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COAL RESOURCE OCCURRENCE AND COAL DEVELOPMENT POTENTIAL MAPS OF THE BALD KNOLL QUADRANGLE, KANE COUNTY, UTAH

(Report Includes 13 Plates)

Prepared for

UNITED STATES DEPARTMENT OF THE INTERIOR

GEOLOGICAL SURVEY

By

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

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INTRODUCTION

Purpose

This report is to be used with the Coal Resource Occurrence (CRO) and Coal Development Potential (CDP) Maps of the Bald Knoll 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 Bald Knoll 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 Published and unpublished information was used as the data base of this study. Neither new drilling nor field mapping was done, and confidential data were not used.

Location

The Bald Knoll 7½-minute quadrangle is located in west-central Kane County of southwestern Utah, in the southwestern portion of the Alton-Kanab Known Recoverable Coal Resource Area (KRCRA). The northern boundary of the quadrangle is nine miles (14.5 m) south of Alton, Utah, and the western boundary is eight miles (13 m) east of Glendale, Utah. The Bald Knoll quadrangle lies 30 miles (48 km) northeast of Kanab, Utah, the nearest town with full services. No towns are located within the quadrangle.

Accessibility

U.S. Highway 89 extends north from Kanab 27 miles to Glendale, where a number of roads connect U.S. 89 with the Bald Knoll quadrangle, eight miles (13 km) to the east. The most important of these, and the only one partly paved, is Utah State Road 136 which runs east from U.S. 89 north of Glendale to Alton. From Alton, Road 136 cuts south through the center of the quadrangle to the southwest quarter, where it splits to the west and to the east. The road to the east crosses the southern part of the quadrangle. Numerous dirt and jeep roads branch from Utah 136, providing access to other parts of the quadrangle, including the coal outcrops. No rail service to the quadrangle is available.

Physiography

The Bald Knoll quadrangle lies within the High Plateaus section of the Colorado Plateau physiographic province (Sargent and Hansen, 1976). Characteristic landforms are broad mesas and valleys, bounded by moderately steep canyon walls. In the northeast corner, steep, narrow canyon walls separate narrow ridges, while in the south, broad, gently sloping valleys and terraces have been etched by small, ephemeral streams. In the south elevations vary from approximately 6000 feet (1829 m) downstream to 6600 feet (2019 m) on the high terraces. In the northeast corner, elevations average 7600 feet (2317 m) on the ridge tops to 6800 feet (2073 m) in the neighboring canyons. The remainder of the quadrangle is within these ranges, with relief of approximately 500 feet (152 m).

Altitudes range from 7900 feet (2408 m) in the northeast corner of the quadrangle to 5900 feet (1798 m) in the southeast corner, along Johnson's Canyon.

Kanab Creek, the only perennial stream in the Bald Knoll quadrangle, flows south along the west quadrangle boundary. Kanab Creek drains roughly the west half of the quadrangle, while the east half is drained by Thompson Creek and its tributaries. Thompson Creek flows into Kanab Creek south of Kanab.

Climate and Vegetation

The climate of southern Utah is generally arid to semi-arid. Annual precipitation for the Bald Knoll quadrangle averages 16 inches (40 cm) per year but varies widely with elevation. The lower valleys average as little as 10 inches (25 cm) of precipitation a year, while some of the higher areas average about 25 inches (64 cm).

Annual temperatures in the valleys range from an average low of 14° C (-10° C) to an average high of 88° F (31° C). They average 10° F to 15° F (5.5° C to 8° C) cooler at the higher elevations. (See United States Department of the Interior, part I, p. II-1 to II-4.)

Vegetation types show little variation. Sagebrush and grasses predominate at the lower elevations, while a Pinyon-Juniper Woodland predominates at higher elevations. (See United States Department of the Interior part I, p. II-31 to II-35, fig. II-11.)

Land Status

The Bald Knoll quadrangle lies in the southwestern portion of the Alton-Kanab KRCRA. Forty-one percent of the quadrangle, about 14,000 acres (5668 ha) in the northeast quarter of the quadrangle, is included within the KRCRA boundary (see plate 2). Virtually all of the coal deposits are within the boundaries of the KRCRA. Ninety-five percent of the coal is owned by the Federal Government (Doelling and Graham, 1972). Almost all of the coal under less than 200 feet (61 m) of overburden is under lease (see plates 7 and 11).

