Strippable Lignite Deposits, Slope and Bowman Counties North Dakota

GEOLOGICAL SURVEY BULLETIN 1015-E

DEPARTMENT OF THE INTERIOR
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Strippable Lignite Deposits, Slope and Bowman Counties North Dakota

By ROY C. KEPFERLE *and* WILLIAM C. CULBERTSON

A CONTRIBUTION TO ECONOMIC GEOLOGY

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A description of two deposits that contain 1,370 million short tons of strippable lignite

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A CONTRIBUTION TO ECONOMIC GEOLOGY

STRIPPABLE LIGNITE DEPOSITS, SLOPE AND BOWMAN COUNTIES, NORTH DAKOTA

By Roy C. Kepferle and William C. Culbertson

ABSTRACT

Slope and Bowman Counties, N. Dak., include an area of about 2,450 square miles in the southeastern part of the Fort Union coal region of North Dakota, South Dakota, and Montana. In anticipation of a future increase in the demand for the low-rank coal of this region as a fuel for electric power plants and as a raw material for various chemical synthesizing processes, Slope and Bowman Counties were investigated for deposits of lignite that could be mined by large scale strip mining methods. All the lignite beds of economic importance in this area are in the Fort Union formation, particularly in the Tongue River member. The beds are nearly horizontal, dipping about 25 to 50 feet per mile north and northeast from the Cedar Creek anticline in the southwest corner of the area. The rocks overlying the lignite beds are generally incompetent and consist mainly of massive friable sandstone, shale, clay, and a few thin beds of fresh water limestone. At least 9 lignite beds in the Fort Union formation are known to attain a thickness of 5 feet, and the thickest and most extensive of these, the Harmon bed, attains a thickness of about 40 feet. Two large deposits in the Harmon bed, the Bowman deposit lying north of Bowman, N. Dak., and the Scranton deposit lying east of Scranton, N. Dak., are particularly well suited to mining by large scale strip mining methods. Two other deposits in the Harmon bed and one deposit in the Hansen and one in the T Cross bed are possibly suited to large scale strip mining.

The coal in the Bowman and Scranton deposits is a woody-textured dark-brown lignite, containing some impurities of pyrite and gypsum, but generally free of partings. On the "as received" basis the heating value is about 6,300 Btu, slightly less than the average for North Dakota lignites. The ash and sulfur content are fairly low and the moisture content is high. On exposure to air, the lignite loses moisture rapidly and slacks readily into small pieces. It is well suited to the manufacture of synthetic liquid fuels, ammonia, dyes and other chemicals.

Both the Bowman and the Scranton deposits lie beneath less than 120 feet of overburden. The reserves in the two deposits, in a bed averaging 24 feet thick,

