UNITED STATES DEPARTMENT OF THE INTERIOR

GEOLOGICAL SURVEY

Text to Accompany:

COAL RESOURCE OCCURRENCE MAP
COAL DEVELOPMENT POTENTIAL MAP OF THE MANDAREE SE QUADRANGLE, DUNN COUNTY, NORTH DAKOTA

[Report includes 6 plates]

By

WOODWARD-CLYDE CONSULTANTS

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

TABLE OF CONTENTS

PLATES

INTRODUCTION

The occurrence, extent, and preliminary geologic evaluation of coal beds in the Mandaree SE quadrangle in west-central North Dakota are described in this report. Since no detailed data are available in this quadrangle, the geological mapping has been entirely dependent on knowledge of the regional geology as well as the geology of adjacent and surrounding quadrangles. In surrounding quadrangles, subsurface data consisting of oil and gas well and exploration drill hole logs and surface data comprised of measured sections were compiled for study and presentation. A composite section of the project geology of this quadrangle is shown on Figure 1. Federal ownership of coal and total Reserve Base of coal per section are presented on the Boundary and Coal Data Map, Plate 2. Derivative maps consisting of coal isopachs, structure contours, overburden/interburden, mining ratios, reserve categories, and Reserves and Reserve Base, are compiled for each coal seam of reserve base thickness underlying the quadrangle, and are presented on Plates 3 through 5, respectively. A Coal Development Potential Map for surface mining is presented on Plate 6.

This work has been performed under contract with the Conservation Division of the U.S. Geological Survey (Contract No. 14-08-0001-17118).

