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STRIPPABLE LIGNITE RESERVES OF NORTH DAKOTA

Location, Tonnage, and Characteristics of Lignite and Overburden

by

Benjamin C. Pollard,¹ Joseph Blake Smith,¹ and Clinton C. Knox¹

ABSTRACT

The location and production potential of a large block of strippable reserves in North Dakota were determined by using published data as a base and adding new drill hole data or other data contributed by companies that presently own or lease coal lands. Only beds exceeding 5 feet in thickness, under less than 120 feet of overburden, and in large blocks of 5 million tons or more were included in the estimates. All such reserves are in the Fort Union Formation of western North Dakota and are lignite in rank. Sixteen large blocks of reserves evaluated in this study are estimated to contain a total of 4.1 billion tons of strippable lignite.

INTRODUCTION

Several factors have recently stimulated interest in the acquisition and development of North Dakota lignite reserves. One important factor is the increasing need for electric power. Major power markets are expected to develop, perhaps through extra-high-voltage interties with more populous regions, and will require substantial additions to thermal power generating capacities. Another factor stimulating interest, especially in large strippable blocks of low-cost lignite, is the impending development of economic processes for the conversion of solid fuels to liquid and gaseous hydrocarbon fuels.

It is estimated that North Dakota contains a lignite resource of 351 billion tons (6),² only a small fraction of which can be recovered by low-cost surface mining. This Bureau of Mines report discusses the relatively few and scattered lignite reserve blocks that have been sufficiently well defined through drilling programs or geologic fieldwork to permit appraisal of their minability. In contrast, previous estimates of strippable reserves in North Dakota either have relied on probabilistic methods (3-4), or have sought to identify only those reserves suitable for a specific industrial purpose (9). The strippable reserves in the 16 areas with which this report deals are listed in table 1, and their locations are shown in figure 1.

¹Mining engineer.

²Underlined numbers in parentheses refer to items in the bibliography at the end of this report.

TABLE 1. - Strippable lignite reserves of North Dakota

Deposit	Location on fig. 1	Strippable reserves, million short tons	Maximum overburden thickness, ft
Noonan-Kincaid.....	1	15	50
Niobe.....	2	146	100
Avoca.....	3	380	75
M & M.....	4	100	120
Velva.....	5	5	50
Washburn.....	6	30	50
Wilton.....	7	15	50
Renner's Cove.....	8	78	50
Hazen.....	9	71	50
Beulah-Zap.....	10	380	120
Stanton.....	11	21	50
Center.....	12	253	50
Dunn Center.....	13	29	50
Dickinson.....	14	798	100
Beach.....	15	450	120
Bowman-Gascoyne.....	16	1,372	120
Total.....	-	4,143	-

To define these potential stripping areas, the published information on lignite occurrences in North Dakota was analyzed. All accessible data were collected from firms and individuals engaged in the exploration and acquisition of coal lands in North Dakota. Outcrop and resource data in reports and files of the U.S. Geological Survey, U.S. Bureau of Land Management, and State agencies were also used.

ACKNOWLEDGMENTS

Recognition is due to personnel of the U.S. Geological Survey for furnishing results of their work in the coalfields of North Dakota. Clarence A. Armstrong and Henry Trapp, Jr., of Bismarck, N. Dak., and Henry L. Smith of Denver, Colo., provided unpublished data.

Detailed data from drilling programs were provided by Thomas P. Wollenzien and Ralph A. Watson, both formerly with the Great Northern Railway Co., now merged into Burlington Northern, Inc.; A. Elberg, Husky Briquetting, Inc.; Robert W. Rovelstad, Baukol-Noonan, Inc.; Curt Burrows and Mack H. Shumate, Consolidation Coal Co., and Melville H. Ireland, formerly with that company; and Andrew Freeman, Minnkota Power Cooperative, Inc. Other useful data were provided by Arthur S. Kane, Knife River Coal Mining Co.; Thomas J. Pearce, United Power Association; Virgil W. Carmichael, The North American Coal Corp.; and Ernest Thurlow and Loren A. Williams, Burlington Northern, Inc.

Constance Mull of the Mining and Oil Lease Service provided coal lease information. James L. Elder of the Bureau of Mines Grand Forks Energy Research Laboratory provided recent coal analyses.

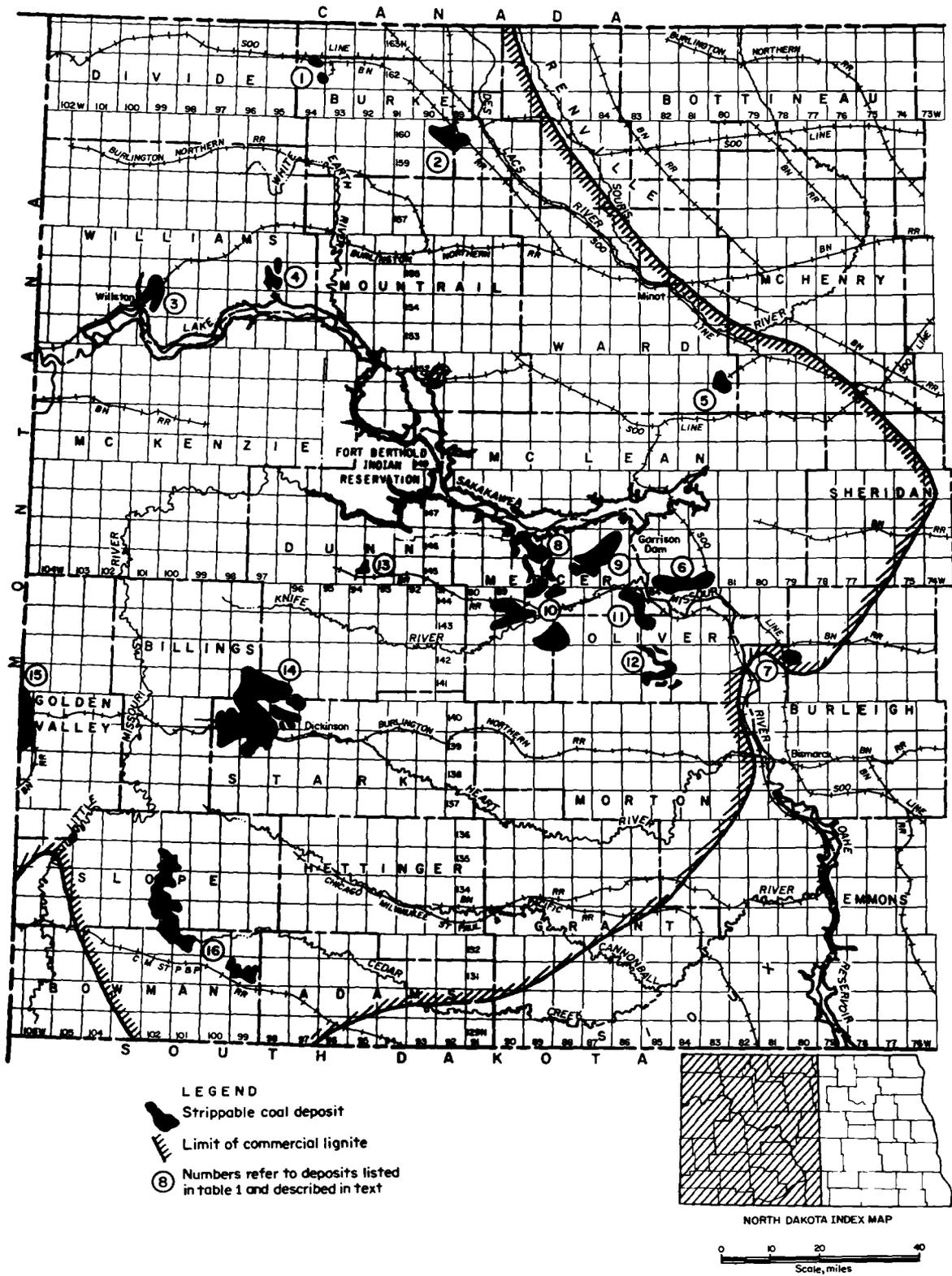


FIGURE 1. - Location of Major Strippable Lignite Deposits in North Dakota.

PREVIOUS INVESTIGATIONS

During 1947-51, at the request of the Bureau of Mines, the Corps of Engineers retained the consulting engineering firm of Ford, Bacon & Davis, Inc., as prime contractor, and surveyed the synthetic liquid fuel potential of North Dakota. The subsequent report (9) identified nine general areas containing an indicated 534 million tons of recoverable coal (lignite) in strip-pable blocks in North Dakota.

In 1966, Ball (4) foresaw total strippable reserves of 7 to 10 billion tons of lignite in North Dakota. In 1968, Averitt (3) reasoned that probably 50 billion tons of the lignite resources in North Dakota were under less than 100 feet of overburden.

GENERAL INFORMATION

North Dakota lies in the Great Plains where the terrain ranges from level to rolling grasslands, all virtually unforested, and where the elevation rises at an average rate of 5 feet per mile westward.

The climate is semiarid, and is characterized by long cold winters, moderately warm to hot summers, and irregular precipitation. Average annual precipitation is about 15 inches, the greatest part of which falls as rain from April to September. High winds, heavy snowfall in some years, and subzero temperatures are prevalent in the winter.

The population of North Dakota, as reported in the 1970 U.S. Census, is 610,648, which represents an average population density of 8.6 persons per square mile. Counties containing extensive lignite reserves generally have a population density of fewer than five inhabitants per square mile. Of some 358 communities in the State, 294 have populations under 1,000, and only 15 have populations exceeding 2,500.

The three major railroads serving the lignite area are the Burlington Northern, Inc.; the Chicago, Milwaukee, St. Paul, and Pacific (The Milwaukee Road); and the Minneapolis, St. Paul, and Sault Ste. Marie (Soo Line).

Agriculture is the principal industry of North Dakota. The State ranks second in the Nation in the production of wheat and first in the production of barley, rye, and flax. Beef cattle are raised on grasslands in the western part of the State and sold to feeders for fattening in the eastern part. Sheep, poultry, and swine production is important for the utilization of feed crops on smaller diversified farms.

Lignite mining has contributed to the State economy since 1884. Beginning with small underground mines that provided heating fuel for local consumption, the industry now is dominated by large-scale, open pit mines that fuel powerplants throughout North Dakota and neighboring States (table 2). Some lignite is still being mined for heating purposes, but this use is becoming less significant. More important is the mining of lignite for the manufacture of cooking briquets and for the recovery of uranium minerals in the

ash. Reserves devoted to these two purposes have been omitted from this report because they are not known, and because they are of no competitive value as a source of heat energy.

TABLE 2. - Lignite production of North Dakota,
1940-69
(Thousand short tons)

Year	Strip	Total production, strip and underground
1940.....	1,406	2,218
1941.....	1,527	2,309
1942.....	1,715	2,537
1943.....	1,750	2,500
1944.....	1,656	2,366
1945.....	1,860	2,522
1946.....	2,128	2,555
1947.....	2,288	2,760
1948.....	2,476	2,961
1949.....	2,497	2,967
1950.....	2,828	3,260
1951.....	2,973	3,224
1952.....	2,800	2,984
1953.....	2,641	2,803
1954.....	(¹)	(¹)
1955.....	3,081	3,102
1956.....	2,806	2,815
1957.....	2,557	2,561
1958.....	2,311	2,314
1959.....	2,409	2,413
1960.....	2,523	2,525
1961.....	2,724	2,726
1962.....	2,731	2,733
1963.....	2,397	2,399
1964.....	2,635	2,637
1965.....	2,731	2,732
1966.....	3,543	3,543
1967.....	4,156	4,156
1968.....	4,487	4,487
1969.....	4,704	4,704

¹Unpublished.

At present, the largest and most efficient strip mines in North Dakota each have an annual production of more than one-half million tons. Such mines receive about \$1.70 per ton for their product, which represents a cost to the consumer of \$0.12 to \$0.13 per million Btu (17).

In a typical operation, the overburden is removed without blasting, using a dragline having a bucket size up to 28 cubic yards. An attempt was made recently in the Stanton deposit to use a large, bucket-wheel excavator for overburden removal (8). Owing to difficulties encountered in handling large cemented sand lenses in the overburden, the project was abandoned in favor of conventional dragline stripping. The lignite requires blasting to facilitate loading by power shovels, which are preferred over front-end loaders for digging in the thick seams.

A common problem throughout the State is ground water flowing into the pits. Some pits are self-draining, but often such water must be drained by pumping because many mining operations are proceeding downdip. The water problem is compounded during wet weather when clay-based haulage roads become all but impassable. In fact, some operators prefer the severe winter months for stripping and haulage operations because of the improved trafficability of the frozen ground.

As mined, the lignite is satisfactory without beneficiation for direct use as boiler fuel. Some care is needed in storing the lignite for more than a couple of weeks, however, owing to a marked tendency towards spontaneous ignition. When long-term storage is required, wetting and compacting the stockpiles suffices to preserve the lignite.

GENERAL GEOLOGY

The Sentinel Butte and Tongue River Members of the Paleocene Fort Union Formation contain all the known, commercially strippable lignite reserves in North Dakota. Loosely consolidated clays and shales are the dominant constituents of the lignite-bearing formations which, except for local areas of minor folding, have a gentle, westerly, regional dip. From a maximum thickness along the North Dakota-Montana boundary, the Fort Union Formation thins to an outcrop line running north to south through the center of the State; this line marks the eastward limit of commercial lignite. Some clinker has formed where lignite has burned at the outcrop. There is also a scattering of outlying younger sediments atop the Fort Union Formation, but a more pervasive covering is provided by glacial till that blankets the uplands in the northeastern half of the outcrop area. This area of glaciation presents special hazards to lignite reserve estimation because of the presence of hidden erosional channels and subsurface weathering caused by the glacial activity.

