UNITED STATES DEPARTMENT OF THE INTERIOR

GEOLOGICAL SURVEY

Text to Accompany:

COAL RESOURCE OCCURRENCE MAP
COAL DEVELOPMENT POTENTIAL MAP OF THE GOLDEN VALLEY NW QUADRANGLE, DUNN AND MERCER COUNTIES, NORTH DAKOTA

[Report includes 17 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 Golden Valley NW quadrangle in west-central North Dakota are described in this report. Subsurface data consisting of oil and gas well, and exploration drill hole logs, and surface data comprised of measured sections, 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 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 4 through 16, respectively. A Coal Development Potential Map for surface mining is presented on Plate 17.

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 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 Golden Valley NW 7 1/2 minute quadrangle is located in northeastern Dunn County and northwestern Mercer County, North Dakota about 45 miles (72.4 km) northwest of Dickinson and 37 miles (59.7 km) west of Riverdale.

ACCESSIBILITY

The area is accessible by county road to State Highway 8, two miles (3.2 km) to the west of the western quadrangle boundary. State Highway 8 connects with Interstate 94 at Richardton, 42 miles (67.7 km) to the south.

The Burlington Northern Railroad operates and maintains an east-west route which extends through Halliday, Dunn Center and Killdeer about 4 miles (6.4 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 generally hilly and along the Missouri River there are bluffs 500-600 (152-183 m) feet high. The western part of the Missouri Plateau of characterized by more irregular topography than that which is prevalent throughout the remainder of the plateau. This area, known collectively as the "the Badlands", comprises an intricate maze of narrow ravines, sharp crested ridges, and pinnacles.

The Golden Valley NW quadrangle may be characterized as gently rolling to hilly. Goodman Creek, the major drainage system of the area is an intermittent stream which forms a meandering belt from west to east across the quadrangle. Numerous shallow drainages feed into Goodman Creek throughout the quadrangle. The maximum relief across the quadrangle of Golden Valley NW is 300 feet (91.4 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 18 miles (29.0 km) west of the quadrangle.

Maximum precipitation occurs during 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 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 northern one-half of the Knife River Known Recoverable Coal Resource Area (KRCRA). The Federal Government owns the coal rights to approximately 30 percent of the quadrangle.

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

Lithologic and geophysical logs from eight drill holes provided the basic data for this study. The most important sources of data were United States Geological Survey and North

Dakota Geological Survey (1976,1977); Croft (1970); and Klausing (1971, 1974 and 1976). 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 less detailed and less reliable, but they provide usable information in some 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 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. Where the data base was sufficient to justify the projection of coal parting thicknesses, and both of the coal splits are greater than reserve base thickness, interburden isopach maps were constructed.

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 locally 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 Golden Valley NW quadrangle and the adjoining Halliday NE, Golden Valley NE and Dodge quadrangles were then integrated and coal structure contours, isopachs, overburden/interburden isopachs and mining ratio maps were constructed for coal beds of reserve base thickness (5 feet minimum) (Plates 4 through 16).

GEOLOGY

STRATIGRAPHY

The oldest rocks present in the uppermost 1000 feet (305 m) of stratigraphic section in the Golden Valley NW quadrangle are the Ludlow-Cannonball, and 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.

Ludlow-Cannonball member - these sediments underlie but do not crop out in the study area. The Cannonball is the youngest known marine strata in the northern Great Plains region. Where it has been measured in the vicinity, it is about 350 feet (107 m) thick and consists of shale and thin-bedded sandstone which thins and interfingers to the west with the time-equivalent continental deposited Ludlow.

Tongue River member - this member ranges from 350 to 900 feet (107 to 274 m) thick 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 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 grained 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.

DEPOSITIONAL ENVIRONEMTNS OF THE LIGNITES

Many of the Ludlow member lignites are of small areal extent, display lenticularity and are interbedded with distributary channels indicative of deposition in a delta plain.

The thinner Ludlow lignites are laterally more extensive than the lenticular beds; there is evidence of them having been deposited on the plains of abandoned detla lobes (Rehbein, 1977).

The Tongue River lignites differ from the Ludlow lignites of deltaic origin in that they are thicker and laterally more extensive. The HT Butte bed at the toip of the Tongue River Formation can be traced over thousands of square miles. The lignite beds of the Tongue River member in contrast to the Ludlow lignites were formed in large swamps adjacent to fluvial channels (Rehbein, 1977).

