UNITED STATES DEPARTMENT OF THE INTERIOR

GEOLOGICAL SURVEY

Text to Accompany:

COAL RESOURCE OCCURRENCE MAP AND COAL DEVELOPMENT POTENTIAL MAP OF THE ZINER BUTTE QUADRANGLE, DUNN COUNTY, NORTH DAKOTA

[Report includes 18 plates]

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

The occurrence, extent, and preliminary geologic evaluation of coal beds in the Ziner Butte quadrangle in west-central North Dakota are described in this report. Subsurface data consisting of oil and gas well and exploration drill hole logs are presented on the Coal Data Map and Coal Data Sheet, Plates 1 and 3, respectively. Federal ownership of coal and total Reserve Base and Hypothetical Resources of coal by section are presented on the Boundary and Coal Data Map, Plate 2. Derivative maps, which consist of coal isopachs, structure contours, overburden, mining ratios, reserve categories, and Reserves and Reserve Base, have been compiled for each coal seam of reserve base thickness underlying the quadrangle and are presented on Plates 4 through 17, respectively. A Coal Development Potential Map for surface mining is presented on Plate 18.

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

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 (USGS) coal program. The 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 Ziner Butte 7 1/2 minute quadrangle is located in southern Dunn County, North Dakota, about 10 miles (16 km) south of Dunn Center and 8 miles (12.8 km) west of Marshall.

ACCESSIBILITY

The area is accessible by county roads connecting to State Highway 8, about eight miles (13 km) to the west. State Highway 8 connects with Interstate 94 at Dickinson, 17 miles (27 km) to the south.

The Burlington Northern Railroad operates and maintains an east-west route which extends through Halliday, Dunn Center and Killdeer about 7 miles (11 km) north of the quadrangle. No railroad route currently pass through or closer to the quadrangle than the existing Burlington Northern route to the north.

PHYSIOGRAPHY

The quadrangle lies in the central portion of a large topographic high known as the Missouri Plateau, which is being dissected by the Knife, Heart, Cannonball and Cedar Creek Rivers. In the eastern portion of the plateau the topography is quite 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 which is prevalent throughout 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 Ziner Butte quadrangle may be characterized as gently rolling to hilly. Knife River, the major drainage system of the area, flows from west to east in the central portion of the quadrangle. Numerous shallow drainages feed into the Knife River throughout the quadrangle. The maximum relief across the quadrangle is 400 feet (122 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, which is located 9 miles (14.5 km) north 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 recorded at the Dunn Center weather station by the U.S. Department of Commerce can range from 102°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 Coal Resource Area (KRCRA). The Federal Government owns the coal rights to approximately 35 percent of the quadrangle. In addition, the Federal Government has restricted coal rights on less than two percent of the area incorporated in the quadrangle.

PREVIOUS WORK

This report has drawn on a number of basic data reports on the coal occurrences 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 data reports in the Knife River area were also used, including: Croft (1970) and Klausing (1971, 1974, 1976).

METHOD OF STUDY

Lithologic and geophysical logs from 10 drill holes provided the basic data for this study. The most important sources of data were (Klausing, 1976; Law, 1977; USGS and NDGS, 1976). The quality of the available coal 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 less detailed

and 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, they were not included in the data base that was used for construction of derivative maps for that coal bed. For instance, in some drill holes coal intervals were not noted and the data appeared anomalous in relation to data from adjacent drill holes; rather than plotting a 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.

Drill hole data and 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 alluvial, colluvial, 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 (Coal Data Sheet, Plate 3). Correlation diagrams for the Ziner Butte quadrangle and the adjoining Emerson, Marshall SW and Dunn Center 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 4 through 17).

GEOLOGY

STRATIGRAPHY

The oldest rocks present in the uppermost 500 feet (152 m) of the stratigraphic section in the Ziner Butte quadrangle are the coal-bearing Tongue River and Sentinel Butte members of the 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 ranges in thicness 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. Locally, there are thin calcareous or silicious concretions. Shales range from soft, plastic clay to moderately indurated claystone. Shale 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 overlie the Sentinel Butte member, have been eroded away in much of the study area.

Channel Deposits - Pleistocene.