COMPOSITE COLUMNAR SECTION, MANDAREE SE

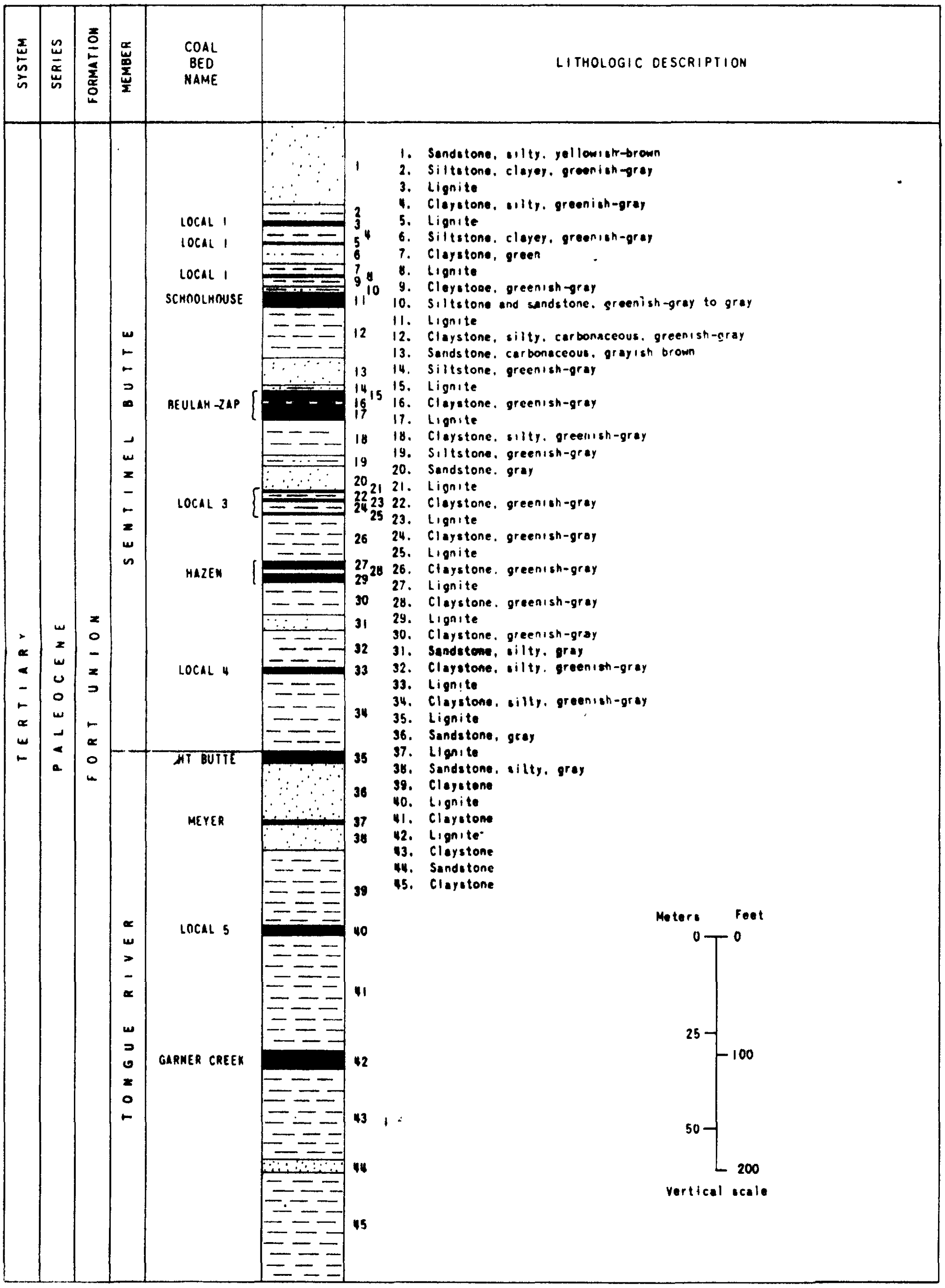

FIG. 1

The resource information gathered in this program is in response to the Federal Coal Leasing Amendments Act of 1975 and is a part of the U.S. Geological Survey's coal program. This information is intended to provide basic data on coal resources for land-use planning purposes by the Bureau of Land Management, state and local governments, and the public.

LOCATION

The Mandaree SE 7 1/2 minute quadrangle is located in northern Dunn County, North Dakota about 11 miles (17.7 km) northeast of Killdeer and 56 miles (90.1 km) west of Riverdale.

ACCESSIBILITY

The area is accessible by county road to State Highway 22, 5 miles (8 km) west of the western quadrangle border. State Highway 22 connects with Interstate 94 at Dickinson, 56 miles (90.1 km) to the south.

The Burlington Northern Railroad operates and maintains an east-west route which extends through Halliday, Dunn Center and Killdeer about 11 miles (17.7 km) south of the quadrangle. No railroad routes currently pass through or closer to the quadrangle than the existing Burlington Northern route to the south.

PHYSIOGRAPHY

The quadrangle lies in the central portion of a large topographic high known as the Missouri Plateau. The plateau is being dissected by the Knife, Heart, Cannonball and Cedar Creek Rivers. In the eastern portion of the plateau the topography is qenerally hilly and along the Missouri River there are bluffs 500-600 feet (152-183 m) high. The western part of the Missouri Plateau is characterized by more irregular topography than that in the remainder of the plateau. This area, known collectively as "the Badlands", comprises an intricate maze of narrow ravines, sharp crested ridges, and pinnacles.

The Mandaree SE quadrangle, except in the northwestern sector which is heavily dissected by intermittent stream drainage which drains into Lake Sakakawea, may be characterized as gently rolling to hilly. The topography of the quadrangle is controlled by the Little Missouri River which meanders west to east in the southern portion of the quadrangle. The maximum relief across the quadrangle is 600 feet (182.9 m).

The vegetation is mixed prairie grasses and some of the land is cultivated.

CLIMATE

North Dakota's climate may be characterized as semi-arid; the average annual precipitation is 17 inches (43.2 cm) at Dunn Center 10 miles (16.1 km) south of the quadrangle.

Maximum precipitation occurs during the late spring and early summer with slightly over half the total annual precipitation occuring during May, June and July. Although the mean annual temperature is about 40°F (4.4°C), temperatures as recorded at the Dunn Center weather station by the U.S. Department of Commerce, can range from 120°F (38.9°C) in summer months to -25°F (-31.7°C) in winter months. The prevailing northerly winds increase in velocity during the colder months of November through March.

LAND STATUS

The quadrangle lies in the western one-half of the Knife River Known Recoverable Coal Resource Area (KRCRA). The Federal Government owns the coal rights to approximately 10 percent of the quadrangle. The Bureau of Indian Affairs administers approximately 60 percent of the quadrangle. Coal resources on the Fort Berthold Indian Reservation lands are not evaluated.