The Sentinel Butte lignite, though fewer in number, are almost as continuous as the Tongue River lignites and had 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 in 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.

COAL GEOLOGY

Seven major coal beds and several local coal beds are either mapped at the surface or identified in the subsurface in this quadrangle. The H-Lignite coal bed is stratigraphically the lowest recognized coal bed. It is successively overlain by a sequence of rocks approximately 250 feet (76.2 m) thick containing one local coal bed (a local bed correlatable between several quadrangles) and non-coal bearing rocks; the Garner Creek coal bed; a sequence of non-coal bearing rocks approximately 120 feet (36.6 m) thick; the Meyer coal bed; a sequence of non-coal bearing rocks approximately 225 feet (68.6 m) thick; the HT Butte coal bed; a sequence of non-coal bearing rocks approximately 100 feet (30.5 m) thick; The Hazen coal bed; a sequence of rock which averages 170 feet (51.8 m) thick and includes up to two local coal beds; the Beulah-Zap coal bed; a sequence of rock which averages 65 feet (19.8 m) thick and contains a local coal bed; and the Schoolhouse coal bed which is overlain by non-coal bearing rocks. 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 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

Table 1 -- Coal Bed Names and Stratigraphic Position

Bed Names	Stratigraphic Equivalent
Schoolhouse	Otter Creek
↑ 65 feet ↓	
Beulah-Zap	Dunn Center, Herman
↑ 170 feet ↓	
Hazen	Spear, Hazan "B", Kruckenberg, Red Butte
↑ 100 feet ↓	
HT Butte	Hazen "A", Garrison Creek, Yeager, Hagel Berg, Keuther, Stanton
↑ 225 feet ↓	
Meyer	
↑ 120 feet ↓	
Garner Creek	
↑ 250 feet ↓	
H Lignite	

coal beds in other areas of the northern Great Plains coal province (Tables A-2 through A-5).

H-LIGNITE COAL BED

The lowest mapped coal bed, the H-Lignite bed does not crop out in the Golden Valley NW quadrangle and is not found in any drill holes in this quadrangle. Based upon the drill hole data and projections from adjacent quadrangles it is possible that the H-Lignite coal bed is not present under all the quadrangles. Based upon data from adjacent quadrangles the H-Lignite probably dips northeast at 33 feet per mile (6.3 m per km) as shown on Plate 4.

The thickness of the bed varies from 6.5 feet (2.0 m) to 15 feet (4.6 m) with the bed increasing in thickness from southeast to northwest as shown on Plate 4. The overburden varies in thickness from 900 feet (274.3 m) to 1000 feet (304.8 m) as shown on Plate 4.

Chemical Analyses of the H-Lignite Coal Bed - No proximate or elemental analyses of the H-Lignite 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.

GARNER CREEK COAL BED

The Garner Creek coal bed overlies the H-Lignite coal bed.

It is separated from it by approximately 250 feet (76.2 m) of rock with one local coal bed. No records of drill holes penetrating the Garner Creek coal bed in this quadrangle were found. Based upon these records and projections from adjacent quadrangles, the Garner Creek coal bed dips northeast at approximately 32 feet per mile (6.1 m per km) as shown on Plate 6.

The bed varies from 1 foot (0.3 m) to 7 feet (2.1 m) thick with the thickness increasing from northeast to southwest as shown on Plate 6. The overburden ranges from 700 feet (213.4 m) to 800 feet (243.8 m) thick, as shown on Plate 6.

Chemical Analyses of the Garner Creek Coal - No known chemical analyses of the Garner Creek coal have been found in the literature; however, it is assumed the quality of the coal is comparable to that of other coal beds in the Fort Union Formation and is lignite in rank.

HT BUTTE COAL BED

The HT Butte coal bed overlies the Garner Creek coal bed. It is separated from the Garner Creek coal bed by approximately 345 feet (105.2 m) of rock and one local coal bed. Records of five drill holes penetrating the HT Butte coal bed in this quadrangle were found. The HT Butte coal bed dips south at approximately 19 feet per mile (3.6 m per km), as shown on Plate 8.