GENERAL GEOLOGY

Previous Work

The first preliminary report on coal in southern Utah was authored by G.B. Richardson (1909), who examined coal outcrops in the vicinity of Alton, Utah, nine miles (14.5 m) north of the Bald Knoll quadrangle. Richardson reported that the coal rapidly thinned to the east of Kanab Creek. The first stratigraphic study of the region was made by Gregory and Moore in 1931, who performed a brief reconnaissance of the region and noted the coal occurrences.

In 1951 H.E. Gregory published a more focused investigation of the Cretaceous stratigraphy within the Bald Knoll quadrangle. In this report, he discussed the Cretaceous coals and gave a brief description of the Bald Knoll coal mine.

Most of the coal beds were mapped by Cashion (1961), who also measured six coal sections in the Bald Knoll coal zone and mapped and described the rock units adjacent to the coal beds in greater detail. Grose (1965) and Grose, Hileman, and Ward (1967) investigated the regional coal geology and coal mines, including the Bald Knoll mine. The Utah Geological and Mineralogical Survey performed additional investigations within the quadrangle which were compiled, along with the earlier data, and published in a monograph on southwestern Utah coal fields (Doelling and Graham, 1972). Bowers (1979) measured 12 coal outcrop sections, which have greatly added to the available coal information.

Areas adjacent to the coal beds in the northern one-third of the quadrangle were mapped by Cashion (1961). Later, Goode (1973) mapped the entire quadrangle, identifying the members of the Carmel Formation with the terminology of Cashion (1961), rather than that of Thompson and Stokes (1970). Thompson and Stokes' terminology is used in this report. Several other authors discuss the stratigraphy, structure, and depositional environments of rock units in this quadrangle, notably Van DeGraff (1963), Lawrence (1965), and Sargent and Hansen (1976).

Only one drill hole is present in the quadrangle. The United States Department of the Interior (1975) drilled one hole (DH-105), adjacent to the eastern quadrangle boundary, which showed 16.5 ft. (5.0 m) of coal in the Smirl coal bed.

Stratigraphy

Sedimentary strata which crop out in the Bald Knoll quadrangle range from Jurassic to Recent in age. The Jurassic Navajo Sandstone is the oldest exposed formation and underlies the entire quadrangle. It is a massive, cliff-forming sandstone, at least 1000 ft. (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 are responsible for the informal designation "white cliffs" for Navajo Sandstone outcrops in southern Utah. The only outcrop in the quadrangle is a 100 foot (30 m) section exposed along Johnson Canyon in the southeast corner of the quadrangle.

The Jurassic Carmel Formation unconformably overlies the Navajo Sandstone. The Carmel Formation is divided into six members, four of which are present in the Bald Knoll quadrangle. The lowest member of the Carmel Formation is the Kolob Limestone, which correlates with the limestone member identified by Cashion (1967). The member is composed of dense gray to tan, silty limestone, with thin, sandy, red shale near the base and thin gypsum interbeds near the top. The Carmel is 120 ft. (37 m) thick in the eastern part of the quadrangle, increasing to 180 ft. (55 m) in the western part of the quadrangle.

The Crystal Creek Member conformably overlies the Kolob Limestone Member. The Crystal Creek Member 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. The thickness is estimated to be about 125 ft. (38 m) in the Bald Knoll quadrangle area. This member corresponds to the banded member reported by Cashion (1967).

The Paria River Member overlies the Crystal Creek Member and corresponds to the gypsiferous member reported by Cashion (1967). The unit consists of about 200 ft. (61 m) of interbedded gypsum, sandstone, limestone, siltstone, and shale. The color is light gray with some red beds.

The youngest member of the Carmel Formation in the Bald Knoll quadrangle is the Winsor Member, which is a fine-to very fine-grained, gray to light brown sandstone, interbedded in the lower one-quarter with thin red siltstone or mudstone beds. The upper portion of the member has been truncated by an unconformity. It is 280 ft. (85 m) to 350 ft. (107 m) thick, though generally thinner in the western part of the quadrangle.

