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

[Report includes 3 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) Maps of the Northeast Quarter of the Mt. Ellen 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 Published and unpublished public information available through June 1979 was used as the data base for this study.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 confidential data used.

Location

The quadrangle lies in the east-central part of the Henry Mountains coal field and contains part of the common, central border of Wayne and Garfield Counties. Hanksville, Utah is 10.5 miles (17 km) northeast of the map area's northern border.

Accessibility

Several unimproved roads provide access across the north half of the map area to the base of mountains in the south central map area. The roads follow gradually steepening slopes southward along lowlands and across incised benches bordering the mountains. The principal access road parallels Dry Valley wash southward from an intersection with Highway 95 three miles (4.8 km) south of Hanksville. Two additional dirt roads depart Highway 24 west of Hanksville and traverse the Steamboat Point quadrangle southward to enter the east half of this map area. A few jeep trails cross-connect dirt roads and encroach slightly into the mountains in the south-central part of the map area.

Physiography

The Northeast Quarter of the Mt. Ellen 15-minute quadrangle encompasses the north end of the Henry Mountains intrusive domes and, as a consequence, two distinct, sharply defined physiographic subprovinces.

In the north, benches and broad, shallow valleys have evolved through mass wastage upon gently north dipping sandstone and shale. Topography is subdued by a surficial veneer of colluvium and recent alluvium. Low elevations in the area range around 4,960 ft (1512 m).

The high peaks of mountains to the south contrast with relatively level terrain to the north. Table Mountain, a pronounced feature in the southwest-central map area, is a symmetric dome with a central intrusive stock. The highest peak in the map area, Deer Heaven, reaches an altitude of 10,687 ft (3,257 m) due south of Table Mountain. In the southeast quarter of the quadrangle, intrusive rocks are locally overlain by remnants of deformed sedimentary rocks on a number of otherwise smooth mountain sides. Patches of steeply inclined landslide debris mantle many of these slopes.

All runoff from the map area originates in the south-lying mountains, and even this is intermittent. Streams at elevations below 8,800 ft (2,682 m) commonly dry up in the late summer. Water quality also reflects seasonal climatic changes. Surface water is typically saline due to high summer evaporation rates.

Most ephemeral streams in the map area flow northward. Principal collectors in the north half of the map area are, from east to west, Bull Creek, Birch Creek and Cottonwood Creek. These discharge to the Fremont River north of the map area. The Fremont River joins with Muddy Creek River near Hanksville to form the Dirty Devil River which eventually flows into the Colorado River.

Climate and Vegetation

The map area's climate is arid. Average annual precipitation is about 12 inches (30 cm). Annual precipitation varies from year to year due to the periodic nature of desert rainfall. Localized, late summer thundershowers and light, winter snows and rains bring the majority of moisture to the area, most of which falls in the mountainous, southern half of the map area. Droughts lasting three or more years are common.

Temperatures range from over 100°F (38°C) during late summer to less than 0°F (-18°C) during the winter months; as elevation increases, temperatures drop. The yearly average for the region is 56°F (13°C) (U.S. Bureau of Land Management, 1978). Winds usually blow from the west and southwest. The highest seasonal velocities occur in the spring and early 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

Two isolated portions of the Henry Mountains Known Recoverable Coal Resource Area totaling 760 acres are located in the southern half of the map area. The Federal government owns the coal rights for lands over most of the map area, as shown on plate 2 of the Coal Resource Occurrence Maps. The state of Utah controls 11.1 percent of the area, comprising sections 2, 16, 32 and 36; private individuals hold the remaining 2.5 percent for ranching. There are no outstanding Federal coal leases, prospecting permits or licenses in the map area.

GENERAL GEOLOGY

Previous Work

John Wesley Powell, one of the first explorers of the region, named the Henry Mountains in 1869 (Gilbert, 1877). G. K. Gilbert studied the area during 1875 and 1876. His report (Gilbert, 1877) is considered a classic of geologic literature. Detailed studies of coal and related geology were completed by C. B. Hunt and others in 1939. The results of Hunt's study appeared in 1953 as U.S. Geological Survey Professional Paper 228. An investigation of Utah jet coal by Traverse and Kolvoord (1968) supplied information on Dakota coal in the quadrangle. The Henry Mountains coal deposits were also studied 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 the evaluation of Ferron and Emery coals in this study. Additional publications which describe geologic features in the region are included in the bibliography.

Stratigraphy

A composite columnar section accompanied by lithologic descriptions on CRO plate 3 illustrates the relationship between sedimentary units in the Northeast Quarter of the Mt. Ellen 15-minute quadrangle. These include the Brushy Basin member of the Jurassic Morrison Formation; the Cretaceous Dakota Sandstone; and the Tununk Shale, Ferron Sandstone and Blue Gate Shale members of the Mancos Shale, all of upper Cretaceous age.

The oldest known coal bearing formation in the area, the Dakota Sandstone, crops out in Jet Basin in the center of the quadrangle. The formation consists of interbedded yellow to gray friable sandstone, coaly, carbonaceous shale and coal and is fossiliferous at its upper contact. The Dakota Sandstone represents a westward transgressive littoral sequence and lies unconformably atop the Morrison Formation (Doelling, 1972). It is generally thin in the map area, ranging between 14 ft (4.3 m) and 60 ft (18.3 m). Coal lenses occur randomly in the formation; seams up to 1.0 foot (30 cm) thick have been mapped.

The Dakota Sandstone is conformably overlain by the Mancos Shale, a marine and littoral deposit of Cretaceous shale and sandstone which regionally consists of five members. Only three of the five members are present in this quadrangle. The uppermost Emery Sandstone and Masuk Shale members of the Mancos Shale have been removed by erosion. Remaining are the Tununk Shale member, Ferron Sandstone member and Blue Gate Shale member.

The lowermost Tununk Shale member of the Mancos Shale is 600 ft (183 m) thick in the map area and represents a continuation of the westward transgression of an upper Cretaceous Sea in which the Dakota Sandstone was deposited (Peterson and Ryder, 1975). Its lower contact is gradational and interfingering with the Dakota Sandstone.