The bed varies from 6 feet (1.8 m) to 10 feet (3.0 m) thick with the thickness increasing from west to east as shown on Plate 8. The overburden varies from 250 feet (76.2 m) to 600 feet (182.9 m) thick, as shown on Plate 8. The interburden varies from 2 feet (0.6 m) to 15 feet (4.6 m), as shown on Plate 9.

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, and indicate that the HT Butte coal is lignite in rank. Although no samples were analyzed in this quadrangle, analyses of coal samples from the Center quadrangle indicate the following: ash content varies between 4.9 and 5.9 percent; the sulfur content varies between 0.5 and 0.7 percent; and the BTU/lb vary between 6970 and 7150.

HAZEN COAL BED

The Hazen coal bed overlies the HT Butte coal bed. It is separated from the HT Butte coal bed by approximately 100 feet (30.5 m) of rock. Records of five drill holes penetrating the Hazen coal bed in this quadrangle were found. The Hazen coal bed dips east at approximately 46 feet per mile (8.6 m per km) as shown on Plate 11.

The bed varies from 1 foot (0.3 m) to 9 feet (2.7 m) thick with the thickness increasing from the south and north towards the center of the quadrangle as shown on Plate 12. The overburden varies from 15 feet (45.7 m) to 400 feet (121.9 m) thick, as shown on Plate 11.

Chemical Analyses of the Hazen Coal

Only one chemical analysis of the Hazen coal bed from within the KRCRA is available. It is shown on Table A-1. 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. Analyses of the coal sample indicates the following: as content is approximately 4.2 percent; the sulfur content is approximately 0.5 percent; and the BTU/lb are approximately 6290.

BEULAH-ZAP COAL BED

The Beulah-Zap coal bed is the uppermost mapped coal bed in the quadrangle. The bed overlies the Hazen coal bed and is separated from it by 170 feet (51.8 m) of rock and an occasional thin coal bed. The bed dips southeast at approximately 25 feet per mile (4.7 m per km) as shown on Plate 14.

The bed varies from 4 feet (1.2 m) to 10 feet (3.0 m) and increases in thickness from the center of the quadrangle to the north and south as shown on Plate 15. The overburden varies from 0 feet (0.0 m) to 350 feet (106.7 m) thick, as shown on Plate 14. The interburden varies from 7 feet (2.1 m) to 21 feet (6.4 m) as shown on Plate 14.

Chemical Analyses of the Beulah-Zap Coal - Proximate and elemental analyses of the Beulah-Zap coal bed are presented in Tables A-1 and A-4, respectively, and indicate the Beulah-Zap coal is lignite in rank. Analyses of coal samples from the Dunn Center area, Dunn County indicate the following: ash content varies between 4.9 and 8.0 percent; the sulfur content varies between 0.4 and 1.16 percent; and the BTU/lb vary between 5910 and 7330.

SCHOOLHOUSE COAL BED

The Schoolhouse coal bed is the uppermost coal bed in the quadrangle. It is separated from the underlying Beulah-Zap coal bed by approximately 65 feet (19.8 m) of rock.

Drill holes intersecting the Schoolhouse coal seam in the Golden Valley NW quadrangle, and drill hole data from the adjacent quadrangles indicate the generalized stratigraphic relationships shown on the composite section. This relationship was used to determine the approximate location of the outcrop of the Schoolhouse coal bed (Plate 1).

Due to the lack of detailed information, reserves for the Schoolhouse coal bed were not calculated.

LOCAL COAL BEDS

In the Golden Valley NW quadrangle, five local coal beds, varying in thickness from 1 to 4.5 feet (.3 to 1.4 m), occur in the Sentinel Butte and Tongue River member of the Fort Union Formation. The thickest coal bed is the local bed that is 50 feet (15.2 m) below the HT Butte coal bed. Generally, the coal beds are thin, less than 5 feet thick, and of limited areal extent. Therefore, derivative maps were not constructed and coal resources and reserves were not calculated.

COAL RESOURCES

Coal resource classification, 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

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 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 H Lignite, Garner Creek, and HT Butte beds are shown on Plates 5, 7, and 10, respectively. Reserve Base and Reserve values for the Hazen and Beulah-Zap beds are shown on Plate 13 and 16, respectively. 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 six 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 projectd 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 surafce 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 17 and summarized in Table 2.

The Golden Valley NW quadrangle has only two small areas which have a high or moderate coal development potential.