Sand and gravel channel deposits of indeterminate 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.

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 have a similar depositional environment.

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 the 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.

COAL GEOLOGY

Five major coal beds and several local coal beds are either mapped at the surface or identified in the subsurface in this quadrangle. The Local 5 coal bed, a local bed correlatable between several quadrangles, is stratigraphically the lowest recognized bed. It is successively overlain by a sequence of non-coal bearing rocks approximately 40 feet (12 m) thick; the Meyer coal bed; a sequence of non-coal bearing rocks approximately 80 feet (24 m) thick; the HT Butte coal bed; a

sequence of rocks approximately 125 feet (38 m) thick which contains one local bed coal (Local 4, a local bed correlatable between adjacent quadrangles) and non-coal rocks; the Hazen coal bed; a sequence of non-coal bearing rocks approximately 50 feet (15 m) thick; the Beulah-Zap coal bed; a sequence of non-coal bearing rocks which averages 50 feet (15 m) thick; the Schoolhouse coal bed, and non-coal bearing rock overburden. Table 1 shows the coal bed names and their stratigraphic position.

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 sulphur, 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, does not crop out in the Ziner Butte quadrangle and was only found in one drill hole. Based upon these data and projections from adjacent quadrangles, the Meyer bed forms a gentle anticlinal fold with a northeasterly striking axis in the center of the quadrangle. The northerly limb dips gently northwest at 4.4 feet per mile (0.8 m per km). The southerly limb dips southeast at 40 feet per mile (8 m per km) as shown on Plate 4.

Table 1 - Coal Bed Names and Stratigraphic Position

Bed Name	Stratigraphic Equivalent
Schoolhouse	Otter Creek
↑ 45 ft ↓	
Beulah-Zap	Dunn Center, Herman
↑ 52 ft ↓	
Hazen	Spear, Hazen "B", Kruckenberg, Red Butte
↑ 63 ft ↓	
Local 4	
↑ 75 ft ↓	
HT Butte	Hazen "A", Garrison Creek, Yeager, Hagel, Berg, Keuther, Stanton
↑ 80 ft ↓	
Meyer	
↑ 38 ft ↓	
Local 5	

The thickness of the bed ranges from 4 feet (1 m) to 6 feet (1 m) with the bed increasing in thickness from west to east as shown on Plate 4. The overburden varies in thickness from 250 feet (76 m) to 600 feet (183 m) as shown on Plate 4.

Chemical Analyses 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 coal is comparable to that of the other coal beds of the Fort Union Formation and is lignite in rank.

HT BUTTE COAL BED

The HT Butte coal bed is separated from the underlying Meyer coal bed by approximately 80 feet (24 m) of non-coal bearing rocks and dips to the center of the quadrangle at approximately 12 feet per mile (2 m per km), forming a gentle east-west trending syncline as shown on Plate 6.

The bed varies in thickness from 4 feet (1 m) to 12 feet (4 m) with the thickness increasing from northeast to southwest, as shown on Plate 7, and it has one parting which reaches 5 feet (2 m) in thickness. The overburden varies from 100 feet (46 m) to 400 feet (122 m) thick, as shown on Plate 6.

Chemical Analyses of the HT Butte Coal - Proximate and elemental analyses of the HT Butte coal bed are presented in Tables A-1 and A-2, respectively. Analysis of coal samples

indicate the following: Ash content varies between 4.9 and 5.9 percent; Sulphur content varies between 0.5 and 0.7 percent; and BTU/lb varies between 6970 and 7150. These data show the HT Butte coal to be lignite in rank.

HAZEN COAL BED

The Hazen coal bed overlies the HT Butte coal bed. It is separated from the HT Butte coal bed by approximately 125 feet (38.1 m) of rock and one local coal bed.

Records of five drill holes penetrating the Hazen coal bed in this quadrangle were found. Based upon these records and projections from adjacent quadrangles, the Hazen coal bed dips towards the east central side of the quadrangle at approximately 20 feet per mile (3.8 m per km), forming a gentle easterly plunging trough as shown on Plate 9.