The Cretaceous Dakota Formation unconformably overlies the Jurassic Carmel Formation. The lower contact is distinct in color and lithology and is easily located. However, 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 that advocated by Lawrence (1965) and modified by Utah Geological and Mineralogical Survey practice (Doelling and Graham, 1972) which places the contact at the top of the highest coal bed in the Upper or Smirl coal zone in the Alton-Kanab KRCRA.

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 ft. (11.5 m) or more in thickness occur in two zones named the lower and upper coal zones by Cashion (1961). These lower and upper coal zones were later renamed the Bald Knoll and Smirl coal zones by Doelling and Graham (1972). Both zones are composed of gray to dark-gray shale, carbonaceous shale and coal. The Bald Knoll coal zone is within the lower 50 ft. (15 m) of the Dakota Formation, while the Smirl coal zone is within the upper 50 ft. (15 m). The total thickness of the Dakota Formation in the Bald Knoll quadrangle is about 200 ft. (61 m).

The Dakota Formation was deposited on 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 fluvial or near-shore deposits overlain by a complex interfingering of paludal, lagoonal, near-shore and marine sediments. The marine advance was generally continuous but marked by numerous local, or occasionally regional, regressions followed by renewed transgression.

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

The contact between the Cretaceous Tropic Formation and the underlying Dakota Formation is gradational. The Tropic Formation has been described by a number of authors (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.

Some thin, brown sandstone and thicker, yellow-gray sandstone beds of near-shore origin are also present. The sandstones are concentrated toward the lower and upper contacts with the underlying Dakota Formation and overlying Straight Cliffs Sandstone.

The Tropic Shale is predominantly marine shale in the Bald Knoll quadrangle. To the west, the Tropic Shale interfingers with the Straight Cliffs Sandstone (Cashion, 1961; Lawrence, 1965; Doelling and Graham, 1972), while to the east it is correlated with the Tununk Member of the Mancos Shale of eastern and central Utah. The close proximity of the time-equivalent, near-shore Straight Cliffs Sandstone to the west and underlying interbedded sandstones and coal beds within the Alton area suggest that the Tropic Shale was deposited in a shallow marine environment. Total thickness of the Tropic Shale in this quadrangle was measured at 650 ft. (198 m) to 700 ft. (213 m) by Goode (1973).

The Cretaceous Straight Cliffs Formation conformably overlies the Tropic Shale. The base of the Straight Cliffs Formation is the first massive sandstone above the transition sandstone and shale of the Tropic Shale (Goode, 1973a). The formation consists of massive, cliff-forming, tan or buff, fine-grained marine sandstone, with some beds of shale and siltstone. Occasional thin coal or lignite beds are present and concentrated towards 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 Straight Cliffs Formation is 200 ft. (61 m) to 250 ft. (76 m) thick in the area.

The Upper Cretaceous Wahweap Formation is differentiated from the underlying Straight Cliffs Formation by the silty and feldspathic nature of the sandstone. It also contains lenses and crossbeds of fine pebbles and interbeds of blue-gray, green and tan shale. The lower contact is conformable and placed by Goode at the boundary between a crossbedded iron-stained, coarse-grained sandstone, and an underlying white, fine-grained sandstone bed at the top of the Straight Cliffs Formation. Only the lower portion of the Wahweap Formation is exposed on this quadrangle.

Quaternary pediment gravels are found from near stream level to 600 ft. (183 m) above present stream levels. Most commonly, they have been deposited on the Tropic Shale or Winsor Member of the Cretaceous Carmel Formation. The gravels and cobbles are derived primarily from the Eocene Claron Formation, which crops out several miles northeast of the Bald Knoll quad.

Olivine basalt from Bald Knoll,a cinder cone, has filled much of the drainage of upper Johnson Creek. The ash and ejecta have built Bald Knoll to a height of 450 ft. (137 m) above the surface. The unweathered appearance and interfingering of flows and ash with alluvium indicate a late Quaternary age. Buck Knoll, another cinder cone near the western boundary of the quadrangle, is smaller and more eroded, but otherwise similar to Bald Knoll.