Table 2 - Strippable Coal Reserve Base Data for Federal Coal Lands (in millions of short tons) in the Golden Valley NW Quadrangle, Dunn and Mercer Counties, 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
Beulah-Zap	1.30	14.81	84.21	100.32
Hazen	0.00	0.00	2.06	2.06
HT Butte	0.00	0.00	0.00	0.00
Garner Creek	0.00	0.00	0.00	0.00
H Lignite	0.00	0.00	0.00	0.00
Total	1.30	14.81	86.27	102.38

These lie along the southwestern side and in the northeastern corner of the quadrangle and result from the relatively thick 8 feet (2.4 m) Beulah-Zap bed at a shallow (less than 150 feet) (45.7 m) overburden depth. The Beulah-Zap is of less than reserve base thicknesses; less than 5 feet (1.5 m) in the west central area where a low rating is due to the presence of the Hazen bed at a depth of less than 200 feet (61 m).

DEVELOPMENT POTENTIAL FOR UNDERGROUND MINING METHODS AND IN SITU GASIFICATION

The H Lignite coal bed, which is the lowest identified coal bed in the quadrangle, and the Garner Creek, HT Butte and Hazen 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, 7, 10, and 13, 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.

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

Table 3 - Nonstrippable Coal Reserve Base Data for Federal Coal Lands (in millions of short tons) in the Golden Valley NW Quadrangle, Dunn and Mercer Counties, North Dakota.

To convert short tons to metric tons, multiply

Coal Bed	High development potential	Moderate development potential	Low development potential	Total
Beulah-Zap	0.0	0.0	35.94	35.94
Hazen	0.0	0.0	69.82	69.82
HT Butte	0.0	0.0	151.02	151.02
Garner Creek	0.0	0.0	28.55	28.55
H Lignite	0.0	0.0	15.03	15.03
Total	0.0	0.0	300.36	300.36

REFERENCES

Bauer, C.M., and Herald, F.A., 1921, Lignite in the western part of the Fort Berthold Indian Reservation south of Missouri River, North Dakota: U.S. Geological Survey Bulletin 726-D, 77 p.

Bensen, W.E., 1951, Geologic map of North Dakota southwest of the Missouri River: U.S. Geological Survey Preliminary Map, Scale 1:500,000.

____________, 1953, Geology of the Knife River area, North Dakota: U.S. Geological Survey Open-File Report 1953, 323 p.

Bluemle, J.P., 1971, Geology of McLean County, North Dakota: North Dakota Geological Survey, Bulletin 60, Part I, 65 p.

Brant, R.A., 1953, Lignite resources of North Dakota: U.S. Geological Survey Circular 226, 78 p.

Carlson, C.G., 1972, Stratigraphic position of lignite beds in Tertiary rocks of Mercer and Oliver Counties, North Dakota, in Ting, T.T.C. (Ed), Depositional environments of the lignite-bearing strata in western North Dakota: North Dakota Geological Survey Guidebook No. 3, Miscellaneous Series No. 50, p 95-104.

____________, 1973, Geology of Mercer and Oliver Counties, North Dakota: North Dakota Geological Survey Bulletin 56, Part I, 72 p.

Clayton, Lee, 1969, Geologic map of Dunn County, North Dakota: North Dakota Geological Survey Miscellaneous Map 11, Scale 1:2 miles.

Colton, R.B., Lemke, R.W., and Lindvall, R.M., 1963, Preliminary glacial map of North Dakota: U.S. Geological Survey Miscellaneous Geological Investigations Map I-331, Scale 1:500,000.

Croft, M.G., 1970, Ground water basic data, Mercer and Oliver Counties, North Dakota: North Dakota State Water Commission County Ground Water Studies 15, Part II, 268 p.

Electric Log Services, Inc., 1977, Electrical, radioactivity and hydrocarbon survey: Rocky Mountain Well Log Service Index to Northern Rockies, 1702 p.

REFERENCES (Continued)

Hainer, J.L., 1956, The geology of North Dakota: North Dakota Geological Survey Bulletin 31, 52 p.

Hancock, E.T., 1921, The New Salem lignite field, Morton County, North Dakota: U.S. Geological Survey Bulletin 726-A, 39 p.

Johnson, W.D., and Kunkel, R.P., 1959, The Square Buttes coal field, Oliver and Mercer Counties, North Dakota: U.S. Geological Survey Bulletin 1076, 91 p.