The bed varies from 1 foot (.3 m) to 7 feet (2 m) thick with the thickness increasing from southwest to northeast as shown on Plate 10, and it has one parting 5 feet (2 m) thick. The overburden ranges from 0 feet (0 m) to 300 feet (91 m) thick, as shown on Plate 10.

Chemical Analyses of the Hazen Coal - Only one chemical analysis of the Hazen coal bed from within the KRCRA is available (Table A-1). Analysis of the coal sample indicates the following: Ash content is approximately 4.2 percent; Sulphur content is approximately 0.5 percent; and the BTU/lb is

approximately 6290. Two elemental analyses are given in Table A-3. All are from the same locality near Center in Oliver County. The Hazen coal bed is lignite in rank.

BEULAH-ZAP COAL BED

The Beulah-Zap coal bed overlies the Hazen coal bed. It is separated from the Hazen coal bed by approximately 50 feet (15 m) of rock. The Beulah-Zap coal bed underlies approximately 60 percent of the quadrangle. In the remainder of the quadrangle the Beulah-Zap coal bed has been removed by erosion.

Records of three drill holes penetrating the Beulah-Zap coal bed in this quadrangle were found. Based upon these records and projections from adjacent quadrangles, the Beulah-Zap coal bed dips to the south center of the quadrangle at approximately 25 feet per mile (5 m per km) as shown on Plate 12.

The bed varies in thickness from 2 feet (0.6 m) to 14 feet (4 m) with the thickness increasing from center to north, east and west as shown on Plate 13, and it has one parting 8 feet (2 m) thick. The overburden ranges from 0 feet (0 m) to 250 feet (76 m) thick, as shown on Plate 12.

Chemical Analyses of the Beulah-Zap Coal - A number of proximate and elemental analyses of the Beulah-Zap coal bed are presented in Tables A-1 and A-4, respectively. Analyses of

coal samples from the Dunn Center area, Dunn County, indicate the following: Ash content varies between 4.9 and 8.0 percent; Sulphur content varies between 0.4 and 1.16 percent; and BTU/lb varies between 5910 and 7330. They show the Beulah-Zap coal is lignite in rank.

SCHOOLHOUSE COAL BED

The Schoolhouse coal bed, the uppermost mapped coal bed, underlies approximately 15 percent of the quadrangle. Most of the bed has been removed by erosion. Where present, the bed overlies the Beulah-Zap coal bed and is separated from it by 50 feet (15 m) of rock which contains a thin coal bed. The bed dips southeast at approximately 25 feet per mile (5 m per km) as shown on Plate 15.

Where the bed is present, it ranges in thickness from 6 feet (2 m) to 11 feet (3 m), and increases in thickness from southwest to northwest (Plate 16), and it has one rock parting totaling 4 feet (1 m) thick. The overburden ranges in thickness from 0 feet (0 m) to 200 feet (60 m) (Plate 15).

Chemical Analyses of the Schoolhouse Coal - Proximate and elemental analyses of the Schoolhouse coal bed are presented in Tables A-1 and A-5, respectively. Analyses of coal samples indicate the following: Ash content varies between 5.7 and 6.6 percent; Sulphur content varies between 1.0 and 1.2 percent; and BTU/lb varies between 6720 and 6910. They show the Schoolhouse coal is lignite in rank.

LOCAL COAL BEDS

In the Ziner Butte quadrangle, two local coal beds, ranging in thickness from 2 to 8 feet (.61 to 2 m), occur in the Sentinel Butte and Tongue River members of the Fort Union Formation. The thickest coal bed is the Local 4, which is 63 feet (19 m) below the Hazen coal bed. Generally, the coal beds are thin, usually less than 5 feet thick, and of limited areal extent. Derivative maps were not constructed and coal resources and reserves were not calculated for the local coal beds due to insufficient data.

COAL RESOURCES

The coal resource classification used in this report is based on the degree of geological assurance of the existence and minability of the coal bed. The criteria for resource classification are 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 Federal government coal lands in the quadrangle. Where Federal coal ownership is restricted, the Reserve Base/Reserve tonnage was multiplied by the appropriate ownership percentage.