STRIPPABLE RESERVE CRITERIA

Adequate data were available only for the 16 areas discussed in this report. The smallest reported reserve, the 5-million-ton Velva deposit, is large enough to support a commercial strip mine. A reserve of this size probably approaches the minimum necessary to support a competitively efficient mining operation in the future. All the other reported deposits are considerably larger than the Velva deposit and thus are believed to qualify easily as commercial reserves.

Large blocks of lignite that have been mined in the past have been deducted from reserve tonnages. No effort was made to deduct tonnage removed in small wagon mines, because these negligible quantities would have no significant effect on the totals.

Because a variety of data forms and sources was used in compiling this report, it has proven necessary to present strippable reserve figures derived from several different criteria. Where drill hole data were available, reserves were calculated using criteria derived from observations of current practices in North Dakota strip mines. These calculations, made with the use of a digital computer, were based on the following limiting criteria: (1) Seam thickness greater than 5 feet; (2) overburden thickness less than 50 feet; and (3) stripping ratio less than 10 yards of overburden per ton of coal. (A lignite density factor of 1,750 tons per acre-foot was used.)

In some deposits, the lack of drill hole data necessitated the acceptance of reserve tonnages calculated by others and the acceptance of the limiting criteria employed in such calculations.

Where strippable reserves have been reported with up to 120 feet of overburden or with stripping ratios up to or exceeding 10 cubic yards of overburden per ton of lignite, it is unlikely that more than a fraction of the total reserves would be commercially strippable in the foreseeable future. Despite the improbability of strip mining such reserves in their entirety, some insight is provided as to the short-range prospects for partial recovery of the deposits.

The reserve tonnages listed in table 1 have not been reduced by a recovery factor. Current strip-mining practice in North Dakota indicates that a 90-percent-recovery factor of reserves in place is quite normal.

NORTH DAKOTA MINED LAND RECLAMATION LAW

Effective with the passage of S.45 by the State legislature in 1969, strip mining of all minerals in North Dakota, including lignite, has been subject to regulation in the matter of land reclamation. In general, the law requires that strip-mined areas be restored to a condition that will minimize adverse economic and aesthetic effects and maximize future utility of the land. These objectives may be accomplished by a variety of alternative landscaping and planting programs.

Prior to beginning operations, a strip mine operator must obtain a permit from the State Coal Mine Inspector. As a condition for obtaining the permit, the operator must define the geographic limits of anticipated strip mining, state the goal of his reclamation plan, and describe the means by which this goal is to be achieved. The objective may be the establishment either of forest or woods, or of agricultural land. The law requires, in the first case, that spoil ridges be graded to a crown width of not less than 24 feet, and in the second, to a crown width of not less than 35 feet. When forestation is the objective, it is further required that access roads be constructed with a minimum spacing of 660 yards. Whichever approach to reclamation is taken, the

permittee must landscape to a rolling topography, traversable by farm-type machinery, all spoil banks within 650 feet of, and visible from, a public highway. All of this landscaping as well as the appropriate planting and/or seeding is to be accomplished within the permit time period of 3 years. An extension of this period may be granted for good and sufficient reason.

Strip mining without a permit is a misdemeanor punishable by a fine of from \$50 to \$1,000, and each day of such operation is counted as a separate violation. Contingent upon acceptance of the reclamation plan and the issuance of the strip mining permit, the operator is required to post a bond in the amount of \$200 per acre as well as a fee. The bond is forfeited in the event that the permittee fails to comply with his obligations under the approved reclamation plan.

STRIPPABLE LIGNITE DEPOSITS

Noonan-Kincaid Deposit (1)

The Noonan-Kincaid lignite deposit occurs in the Sentinel Butte Member of the Fort Union Formation in Burke County, N. Dak. There has been extensive open pit coal mining by the Baukol-Noonan Coal Co. north and west, and by the Truax-Traer Division of Consolidation Coal Co. northeast, of the property under consideration. These mining operations are served by a branch of the Burlington Northern Railroad.

It has been calculated from company data that the deposit contains 14.7 million tons of strippable coal (fig. 2). Of the two commercial seams present, the uppermost (Noonan) includes all but 1.6 million tons of the strippable reserve. Criteria used to compute this reserve are as follows: Seam thickness greater than 5 feet; overburden or interburden less than 50 feet; and combined stripping ratio less than 5 yards per ton of overburden. The overburden, composed of variable proportions of glacial drift, shale, and clay, increases southwesterly from the outcrop as the lignite beds pass beneath a row of low hills. Except for a series of rather pronounced gullies that dissect these hills, the local terrain is generally a flat to gently rolling prairie liberally pockmarked with bogs and ponds of glacial origin.

Typical as-received analyses from the Baukol-Noonan and Kincaid mines are as follows (21):

Deposit	Analysis, percent					Btu per lb
	Moisture	Volatile	Fixed C	Ash	Sulfur	
Baukol-Noonan.....	37.6	26.1	32.9	5.5	0.3	7,260
Kincaid.....	36.8	25.7	29.1	8.4	.7	6,730

Niobe Deposit (2)

The Niobe lignite deposit lies in Ward and Burke Counties, in northwestern North Dakota. Located about three-fourths of a mile southwest of Niobe, a station on the Crosley Branch of the Burlington Northern Railroad, the

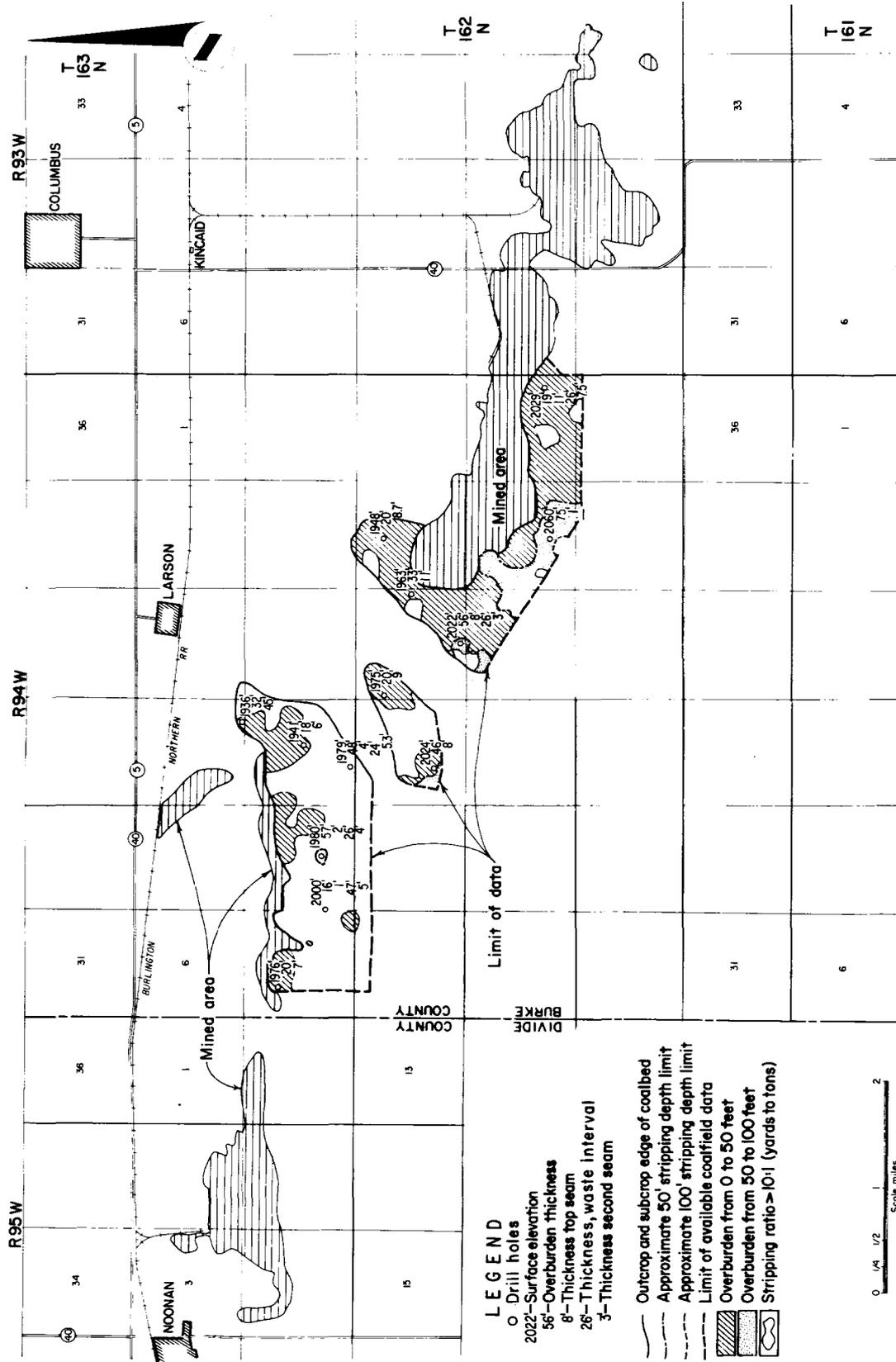


FIGURE 2. - Noonan-Kincaid Deposit, Burke County. (Based on company data.)

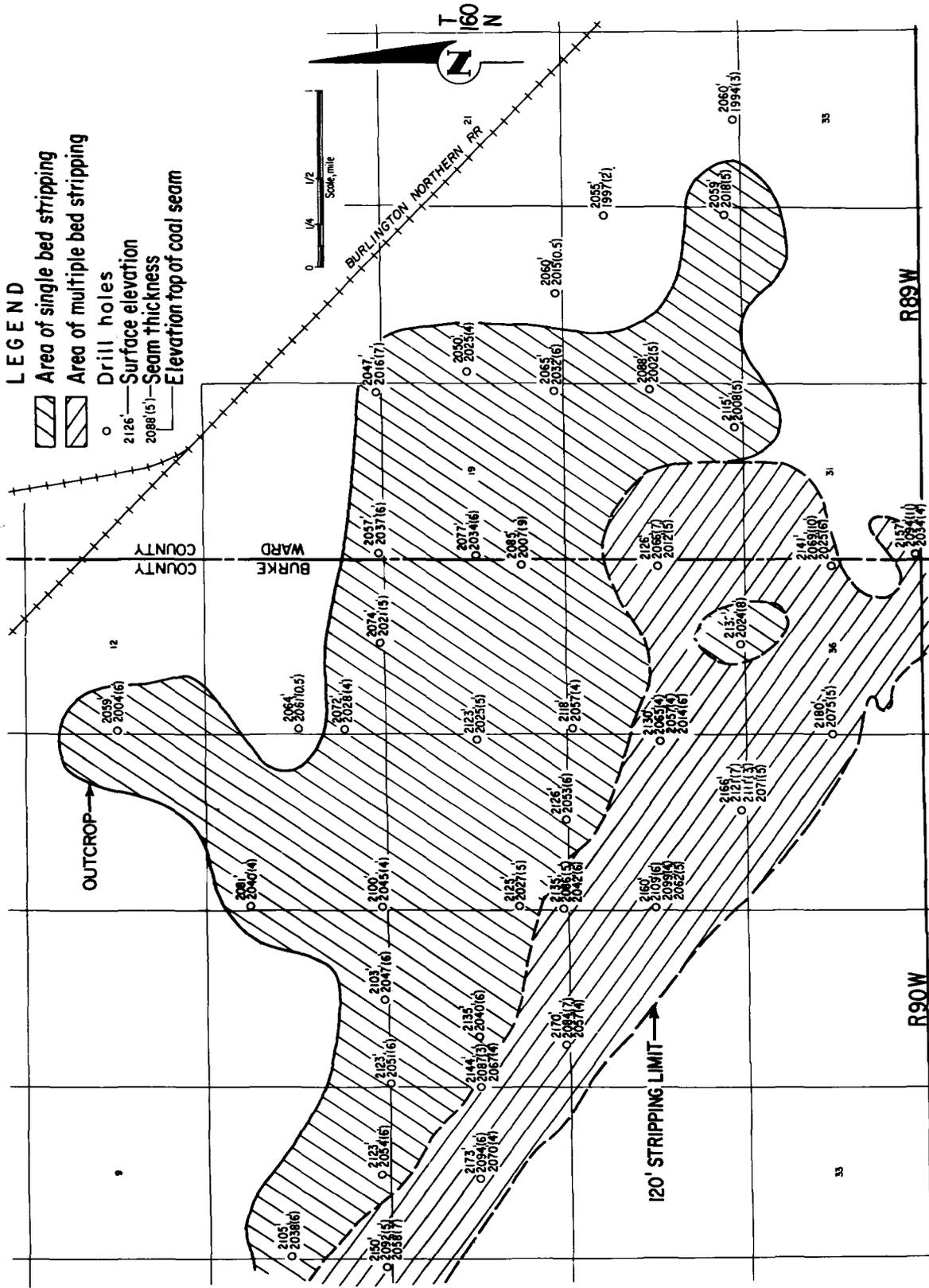


FIGURE 3. - Niobe Deposit, Ward and Burke Counties. (Based on company data.)

deposit is about 8 miles west of Kenmare (population about 1,700), which is on U.S. Highway 52.

Based on data developed in a coal company drilling program, it is estimated that there are 145.9 million tons of lignite in this deposit, under less than 100 feet of overburden.