The Tununk Shale member is a gray, marine shale with occasional thin sandstone and bentonitic shale beds in the upper third. The member weathers to a bluish-gray, is generally poorly exposed and forms broad benches or alluvial filled valleys (Peterson and Ryder, 1975). The lowest few feet of the member everywhere contain abundant oysters (Hunt, Averitt, and Miller, 1953). A regressive sequence is evident in the upper part of the Tununk Shale member and is believed to be the result of deltaic progradation (Peterson and Ryder, 1975). At its upper contact, the Tununk Shale member grades into and intertongues with the overlying Ferron Sandstone member.

The Ferron Sandstone member has the best developed coal in the map area. This member can be subdivided into three units (Doelling, 1972). The lower unit is a transitional zone composed of interbedded gray shale and gray to brown, fine- to medium-grained, thick- to thin-bedded sandstone. The middle unit, a coastal plain deposit, is a thick-bedded, reef-forming, yellow to tan sandstone. The upper unit, possibly of coastal plain origin, is composed of interbedded gray and carbonaceous shale; medium-grained, yellow to tan lenticular sandstone and coal (Hunt, Averitt, and Miller, 1953). This upper unit is poorly exposed and individual beds are difficult to trace. Coal beds up to 5.5 ft (1.7 m) have been mapped in the unit.

The Ferron Sandstone member averages 200 ft (61 m) thick in the map area and represents regressive marine deposition. The contact with the overlying Blue Gate Shale member is an erosional unconformity. Detailed correlation of sandtone 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 have been removed by erosion at the unconformity in the region (Peterson and Ryder, 1975).

The overlying Blue Gate Shale member of the Mancos Shale, like the Tununk Shale member, is a transgressive marine sequence. Dark-gray, finely-laminated shale with thin beds of shaly sandstone and shaly limestone in the upper third typify the unit.

The average thickness of the Blue Gate Shale member in the map area is 1,500 ft (457 m). It is the youngest consolidated sedimentary unit in the map area. Although currently undergoing erosion, little has been removed and the unit's remaining thickness differs little from that of complete sections elsewhere in the region.

Structure

The Northeast Quarter of the Mt. Ellen 15-minute quadrangle is on the east flank of the Henry Mountains structural basin. Where not disturbed by igneous intrusion, sedimentary rocks in the map area dip gently to the west, toward the basin's axis. Dips on benches in the north part of the map area are about 5 degrees westward.

In the southern part of the map area, intrusive rocks have domed and broken through Jurassic and Cretaceous strata. Generally, older rocks are closest to domes or stocks and younger rocks are further away. However, structural attitudes are often irregular due to the emplacement of dikes, sills and laccoliths. Beds near the stocks may be vertical to overturned. Elsewhere the inclination of strata ranges from 10 to 30 degrees away from intrusive centers.

Three faults occur near the north-central border of the quadrangle, on the Blue Valley benches. Displacement on the faults is small and coal resources do not appear to have been affected.

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 the period were eolian, intertidal mudflats, lacustrine, fluvial and flood plains.

The Cretaceous history of the Henry Mountains coal field is similar to that encountered in the coal fields of 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 fluvial sand and clay were 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.

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 Sandstone 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 Henry Mountains structural basin was formed between the close of Cretaceous time and the Eocene epoch. Eocene deposits are found 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

Coal occurrences in the Dakota Sandstone and Ferron sandstone member of the Mancos Shale have been studied in the quadrangle. No appreciable exposures of coal bearing Emery sandstone have been located.

Significant Dakota Sandstone coal appears only in Jet Basin, near the center of the map area. The basin derives its name from the occurrences of jet, a lustrous, compact variety of coal that breaks with a glassy conchoidal fracture and takes a high polish. Coal in Jet Basin ranges up to one foot (30 cm) in thickness, beneath a thin layer of friable sandstone immediately under fossiliferous Tununk Shale member. The coal contains abundant sulfur along bedding planes and in veinlets. It is underlain by a clayey shale which bears logs of jetified coal, usually flattened normal to the bedding.

The Ferron Sandstone member is poorly exposed in the map area and coal data from drill holes and measured section is rare. However, four Ferron zone coal beds have been identified in an isolated drill hole and measured sections. East of Table Mountain, near Bacon Slide, and directly to the northwest are two measured sections (Fe-3 and Fe-4) containing 5.0 ft (1.5 m) of Ferron coal. One drill hole just west of Cottonwood Creek in section 8, T. 30 S., R. 10 E. encountered 5.5 ft (1.7 m) of Ferron coal (Fe-2) at a depth of 302 ft (92 m) and 9.5 ft (2.9 m) of coal in three beds (Fe-1) separated by 1.5 and 1.0 ft (46 and

30 cm) of rock partings, underlying Fe-2 at a depth of 344 to 356 ft (105 to 108.5 m) below ground surface. Coal reported elsewhere in the map area is less than 2 ft (61 cm) thick.

Chemical Analyses of Coal

One sample of Dakota jet coal was taken from Jet Basin by Doelling (1972). Analytical results are shown in table 1. The coal rank is high volatile B bituminous (ASTM, 1966).

No analyses have been made of Ferron coal from this map area, but four channel samples of Ferron coal taken at the Factory Butte Mine in the Southwest Quarter of the Mt. Ellen 15-minute quadrangle are reported by Doelling (1972). Analytical results are shown in table 1. The coal rank is subbituminous A (ASTM, 1966).

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

	Moisture	Volatile Matter	Fixed Carbon	Ash	Sulfur	Btu/lb
Outcrop Dakota Coal Zone	5.5	58.11	34.15	1.74	2.91	13,450
Sec. 22, T.30S., R.10E.	--	61.82	36.33	1.85	3.10	14,308
Average	5.9	59.97	35.24	1.80	3.01	13,879
Factory Butte Mine	5.5	33.6	44.9	16.0	2.5	10,840
Ferron Coal Zone	7.5	32.9	44.0	15.6	2.4	10,620
Sec. 11, T.27S., R.9E.	--	35.6	47.5	16.9	2.6	11,470
	--	42.8	57.2	--	3.2	13,810
Average	6.5	36.2	48.4	16.2	2.7	11,685

Doelling (1972)

COAL RESOURCES

Data from 5 U.S. Geological Survey coal test holes and 12 measured surface sections and surface mapping by Doelling (1972) of the Utah Geological and Mineralogical Survey were used to construct an outcrop and data map of coal zones in the map area, (CRO plate 1). Measured sections and drill hole intercepts were plotted on correlation diagrams in an attempt to establish continuity between thicker coal beds in the Ferron Sandstone member. No such correlations could be supported.