PREVIOUS WORK

This report has drawn on a number of basic data reports on the coal in the Knife River KRCRA, including: Law (1977), Benson (1953), and United States Geological Survey (USGS) and North Dakota Geological Survey (NDGS) (1976, 1977). Ground water basic data reports in the Knife River area were also used including: Croft (1970) and Klausing (1971, 1974, 1976).

METHOD OF STUDY

No records of drill holes in Mandaree SE quadrangle were found. Lithologic and geophysical logs from drill holes and measured sections from adjacent quadrangles provided the basic data for this study. The quality of the information is variable. Lithologic and geophysical logs from exploration holes drilled by the North Dakota Geological Survey, North Dakota State Water Commission and private coal companies generally provide the most detailed and reliable subsurface data. Lithologic logs of private water wells are somewhat less detailed and less reliable, but they provide usable information in many cases. Where the data for a specific coal bed appeared to be inaccurate or inconsistent with surrounding drill hole data, it was not included in the data base used for construction of derivative maps for that coal bed. For instance, in some drill holes where coal intervals were not noted and the data appeared anomalous in relation to data from adjacent drill holes; rather than plotting zero coal thickness, the coal bed was assumed to be laterally extensive. Many coal splits were not mapped because of inconsistent data that did not allow projection of split thicknesses with reasonable reliability or accuracy.

Projected coal outcrop traces from previous investigations

(Law, 1977) were plotted on the coal data map, Plate 1. These outcrop data were then modified in accordance with structural trends in the present mapping. It was assumed that all beds extended to the surface although it is known that thick alluvium, colluvium, and glacial materials are sometimes present. Subsurface information (collected to depths of 1,000 feet (305 m)) was used to construct correlation diagrams of coal beds (Figure 1). Correlation diagrams for the Mandaree SE quadrangle and the adjoining Mandaree SW, Saddle Butte SW and Dunn Center NE quadrangles were then integrated and coal structure contours, isopachs, overburden isopachs and mining ratio maps were constructed for coal beds of reserve base thickness (5 feet minimum) (Plates 3 and 4).

GEOLOGY

STRATIGRAPHY

The oldest rocks present in the uppermost 1000 feet (305 m) of stratigraphic section in the Mandaree SE quadrangle are the coal-bearing Tongue River and Sentinel Butte members of the Paleocene age Fort Union Formation (Rehbein, 1977). Sandstones, siltstones and shales of this formation are locally mantled by erosional remnants of the Upper Paleocene-Lower Eocene Golden Valley Formation, and by Quaternary glacial, eolian, and alluvial deposits.

Fort Union Formation - Paleocene.

Tongue River member - this member varies in thickness from 350 to 900 feet (107 to 274 m) and consists of an alternating sequence of fluvially deposited sandstone, siltstone, shale, and lignite. It conformably overlies the marine Cannonball member and the time-equivalent nonmarine Ludlow member. The Tongue River member is similar to the overlying Sentinel Butte member, and in places cannot be distinguished from it. The contact between the Tongue River and Sentinel Butte members, which has been arbitrarily set at the top of the HT Butte lignite, is conformable.

Sentinel Butte member - this member averages 500 feet (152 m) in thickness and consists of an alternating sequence of fluvially deposited sandstone, siltstone, shale, carbonaceous shale, and lignite. In general, the sandstones are fine grained and poorly cemented. Shales range from soft plastic near-clay to moderately indurated claystone. Locally, there are thin calcareous or silicious concretions. Shales and siltstones readily break down and form gentle slopes beneath the sandstone ledges.

Golden Valley Formation - Eocene.

This formation consists of about 200 feet (61 m) of alternating shales, siltstones, and crossbedded sandstones. These sediments which comformably overlie the Sentinel Butte member, have been eroded away in much of the study area.

Channel Deposits - Pleistocene.

Sand and gravel channel deposits of an undetermined thickness lie beneath alluvial deposits. These deposits underlie early Wisconsinan glacial till and Quaternary alluvium in the area.

Glacial Till - Pleistocene.

The glacial till is a heterogeneous mixture of clay, silt, sand, gravel, cobbles, and boulders which was deposited during Wisconsinan episodes of continental glaciation.