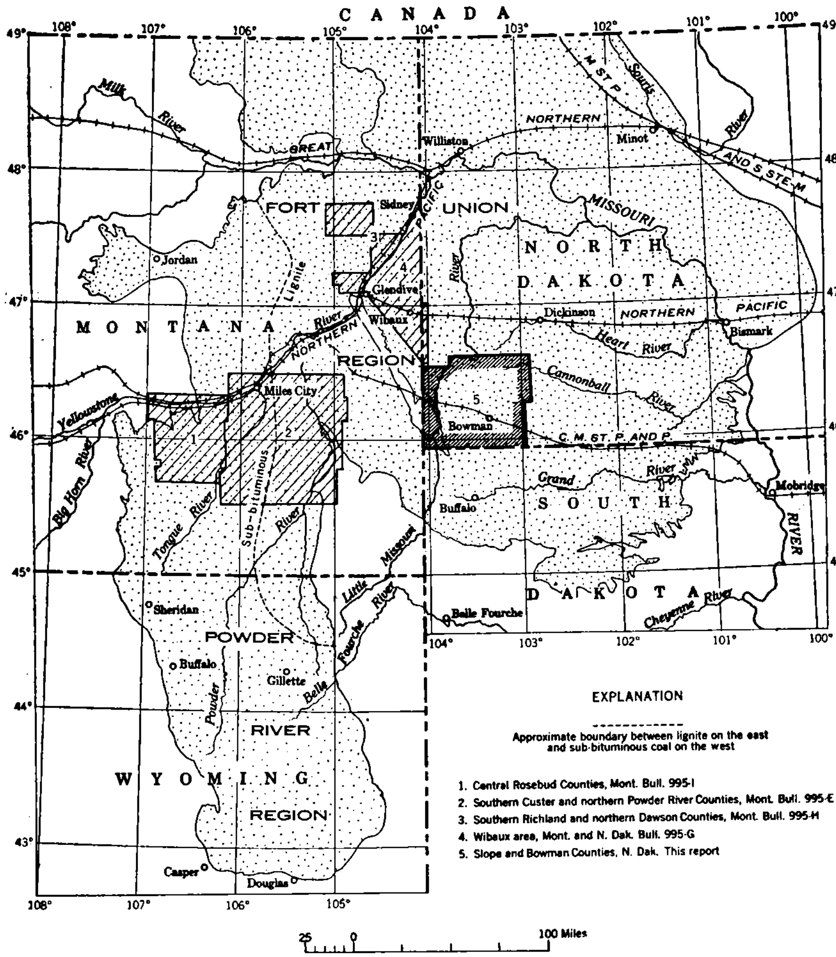

FIGURE 18.—Index map of the Fort Union-Powder River coal region, showing location of area described in this report, and the areas in eastern Montana in which deposits of strippable coal have been described in bulletins of the U. S. Geological Survey.

total about 1,370 million short tons of lignite, of which about 590 million tons are under less than 60 feet of overburden and can be recovered at a stripping ratio of about 1.7 to 1. The Bowman deposit contains 80 percent of all reserves. About 75 percent of the reserves under less than 60 feet of overburden are within half a mile of any point at which information about the thickness of the lignite was obtained, and all the reserves are in the indicated category of the reliability classification of coal reserves.

INTRODUCTION

As part of the program of the United States Department of the Interior for the integrated development of the Missouri River basin,

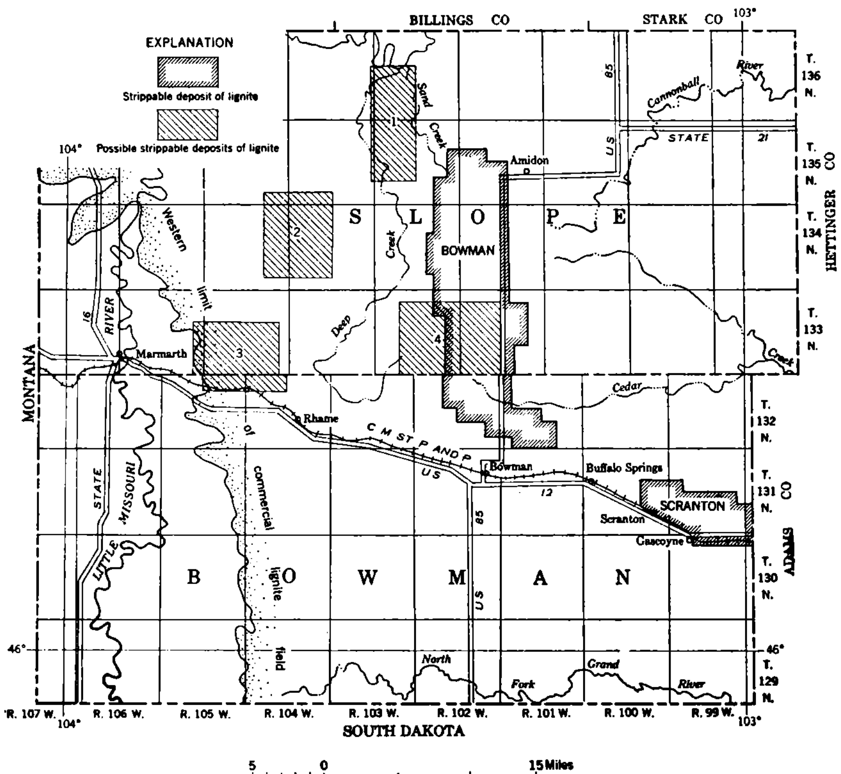

Figure 19.—Index map of Slope and Bowman Counties, N. Dak., showing location of deposits of lignite described in this report.

the United States Geological Survey is reinvestigating some of the coal-bearing areas of the Fort Union coal region (fig. 18) to find deposits of coal that are particularly well suited to recovery by large-scale strip-mining methods. This report describes in detail 2 deposits of strippable lignite in Slope and Bowman Counties, N. Dak., that contain a total of about 1,370 million short tons of lignite under less than 120 feet of overburden (table 1). It also outlines 4 other deposits that are potentially suited to strip mining and that contain additional reserves totaling about 600 million short tons (fig. 19). Slope and Bowman Counties lie in the southwestern corner of North Dakota and comprise an area of about 2,450 square miles. Other reports on strippable coal in the Fort Union coal region described areas in eastern Montana (Brown and others, 1954; Culbertson, 1954; Kepferle, 1954; and May, 1954).

