Miscellaneous Map No. 34
North Dakota Geological Survey
John P. Bluemle, State Geologist

STRIPPABLE LIGNITE DEPOSITS OF NORTH DAKOTA

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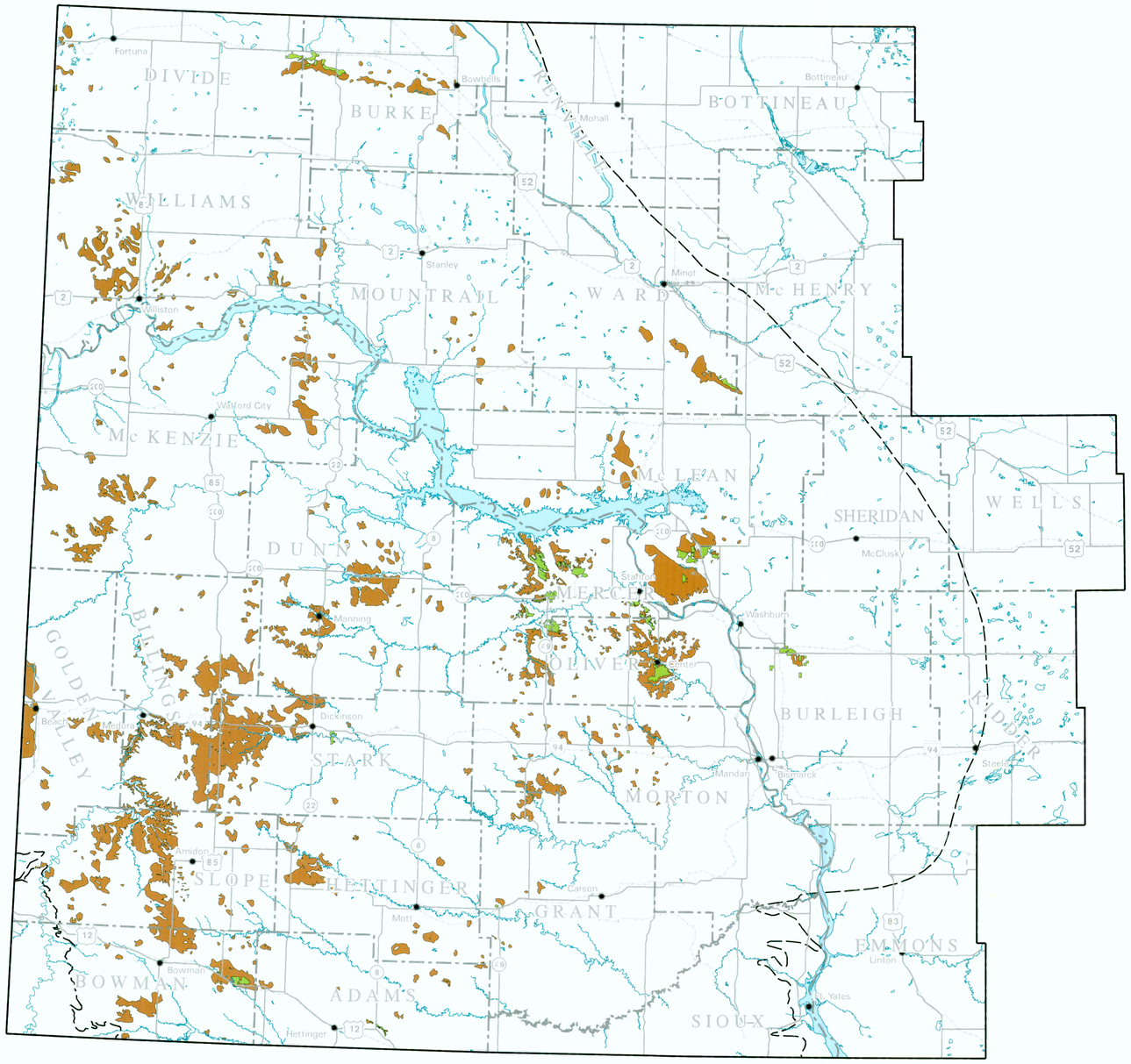
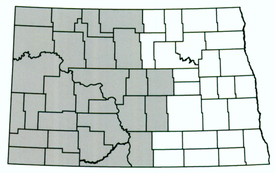
North Dakota Geological Survey
2001