Eolian Deposits - Pleistocene and Recent.

Unconsolidated dune and loess-like deposits, from several inches to more than five feet thick, mantle most of the study area. The loess-like deposits consist of silty clays, clayey silt, and silty to clayey sands and are probably of late Pleistocene to Recent age. Recent dunes consisting of silts and very fine uniform sand, have been deposited on the lee side of knobs and ridges.

Alluvium - Recent.

Alluvium consisting of clay, silt, sand, and gravel mantles valley floors in the study area.

STRUCTURE

Regionally, the Knife River KRCRA is located on the southeastern flank of the Williston Basin, approximately 60 miles (97 km) from the basin center. Generally, the sedimentary units are flat lying or gently undulating, with a northward to northeastward regional dip ranging from less than 10 feet per mile (1.9 m per km) to 180 feet per mile (34 m per km). Upper strata have been warped into a gentle syncline with a northeast to southwest trending axis located approximately 10 miles (16 km) east of the town of Dodge. The dips on the flanks of the syncline are approximately 18 feet per mile (3.4 m per km). The coal beds as mapped within this quadrangle show minor structural variations from the regional structural framework. More definitive descriptions of the structural aspects of the coal seams may be found in the "Coal Geology" section which follows. Major faulting has not been observed in the area (Menge, 1977). Surficial materials generally mask most of the older stratigraphic units, making it difficult to assess the importance of minor faulting.

DEPOSITIONAL ENVIRONMENTS OF THE LIGNITES

The Tongue River lignites are thick and laterally extensive. The HT Butte bed at the top of the Tongue River Formation can be traced over thousands of square miles. The lignite beds of the Tongue River member were formed in large swamps adjacent to fluvial channels (Rehbein, 1977).

The Sentinel Butte lignites, though fewer in number, are almost as continuous as the Tongue River lignites and had a similar depositional environment.

COAL GEOLOGY

Six major coal beds and several local coal beds are projected into the subsurface in this quadrangle (composite section, Figure 1). Because of the laterally continuous nature of the Knife River lignites, the coal beds in this quadrangle can reasonably be expected to be the same. The Garner Creek coal bed is stratigraphically the lowest recognized coal bed. It is successively overlain by a rock interval approximately 195 feet (59.4 m) thick containing one local coal bed (Local 5, a local bed correlatable between several quadrangles); the Meyer coal bed; a sequence of non-coal bearing rocks approximately 50 feet (15.2 m) thick; the HT Butte coal bed; a sequence of rocks which contains one local bed (Local 4, a local bed correlatable between several quadrangles) and non-coal bearing rocks approximately 145 feet (44.2 m) thick; the Hazen coal bed; a sequence of rock which contains one local coal bed (Local 3, a local coal bed correlatable between several quadrangles) and non-coal bearing rocks approximately 120 feet (36.6 m) thick; the Beulah-Zap coal bed; a sequence of non-coal bearing rocks which averages 70 feet (24.4 m) thick; and the Schoolhouse coal bed which is overlain by non-coal bearing rocks and a local coal bed, and Local 1 coal bed (which is correlatable between several quadrangles). Table 1 shows the coal bed names and their stratigraphic position.

Table 1 -- Coal Bed Names and Stratigraphic Position

Bed Names	Stratigraphic Equivalent
Schoolhouse	Otter Creek
↑ 70 ft ↓	
Beulah-Zap	Dunn Center, Herman
↑ 60 ft ↓	
Local 3	
↑ 40 ft ↓	
Hazen	Spear, Hazen "B", Kruckenberg, Red Butte
↑ 75 ft ↓	
Local 4	
↑ 65 ft ↓	
HT Butte	Hazen "A", Garrison Creek, Yeager, Hagel, Berg, Keuther, Stanton
↑ 50 ft ↓	
Meyer	
↑ 90 ft ↓	
Local 5	
↑ 100 ft ↓	
Garner Creek	