In instances where non-correlatable isolated measurements of coal beds of Reserve Base thickness (greater than 5 feet or 1.5 meters) are encountered, the standard criteria for construction of isopach, structure contour, mining ratio, and overburden isopach maps are not available (U.S. Geological Survey Bulletin 1450-B). The lack of data concerning these beds limits the extent to which they can be reasonably projected in any direction. For this reason, isolated data points are mapped separately and are included in this report as figures 2 through 5.

Coal resources in this quadrangle were calculated by measuring Federal coal land acreage within a one-half mile radius of each isolated data point in which coal thickness equaled or exceeded the 5.0 ft (1.5 m) minimum recommended by the U.S. Geological Survey. The coal bed acreage multiplied by the measured section or drill hole 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 coal bed. Reserve Base for the Fe-1, Fe-2, Fe-3 and Fe-4 coal beds are shown on CRO plate 2 and are rounded to the nearest tenth of a million short tons. Reserve Base for all coal beds thicker than 5.0 ft (1.5 m), as shown on CRO plate 2, is summarized below:

Source	Location	Coal Bed	Millions Short Tons	Thickness
LAW (1979)	Section 8 T.30S., R.10E.	Fe-1	4.23	9.5 ft (2.9 m)
LAW (1979)	Section 8 T.30S., R.10E.	Fe-2	2.45	5.5 ft (1.7 m)
DOELLING (1972)	Section 29 T.30S., R.10E.	Fe-3	3.78	5.0 ft (1.5 m)
DOELLING (1972)	Section 35 T.30S., R.10E.	Fe-4	3.78	5.0 ft (1.5 m)

○ (13)
C 9.5(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.

▲ (14)
C 5.0(Fe)[3]

POINT OF MEASUREMENT - Showing thickness of coal, in feet. Includes all points of measurement other than drill holes. 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)
2.60	(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 FIGURES 2 through 5.

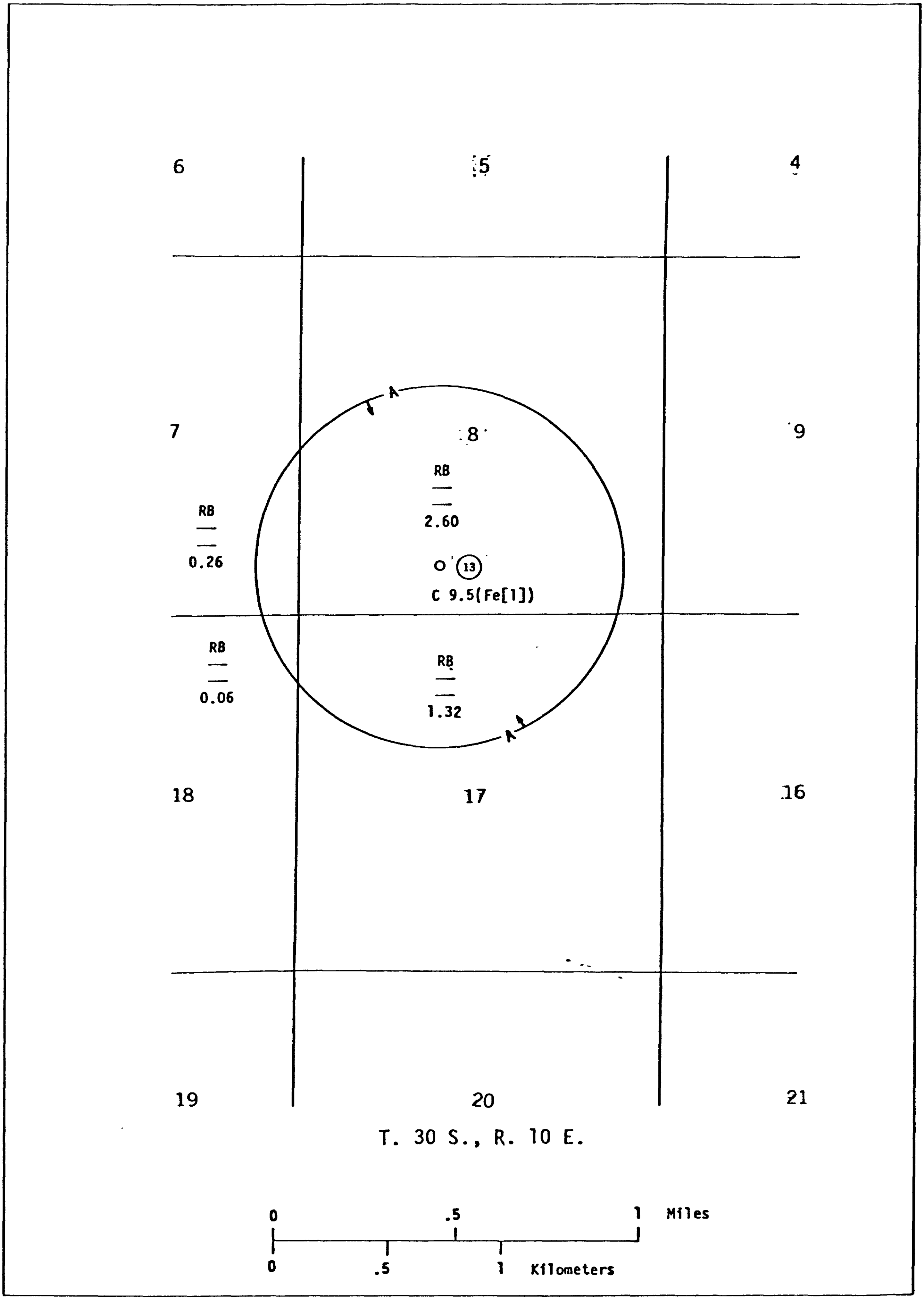

FIGURE 2. - Isolated data point map of the Ferron [1] coal bed.

