lands (in short tons) in the Southeast Quarter of the Mt. Pennell 15-minute quadrangle, Garfield 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	Unknown Development Potential	Total
Fe-1	---	---	---	5,370,000	5,370,000
Fe-2	---	---	---	---	---
Total	---	---	---	5,370,000	5,370,000

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