Drill hole data from the Halliday NW and Dunn Center NE quadrangles to the south, indicate that the Meyer coal bed varies in thickness from 2.5 to 10 feet (0.8 to 3.0 m); the HT Butte coal bed varies in thickness from 5 to 12 feet (1.5 to 3.7 m); the Hazen coal bed varies from 5 to 10 feet (1.5 to 3.0 m); the Beulah-Zap coal bed varies from 4 to 14 feet (1.2 to 4.3 m); and the Schoolhouse coal bed varies from 5 to 11 feet (1.5 to 3.4 m). It is likely that these coal beds maintain comparable thicknesses in the Mandaree SE quadrangle. On the closest drill hole which is located approximately one mile (1.6 km) south of the southern quadrangle boundary, the HT Butte is the lowermost coal bed and is approximately 12 feet (3.7 m) thick. It is successively overlain by 140 feet (42.7 m) of rock; the Hazen coal bed, which is 5 feet (1.5 m) thick and overlain by 75 feet (22.8 m) of rock; the Beulah-Zap coal bed which is 5 feet (1.5 m) thick and overlain by 92 feet (28.0 m) of rock; and the Schoolhouse coal bed which is 8 feet (2.4 m) thick and overlain by 30 feet (8.5 m) of rock.

The coal beds of the Fort Union Formation in the Knife River area are lignite in rank and contain 0.4 to 1.2 percent sulfur , less than 10 percent ash and between 5910 and 7330 BTU / lb (Table A-1). Coal analyses indicate that these coals have less than or about the same amount of trace elements as coal beds in other areas of the northern Great Plains coal province (Tables A-2 through A-5).

MEYER COAL BED

The lowest mapped coal bed, the Meyer bed crops out in the southern portion of the Mandaree SE quadrangle. Based upon projections from adjacent quadrangles, the Meyer probably occurs on a gentle dome dipping to the northwest, north, and northeast at 5 to 50 feet per mile (1 to 9 m per km) as shown on Plate 3.

The thickness of the bed ranges from 6 feet (1.8 m) to 15 feet (4.6 m) with the bed increasing in thickness from east to west as shown on Plate 4. The overburden ranges in thickness from 50 feet (15 m) to 500 feet (152 m) as shown on Plate 3.

Chemical Analysis of the Meyer Coal Bed - No proximate or elemental analyses of the Meyer coal bed have been found in the literature. It is assumed, however, that the quality of the coal is comparable to that of the other coal beds of the Fort Union Formation and is lignite in rank.

COAL RESOURCES

Coal resource classification, is used in this report, is based on the degree of geological assurance of the existence of the coal bed and the feasibility of recovery. The criteria for resource classification is based on the distance from the data point. The resource categories are:

Identified

measured - within 1/4 mile radius of data point

indicated - between 1/4 and 3/4 mile radius of data point

inferred - between 3/4 and 3 mile radius of data point

Hypothetical - beyond 3 mile radius of data point

Coal resource/reserve calculations are made using data presented on isopach and overburden contour maps for all Federally Government coal land in the quadrangle.

In areas suitable for surface mining, Reserve Base and Reserve tonnages are calculated for identified coal resources. Reserves are not calculated for Hypothetical coal resources.

In areas suitable for underground mining (coal bed thickness of 5 feet or greater and overburden from 200 to 1000 feet), Reserve Base and Hypothetical coal resource tonnages are calculated.

The resource tonnages are computed by a computer algorithm which is interactive with an automated planimeter-digitizer. Each area is traced with a magnifying cursor and when a section is completed, a check is made to see that partial areas stored on diskettes sum to the area of the whole section.

The areas measured are converted by the algorithm using given parameters (lignite = 1750 tons per acre foot (1750 tons per acre foot = 12871 metric tons per hectare meter); recovery factor for strippable coal = 0.85) to yield Reserve Base and Reserves in millions of short tons per section for each class. Coal resource values for the Meyer bed are shown on Plate 5. Reserve base and reserve values are rounded off to the hundredth of one million short tons.

Total Reserve Base and Hypothetical resource data for the one coal bed mapped in this quadrangle is shown on Plate 2.

COAL DEVELOPMENT POTENTIAL

Areas considered to have strip mining potential are assigned a high, moderate, or low development potential based on the mining ratio (cubic yards of overburden per ton of recoverable coal).