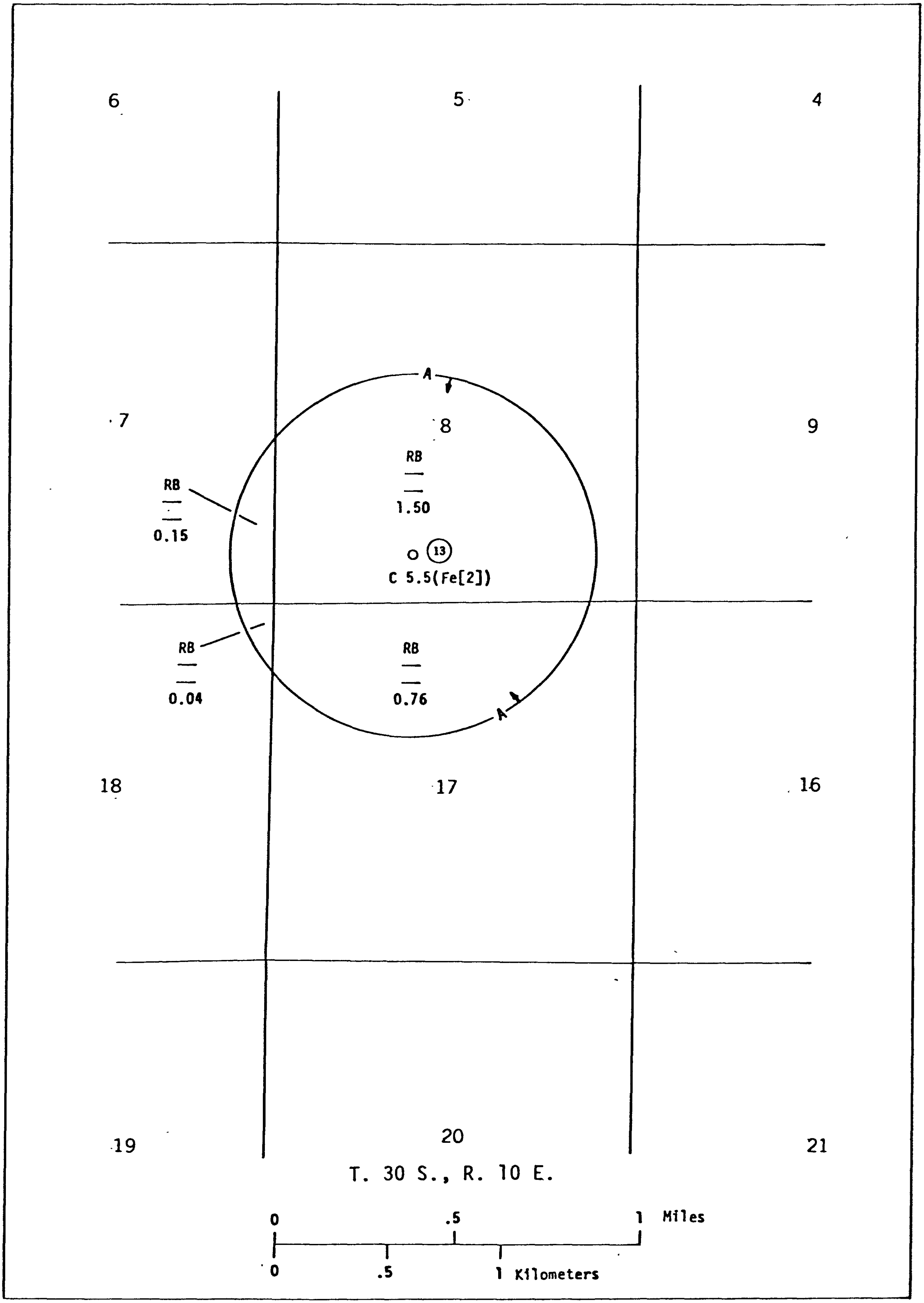

FIGURE 3. - Isolated data point map of the Ferron [2] coal bed.