TABLE 1.—*Thickness, strip ratio, extent, and indicated remaining reserves in Bowman and Scranton deposits, Slope and Bowman Counties, N. Dak., in millions of short tons*

Deposit	Less than 60 feet of overburden				60 to 90 feet of overburden				90 to 120 feet of overburden				Total			
	Average coal thickness (feet)	Strip ratio [1]	Acres	Remaining reserves	Average coal thickness (feet)	Strip ratio [1]	Acres	Remaining reserves	Average coal thickness (feet)	Strip ratio [1]	Acres	Remaining reserves	Average coal thickness (feet)	Strip ratio [1]	Acres	Remaining reserves
Bowman:																
Northern part	25	1.6:1	1,610	70	27	2.8:1	1,330	63	25	4.2:1	1,130	50	26	2.7:1	4,070	183
North-central part	26	1.5:1	2,360	107	29	2.6:1	1,650	83	30	3.4:1	2,040	109	28	2.4:1	6,050	299
South-central part	23	1.7:1	3,800	152	24	3.2:1	3,350	138	21	4.9:1	2,700	99	22	3.1:1	9,850	389
Southern part	23	1.6:1	3,090	126	24	3.0:1	1,340	58	24	4.3:1	1,050	44	24	2.5:1	5,480	228
Total or mean	24	1.6:1	10,860	455	26	3.0:1	7,670	342	25	4.3:1	6,920	302	25	2.7:1	25,450	1,099
Scranton	22	1.9:1	3,700	140	26	2.9:1	1,610	74	25	4.2:1	1,360	59	23	2.6:1	6,670	273
Total			14,560	595			9,280	416			8,280	361			32,120	1,372

[1] Ratio between thickness of overburden and thickness of lignite bed.

Strip-mining methods are particularly advantageous in mining coal in the Fort Union coal region, for this region contains many thick, continuous, and nearly horizontal beds of lignite at shallow depths, and the overburden is soft and easily removed. The trend in this region, as in the nation, has been towards the recovery of coal by strip mining rather than by underground mining. In the 25-year period from 1926 to 1951, for example, the production of lignite from strip mines in North Dakota increased from 37 percent of the national total to 92 percent (Tryon and others, 1926, p. 488; Young and others, 1952, p. 20). Since 1946 all mining in Slope and Bowman Counties has been by strip-mining methods. The primary reason for this trend is that less manpower and more machinery are used in strip mining than in underground mining, and it is correspondingly less expensive. In 1951, the North Dakota coal was produced at the rate of 23.30 tons per man day by strip mining as compared with 7.57 tons per man day for underground mining (Young and others, 1952, p. 67); in Montana the difference is even more striking, for coal was produced at the rate of 89.93 tons per man day for strip mines as compared with 6.83 tons per man day for underground mines. Another advantage of strip mining is its better recovery of coal. Because of the necessity for leaving large amounts of coal in roofs and pillars, only about 50 percent of a bed is usually recovered by underground mining (Averitt and Berryhill, 1950, p. 8), whereas in strip mining as much as 95 percent is recovered (W. V. Styles, 1951, superintendent of Foley Bros., Inc., mining company, at Colstrip, Mont., oral communication). Because of the conspicuous advantages of strip mining, future large-scale coal mining in this area probably will be by strip-mining methods.

PREVIOUS GEOLOGIC WORK

Although the occurrence of lignite along the Little Missouri River was mentioned in the literature as early as 1896 (Darton, 1896, p. 603–694), it was not until 1911 that a detailed investigation was made in this area. In 1911–12 the U. S. Geological Survey investigated that part of Slope and Bowman Counties west of and including R. 102 W. as part of the Marmarth lignite field and published a map of the lignite beds at the scale of 1: 126,720 (Hares, 1928). The North Dakota Geological Survey studied the lignite deposits of western North Dakota intermittently during the early 1900's, and in 1925 published a summary report that contained a section describing the lignite deposits of Slope and Bowman Counties (Leonard, 1925, p. 58–77). In preparing the present report the writers have drawn freely from these reports.