Coal outcrop traces were projected from structure contour maps and checked against previously projected outcrops (Law, 1977). An overlay of the structure contour and topographic maps provides data for computation of overburden thickness. The coal isopach map was overlain by the overburden isopach map and a mining ratio was calculated using the following the formula:

$$MR = \frac{To\ (.922)}{Tc\ (.85)}$$

where:

MR = cubic yards of overburden per ton of recoverable coal

To = thickness of overburden

Tc = thickness of coal

0.922 = factor to convert thickness of overburden and thickness of coal to cubic yards per ton

0.85 = coal recovery factor (85%)

The Coal Development Potential (CDP) map is compiled by overlaying each mining ratio map for the quadrangle on the property base and noting for all Federal coal land whether each 40-acre tract contains Reserve Base coal in any of the mining ratio categories (Plate 6). 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. The highest rating for each tract is plotted on the CDP map. Areas beyond the outcrop are designated "not applicable" and areas of less than 5 feet coal thickness are designated "0" development potential. The development potential for the Meyer coal bed is generally high in this quadrangle with scattered 40 and 80 acre sections of moderate and low development potential where mapped.

The coal development potential for subsurface mining is considered low in this quadrangle, because no criteria for its classification has been established. Mining ratios are not calculated where the coal thickness is less than 5 feet, or overburden thickness exceeds 200 feet.

DEVELOPMENT POTENTIAL FOR SURFACE MINING METHODS

The coal development potential for surface mining methods (less than 200 feet (61 m) of overburden) is shown on Plate 6 and summarized in Table 2.

The Meyer coal bed is the only coal bed with strippable reserves. It also contains non strippable reserves. The strippable reserves are distributed in the southern portion of the quadrangle as shown on Plate 5.

DEVELOPMENT POTENTIAL FOR UNDERGROUND MINING METHODS AND IN SITU GASIFICATION

The Meyer coal bed, which is the lowest coal bed of mineable thickness projected into the quadrangle, and contains some non-strippable (greater than 200 feet of overburden) coal resources as shown in Table 3. The areal distribution of the coal resources is shown on Plate 5.

The development potential for underground mining methods is considered low in this quadrangle because there are no active or planned underground mines in the quadrangle, and no criteria for its classification have been established.

Table 2 - Strippable coal reserve base for Federal Coal Lands (in millions of short tons) in the Mandaree SE Quadrangle, Dunn County, North Dakota.

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 $yard^3$/ton to m^3/t, multiply by 0.8423.

Coal Bed	High development potential (0-10 mining ratio)	Moderate development potential (10-15 mining ratio)	Low development potential (15 mining ratio)	Total
Meyer	12.89	6.78	7.04	26.71

Table 3 - Nonstrippable coal reserve base for Federal Coal Lands (in millions of short tons) in the Mandaree SE Quandrangle, Dunn County, North Dakota.

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

Coal Bed	High development potential	Moderate development potential	Low development potential
Meyer	0.00	0.00	20.64

No criteria have been established for rating the coal development potential by in situ gasification methods in this area.

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APPENDIX A

PROXIMATE AND ELEMENTAL ANALYSES

Table A-1 Proximate Analyses (as received)

Bed Name	No. of Samples	Moisture %	Volatile Matter %	Fixed Carbon %	Ash %	Sulphur (Ultimate) %	Btu/lb*	Data Source
HT Butte	2	36.6	27.9	29.5	5.9	0.7	6970	Pollard et al., 1972
HT Butte	2	32.4	31.6	30.3	5.9	0.7	7024	Brant, 1953
HT Butte	3	35.5	28.6	31.1	4.9	0.5	7150	Johnson & Kunkel, 1959
Hazen	1	41.0	25.9	28.9	4.2	0.5	6290	Johnson & Kunkel 1959
Beulah-Zap	15	36.1	26.9	30.7	6.2	0.73	6890	Sondreal, Kube Elder, 1968
Beulah-Zap	3	34.0	29.0	29.0	8.0	0.8	6800	Pollard, et al., 1972
Beulah-Zap	1	39.5	28.3	25.3	6.9	0.4	5910	Johnson & Kunkel, 1959
Beulah-Zap	2	35.7	28.5	30.8	4.9	0.6	7018	Brant, 1953
Beulah-Zap	2	35.88	27.66	30.18	6.27	1.00	6566	Leonard, et al., 1925
Beulah-Zap	4	36.3	28.1	29.6	6.0	1.16	7028	USGS & Mont.Bur. of Mines & Geol. 1976
Beulah-Zap	10	29.6	29.6	34.2	6.7	0.5	7330	Swanson et al., 1976
Schoolhouse	1	35.8	26.9	31.7	6.6	1.0	6910	Pollard, et al., 1972
Schoolhouse	3	38.1	27.5	28.7	5.7	1.2	6720	Johnson & Kunkel 1959
Ave. Dunn Co.	-	40.6	-	-	7.0	0.6	6310	USDI, 1977
Ave. N.D.	-	36.0	28.0	29.0	6.0	0.7	6600	Leonard, et al., 1925