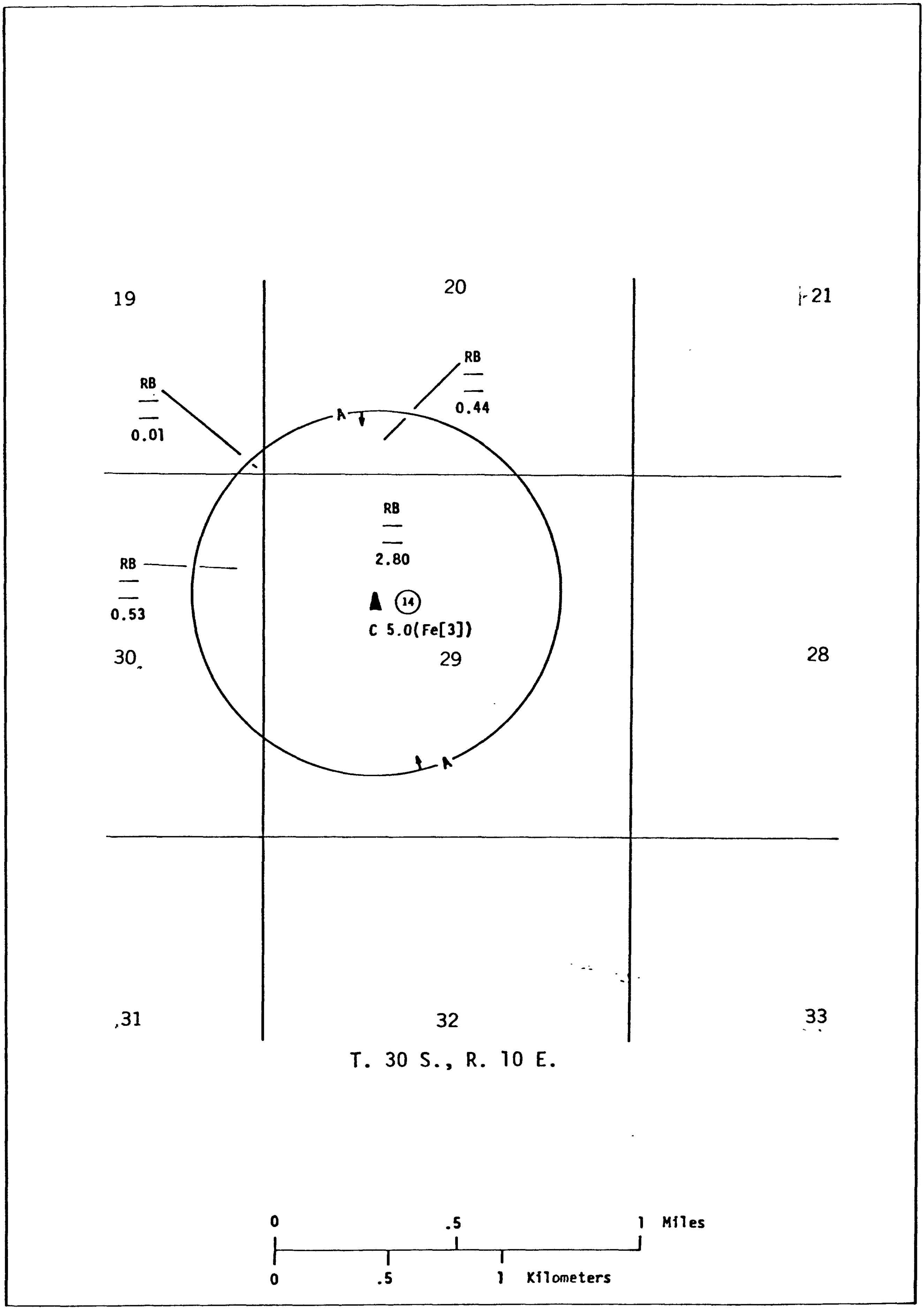

FIGURE 4. - Isolated data point map of the Ferron [3] coal bed.

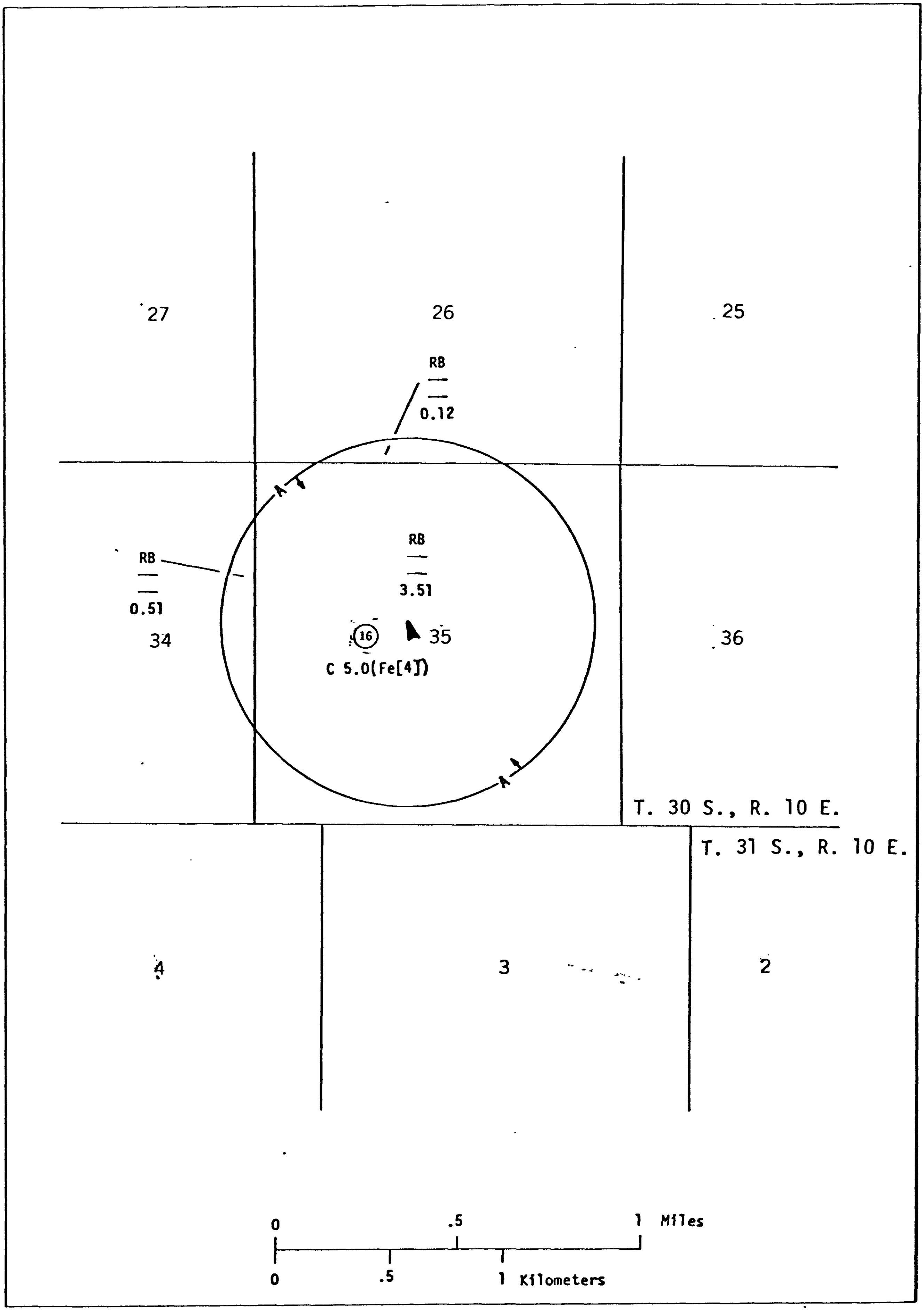

FIGURE 5. - Isolated data point map of the Ferron [4] coal bed.

COAL DEVELOPMENT POTENTIAL

Areas where the coal data are absent or extremely limited 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. Therefore, all Federal lands in the Northeast Quarter of the Mt. Ellen 15-minute quadrangle are regarded as having unknown development potential.