Western North Dakota

0 10 20 30 40 50
Miles
0 10 20 30 40 50
Kilometers

Scale 1:1,000,000
One inch represents approximately 16 miles
Lambert Conformal Conic Projection

Strippable Coal Reserves

Mined Area

Limit of Coal-Bearing Rocks
(modified from Groenewold, 1979)

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Introduction

Approximately 32,000 square miles of western and central North Dakota are underlain by lignite deposits. Lignite-bearing rocks were either not deposited in eastern North Dakota due to the position of the Cannonball Sea during the Paleocene or they were deposited in relatively thin layers that were later removed by erosion. Lignite seams are present at the surface throughout much of western and central North Dakota, and they may extend to depths of 1,800 feet or more. The quality of the lignite mined in North Dakota is variable, but generally falls within a standard range (Table 1).

Table 1.Typical Values for Lignite Currently Mined in North Dakota

Moisture	37-38%
Volatile Matter	26-29%
Fixed Carbon	28-29%
Ash	6.5-11.3%
Sulfur	0.6-0.9%
Btu	6,239-7,000/lb

Figure 1. An early lignite mine (*wagon mine*) along Spring Creek in southwestern North Dakota. *Photo courtesy of the State Historical Society of North Dakota.*.

Mining History

The recorded history of lignite mining in North Dakota goes back to 1873 (Oihus, 1983). The earliest mines were small, seasonal wagon mines, so named because farmers and ranchers would bring their own wagons to the mine to be filled with coal removed from the face of an outcrop (Figure 1). By the 1890s, large-scale mining began, much of it underground, and Sims, Lehigh, Minot, Burlington, Kenmare, Washburn, Wilton, and Williston became important mining centers. By the early 1900s, Scranton, Haynes, Beulah, Hazen, Velva, Center, New Salem, Hanks, Noonan, Columbus, and Garrison had also become important mining centers. During this period (1880s to 1920s), the number of active coal mines grew to almost 200 and annual coal production steadily increased, but did not exceed one million tons until 1922 (Figure 2). In 1939, 306 mines were operating in North Dakota and over half of these were strip mines. The advent of the steam shovel had increased the profitability of surface mines, and the last underground mine in North Dakota ceased operation in 1966. Large, electric-powered draglines began replacing steam shovels in the mid-1940s. By 1980, the number of mines operating in the state had dropped to a dozen with the mining centers at Larson, Velva, Beulah, Washburn, Center, Dickinson, Glenharold, and Gascoyne. By the mid-1990s, mining had ceased at Larson, Velva, Glenharold, Dickinson, and Gascoyne. Currently, six coal mines are operating in North Dakota: four lignite mines (Coteau's Freedom Mine north of Beulah, Dakota Westmoreland's mine south of Beulah, BNI's mine at Center, and Falkirk's mine south of Underwood) and two leonardite mines (American Colloid's mine at Gascoyne and GeoResource's mine at Williston) (Figures 3 & 4). Despite the historically low number of mines now operating in the state, mine production in 2000 was approximately 31 million tons (Figure 2). While this fell short of 1994's record production of 32.1 million tons, it was nearly equal to the state's entire production during the decade of the 1960s and more than three times that of the average annual production during the 1970s.

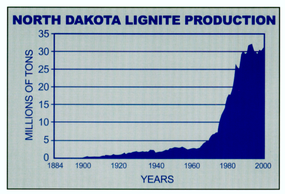

Figure 2. Annual lignite production in North Dakota for the years 1884 to 2000. Production in the year 2000 (30.97 million tons) is only one million tons less than the total of all of the lignite produced in the state during the first 50 years of mining, 1884 -1934.