Two lignite beds, referred to as the Niobe and Bonus beds, are present in the 14-square-mile area of the deposit (fig. 3). The northern portion of the area, consisting of about 9.5 square miles, is underlain by only the Niobe bed, which is about 6 feet thick, and is estimated to contain about 77.1 million tons of lignite with a stripping ratio of about 10.7 cubic yards of overburden per ton of lignite. The overburden in the area is for the most part glacial till. The southwestern portion of the deposit, about 4.6 square miles, is underlain by both the Niobe and the stratigraphically higher Bonus bed. The Bonus lignite seam has an average thickness of about 8.5 feet, and contains about 40.3 million tons of coal with a stripping ratio of about 9.2 to 1. An additional 28.5 million tons under less than 100 feet of overburden would be available from the Niobe bed if the Bonus bed is removed up to its 100-foot overburden isopach. The drilling program working in the Niobe lignite deposit has reported the two following as-received analyses:

Analysis, percent				Btu
Moisture	Volatile	Fixed C	Ash	per lb
33.5	29.7	31.6	5.2	7,487
38.5	27.6	28.3	5.6	6,749

Avoca Deposit (3)

The Avoca lignite deposit covers about 25 square miles in Williams County, N. Dak. Located 6 miles east of Williston (population 12,000), the deposit is on the main line of the Burlington Northern Railroad. Access is by all-weather gravel and paved county roads. Lake Sakakawea (Garrison Reservoir), which is adjacent to the west side of the Avoca deposit, provides an ample source of industrial water at the site.

All data and estimates of measured reserves are based on 39 drill hole logs, cross sections, structure contour, isopach, and topographic maps. The area used in calculating reserve data is shown in figure 4.

Within the area, four lignite beds, ranging from 1 to 12 feet thick, lie within 220 feet of the surface. The Avoca deposit contains 380.4 million tons of lignite with an overall stripping ratio of 5.2 cubic yards of overburden per ton of lignite (11).

In multiple-seam mining, a maximum of 75 feet of waste rock would have to be removed from any of the four lignite beds to recover the entire strippable reserve.

The lignite beds are in the Sentinel Butte Member of the upper Fort Union Group of Paleocene age. The Sentinel Butte Member is predominantly clay and

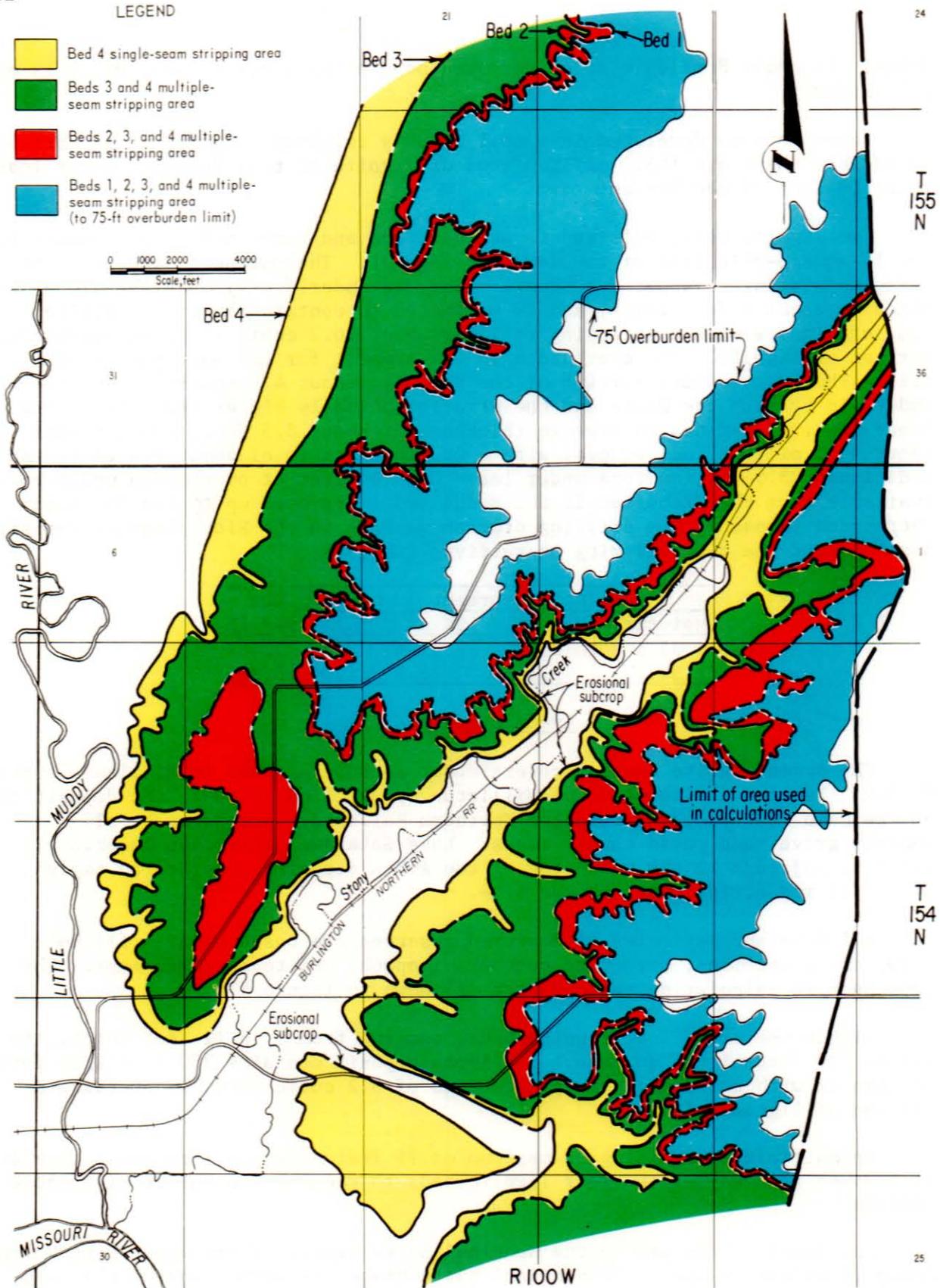


FIGURE 4. - Avoca Deposit, Williams County. (Based on company data.)

claystone with interbedded silt, silty clay, shale, and lignite. Glacial drift averages about 20 feet thick on the uplands and is up to 100 feet thick in the valleys.

Bed 4, the lowest, has an average thickness of 8.4 feet and contains 160,661,000 tons of lignite under an area of 11,000 acres. Cover totals less than 220 feet, of which 20 feet is lignite contained in beds 1, 2, and 3. Elevations at the top of bed 4 range from 1,940 feet to 1,840 feet. The dip is northeasterly at 10 feet per mile.

Bed 3, 40 feet above bed 4, has an average thickness of 9.2 feet and contains 138,414,000 tons of lignite. A clay-shale interval, 72 feet thick, separates bed 3 from bed 2.

Beds 1 and 2 each average 5.3 feet in thickness and are separated by a 16-foot-thick clay interval. Bed 2 underlies 5,258 acres and has less than 95 feet of cover, of which 5 feet is lignite in bed 1. Bed 1 underlies 3,915 acres, and cover is less than 75 feet thick. Beds 1 and 2, respectively, contain 32,250,000 and 49,102,000 tons of lignite under a total of 328,281,000 cubic yards of overburden. The combined stripping ratio for beds 1 and 2 is 3.9 to 1.

Analyses of lignite samples recently obtained by drilling at the Avoca deposit give the following results (10):

Bed	Analysis, percent					Btu per lb
	Moisture	Volatile	Fixed C	Ash	Sulfur	
1	37.9	27.5	27.6	7.2	1.4	6,734
2	40.4	26.1	26.7	6.6	.7	6,578
3	42.6	25.2	27.4	5.2	.5	6,480
4	40.6	25.6	26.8	7.0	.5	6,477

M & M Deposit (4)

The M & M lignite deposit is in Williams County, in northwestern North Dakota. The deposit (fig. 5) is about midway between the Missouri River and the town of Ray, which are about 15 miles apart. U.S. Highway 2 and the Burlington Northern Railroad serve Ray, which has a population of about 1,000 people.

A drilling program consisting of nine holes has established a strippable reserve of 100 million tons of lignite in an area of 5.8 square miles (10). Two lignite beds are included in the tonnage figures: Bed 1 thicknesses range from 7 feet 7 inches to 15 feet 9 inches; bed 2 thicknesses, from 7 feet 1 inch to 12 feet 2 inches. The overall stripping ratio is reportedly about 5.0 cubic yards of overburden, consisting of sand, gravel, clays, and shale, per ton of lignite. The maximum overburden is 120 feet. The lignite seams dip about 20 feet per mile to the west.

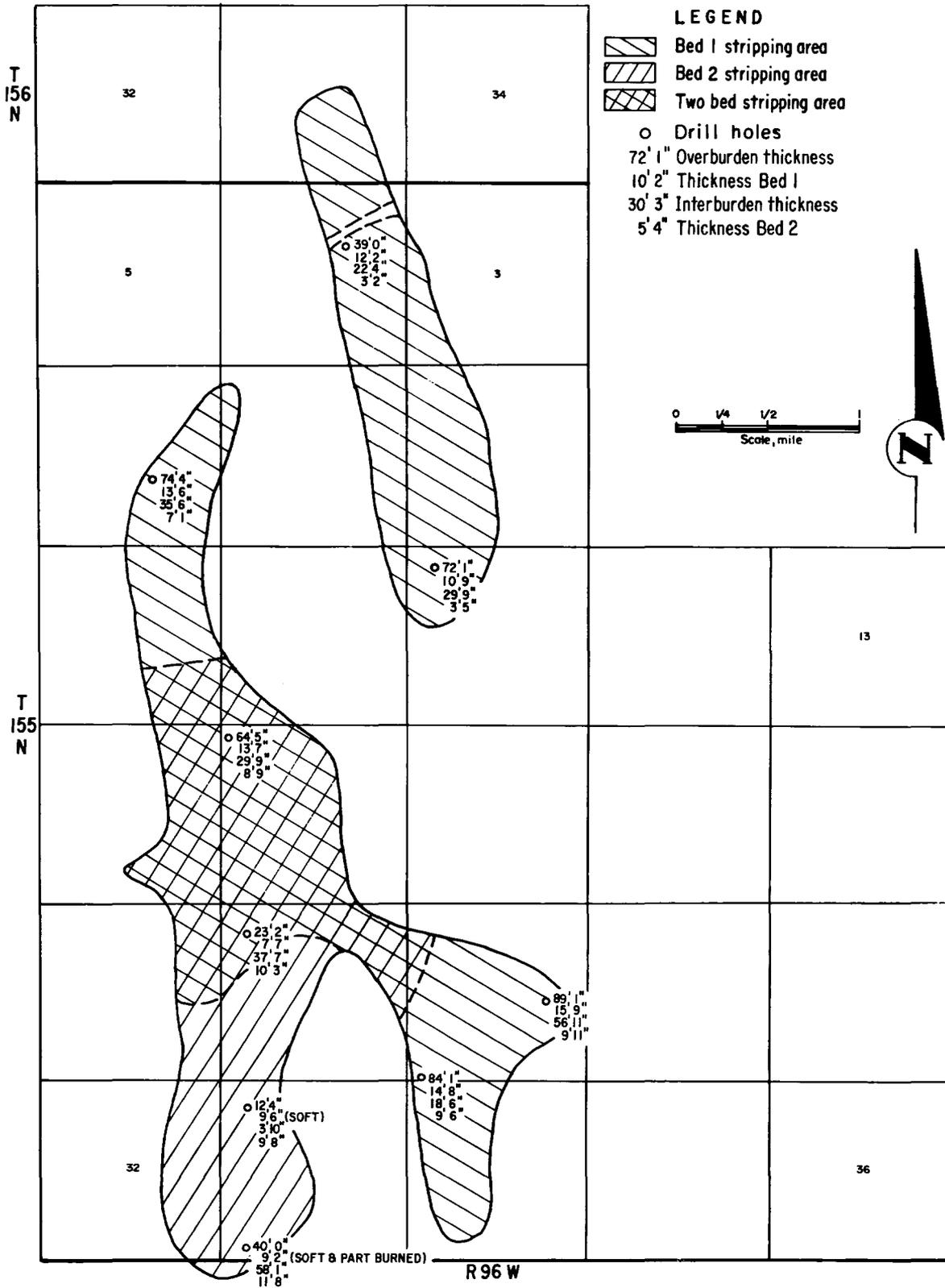


FIGURE 5. - M & M Deposit, Williams County. (Based on company data.)

An average as-received analysis of the lignite is as follows (10):

Analysis, percent					Btu per lb
Moisture	Volatile	Fixed C	Ash	Sulfur	
41.3	25.2	27.7	4.9	0.3	6,409

Velva Deposit (5)

The Velva lignite deposit, on which the large Velva strip mine is operated by Consolidation Coal Co., Inc., is in the Coteau lignite bed of the Tongue River Formation in southeastern Ward County (fig. 6). The mine is about 13 miles southwest of Velva, a town of about 1,400 people on the Minneapolis, St. Paul, and Sault Ste. Marie (Soo Line) Railroad. The flat prairie land in and around the Velva deposit reflects the deposition of glacial debris in an ancient lake of Pleistocene age. Only 1 mile south of the map area shown in figure 6, the terrain becomes a patchwork of low hills and bogs where ground moraines were deposited beyond the margins of the old lake (1).