REFERENCES

American Society for Testing and Materials, 1966, D388-66

Doelling, H. H., 1972, Henry Mountains coal field, in Eastern and northern Utah coal fields: Utah Geological and Mineralogical Survey Monograph 2.

Gilbert, G. K., 1877, Report on the geology of the Henry Mountains, Utah: U.S. Geological Survey, Rocky Mountain Region, 160 p.

Hunt, C. B., Averitt, Paul, and Miller, R. L., 1953, Geology and geography of the Henry Mountains region, Utah: U.S. Geological Survey Professional Paper 228, p. 234.

Law, B. E., 1977, Geophysical logs of test holes from the Henry Moutains coal field, Garfield and Wayne Counties, southeastern Utah: U.S. Geological Survey Open-File Report 77-41, 4 p. 28 figs.

______1979, Coal deposits of the Emery coal zone, Henry Mountains coal field, Garfield and Wayne Counties, Utah: U.S. Geological Survey Miscellaneous Field Studies Map MF-1082A and B.

Peterson, Fred, and Ryder, R. T., 1975, Cretaceous rocks in the Henry Mountains region, Utah, and their relation to neighboring regions: Four Corners Geological Society Guidebook, no. 8, p. 167-189.

Traverse, A., and R. W. Kolvoord, 1968, Utah jet - a vitrinite with aberrant properties: Science, v. 159, p. 302-305.

U.S. Bureau of Land Management, 1978, Energy Mineral Rehabilitation Inventory and Analysis. Henry Mountain coal field: U.S. Bureau of Land Management EMRIA Report no. 15.

U.S. Geological Survey, 1976, Coal resource classfication system of the U.S. Bureau of Mines and U.S. Geological Survey: U.S. Geological Survey Bulletin 1450-B.

BIBLIOGRAPHY

Averitt, Paul, 1961, Coal reserves of the U.S. - a progress report, January 1, 1960: U.S. Geological Survey Bulletin 1136, 116 p.

______1964, Mineral fuels and associated resources, coal in Mineral and water resources of Utah: U.S. 88th Cong., 2nd sess., comm. print, p. 39-51.

______1975, Coal resources of the U.S., January 1, 1974: U.S. Geological Survey Bulletin 1412, 131 p.

Bain, G. W., 1952, Uranium in the Dirty Devil Shinariump channel deposit: U.S. Atomic Energy Commission, RMO-66, 40 p.

Baker, A. A., 1935, Geologic structure of southeastern Utah: American Association Petroleum Geologists Bulletin, v. 19, p. 1472-1507.

______1946, Geology of the Green River Desert-Cataract Canyon region, Emery, Wayne and Garfield Counties, Utah: U.S. Geological Survey, Bulletin 951, 122 p.

Baker, A. A., Knechtel, M. M., Andrews, D. A., Eardley, A. J., Henbest, L. G., Bumgardner, L. S., Curry, H. D., and Miller, R. L., 1957 (1933), Preliminary map showing geologic structure of parts of Emery, Wayne and Garfield Counties, Utah: U.S. Geological Survey Oil and Gas Inventory Map OM-197.

Bissell, H. J., 1954, The Kaiparowitz region, in Geology of portions of the High Plateau and adjacent canyon lands central and southcentral Utah: Intermountain Association Petroleum Geologists, 5th Annual Field Conference Guidebook, p. 63-70.

Brooke, G. F., Shirley, R. F. and Swanson, M. A., 1951, Geological investigation of the Trachyte district, Henry Mountains: U.S. Atomic Energy Commission, RMO-912, 7 p.

Brown, H. H., 1973, The Dakota formation in the plateau area, southwest Utah, in Cretaceous and Tertiary rocks of the southern Colorado Plateau: Four Corners Geological Society, Memoir 1, p. 52-56.

Buell, E. H., 1974, The Kaiparowitz project in Pacific Southwest energy and minerals conference: U.S. Bureau of Land Management, p. 107-117.

Butler, B. S., Loughlin, G. F., Heikes, V. C., and others, 1920, Ore deposits of Utah: U.S. Geological Survey Professional Paper 111, 672 p.

Campbell, J. A., 1969, Upper Valley oil field, Garfied County, Utah in Geology and natural history of the Grand Canyon region: Fifth Field Conference, Powell Centennial River Expedition: Four Corners Geological Society, p. 195-200.

Cobban, W. A., and J. B. Reeside, Jr., 1952, Correlation of the Cretaceous formations of the Western Interior of the U.S.: Geological Society of American Bulletin 63, p. 1011-1044.

Cotter, Edward, 1969, Identification and interpretation Upper Cretaceous fluvial and deltaic sandstones (abs.): American Association Petroleum Geologists Bulletin v. 53, no. 3, p. 713-714.

______1971, Paleoflow characteristics of late Cretaceous River in Utah from analysis of sedimentary structures in the Ferron sandstone: Journal of Sedimentary Petrology, v. 41, p. 129-138.

______1975, Late Cretaceous sedimentation in a low-energy coastal zone: The Ferron sandstone of Utah: Journal of Sedimentary Petrology, v. 45, no. 3, p. 669-685.

______1975, Deltaic deposits in the Upper Cretaceous Ferron sandstone, Utah in Broussared, M.L.S. (editor), Deltas, Models for exploration: Houston Geological Society, p. 471-484.

______1975, The role of deltas in the evolution of the Ferron sandstone and its coals, Castle Valley, Utah: Geological Society of America, Abstract Program, v. 7, no. 7, p. 1039-1040.

Craig, L. C., Holmes, C. N., Cadigan, R. A., Freeman, V. L., Mullens, T. E., and Weir, G. W., 1955, Stratigraphy of the Morrison and related formations, Colorado Plateau region, a preliminary report: U.S. Geological Survey Bulletin 1009-E, p. 125-168.

Dana, J. D., 1880, Gilbert's report on the geology of the Henry Mtns: American Journal of Science, 3rd ser., v. 19, no. 109, article 3, p. 17-25.

Davidson, E. S., 1967, Geology of the Circle Cliffs area, Garfield and Kane Counties, Utah: U.S. Geological Survey Bulletin 1229, 140 p.