ACKNOWLEDGMENTS

Important information about the depth and thickness of the lignite beds was generously given by the following companies and individuals: Magnolia Petroleum Co. and the Shell Oil Co., who provided the logs of seismograph shotholes; Mr. T. Harris of the H and H Drilling Co., and Mr. W. Wagner, who furnished the logs of water wells that had been drilled in the area; Mr. B. Meggers, operator and co-owner of the Meggers Bros. mine, north of Rhame; Mr. T. Carignan, superintendent of the Knife River Coal Co.'s Peerless mine near Gascoyne; Gustav Helm of Helms Bros. Inc., the company that maintains the stripping operation at the Peerless mine; and W. M. Edmunds of Grand Forks; all permitted the use of drill-hole data in their possession. The staff of the area office of the U. S. Soil Conservation Service kindly allowed the use of their office facilities and aerial photographs. The hospitality and information given by the Harold Brooks family, the Roen brothers, and other farmers and ranchers in the area greatly aided the investigation. Robert L. McMurtrie, Alexander C. Burr, Alfred F. Traverse, and other members of the staff of the U. S. Bureau of Mines Lignite Research Laboratory at Grand Forks, N. Dak., freely furnished much valuable information about the composition and utilization of lignite.

The field work forming the basis of this report was done during the summer and fall of 1952 with the assistance of W. T. Arnesen.

GEOGRAPHY

SURFACE FEATURES

The area covered by this report is in the unglaciated Missouri Plateau section of the Great Plains physiographic province. The topography reflects the position of the area, for the western half has the dissected uplands of the western part of the Missouri Plateau and the eastern half has the nearly featureless plains of the eastern part of the plateau.

The conspicuous surface feature of the western part of the area is the valley of the Little Missouri River. The Little Missouri River flows northward through the area in a meandering channel that is from 100 to 200 feet below the old, nearly level surface of the adjacent countryside (Hares, 1928, p. 8). Many tributaries have dissected the adjacent rocks into a zone of badlands that extend several miles back from the river. The character of the badlands depends largely upon the kind of rocks in which they are cut. In western Bowman County, where the rocks are predominantly soft clayey sediments, the badlands consist of many low rounded hills and deep, vertical-sided gullies. In northwestern Slope County, where the sediments contain many hard strata, erosion has produced steep cliffs, pinnacles, narrow serrate ridges, and other weirdly shaped features that have made the badlands of the Little Missouri River the primary scenic attraction of North Dakota. In the eastern two-thirds of Slope and Bowman Counties, the surface is predominantly level to rolling, although somewhat hilly in the upper part of the Deep Creek drainage basin.

The most conspicuous surface features in this part of the area are the many buttes that project as much as 500 feet above the adjacent countryside; their tops are capped by layers of resistant rock, including clinker, ortho-quartzite, and sandstone. H T Butte, the largest and highest, is capped by a bed of massive sandstone. Its level top, 3,468 feet above sea level, is the highest point in North Dakota and dominates the central part of Slope County.

The total relief of the area, measured from the Little Missouri River in T. 136 N., R. 102 W., to the top of H T Butte, is about 1,070 feet. Throughout most of the area, however, the relief seldom exceeds 400 feet.

DRAINAGE AND WATER SUPPLY

The drainage of Slope and Bowman Counties is divided almost equally between the northward-flowing Little Missouri River, on the west, and the eastward-flowing Cannonball and Grand Rivers, on the east. All three are perennial streams and tributaries of the Missouri River. Runoff reaches these rivers from many creeks, which usually are dry except during heavy rains and during the spring thaw. Springs furnish a small but steady flow to parts of the larger creeks throughout the year. The area is well drained by these creeks; in fact, rain and melt water drain away so rapidly that many farmers have built small earthen dams in the creek beds to retain the water for the use of the livestock, and to check erosion. Several large dams that back up perennial lakes about half a square mile in area have been built to aid wildlife.