Strippable reserves of lignite, according to data from test drilling on the Velva deposit, amount to 5 million tons under less than 50 feet of

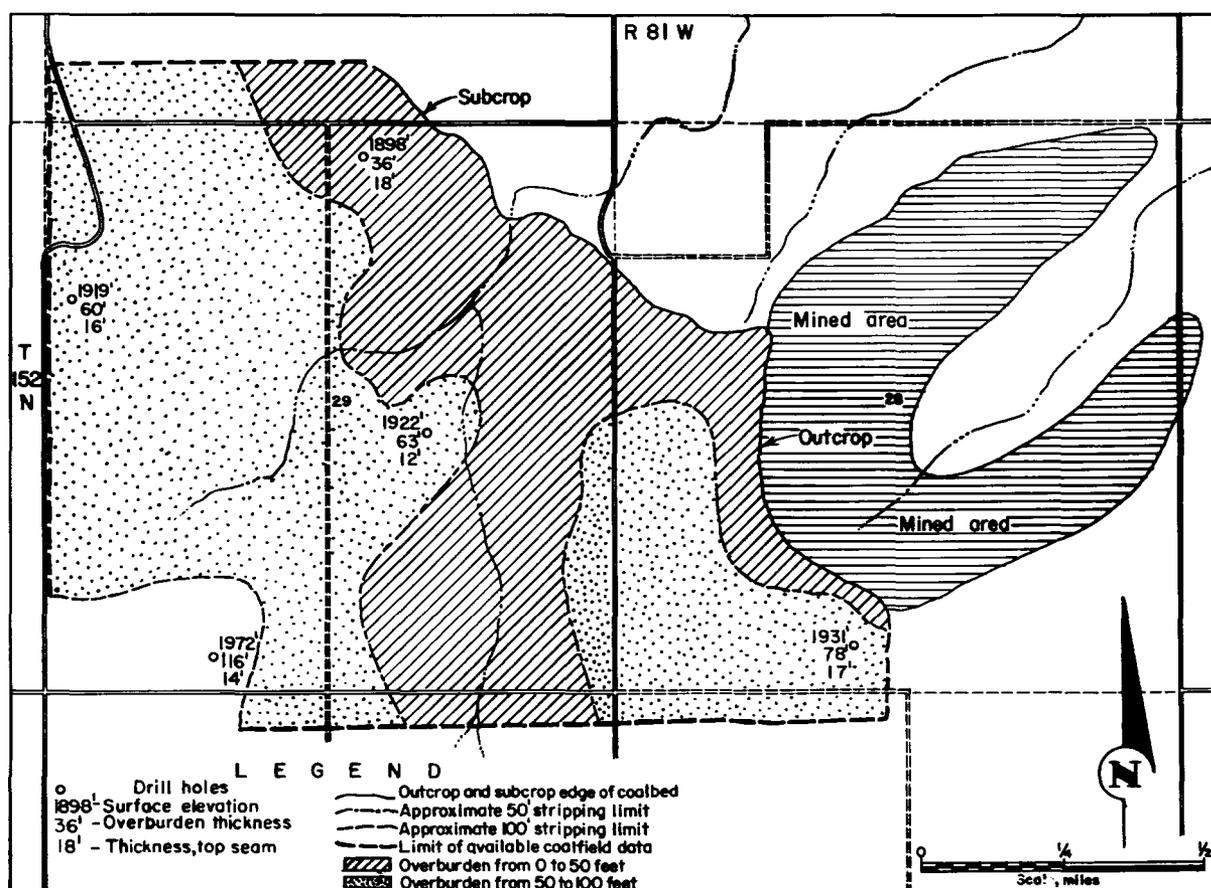


FIGURE 6. - Velva Deposit, Ward County. (Based on company data.)

overburden. The overburden consists of up to 20 feet of glacial till overlying Tongue River sediments, mainly soft sandstone and clay (1). The following is a typical as-received analysis of lignite from the Velva mine (7):

Analysis, percent					Btu per lb
Moisture	Volatile	Fixed C	Ash	Sulfur	
37.2	26.9	31.1	4.7	0.2	6,790

The Coteau lignite bed crops out intermittently for about 35 miles in McHenry and McLean Counties, at elevations ranging from 1,830 to 1,910 feet above sea level (1). The Coteau lignite averages 12 feet thick in the Velva mine locality.

Washburn Deposit (6)

The Washburn lignite deposit is in the Stanton bed of the Tongue River Formation north of the Missouri River in southeastern McLean County. It is located in gently rolling prairie about midway between Lake Sakakawea (Garrison Reservoir) on the Missouri River and the town of Washburn about 25 miles downstream. Washburn, a town of some 1,000 residents, is on the north bank of the river, and on the Minneapolis, St. Paul, and Sault Ste. Marie (Soo Line) Railroad.

Strippable reserves of lignite, according to data from prospect drilling on the Washburn deposit (fig. 7), amount to 30 million tons under less than

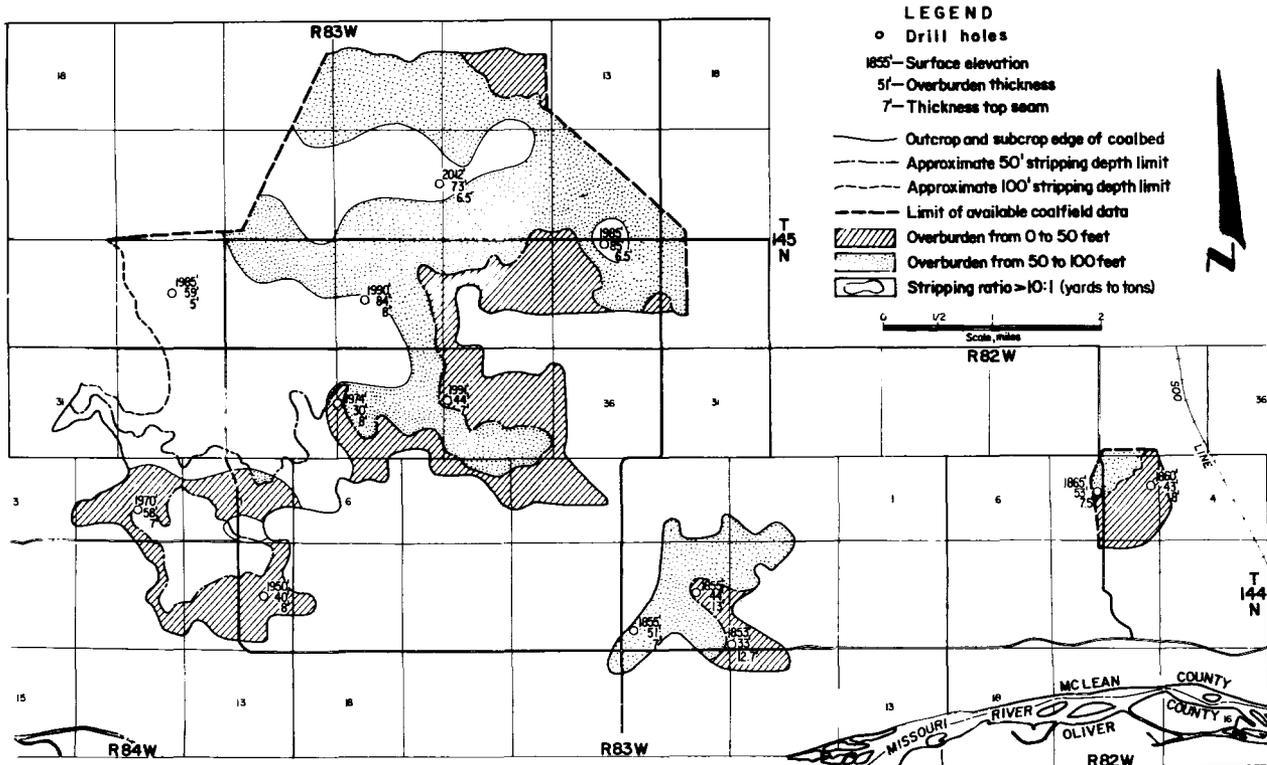


FIGURE 7. - Washburn Deposit, McLean County. (Based on company data.)

50 feet of overburden. The overburden is composed of a patchy veneer of glacial till underlain by Tongue River sediments in which there are roughly equal proportions of sands, clays, and sandy clays (20).

The following average as-received analysis of lignite in McLean County is in close agreement with the moisture, ash, and heating values in a number of partial analyses from company maps of the Washburn deposit (9):

Analysis, percent					Btu
Moisture	Volatile	Fixed C	Ash	Sulfur	per lb
38.1	26.1	31.4	4.4	0.5	7,100

Wilton Deposit (7)

The Wilton lignite deposit is in the Wilton bed of the Tongue River Formation in northwestern Burleigh County. It is about 4 miles southeast of Wilton, a town of about 800 people east of the Missouri River, at the junction of the Burlington Northern and the Minneapolis, St. Paul, and Sault Ste. Marie (Soo Line) Railroads (fig. 8).

The strip mine of Ecklund-Taplin Coal Co. in the Wilton bed is the only lignite producer in Burleigh County.

Based on data from exploratory drilling on the Wilton deposit, strippable reserves of lignite amount to 15 million tons under less than 50 feet of overburden; the average stripping ratio is less than 5 cubic yards of overburden per ton of lignite. The overburden is made up of sand, clay, and sandy clay in the Tongue River Formation. A thin mantle of till in a sheet moraine blankets the higher ground, but it constitutes a minor fraction of the total overburden. A typical as-received analysis of Wilton lignite follows (2):

Analysis, percent					Btu
Moisture	Volatile	Fixed C	Ash	Sulfur	per lb
38.1	26.1	31.4	4.4	0.5	7,100

Renner's Cove Deposit (8)

An extension of the Zap lignite bed, in Mercer County north of Beulah, lies at shallow depths under the grassy uplands south of Lake Sakakawea (Garrison Reservoir). To date there has been no large-scale mining in the deposit nor any local development of heavy-duty transportation facilities closer than the railroad spur at Hazen, 8 miles to the east. Data from a coal company exploration project in the Renner's Cove property (fig. 9) were used in calculating strippable reserves of 77.7 million tons of lignite where the seam exceeds 5 feet in thickness, lies under less than 50 feet of overburden, and is recoverable at a stripping ratio of less than 5 yards of waste per ton of coal. The Zap lignite bed maintains a thickness of about 18 feet. Although there are no available analyses of lignite from the Renner's Cove deposit, the following is an average as-received analysis from northern Mercer County (9):

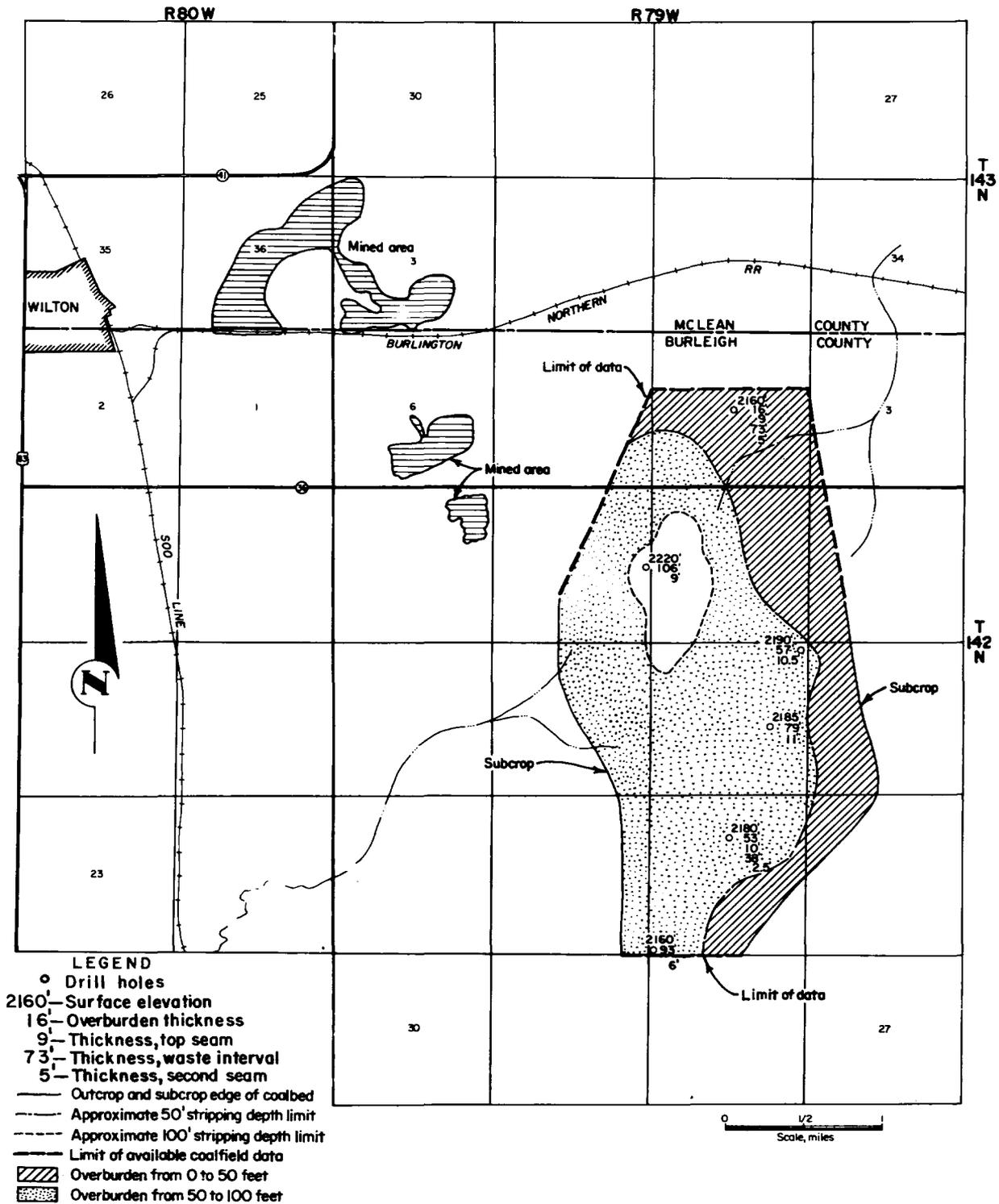


FIGURE 8. - Wilton Deposit, Burleigh County. (Based on company data.)