Doelling, H. H., 1967, Escalante - Upper Valley coal area, Kaiparowits Plateau, Garfield County, Utah: Utah Geological and Mineralogical Survey Special Studies 20, p. 16.

______1967, Uranium deposits of Garfield County, Utah: Utah Geological and Mineralogical Survey Special Studies 22, p. 113.

______1975, Geology and mineral resources of Garfield County, Utah: Utah Geological and Mineralogical Survey Bulletin 107, 175 p.

______1977, Overview of Utah coal deposits: Geological Society of America, Abstract Program, v. 9, no. 1, p. 15-16.

Eardley, A. J., 1952, Wasatch hinterland in Utah, Geological Society Guidebook to the geology of Utah, no. 8, p. 52-60.

Felix, C., 1964, Coal deposits of the Intermountain West: Proceedings, 1st Intermountain Symposium on fossil hydrocarbons, p. 47.

Gilkey, A. K., 1953, Fracture patterns of the Zuni Uplift (New Mexico), pt. 1 of progress report for June 15 to December 15, 1952: U.S. Atomic Energy Commission, RME-3024.

Gill, J. R., and Hail, W. J., Jr., 1975, Stratigraphic sections across Upper Cretaceous Mancos Shale - Mesa Verde Group Boundary, eastern Utah and western Colorado: U.S. Geological Survey, OC-68.

Gilluly, James, and Reeside, J. B., Jr., 1928, Sedimentary rocks of the San Rafael Swell and some adjacent areas in eastern Utah: U.S. Geological Survey, Professional Paper 150-D, p. 61-110.

Godfrey, A. E., 1970, Processes of fan and pediment development in the northern Henry Mountains, Piedmont, Utah in American Quaterly Association: Abstracts, 1st meeting AMQUA, p. 53.

Gray, R. J., Patalski, R. M., Schapiro, N., 1966, Correlation of coal deposits from central Utah: Utah Geological and Mineralogical Survey Bulletin 80, p. 81-86.

Gregory, H. E., 1938, The San Juan country, a geographic and geologic reconnaissance of southeastern, Utah: U.S. Geological Survey, Professional Paper 188, 123 p.

Gregory, H. E., and Anderson, J. C., 1939, Geographic and geologic sketch of the Capitol Reef region, Utah: Geological Society of America Bulletin, v. 50, p. 1827-1850.

Gregory, H. E., and Moore, R. C., 1931, The Kaiparowits region, a geographic and geologic reconnaissance of parts of Utah and Arizona: U.S. Geological Survey Professional Paper 164, 161 p.

Hale, L. A., 1972, Depositional history of the Ferron Formation, in Plateau--basin and range transition zone, central Utah: Utah Geological Association, publication no. 2, p. 29-40.

Heylmun, E. B., 1964, Shallow oil and gas possibilities in east and south-central Utah: Utah Geological and Mineralogical Survey, Special Studies 8, 39 p.

Hohl, A. H., 1972, Periglacial features and related surficial deposits (Quaternary) of Bull Creek Basin, Henry Mountains, Utah: Ph.D. thesis, 1972, Johns Hopkins University.

Holmes, A. W., 1970, Upper Cretaceous stratigraphy of northeastern Arizona and south central Utah: Utah Geological and Mineralocial Survey Bulletin 86, p. 79.

Howard, A. D., 1971, A study of process and history in desert landforms near the Henry Mountains Utah: Diss. Abs., v. 31 no. 7, p. 4129B.

Howard, J. D., 1969, The influence of channel deposits on Upper Cretaceous sedimentation and their effect on coal mining: Geological Society of America, Abstract Programs, 1969, part 5 (Rocky Mtn. Sect.), p. 34-35.

Hunt, C. B., 1942, New interpretation of some laccolithic mountains and its possible bearing on structural traps for oil and gas: American Association of Petroleum Geologists Bulletin, v. 26, no. 2, p. 194-203.

______1946, Guidebook to the geology and geography of the Henry Mountains region: Utah Geological Society Guidebook, no. 1, 51 p.

______1952, Geologic map of the Henry Mountains region, Utah: U.S. Geological Survey Oil and Gas Inventory Map, OM-131.

______1956, Cenozoic geology of the Colorado Plateau: U.S. Geological Survey Professional Paper 279, 99 p.

Intermountain Association of Petroleum Geologists, 5th Annual Field Conference, 1954: Salt Lake City, Utah, p. 145.

Johnson, A. M., and Pollard, D. D., 1973, Mechanics of growth of some laccolithic intrusions in the Henry Mountains, 1, field observations; Gilbert's model, physical properties and flows of the magma: Tectonophysics, v. 18, no. 3-4, p. 261-309.

Johnson, H. S., 1955, Utah and Arizona: U.S. Geological Survey Trace Element Investigation Report 590, p. 99-104.

______1956, Utah and Arizona: U.S. Geological Survey Trace Element Investigation Report 620, p. 110-113.

______1959, Uranium resources of the Green River and Henry Mountains districts, Utah - a regional synthesis: U.S. Geological Survey Bulletin 1087-C, p. 59-104.

Katich, P. J., 1954, Cretaceous and early Tertiary stratigraphy of central and south-central Utah with emphasis on the Wasatch Plateau, in Intermountain Association of Petroleum Geologists, 5th Annual Field Conference, p. 42-54.

______1958, Cretaceous of southeastern Utah and adjacent areas in Intermountain Association of Petroleum Geologists, 9th Annual Field Conference Guidebook, p. 193-196.

Knight, L. L., 1954, A preliminary heavy mineral study of the Ferron sandstone: Brigham Young University research studies in geology, v. 1, no. 4, p. 31.

Lawyer, G. F., 1972, Sedimentary features and paleoenvironment of the Dakota sandstone (early Upper Cretaceous) near Hanksville, Utah: Brigham Young University, Geology Studies, v. 19, pt. 2, p. 89-120.

Miesch, A. T., and Connor, Jon J., 1956, Distribution of elements: U.S. Geological Survey Trace Element Investigation Report 620, p. 128-142.

Nummedal, Dag, 1973, Paleoflow characteristics of late Cretaceous river in Utah from analysis of sedimentary structures in the Ferron sandstone: Journal of Sedimentary Petrology, v. 43, no. 4, p. 1176-1179.