Immediate supplies of water in this area probably are not adequate for thermal electric power plants, synthetic liquid fuels plants or other potential industrial consumers of large amounts of lignite. The sandstone and lignite beds of the Fort Union formation furnish sufficient ground water for the needs of the farmers and ranchers in the area, but most of the towns are supplied from deep wells reaching the Fox Hills sandstone. All ground water, however, is so highly mineralized that it must be treated before being used in boilers. In a few places "black" water is obtained from shallow wells, the dark color presumably resulting from the flow of ground water through weathered lignite. The nearest large, reliable supplies of water are

TABLE 2.—*Monthly and annual runoff in acre-feet of three rivers at selected gaging stations*

[Adapted from U. S. Geological Survey Water-Supply Papers]

Water year	Little Missouri River at Marmarth, N. Dak.				Missouri River at Mobridge, S. Dak.				Yellowstone River at Miles City, Mont.			
	Monthly			Annual	Monthly			Annual	Monthly			Annual
	Maximum [1]	Minimum [2]	Mean		Maximum [3]	Minimum [4]	Mean		Maximum [3]	Minimum [4]	Mean	
1939–40	29,600	0	11,000	131,900	1,750,000	207,900	802,000	9,623,000	1,488,000	142,800	421,000	5,052,000
1940–41	159,500	0	23,200	278,900	2,474,000	325,300	986,000	11,830,000	1,521,000	219,700	546,000	6,555,000
1941–42	58,570	12	16,590	199,060	3,305,000	336,400	1,220,000	14,640,000	2,415,000	282,700	786,000	9,430,000
1942–43	119,200	719	26,300	315,500	4,405,000	320,300	1,848,000	22,180,000	3,339,000	256,900	1,005,000	12,060,000
1943–44	300,700	0	54,780	657,370	4,799,000	705,100	1,816,000	21,790,000	3,485,000	231,000	839,000	10,070,000
1944–45	140,900	60	16,600	199,000	2,521,000	707,800	1,403,000	16,840,000	2,390,000	242,500	740,000	8,879,000
1945–46	81,670	309	14,500	173,900	2,122,000	419,300	1,151,000	13,810,000	2,051,000	286,800	654,000	7,842,000
1946–47	170,100	877	41,100	493,700	3,785,000	480,200	1,833,000	21,990,000	2,453,000	186,200	822,000	9,860,000
1947–48	92,090	379	18,800	225,300	3,882,000	548,800	1,906,000	22,870,000	3,467,000	253,400	865,000	10,380,000
1948–49	217,200	0	26,200	314,100	3,371,000	505,200	1,616,000	19,390,000	2,097,000	182,500	629,000	7,544,000

[1] Maximum monthly runoff usually occurs in March, but in some years as late as in July.
[2] Minimum monthly runoff usually occurs in January, but discharge in fall months is also low.
[3] Maximum monthly runoff usually occurs in June.
[4] Minimum monthly runoff usually occurs in December, January, or February.

the Missouri River at Mobridge, S. Dak., and the Yellowstone River at Fallon, Mont. Mobridge is about 170 miles east of Bowman, N. Dak., and Fallon is about 115 miles west. During the period 1939–49 the Missouri River at Mobridge had an average annual runoff of about 17,500,000 acre-feet (table 2), while the Yellowstone River at Miles City, Mont.—the gaging station nearest Fallon—had an average annual runoff of 8,767,000 acre-feet. The only large source of water within the area is the Little Missouri River. During the 10-year period from 1939 to 1949 the annual runoff averaged about 300,000 acre-feet, but runoff is so variable from year to year and during the year that the river would have to be dammed to assure a continuous supply.

CLIMATE

The climate of Slope and Bowman Counties is semiarid. The average annual precipitation is about 15 inches; 70 percent falls as rain from April to September, and the rest as snow during the other months. The precipitation is variable, however, and drouths are sometimes severe. Summer is a relatively pleasant time of year in this area, for, although the daytime temperatures sometimes exceed 100° F., the humidity is low and the nights are usually cool. Winter is a time of extreme cold. Although the winter is milder in this area than that of the rest of North Dakota—January temperatures average 14° F. compared to a State average of 7° F.—temperatures of −30° F. and lower are often recorded. Heavy snows are uncommon, but each year one or two blizzards—violent storms combining high winds, snow, and low temperatures—can be expected to stall traffic and endanger the lives of any who venture out in them. The growing season is short; killing frosts can be expected as late in the spring as the middle of May, and as early in the fall as the middle of September.

SETTLEMENT AND LAND USE

According to the 1950 census, the combined population of Slope and Bowman Counties is 6,316. Bowman, the county seat of Bowman County, is the largest of the incorporated towns, having a population of 1,382. The other incorporated towns are Marmarth (469), Scranton (360), Rhame (340), Amidon (82), and Gascoyne (76). With the exception of Amidon, the county seat of Slope County, these towns are all located on the main line of the Chicago, Milwaukee, St. Paul, and Pacific Railroad, and on U. S. Highway 12. The townspeople constitute only 43 percent of the population; the others live on farms and ranches and are settled mostly throughout the central and eastern parts of the area; the western part is very sparsely settled. Exclusive of the towns, the population density is 1½ persons per square mile.