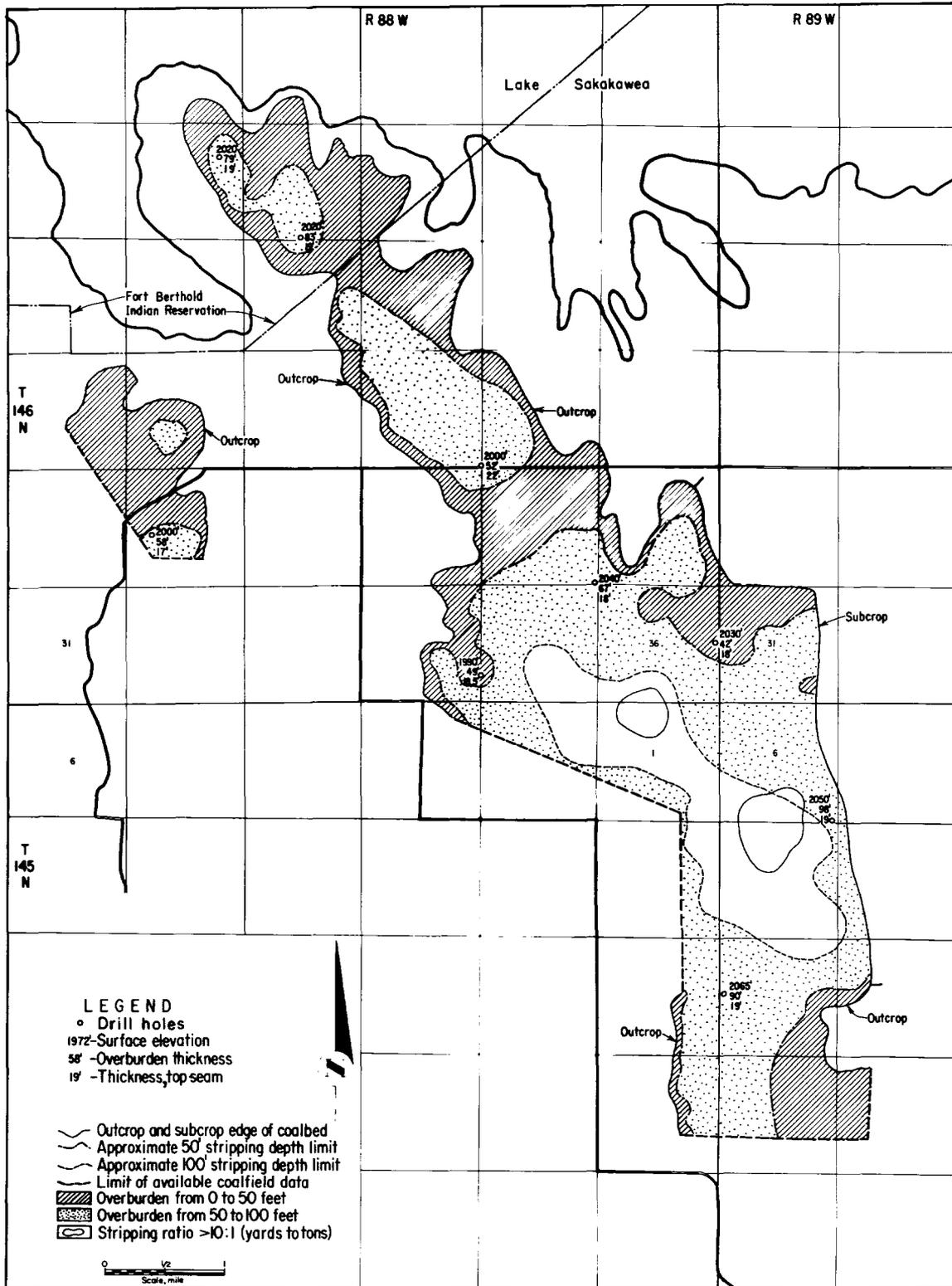


FIGURE 9. - Renner's Cove Deposit, Mercer County. (Based on company data.)

Analysis, percent					Btu
Moisture	Volatile	Fixed C	Ash	Sulfur	per lb
34.0	30.0	30.0	6.0	0.5	7,050

Hazen Deposit (9)

The Hazen lignite field (fig. 10) lies about 5 miles north of the town of Hazen in Mercer County. Topographically, this area is rolling prairie dissected by dry washes and broad valleys. Excellent transportation facilities adjoin the deposit in the form of a 6-mile railroad spur from the Dakota Star mine south to Hazen and the Burlington Northern branch running alongside the Knife River. Near-surface occurrences of substantial lignite seams have been reported in various places northward to the Missouri River from the Hazen field, but the sparsity of data in those regions plus the vagaries of glacial erosion preclude reserve calculation. Where definitive drilling data exist, strippable reserves have been calculated to be 71.1 million tons in a seam more than 5 feet thick, under less than 50 feet of overburden, and having a stripping ratio of less than 5 cubic yards per ton.

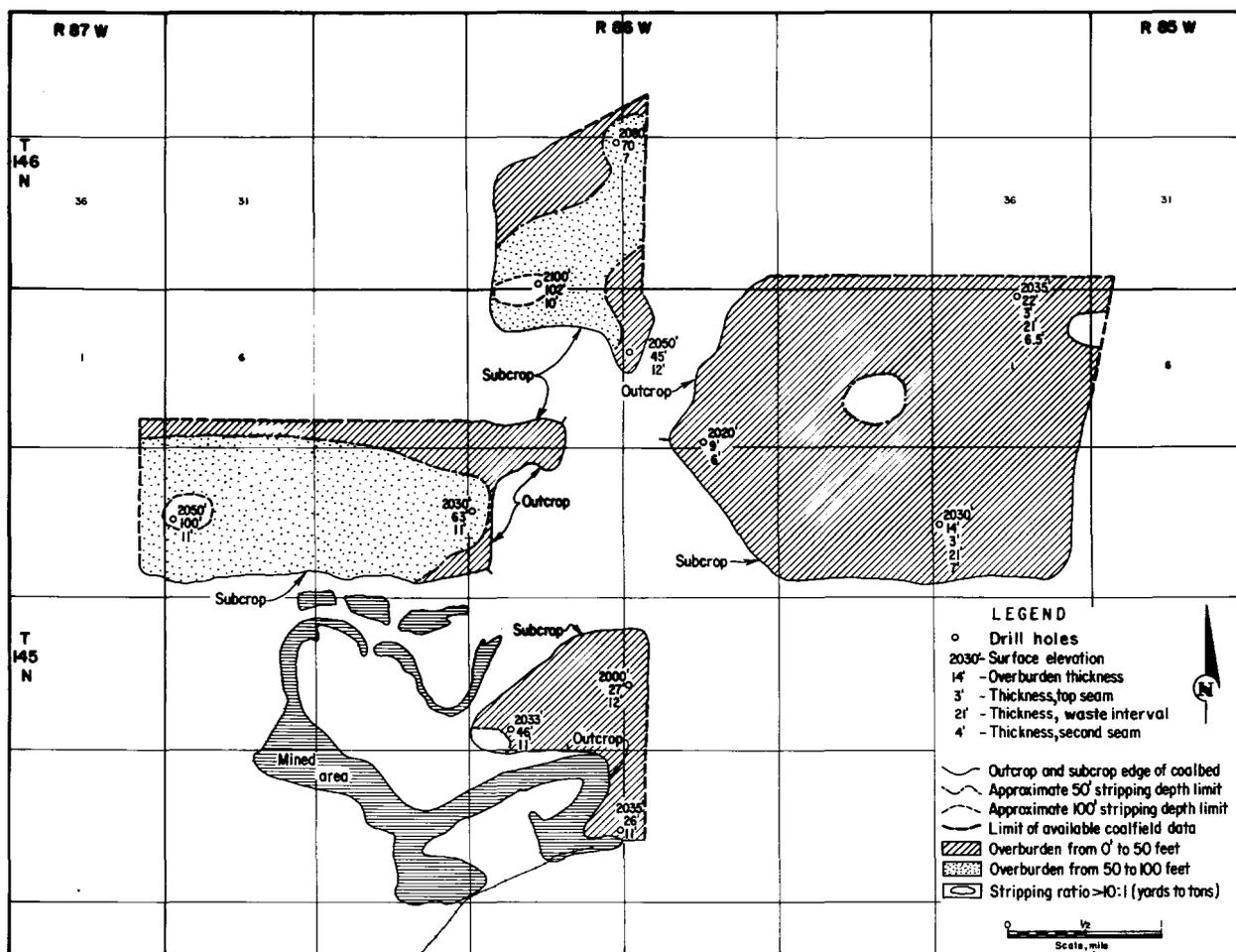


FIGURE 10. - Hazen Deposit, Mercer County. (Based on company data.)

Prior to 1966, Consolidation Coal Co. operated the Dakota Star strip mine on the southern fringe of the deposit. This mine and the reserves cited are in the Beulah-Zap lignite bed of the Tongue River Formation. A typical as-received analysis of lignite from this deposit is as follows (21):

Analysis, percent					Btu per lb
Moisture	Volatile	Fixed C	Ash	Sulfur	
37.3	26.4	30.7	5.8	0.7	6,870

The seam itself maintains a thickness of about 11 to 12 feet, except towards the eastern limit of the area studied, where it thins to 6 to 7 feet. Sandstone and clay predominate in the Tongue River portion of the overburden, which is capped by an uneven layer of glacial till.

Beulah-Zap Deposit (10)

The Beulah-Zap lignite field occupies parts of six townships on both sides of the Knife River in Mercer County (fig. 11). This deposit will be considered in three segments, the North Beulah, South Beulah, and Zap coal-fields. In the combined North and South Beulah field, strippable reserves amount to 200 million tons (16). North of the Knife River the strippable coal is in the Zap bed, which is 17 feet thick under an average of 76 feet of overburden. South of the river are three minable beds, 12, 11, and 4-1/2 feet thick, which apparently represent divisions of the Schoolhouse bed. Overburden at South Beulah averages 62 feet; the maximum overburden is 120 feet. Strippable reserves of 180 million tons are estimated to be present near the town of Zap (16). This reserve is in the Beulah bed, which in that area is about 8 to 10 feet thick. Highwalls of the old pits in the Zap deposit roughly conform with the 75-foot overburden isopach (fig. 11), which is assumed to be the maximum overburden under which the strippable reserve was calculated. West of the map area the Beulah bed thins to less than 5 feet, thus losing its commercial interest (5). Typical as-received analyses of lignite from each of the three segments of the deposit are as follows (21):

Deposit	Analysis, percent					Btu per lb
	Moisture	Volatile	Fixed C	Ash	Sulfur	
North Beulah.....	37.1	26.1	31.0	5.7	0.5	6,790
South Beulah.....	35.8	26.9	31.7	6.6	1.0	6,910
Zap.....	35.3	26.6	31.3	6.7	.8	7,070

The landscape around the Beulah-Zap field is a rolling prairie. There has been some entrenchment of the larger streams in their lower valleys, but elsewhere in the upland regions a mature topography prevails. Little surficial evidence remains of the Pleistocene glaciation that covered the area, except for a thin and scattered mantle of till. The latter is a relatively minor constituent in the overburden, the bulk of which is comprised of clay and minor sandstone. An east-west branch of the Burlington Northern Railroad runs alongside Spring Creek and the Knife River, bisecting the coalfield. This artery provides an outlet for the lignite produced by North American Coal Corp. at its Zap mine, from which it is shipped 25 miles to a powerplant