Klausing, R.L., 1971, Ground water basic data, McLean County North Dakota: North Dakota State Water Commission County Ground Water Studies 19, Part II, 468 p.

__________, 1974, Ground water resources of McLean County North Dakota: North Dakota State Water Commission County Ground Water Studies 19, Part III, 73 p.

__________, 1976, Ground water basic data for Dunn County, North Dakota: North Dakota State Water Commission County Ground Water Studies 25, Part II, 501 p.

Law, R., 1977, Preliminary report on the geology of the near-surface coal beds in the Knife River area, North Dakota: U.S. Geological Survey Open File Report 77-481, 12 p.

Leonard, A.G. Babcock, E.J., and Dove, L.P., 1925, The lignite deposits of North Dakota: North Dakota Geological Survey Bulletin No. 4, 240 p.

Menge, M., 1977, A preliminary report on the near-surface Federal Coal Reserve Base underlying the south half of the Dunn Center Lignite Field, Dunn County, North Dakota: U.S. Geological Survey Open-File Report, in preparation, 127 p.

North Dakota Geological Survey, 1973, Mineral and water resources of North Dakota: North Dakota Geological Survey Bulletin 63, 252 p.

___________, 1977, Unpublished Summary of 1977 Drilling, 19 p.

Pollard, B.C., Smith, J.E., and Knox, C.C., 1972, Strippable lignite reserves of North Dakota, location, tonnage, and characteristics of lignite and overburden: U.S. Bureau of Mines Information Circular 8537, 37 p.

REFERENCES (Continued)

Rehbein, E.A., 1977, Preliminary report on stratigraphy and depositional environments of the lignites in the Fort Union Formation, west-central North Dakota: U.S. Geological Survey Open-File Report 77-69, 23 p.

Royse, C.F. & Jr., 1967, Tongue River-Sentinel Butte contact in western North Dakota: North Dakota Geological Survey Report of Investigation No. 45, 53 p.

__________, 1971, A sedimentologic analysis of the Tongue River-Sentinel Butte interval (Paleocene) of the Williston Basin, western North Dakota: North Dakota Geological Survey Miscellaneous Series No. 43, 80 p.

__________, 1972, the Tongue River and Sentinel Butte Formations (Paleocene) of western North Dakota, In Ting, T.T.C. (Ed), Depositional environments of the lignite-bearing strata in western North Dakota: North Dakota Geological Survey Guidebook No. 3, Miscellaneous Series No. 50. p 31-42.

Sondreal, E.A., Kube, W.R., and Elder, J.L., 1968, Analysis of the Northern Great Plains province lignite and their ash -- A study of variability: U.S. Bureau of Mines Report Inv. 7158, 94 p.

Swanson, Vernon E. et.al., 1976, Collection, chemical analysis and evaluation of coal samples in 1975, U.S. Geological Survey Open-File Report 76-468, 503 p.

United States Department of Interior, 1977, Resource and potential reclamation evaluation of Horse Nose Butte study area. Dunn Center lignite field: U.S. Department of Interior EMRIA Report No. 9, 83 p.

United States Geological Survey and Montana Bureau of Mines and Geology, 1976, Preliminary report of coal beds in Campbell and Sheridan Counties, Wyoming: Custer, Praire, Garfield Counties, Montana; and Mercer County, North Dakota: U.S. Geological Survey Open-file Report 76-319, 377 p.

United States Geological Survey and North Dakota Geological Survey, 1976, Preliminary report on 1975 drilling of lignites in western North Dakota: Adams, Bowman, Dunn, Hettinger, McLean, Mercer, Oliver, Slope, and Williams Counties: U.S. Geological Survey Open-File Report 76-869, 144 p.

REFERENCES (Continued)

__________, 1977, Preliminary report of 1976 drilling of lignites in western North Dakota: Adams, Billings, Dunn, Hettinger, McKenzie, Mercer, Morton, Oliver, Slope, and Stark Counties: U.S. Geological Survey Open-File Report 77-857, 336 p.

Zubovic, Peter, Stadnichanko, Taisia, and Shaffey, N.B., 1961, Geochemistry of minor elements in coals of the Northern Great Plains coal province: U.S. Geological Survey Bulletin 117-A, 58 p.

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