In the early days of settlement the land was used only for raising cattle, horses, and sheep, and the grass proved to be well suited to this purpose. With the coming of the railroad in 1907, however, large numbers of homesteaders moved in and started to raise wheat and other crops on most of the arable land. Eventually most of the farms reverted to grassland. In 1940, only about 25 percent of the land was cultivated. The subsequent high crop prices, however, again focussed interest on the raising of grain. Cultivated acreage was increased until at present (1952) about 60 percent of the central and eastern part of the area is devoted to the raising of grain, principally wheat. In the western part of the area—mostly badlands—livestock raising is still the principal industry.

TRANSPORTATION

The only railroad within Slope and Bowman Counties is the main line of the Chicago, Milwaukee, St. Paul, and Pacific Railroad. This line connects the area with Mobridge and Aberdeen, S. Dak., on the east, and with Miles City, Mont., by way of Terry, Mont., on the west.

The two main roads are U. S. Highways 12 and 85. U. S. 12 is an all-weather paved road that crosses the area from east to west, paralleling the railroad. U. S. Highway 85 is paved only from the northern border of Slope County to Amidon, elsewhere it is gravelled. U. S. 85 extends south from Belfield, N. Dak., passes through Amidon and Bowman, and continues on to the Black Hills. North Dakota State Route 21, which is paved in part, leads east from U. S. 85 to New England, N. Dak. On the west side of the Little Missouri, the only north-south road of any consequence is gravelled North Dakota State Route 16, which connects with U. S. 10 to the north at Beach, N. Dak. With the exception of these roads the ease of travel within the area depends largely on the topography. The badlands area of the Little Missouri River, which comprises the western quarter of Bowman County and the northwestern half of Slope County, contains only a few scattered roads, usually of poor quality. The uplands area, on the other hand, which makes up the rest of Slope and Bowman Counties, contains roads on nearly every section line. Some of these roads are clinker or gravel surfaced, although most are merely graded or unimproved. Travel by car is possible almost anywhere on the uplands area in dry weather; in wet weather only the surfaced roads are passable.

ELECTRIC POWER

Electric power for this area is furnished by means of a line extending from Mobridge, S. Dak., roughly paralleling U. S. Highway 12 through Hettinger, Gascoyne, Bowman, and Marmarth, N. Dak., to Baker, Mont. This line is a 44,000 volt transmission line between

Hetttinger and Baker. Power is furnished by steam electric plants operated by the Montana-Dakota Utilities Co. at Mobridge, S. Dak., and Bismarck, N. Dak. A connection with a line from Fort Peck, Mont., is made by a line extending from Baker to Glendive, Mont. Future plans include a connection of this network with the power supplied by the Garrison Dam project in N. Dak. Rural domestic consumers of power in Slope and Bowman Counties are supplied by local electric cooperatives, which in turn are furnished by the Montana-Dakota Utilities Co. line.

LAND OWNERSHIP

All the land in Slope and Bowman Counties originally belonged to the Federal Government. Sections 16 and 36 of every township in the State of North Dakota were set aside as school lands, and practically all the rest of the land passed into private ownership. Much of the school land has since been sold to private interests. In the late 1930's the Federal Government commenced buying submarginal farm land for soil conservation purposes, and now owns about 160,000 acres, nearly all in Slope County. The surface rights of nearly all the land overlying the strippable deposits are now in private hands.

Before 1950 the coal rights in this area belonged to individual farmers, to coal mining companies, and, in small part, the Federal Government. Since the discovery of oil in commercial amounts in North Dakota in 1951, however, there has been much selling and leasing of mineral rights. Some of the leases specify only oil and gas rights, but many of them include coal rights as well.