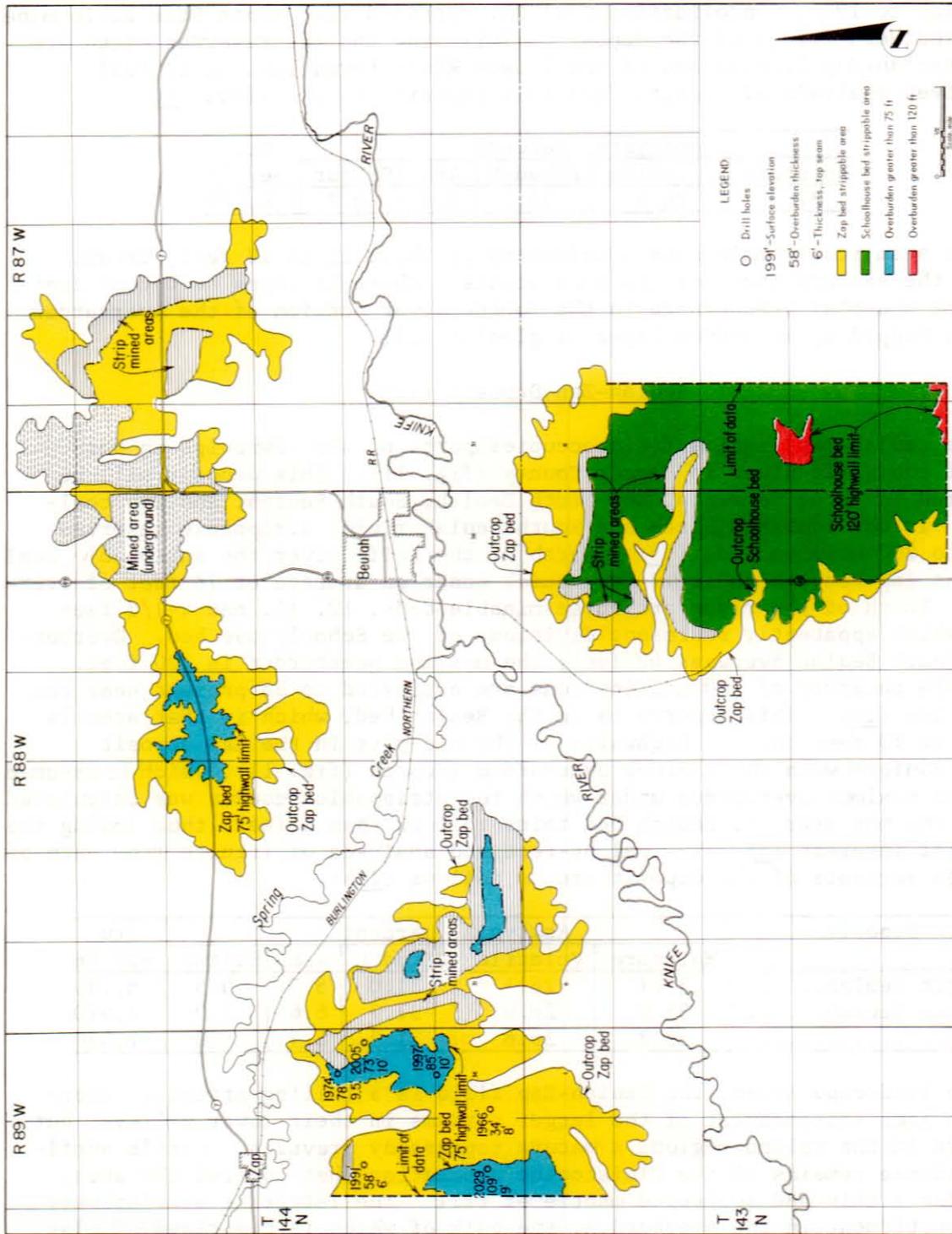


FIGURE 11. - Beulah-Zap Deposit, Mercer County. (Adapted from U.S. Geol. Survey open-file geologic map of Medicine Butte and Beulah quadrangles by W. E. Benson and R. M. Lindvall.)

beside the Missouri River. The Knife River Coal Mining Co. production from its Beulah mines is consumed locally at a Beulah powerplant.

Clay in the overburden has inhibited land reclamation in existing strip pits. Despite the generally hostile environment, Knife River Coal Co. has made some headway in revegetating its Beulah spoil banks. Of all the mining companies active in North Dakota, Knife River has the greatest documentation on land reclamation activities. Its reports describe the successes and failures of several experimental approaches to reclamation. The detrimental effects of leveling spoil banks is a persistent theme in these reports (12).

Stanton Deposit (11)

An eastern extension of the Tongue River Formation south of the confluence of the Knife and Missouri Rivers is known as the Stanton deposit. Strip-pable coal reserves occur under a line of bluffs extending in an arc from southwest of Stanton, in Mercer County, to a point across the line in Oliver County (fig. 12). There are two minable seams, a local bed and the underlying Stanton bed. The latter is the more important commercially because of its greater continuity and greater thickness (8 to 11 feet compared with 4 to 6 feet for the local bed) (13). Of the 20.8 million tons of strippable reserves calculated for the deposit, 14.7 million tons are in the Stanton bed. Reserves were calculated from company-supplied drill hole data, and they meet the criteria of being in seams greater than 5 feet thick, under less than 50 feet of overburden and/or interburden, and having a stripping ratio of less than 5 cubic yards of waste per ton of coal. In the northwest block of strippable coal only the Stanton bed was included in the reserve calculation, but elsewhere both it and the local bed were considered. The overburden above the local bed is composed of soft sandstone and clay capped by varying amounts of glacial till. The waste interval between the two seams is mainly shale but does include a bed of hard, well-cemented sandstone just above the Stanton bed.

Production from the Glenharold mine at the southern end of the field is feeding the 240-Mw Basin Electric Power Cooperative plant on the Missouri River some 3 miles from the mine. Lignite from the Glenharold mine has a typical as-received analysis as follows (21):

Analysis, percent					Btu per lb
Moisture	Volatile	Fixed C	Ash	Sulfur	
38.3	26.8	30.0	4.8	0.4	6,870

Center Deposit (12)

Strippable lignite reserves of the Center deposit underlie gently rolling prairie along Square Butte Creek and its tributaries in Oliver County. The town of Center (population 476), lying at the heart of the coalfield, is 40 miles northwest of the State capital via State Highway 20 and Interstate 94. The nearest railhead is at Fort Clark, on the Missouri River, 9 miles north of Center. The dominant local industry is agriculture, although some small strip and underground lignite mines have been worked intermittently in the past.

Lignite occurs in several seams in the Fort Union Formation, which crops out through a thin veneer of glacial till. Overburden typically consists of loosely consolidated sandstone and shale in addition to the till. Coal company drilling programs have defined two potentially strippable seams in the Center deposit (19), the Hagel bed, which persists throughout the entire Center coalfield; and the stratigraphically higher (45 to 65 feet) Kuether bed, in which commercial thicknesses are generally confined to the central one-third of the area (fig. 13). The Hagel bed is split by a parting of from 1 to 6 feet at the northern and southern ends of the deposit, but appears as one bed in the central portions where it attains a thickness up to 18 feet. The following is an average as-received analysis for the Hagel bed throughout the Center deposit (19):

Analysis, percent					Btu per lb
Moisture	Volatile	Fixed C	Ash	Sulfur	
35.0	29.0	29.0	7.0	0.9	7,066

Strippable reserves in the Center deposit are estimated as 253 million tons where the seams exceed 5 feet in thickness, are under less than 50 feet of overburden, and have a stripping ratio of less than 5 cubic yards of waste per ton of coal. Of the total, 202 million tons is in the Hagel bed and 51 million tons is in the Kuether bed. The maximum allowable stripping ratio is most often decisive in defining the limit of strippable coal in the relatively thin Kuether bed, and the 50-foot overburden isopach limits the strippable portion of the thicker Hagel bed.

Dunn Center Deposit (13)

The Dunn Center lignite field is a small, isolated deposit in the Sentinel Butte Shale Member of the Tongue River Formation, in central Dunn County. The area of strippable coal occupies approximately 3 square miles of gently rolling prairie immediately north of the town of Dunn Center (population 250). An east-west spur of the Burlington Northern Railroad and Spring Creek, the only perennial stream in the district, pass through Dunn Center within 1 mile of the coal outcrop (fig. 14). To date there has been no significant mining locally. However, a coal company has conducted an exploratory drilling program in the deposit. Their drill hole logs form the basis for calculating strippable reserves of 28.6 million tons in one (unnamed) lignite seam which, throughout most of the field, attains a thickness of 17 to 18 feet. This reserve meets the criteria of a seam more than 5 feet thick, under less than 50 feet of overburden, and minable at a stripping ratio of less than 5 cubic yards of waste per ton of coal. The overburden, largely shale, tends to be rather thin, except in the northwest, where it exceeds 50 feet.

Proximity of the railroad could spur development of the property. However, it is thought unlikely that sufficient reserves of cooling water are available locally to warrant the installation of a mine-mouth power or gasification plant. More likely, Dunn Center lignite could augment supply to a plant located near larger deposits, such as the Beulah-Zap field 30 miles to the east.

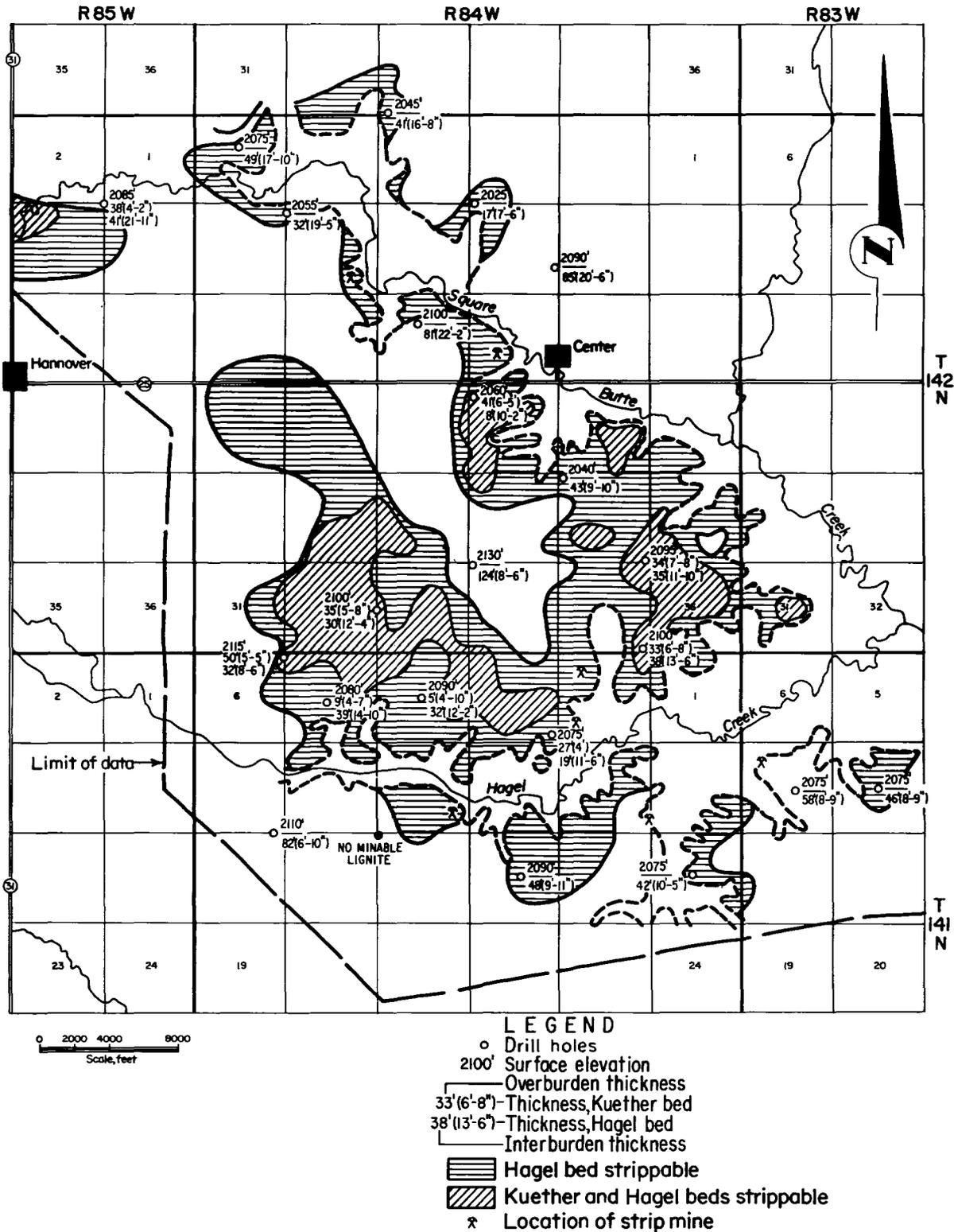


FIGURE 13. - Center Deposit, Oliver County. (Adapted from Exhibit 1, report on lignite reserves, Center area, Oliver County, N. Dak., by Paul Wier Co., April 1962.)