* To convert Btu/lb to Kilojoules/Kilogram, multiply by 2.326

Table A-2 -- Elemental Analysis of HT Butte Coal Bed

	Concentration in %		
Element	Sample No.* D-80824	Sample No.* D-80825	Sample No.* D-80823
Sulphur	0.6	0.4	0.4
Hydrogen	6.8	6.9	6.9
Carbon	41.5	43.1	42.3
Nitrogen	0.7	0.6	0.7
Oxygen	44.0	45.0	45.5

*Johnson and Kunkel, 1959.

Table A-3 -- Elemental Analysis of Hazen Coal Bed

	Concentration-in %	
Element	Sample No.* D-55178	Sample No.* 49875
Sulphur	0.5	
Hydrogen	7.0	
Carbon	38.0	
Nitrogen	0.6	
Oxygen	49.7	
U		0.0001
Ge**		ND
Ga**		0.002
V**		0.005
Cu**		0.004
Cr**		0.002
Zn**		0.01
Ni**		0.005
Co**		0.002
Be**		0.0003
Y**		0.01
La**		0.02
Mo**		ND

* Johnson and Kunkel, 1959
** Results in percent of ash

Table A-4 -- Elemental Analysis of Beulah-Zap Coal Bed

Element	Concentration in %			
	Sample No.* 49879	Sample No.*** ND-KR-Bu	Sample No.**** ND-TT-DS	Sample No.***** D175930 to D17539
Sulphur				0.5
Hydrogen				6.2
Carbon				44.6
Nitrogen				0.7
Oxygen				41.3
U	0.0003			0.00005
Ge**	ND	0.001	ND	ND
Ga**	0.002	0.002	0.004	0.0015
V**	0.008	0.005	0.007	0.0035
Cu**	0.005	0.007	0.02	0.0055
Cr**	0.006	0.005	0.004	0.0025
Zn**	ND	ND	ND	0.0025
Ni**	0.005	0.003	0.006	0.0020
Co**	0.002	0.001	0.002	0.0010
Be**	0.0002	0.0008	0.0008	0.0003
Y**	0.01	0.004	ND	0.0025
La**	0.01	0.004	ND	0.01
Mo**	ND	0.002	0.004	0.0010
B**		0.24		0.110
Ti**		0.2		0.70******
Sn**		ND		---

* Johnson and Kunkel, 1959
** Results in percent of ash
*** Zubovic et al., 1961, average of 4 samples
**** Zubovic et al., 1961, average of 2 samples
***** Swanson et al., 1976
****** as TiO_2

Table A-5 - Elemental Analaysis of Schoolhouse Coal Bed

Element	Concentrations in %				
	Sample No.* D-55179	Sample No.* D-55176	Sample No.* D-55175	Sample No.* 49874	Sample No.* 49880
Sulphur	0.9	0.5	2.1		
Hydrogen	7.1	6.9	6.7		
Carbon	39.9	40.4	39.2		
Nitrogen	0.6	0.6	0.6		
Oxygen	46.4	47.4	43.6		
U				0.0001	0.0001
Ge**				ND	ND
Ga**				0.002	0.002
V**				0.01	0.006
Cu**				0.02	0.004
Cr**				0.007	0.005
Zn**				0.7	0.06
Ni**				0.002	0.003
Co**				0.001	0.001
Be**				0.001	0.0007
Y**				0.01	ND
La**				0.02	ND
Mo**				ND	ND

* Johnson and Kunkel, 1959
** Results in percent of ash