Olsen, D. R., and J. S., Williams, 1960, Mineral resources of the five county area, southeastern Utah: Ag. Expt. Station, Utah State Univiversity, Utah Resources, series 8, p. 16.

Orlansky, Ralph, 1968, Palynology of the Upper Cretaceous Straight Cliffs sandstone, Garfield County, Utah: Diss. abs., v. 28, no. 7, p. 2903B.

______1969, Significance of palynomorphology as sedimentation indicators in Cretaceous Straight Cliffs sandstone: American Association of Petroleum Geologists Bulletin, abstract, v. 53, no. 3, p. 734-735.

Peterson, Fred, Waldrop, H. A., 1965, Jurassic and Cretaceous stratigraphy of south-central Kaiparowits Plateau, Utah: in Utah Geological Society Guidebook to the Geology of Utah, no. 19, p. 47-69.

Peterson, Fred, 1975, Influence of tectonism on deposition of coal in Straight Cliffs Formation (Upper Cretaceous), south-central Utah: American Association of Petroleum Geologists Bulletin, v. 59, no. 5, p. 919-920.

______1975, Regional correlation of some Upper Cretaceous rocks (Santonian - Upper Campanion) in the Henry Basin, Utah: Geological Society of America, Abstract Program, v. 7, no. 7, p. 1226-1227.

Pollard, D. D., 1969, Deformation of host rocks during sill and laccolith formation: Diss. abs., v. 30, no. 3, p. 1204-1205B.

______1972, Elastic - plastic bending of strata over a laccolith: why some laccoliths have flat tops: EOS abstract, v. 53, no. 11, p. 1117.

Reid, J. W., 1954, The structural and stratigraphic history of the Wasatch Plateau and environs, in Intermountan Association of Petroleum Geologists, 5th Annual Field Conference, p. 18-20.

Reinhart, E. V., 1951, Reconnaissance of Henry Mountains area, Wayne and Garfield Counties, Utah: U.S. Atomic Energy Commission RMO-753, p. 7.

Ryder, R. T., 1975, A major unconformity in Upper Cretaceous rocks, Henry Basin, Utah: Geological Society of America, Abstract Program, v. 7, no. 7, p. 1255.

Sargent, K. A., and Hansen, D. E., 1976, General geology and mineral resources of the coal area of south-central Utah: U.S. Geological Survey Open-File Report 76-811, p. 122, 4 pl.

Savage, W. Z., 1974, Stress and displacement fields in stably folded rock layers (abs.) 207 p., Doctoral thesis, 1974, Texas A & M, Diss. abs., v. 36, no. 1, p. 136B, 1975.

Savage, W. Z., and Sowers, G. M., 1972, Separating stable and unstable folding, III, Stable bending: EOS abstract, v. 53, no. 4, p. 523-524.

Scott, J. M., and Hackman, R. J., 1953, Photogeologic maps of Mount Pennell, 5 and 11-14 quadrangles: U.S. Geological Survey.

Smith, J. F., Jr., Huff, L. C., Hinrichs, E. N., and Luedke, R. G., 1957, Preliminary geologic map of the Notom 4 SE quadrangle, Utah: U.S. Geological Survey Miscellaneous Field Studies Map MF-115.

______1963, Geology of the Capitol Reef area, Wayne and Garfield Counties, Utah: U.S. Geological Survey Professional Paper 363, 102 p.

Stewart, J. H., Williams, G. A., Albee, H. F., and Raup, O. B., 1959, Stratigraphy of Triassic and associated formations in part of the Colorado Plateau region, with a section on sedimentary petrology by R. A. Cadigan: U.S. Geological Survey Bulletin 1046-Q, p. 487-576.

Stokes, W. L., 1944, Morrison Formation and related deposits in and adjacent to the Colorado Plateau: Geological Society of America Bulletin, v. 55, p. 951-992.

______1952, Lower Cretaceous in Colorado Plateau: American Association of Petroleum Geologists Bulletin, v. 36, p. 1766-1776.

Storrs, L. S., 1902, The Rocky Moutain coal fields: U.S. Geological Survey, 22nd Annual Report, 1900-1901 pt. 3, p. 415-472.

Spiecker, E. M., 1925, Geology of the coal fields of Utah: U.S. Bureau of Mines, Technical Paper 345, p. 13-22.

______1931, The Wasatch Plateau coal field: U.S Geological Survey Bulletin 819, 210 p.

______1946, Late Mesozoic and Early Cenozoic history of central Utah: U.S. Geological Survey, Professional Paper 205D, p. 117-161.

______1949, The transition between the Colorado Plateau and the great basin in central Utah: Utah Geological Society, Guidebook 4, p. 106.

______1959, Cretaceous coal measures in Utah: Geological Society of American Bulletin, abstract, v. 70, no. 12, pt. 2, p. 1679.

Spieker, E. M., and Reeside, J. B. Jr., 1925, Cretaceous and Tertiary Formations of the Wasatch Plateau, Utah: Geological Society of America Bulletin, v. 36, p. 435-454.

______1926, Upper Createceous shoreline in Utah: Geological Society of America Bulletin, v. 37. no. 3, p. 429-438.

U.S. Bureau of Mines, 1971, Strippable reserves of bituminous coal and lignite in the United States: U.S. Bureau of Mines, Information Circular 8531, 148 p.

Van de Graff, F. R., 1963, Upper Cretaceous stratigraphy of southwestern Utah: Intermountain Assoication of Petroleum Geologists, 12th Annual Field Conference, p. 65-70.

Walton, P. T., 1955, Wasatch Plateau gas fields, Utah in American Association of Petroleum Geologists Bulletin, v. 39, no. 4, p. 385-421.

Wright, J. C., and Dickey, D. D., 1978, East-west cross section of the Jurassic age San Rafael group rocks from western Colorado to central and western Utah: U.S. Geological Survey Open-File Report 78-784, 1 pl.

Zeller, H. D., 1953, Uranium in carbonaceous rocks - Utah - New Mexico: U.S. Geological Survey Trace Element Investigation Report 390, p. 117-118.