Structure

Folds

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

The Bald Knoll quadrangle is located along the axis of the Paunsaugunt Syncline (Doelling and Graham, 1972). The structure plunges north at 1^{o} to 2^{o} and dips do not exceed 3^{o} on either limb. Dips at the outcrop in the Bald Knoll quadrangle area are north to northeast.

Faults

H. D. Goode (1973a) mapped a number of north to northwest-trending normal faults on the quadrangle. Only one of these, the Bald Knoll fault, has a significant displacement. The fault trends north through the central portion of the quadrangle just west of Bald Knoll. Movement was normal, with the east side dropped 200 feet (61 m) to 500 feet (152 m).

COAL GEOLOGY

General

Coal deposition occurred near the beginning and end of the deposition of the Dakota Formation, with some minor deposition in between. The coal was deposited over broad areas as thin to moderately thick, discontinuous, and sometimes overlapping beds. Areas with greater than normal deposition are found within some coal beds, possibly the result of deposition in parts of an oxbow lake, swamp or lagoon. Information on coal geology is sparse for the Bald Knoll quadrangle. Twenty-two outcrop measurements and data from one drill hole have been published. Two coal analyses are also available.

Past Production

Past production from the Bald Knoll quadrangle appears to have been very small (Gregory, 1951; Doelling and Graham, 1972). The Bald Knoll Mine provided the only known production, and no production records are available to substantiate present estimates.

Bald Knoll Coal Zone

The Bald Knoll coal zone is located within the lower 50 feet (61 m) of the Early Cretaceous Dakota Formation. Goode (1973) reported the coal at six to ten feet (1.8 to 3 m) above the base of the Dakota. Twenty-one measured sections of outcrops are available, but no subsurface data are available. Available information does indicate the continuity of coal within the coal zone but is not complete enough to indicate areas where the coal may be absent. A "Limit of Data" line has been drawn to indicate this lack of information, particularly the lack of any subsurface data (see plates 4 and 7).

The coal thickness varies from two to 18 feet (0.6 to 5.5 m) and is probably between two and five ft. (0.6 to 1.5 m) over most of the coal-bearing area. The thicker coal was measured in a small depositional basin, about one and a half miles (2.4 km) wide by four miles (6.4 km) long, located in the center of the quadrangle (see plate 4). Coal beds in the center of this basin reach 18 ft. (5.5 m) in thickness, with an average of 12 ft. (3.7 m). The coal thins outward from the basin center and reaches a thickness of three ft. (0.9 m) to five ft. (1.5 m) at the basin edge. The Bald Knoll coal mine was developed near the basin center but little coal appears to have been mined.

A chemical analysis of the one coal sample from the Bald Knoll mine indicated a sub-bituminous "A" rank coal with low sulfur (0.4%) and ash (5.6%) content. Additional analytical data are not available.

Smirl Coal Zone

The Smirl zone is located at the top of the Cretaceous Dakota Formation. Only two measured coal sections are available for this zone (see plate 8). One section in the north-central quadrangle area shows a seven-foot (2.1 m) coal bed. The other measurement, taken from a drill hole on the eastern quadrangle boundary, penetrated 16.7 ft. (5.1 m) of coal under less than 200 ft. (61 m) of overburden. These two information sources indicate a potential for substantial reserves. The reserve figures shown on table 3 are a projected minimum, but greater tonnages were not considered to be justified because of the limited data available.

Coal from the drill hole (Bowers and others, 1976, drill hole no. 105) was analyzed, indicating a spot ranking of sub-bituminous "B" with 0.9 percent sulfur and 7.4 percent ash.

Coal Resources

Coal reserves are calculated by multiplying the total tons of coal in place (the reserve base) by a recovery factor, which takes into account losses experienced under similar circumstances in other areas, to arrive at an assumed recoverable coal tonnage (the reserve). The recovery factors used, 0.85 for surface mining and 0.50 for subsurface mining, were provided by the U.S. Geological Survey and are based on economic and technical criteria. Reserve base and reserve tonnages are listed in tables 2 and 3.