Figure 3. A dragline undergoing maintenance adjacent to an active pit at Coteau's Freedom Mine north of Beulah. View looking northeast. The Beulah-Zap bed has been removed from the west end of the pit and is in the process of being removed from the east end of the pit with a loader.

Figure 4. Five pits are excavated to the top of the Schoolhouse and/or Beulah beds in Dakota Westmoreland's (formerly Knife River Corporation's) Beulah mine. Note the dozen or so soil and subsoil storage piles in the distance. The soil and subsoil layers are kept separate during mining to enable the company to return layers as closely as possible to pre-mine conditions.

Major Lignite Beds

Over the years, numerous lignite seams have been mined in North Dakota, but only a dozen or so major beds have been mined during the past twenty years (Figure 5). The Beulah bed is currently mined at two localities in Mercer County and the Hagel bed is being mined in Oliver and McLean counties. An oxidized zone of the Harmon bed is being mined as leonardite in Bowman County. The Harmon bed and underlying Hanson bed appear to be the most extensive coals in North Dakota. The Harmon bed underlies parts of at least nine counties in southwestern North Dakota (Bowman, Adams, Hettinger, Slope, Golden Valley, Billings, Stark, McKenzie, and Dunn) and accounts for most of the strippable reserves in Bowman, Slope, and Golden Valley counties (Figure 6).

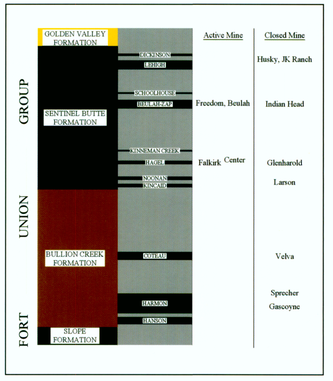

Figure 5. The stratigraphic position of the various lignite beds that are being mined or have been mined in North Dakota in the past twenty years.

Figure 6. C.G. Carlson, who oversaw coal-exploration programs for the ND Geological Survey during the 1970s, is pictured at an outcrop of the Harmon bed in southwestern Billings County. The Harmon bed, the thickest lignite in the state, is over 50 feet thick in southern McKenzie County. The Harmon bed accounts for approximately 23% (5.8 billion tons) of the strippable reserves in North Dakota.

Strippable Reserves

In 1925, State Geologist A.G. Leonard estimated that North Dakota contained 516 billion tons of lignite. Subsequent estimates placed this number between 351 and 600 billion tons. Very little subsurface information was available when these estimates were made so these numbers were only approximate. Whatever the exact amount of reserves, North Dakota contains the worlds largest deposit of lignite. In 1953, R.A. Brant estimated that North Dakota contains 16 billion tons of strippable lignite. Since Brant's report, a number of studies have been undertaken that generated information on coal stratigraphy or strippable reserves for parts of western and central North Dakota (e.g., Pollard et al., 1973; Landis, 1973; Moran et al., 1978; Groenewold et al., 1979; Daley et al., 1985; Flores et al., 1999a, 1999b). But, for almost 50 years, the Brant report has been the only documented study of all of North Dakota's strippable lignite reserves. For the past twenty years or so, the North Dakota Geological Survey has used between 16 and 35 billion tons as an acceptable range for North Dakota's strippable lignite reserves. Few attempts have been made to calculate strippable reserves for North Dakota because of the difficulty in generating accurate numbers and the potential for these numbers to become obsolete due to changing economic conditions. For these reasons, I have used a very conservative approach to calculating reserves in the hope that, regardless of economic downswings, the numbers will remain relatively valid. By following industry format, I have been able to identify the areas in western North Dakota that look most promising for mining based solely on coal thickness and depth. Several other important criteria: coal chemistry, availability of water for cooling, transmission lines, rail lines, etc. are critical components for siting a mine-mouth power plant, but none of these were considered in the construction of this map.