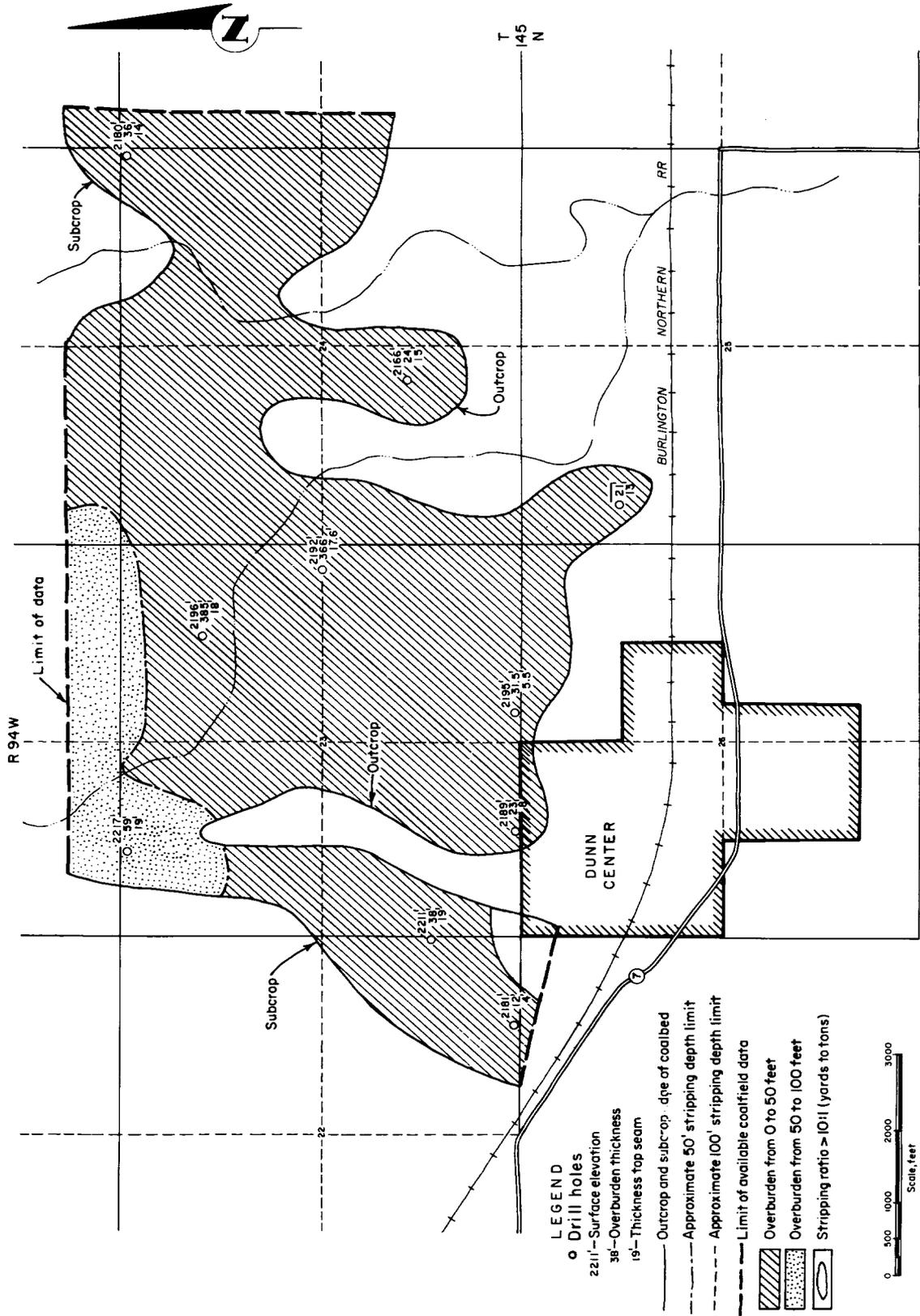


FIGURE 14. - Dunn Center Deposit, Dunn County. (Based on company data.)

Although no analyses are available on lignite in the Dunn Center deposit, an indication of its coal quality may be inferred from an average as-received analysis of lignite in Dunn County (9), which follows:

Analysis, percent					Btu
Moisture	Volatile	Fixed C	Ash	Sulfur	per lb
34.0	29.0	29.0	8.0	0.8	6,800

Dickinson Deposit (14)

The Dickinson lignite field is located in the area where the counties of Dunn, Stark, and Billings meet in southwestern North Dakota. Dickinson, the county seat of Stark County, and Belfield are the principal towns in the area. Belfield, on the southwestern edge of the field, and Dickinson on the southeastern edge, are both on U.S. Highway 10, which parallels the main line of the Burlington Northern Railroad (fig. 15). The topography of the field is characterized by gently rolling hills, and the relief seldom exceeds 300 feet.

The minable lignite in the Dickinson field is in the Tongue River Member of the Paleocene Fort Union Formation. Overlying the Fort Union Formation in several buttes that rise above the general surface is the basal sandstone of the Eocene Golden Valley Formation.

The Tongue River lignite beds range from a few inches to more than 30 feet in thickness. The thicker lignite beds have the greatest continuity over the area as a whole, but even these are subject to pinchout and wide variation in thickness.

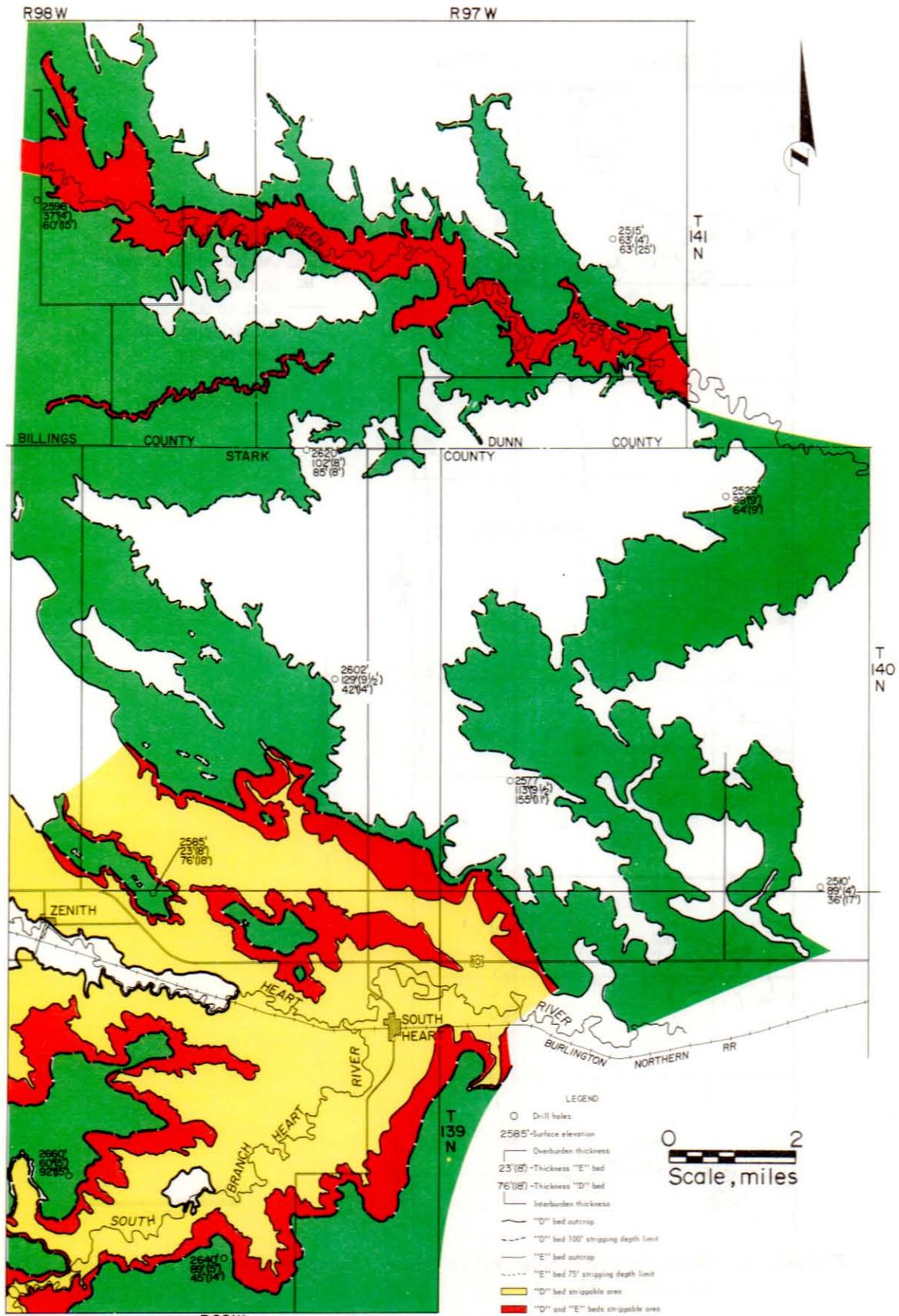
At least four and possibly as many as eight lignite beds occur in the Tongue River Member in the Dickinson field. It is probable that only two, the "D" and "E" beds, are present in sufficient thickness and aerial extent to have an economic potential. Strippable lignite reserves in the "D" and "E" beds, 9 to 18 feet thick, total about 798 million tons under less than 100 feet of overburden (18).

An average as-received analysis computed for the minable lignite within the general area of the Dickinson deposit is as follows (9):

Analysis, percent					Btu
Moisture	Volatile	Fixed C	Ash	Sulfur	per lb
38.9	26.8	26.6	7.7	1.0	6,280

Beach Deposit (15)

The Beach deposit, the North Dakota portion of a 1.3-billion-ton strip-pable lignite reserve straddling the North Dakota-Montana border (15), is estimated to contain 450 million tons under less than 120 feet of overburden (fig. 16). Beach, the county seat of Golden Valley County, N. Dak., is situated on the Burlington Northern Railroad, which bounds the coalfield on the east and north. Low relief and intensive cultivation of wheat characterize



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FIGURE 15. - Dickinson Deposit, Billings, Dunn, and Stark Counties.
 (Based on company data.)

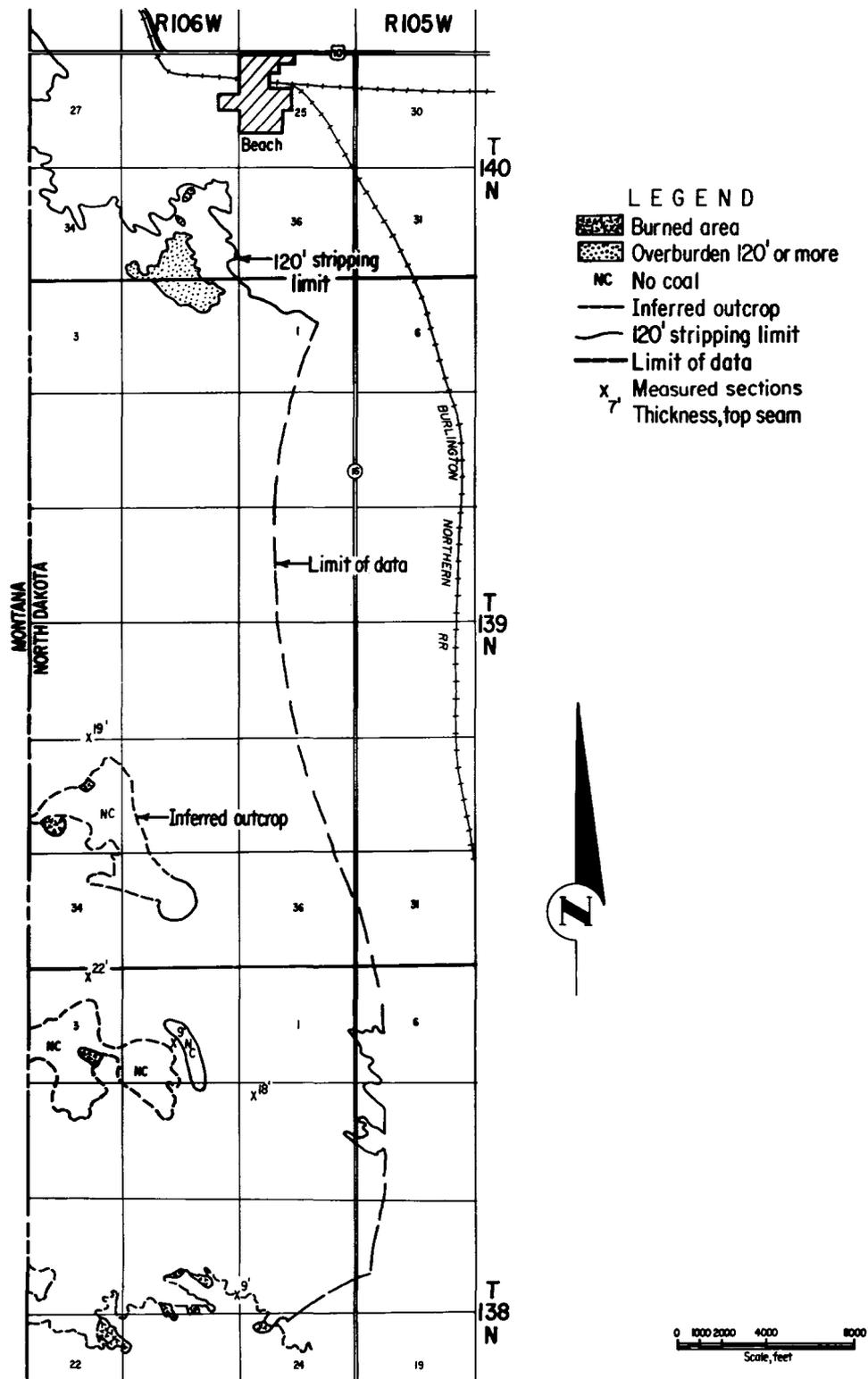


FIGURE 16. - Beach Deposit, Golden Valley County. (Adapted from plate 39, U.S. Geol. Survey Bull. 995-G.)

the countryside. The nearest dependable large water supply is 30 miles northwest of Beach at the Yellowstone River.

Of the several lignite seams identified in the coalfield, only the "C" bed of the Sentinel Butte Member of the Fort Union Formation is sufficiently well defined to permit the calculation of strippable reserves; the 450-million-ton reserve is exclusively in this seam. The "C" bed ranges in thickness from 9 to 40 feet, averaging 20 feet for the deposit. The point nearest to the Beach deposit where this seam has been sampled is at the Peplinski mine, one-half mile across the border in Montana. A typical as-received analysis is as follows (15):

Analysis, percent					Btu per lb
Moisture	Volatile	Fixed C	Ash	Sulfur	
41.0	24.8	26.3	7.9	0.9	6,050

Located southwest of the Williston Basin, the Beach deposit exhibits a regional dip of 1° to the northeast. Since no glaciation reached this far west, the overburden is made up entirely of Fort Union sediments, clay, shale, and an occasional lens of hard sandstone.