Data from outcrop measurements and drill holes 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 4 and 8 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 35,760,000 short tons (32,440,000 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 higher 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 as surface mining areas. The divisions between high, moderate, and low development potential areas for surface mining methods are based on a calculated mining ratio. This ratio is defined as the cubic yardage of overburden overlying each ton of recoverable coal, assuming 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 ton of recoverable coal: 0.911 for sub-bituminous coal

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

A high development potential ranking is applied to those areas between the coal outcrop and a line representing a mining ratio value of 10. A moderate development potential is applied to areas between the mining ratio values of 10 and 15. A low development potential ranking is assigned to areas with mining ratio values over 15, but under less than 200 ft. (61 m) of overburden. These mining ratio values for each development potential category are based on economic and technological criteria and were provided by the U.S. Geological Survey. The surface development potential for this quadrangle is shown on plate 12 and table 2. Thirty-one percent of the coal tonnage is rated high, 23 percent is rated moderate, and 46 percent is rated low. The total surface development potential for this quadrangle is 14,200,000 short tons of coal.

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 to have a high potential. Coal with 1000 ft. (304.8 m) to 2000 ft. (609.6 m) of overburden is rated moderate.

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.

An unknown development potential is assigned to large areas within the KRCRA. The remaining portion is given a high development potential rating. The total subsurface development potential for this quadrangle is 21,560,000 short tons of coal.

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Table 1. Chemical analyses of coal in the Bald Knoll 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
SW¼,Sec.21,R40S,T5W	Bald Knoll	A	11.4	35.2	47.8	5.6	0.4	-	-	-	-	-	10,910
		C	-	39.7	54.0	6.3	0.5	-	-	-	-	-	12,320
NW¼,SW¼,Sec.13,T40S,R5W	Smirl	A	20.6	31.8	40.2	7.4	0.9	-	-	-	-	-	9,530
		C	-	40.0	50.7	9.3	1.0	-	-	-	-	-	11,990

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 Bald Knoll quadrangle, Kane County, Utah.

Coal Bed or Zone	High Development Potential	Moderate Development Potential	Low Development Potential	Total
Bald Knoll Zone	4,310,000	3,320,000	6,360,000	13,990,000
Smirl Zone	70,000	-	140,000	210,000
Total	4,380,000	3,320,000	6,500,000	14,200,000

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 Bald Knoll quadrangle, Kane County, Utah.

Coal Bed or Zone	High Development Potential	Moderate Development Potential	Low Development Potential	Total
Bald Knoll Zone	12,940,000	-	-	12,940,000
Smirl Zone	8,620,000	-	-	8,620,000
Total	21,560,000	-	-	21,560,000

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	Bowers, 1979, U.S.G.S., Unpublished field data	Measured Section
2	Doelling and Graham, 1972, U.G. & M.S., Monograph Series No. 1	"
3	Bowers, 1979, U.S.G.S., Unpublished field data	"
4	Doelling and May, 1970, U.G. & M.S., Unpublished field ata	"
5	Bowers, 1979, U.S.G.S., Unpublished field data	"
6	Doelling and Graham, 1972, U.G. & M.S., Monograph Series No. 1	"
7	Bowers, 1979, U.S.G.S., Unpublished field data	"
8	"	"
9	Doelling and Graham, 1972, U.G. & M.S., Monograph Series No. 1	"
10	Bowers, 1979, U.S.G.S., Unpublished field data	"
11	"	"
12	"	"
13	Doelling and Graham, 1972, U.G. & M.S., Monograph Series No. 1	"
14	"	"
15	"	"
16	"	"
17	Bowers, 1979, U.S.G.S., Unpublished field data	"
18	Doelling and May, 1970, U.G. & M.S., Unpublished field data	"

Table 4 - Continued

Plate 1 Index Number	Source	Data Base
19	Doelling and Graham, 1972, U.G. & M.S., Monograph Series No. 1	Measured Section
20	Bowers, 1979, U.S.G.S., Unpublished field data	"
21	"	"
22	"	"
23	Bowers, Aigen, and Landis, 1976, U.S.G.S., Open-File Report 76-386	Coal Drill Hole No. 105