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 potential 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 estimated 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 coal bed are shown on Plate

5 Reserve Base and Reserve values for the HT Butte, Hazen, Beulah-Zap, and Schoolhouse coal beds are shown on Plates 8,11,14 and 17. Reserve Base and Reserve values are rounded off to ten thousand short tons.

Total Reserve Base and Hypothetical resource data for the five coal beds mapped in this quadrangle are 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 18). 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. Mining ratios are not calculated where coal thicknesses are less than 5 feet or overburden thickness exceeds 200 feet.

The coal development potential for subsurface mining is considered low in this quadrangle because no criteria for its classification have been established.

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 18 and summarized in Table 2.

The Schoolhouse is the uppermost mapped coal bed in the quadrangle with strippable reserves. In addition, the Beulah-Zap, Hazen, and HT Butte coal beds have strippable reserves. They also contain non-strippable reserves. The strippable reserves are distributed uniformly throughout the quadrangle, as can be seen on Plate 2.

The northern 1/3 of the Ziner Butte quadrangle is rated generally high for coal development potential. This high ranking is due to the Beulah-Zap coal bed which is 5 to 14 feet (1.5 to 4.3 m) thick, and is covered by overburden of less than 50 feet (15 m) to approximately 100 feet (31 m) in thickness. A small amount of low coal development potential in the northern 1/3 of this map is caused by the HT Butte bed where 7 to 8 feet (2.1 to 2.4 m) of coal is approximately 200 feet (61 m) underground. Scattered moderate coal development potenial rankings in the area are caused by 7 feet (2.1 m) of Hazen coal covered by approximately 100 feet (31 m) of overburden. The Hazen is below reserve base thickness in the southwestern half of the map. A high coal development potential is shown in the eastern 1/2 of the central part of the Quadrangle. In this

Table 2 - Strippable Coal Reserve Base Data for Federal Coal Lands (in millions of short tons) in the Ziner Butte 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 yd^3/ton coal to m^3/t, multiply by 0.842.

Coal Bed	High development potential (0-10 mining ratio)	Moderate development potential (10-15 mining ratio)	Low development potential (>15 mining ratio)	Total
Schoolhouse	18.75	2.20	1.71	22.66
Beulah-Zap	41.43	8.51	13.31	63.25
Hazen	16.71	14.10	30.65	61.46
HT Butte	0.0	1.67	48.90	50.57
Meyer	0.0	0.0	0.0	0.0
Total	76.89	25.48	94.57	197.94

area the 7 feet (2.1 m) thick Hazen coal bed crops out and is covered by less than 50 feet (15 m) of overburden.

The southwest corner of the Quadrangle displays variable coal development potential ranking of mostly high and low with some scattered modrate tracts. The high development potential in this area is related to the outcrop of Beulah-Zap bed and the thin overburden covering 6 to 8 feet (1.8 to 2.4 m) of coal. Moderate coal development potential results from 6 and 8 feet (1.8 to 2.4 m) of Beulah-Zap coal underneath approximately 100 feet (31 m) of overburden.

Low development potential rankings were made where the Beulah-Zap coal bed is less than 6 feet (1.8 m) thick, and is covered by 150 feet (46 m) of overburden.

DEVELOPMENT POTENTIAL FOR UNDERGROUND MINING METHODS AND IN SITU GASIFICATION

The The Meyer, HT Butte, Hazen, Beulah-Zap and Schoolhouse coal beds all have substantial quantities of non-strippable (greater than 200 feet of overburden) coal resources as shown in Table 3. The areal distribution of these coal resources is shown on Plates 5, 8, 11, 14 and 17, respectively.

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 3 - Nonstrippable Coal Reserve Base Data for Federal Coal Lands (in millions of short tons) in the Ziner Butte Quadrangle, 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	Total
Schoolhouse	0.0	0.0	.14	.14
Beulah-Zap	0.0	0.0	.49	.49
Hazen	0.0	0.0	3.99	3.99
HT Butte	0.0	0.0	93.39	93.39
Meyer	0.0	0.0	28.65	28.65
Total	0.0	0.0	126.66	126.66

No criteria have been established for rating the development potential by in situ gasification 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

Element	Concentration in % 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

Element	Concentration-in % 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