Bowman-Gascoyne Deposit (16)

The Bowman-Gascoyne lignite field includes five potentially strippable deposits covering parts of 20 townships in Slope and Bowman Counties (14). Bowman, the largest town in the area (population 1,300), is located on the Chicago, Milwaukee, St. Paul, and Pacific Railroad (The Milwaukee Road), which skirts the southern fringe of the coalfield. The gently rolling prairie land is well suited to agriculture, the dominant local industry. Apart from small wagon mines, the only extensive lignite mining has been at the Peerless strip mine, which in 1968 produced 131,000 tons. It is necessary to ship the lignite by rail to distant powerplants because the nearest large water supply is about 31 miles west of Bowman at the Little Missouri River.

Of the six deposits identified in Slope and Bowman Counties, only two are sufficiently well defined to permit strippable reserve estimation, the Bowman deposit (figs. 17-18) and the Gascoyne (or Scranton) deposit (fig. 19). Strip-pable reserves in both deposits were computed for the Harmon lignite bed of the Fort Union Formation. Although other potentially strippable seams are present in this coalfield, only the Harmon bed is known to persist in minable thickness and in blocks of commercial size. Strip-pable reserves in the Bowman deposit amount to 1,099 million tons, and the Gascoyne deposit contains a reserve of 273 million tons (14). Both reserves were computed where the Harmon bed exceeds 10 feet in thickness under less than 120 feet of overburden. The overburden is predominately clay and shale. A typical as-received analysis for lignite in the Harmon bed is the following, from the Peerless mine (21):

Analysis, percent					Btu per lb
Moisture	Volatile	Fixed C	Ash	Sulfur	
43.8	24.1	25.2	6.9	0.9	5,960

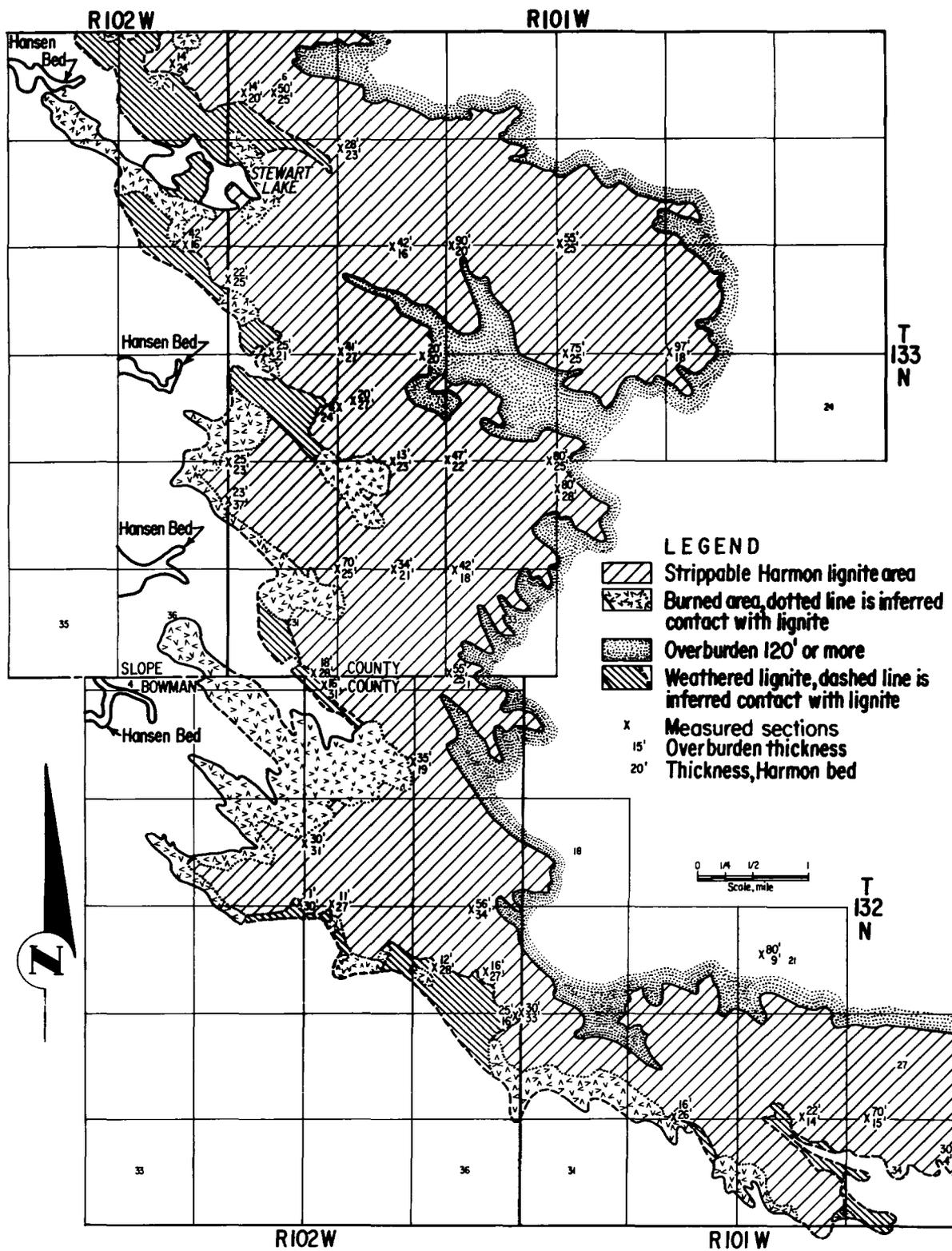


FIGURE 17. - Bowman Deposit (South), Bowman and Slope Counties. (Adapted from plates 16 and 18, U.S. Geol. Survey Bull. 1015-E and company data.)

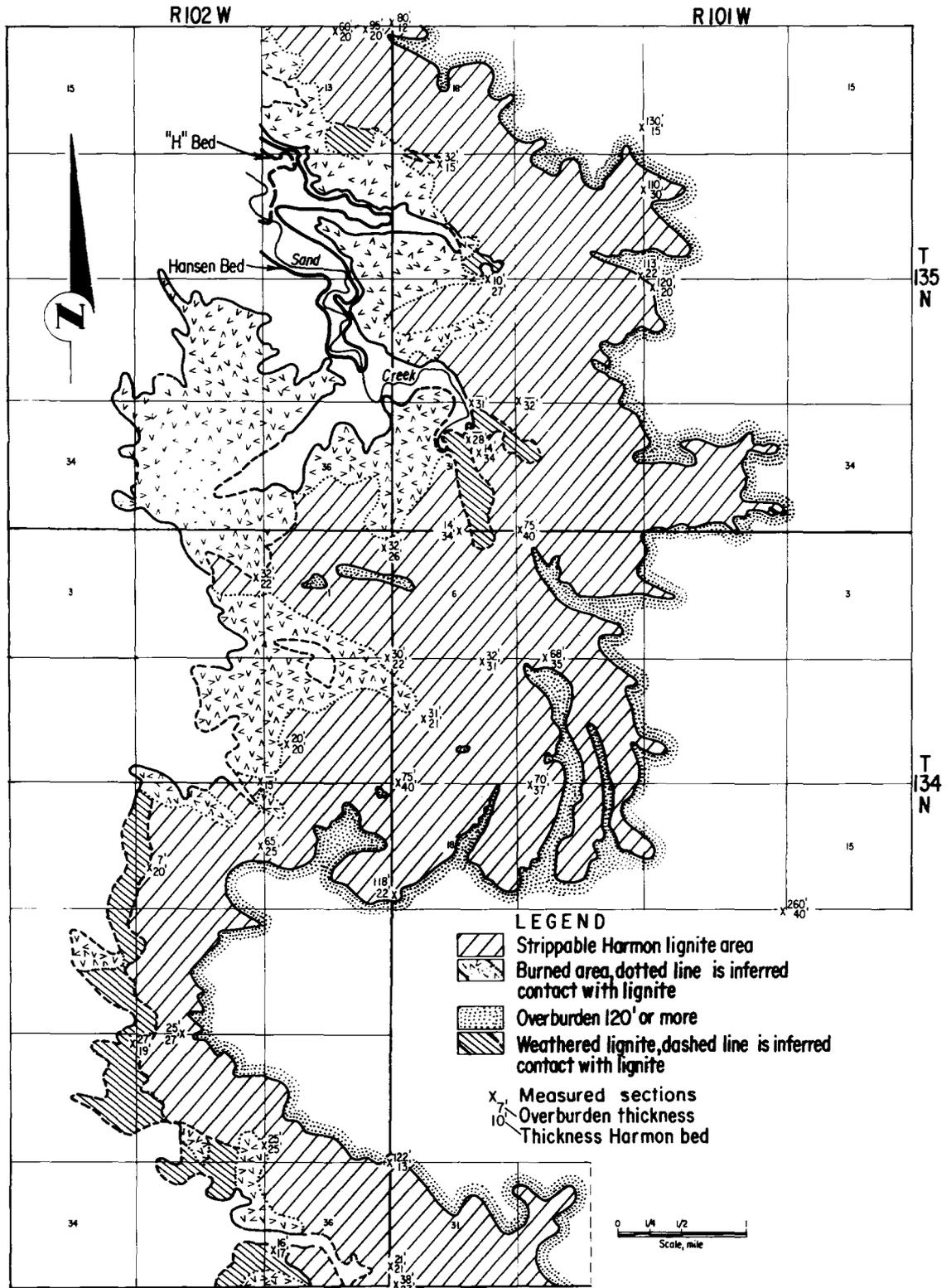


FIGURE 18. - Bowman Deposit (North), Slope County. (Adapted from plates 15 and 17, U.S. Geol. Survey Bull. 1015-E.)

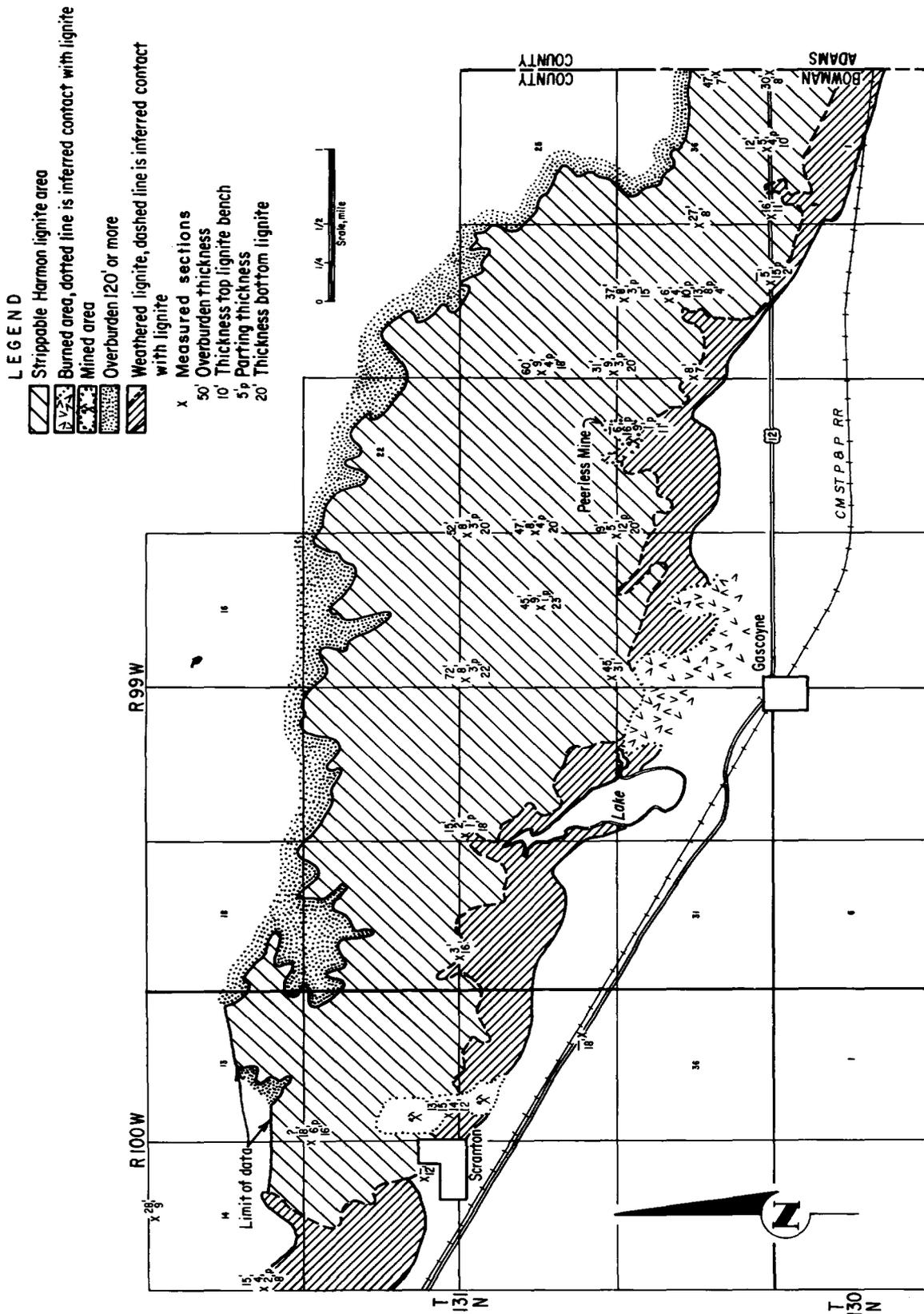


FIGURE 19. - Gascoyne Deposit, Bowman County. (Adapted from plate 19, U.S. Geol. Survey Bull. 1015-E.)

In addition to Bowman and Gascoyne, four outlying deposits in Slope County are estimated to contain a strippable reserve of 660 million tons (14). These deposits are described in the literature as "possible deposits of strip-pable lignite." Owing to the scarcity of data, the reserve tonnage has not been included in this report.

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