Strippable reserves were calculated using economic-based criteria developed by coal companies operating in North Dakota. These criteria include:

- A minimum cumulative lignite thickness of ten feet–typically occurring in one or two beds
- A minimum individual-bed thickness of 2.5 feet
- A maximum stripping ratio of 10 feet of overburden for every foot of coal
- A minimum of 20 feet of overburden to minimize the effects of weathering
- A coal depth generally not more than 170 feet.

Reserves were calculated using geophysical logs from over 18,000 holes. This data base includes industry test holes on file with the North Dakota Geological Survey, and test holes drilled by the North Dakota State Water Commission, the North Dakota Geological Survey, and the United States Geological Survey. Oil company wells were used if gamma logs were recorded to the surface. Reserves were determined by plotting the limits of strippable lignite deposits on 1:24,000-scale topographic maps, averaging the thickness of coal beds across the area and multiplying it by the acreage of the deposit to determine the acre-feet of lignite, and multiplying the acre-feet of lignite by 1,750 tons per acre-foot to determine tonnage.

Using these criteria, it was determined that North Dakota contains 25.1 billion tons of strippable lignite reserves (Table 2). Slope County contains 4 billion tons, the greatest amount of reserves of any of the 21 counties that contain strippable coal. The current top three coal-producing counties, Mercer, Oliver, and McLean, rank 10th, 11th, and 6th respectively in reserves. At the current rate of mining, it would take 835 years to exhaust North Dakota's supply of economically recoverable lignite.

Table 2. Strippable Lignite by County

County	Millions of Tons	Rank
Adams	155	19
Billings	2,700	3
Bowman	1,600	7
Burke	527	14
Burleigh	31	20
Divide	273	16
Dunn	1,700	5
Golden Valley	1,433	9
Grant	173	18
Hettinger	730	12
McHenry	5	21
McKenzie	1,750	4
McLean	1,700	6
Mercer	1,251	10
Morton	594	13
Mountrail	218	17
Oliver	1,100	11
Slope	4,000	1
Stark	3,100	2
Ward	417	15
Williams	1,600	8
Total	25,057	

Over the years, much lignite has been lost to natural weathering processes. Glacial deposits in North Dakota typically contain significant amounts of lignite attesting to the removal of seams by the action of glaciers. No where is this more apparent than in the Beulah area where water flowing in glacial meltwater channels (Beulah and Renner trenches), in all likelihood, removed approximately 635 million tons of mineable lignite. Wherever North Dakota lignite seams have been exposed at or near the surface for a prolonged period of time, they tend to oxidize or weather. Oxidation generally softens or powders the coal and lowers the Btu content making it less desirable for combustion purposes. Leonardite, named for A.G. Leonard, refers to oxidized lignite which has many noncombustion uses, including as a soil enhancer and a drilling-mud additive. Leonardite has been mined for over 50 years in North Dakota with primary production east of Williston and in south-central Adams and eastern Bowman counties (Figure 7). For most of this time, annual production of leonardite has ranged from 20,000 to 60,000 tons, less than 0.2 % of total lignite production in the state.

Over the years, a significant amount of North Dakota's lignite resource has ignited and burned, baking the overlying rocks to form reddish-orange clinker, known locally as scoria. In recent years, wildfires, caused by lightening, have ignited several lignite seams in western North Dakota. Wildfires, along with spontaneous combustion, are thought to have been major causes of lignite burns in the past (Figure 8). Coalbed methane escaping along the face of an outcrop may also have contributed to the tendency of these lignites to ignite.

Figure 7. A seven-foot thick seam of leonardite (weathered lignite) exposed in the minewall of GeoResource's pit at Williston. Although lignite and leonardite look similiar in outcrop, leonardite is characteristically very soft and powdery.

Figure 8. Clinker formed from the burning of lignite in western North Dakota. Lignite seams have been burning periodically in western and central North Dakota for millions of years.

Map Sales

Maps of the strippable lignite deposits in individual counties, at scales ranging from 1:150,000 to 1:200,000, are available from the North Dakota Geological Survey. Strippable lignite deposit boundaries were plotted on approximately 640, seven and a half minute USGS quadrangle maps. These maps are being digitized and will be made available to the public.

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