STRATIGRAPHY

The rocks that crop out in Slope and Bowman Counties, N. Dak., comprise the Pierre shale, the Fox Hills sandstone, and the Hell Creek formation of Late Cretaceous age; the Fort Union formation of Paleocene age; the White River formation (undifferentiated) of Oligocene age; and terrace deposits and alluvium of Pleistocene and Recent age (Benson, 1952). The Pierre shale is a dark-gray or tan marine shale; the uppermost 400 feet is exposed in the extreme western part of Bowman County along the crest of the Cedar Creek anticline. The Fox Hills sandstone rests conformably on the Pierre shale and is exposed along the flanks of the anticline in western Bowman County, and southwestern Slope County. The Fox Hills sandstone consists of 40 to 85 feet of light-brown concretionary, marine sandstone, which grades upward into a light-gray sandstone, 15 to 45 feet thick, that is equivalent to the Colgate member of the Fox Hills sandstone of eastern Montana (W. E. Benson, U. S. Geological Survey, written communication, 1954). The Hell Creek formation, the uppermost Upper Cre-

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taceous formation in this area, is nonmarine in origin and unconformably overlies the Fox Hills formation. It consists of about 575 feet of alternating dark-gray and brown sandstones, shales, bentonitic clay, and—in the lower 200 feet—thin, impure lignite beds. The Hell Creek formation crops out in a narrow strip along the Little Missouri River in the western part of Bowman and the southwestern part of Slope Counties, and forms the badlands in that area.

FORT UNION FORMATION

Rocks of the Fort Union formation crop out over nearly four-fifths of the area of Slope and Bowman Counties. The Fort Union formation in this area is comprised of the Ludlow, Tongue River, and Sentinel Butte members, and has a total thickness of about 1,200 feet.

LUDLOW MEMBER

The Ludlow member of the Fort Union formation consists of dark shale, slightly indurated sandstone, and many thin lignite beds. It overlies the Hell Creek formation conformably and is distinguished from the upper part of the Hell Creek by the absence of fossils of the dinosaur *Triceratops*, by the presence of a Tertiary flora, and by the presence of lignite beds. The base of the Ludlow member is marked in many places by the Cannonball lignite bed, the lowest persistent lignite bed in the area, about 60 feet stratigraphically below the T Cross bed. The outcrop of the Ludlow is a sinuous band about 10 miles wide and extends from southern Golden Valley County southward through northwestern Slope County to southern Bowman County and thence eastward to Adams County. This band of outcrop is generally characterized by low, rolling hills, though buttes are formed locally where a resistant bed of the overlying Tongue River member has prevented the erosion of the softer Ludlow member. The base of the Ludlow coincides with the western limit of commercial lignite shown on the index map (fig. 19). The Ludlow is equivalent to the Tullock and Lebo shale members of the Fort Union formation in eastern Montana, and to the Cannonball formation with which it interfingers to the east in Adams, Grant, and Sioux Counties, N. Dak. One finger of the Cannonball formation crops out along the Grand River and its tributaries in the southeastern corner of Bowman County and two tongues of Cannonball are exposed along the Little Missouri River near Yule. The total thickness of the Ludlow member in Bowman County is about 250 feet.

TONGUE RIVER MEMBER

The Tongue River member in Slope and Bowman Counties comprises 400 to 600 feet of light gray clay and shale, which generally weathers to yellow or buff; gray to buff sandy shale and siltstone; fine- to medium-grained massive to crossbedded calcareous sandstone; thick persistent lignite beds; and a few thin fresh-water limestone lenses. Locally, a massive buff conglomeratic channel sandstone forms the base of the Tongue River member, but this apparently only marks a local unconformity at the top of the underlying Ludlow member. It is difficult to distinguish between clay and shale in the sediments of the Tongue River member inasmuch as the two are gradational. The shale is generally as incompetent as the clay, and the property of fissibility in the shale is obscure.

Where adjacent to the lignite beds, the clays and shales commonly contain well formed crystals of gypsum. Nodules of an iron sulfide, probably marcasite, are also common, as are small limonite concretions, some of which may result from the oxidation of the marcasite nodules. Impressions of leaves and other plant remains are numerous in the sediments of the Tongue River member. At several localities, of which the best known is atop the Twin Buttes a mile north of Bowman, casts of plant stems are preserved in a hard flaggy quartzite (Hares, 1928, p. 34–36). Fossils of several invertebrates and plants have been collected from this member in Slope and Bowman Counties (Hares, 1928, p. 37–39). Numerous fossils of fresh-water mollusks were found in a small knoll about 30 feet above the inferred outcrop of the Harmon lignite bed along the section line in the SE¼SW¼ sec. 34, T. 132 N., R. 101 W.

The Tongue River member can be distinguished from the overlying Sentinel Butte shale member and the underlying Ludlow member by a lighter color, a greater percentage of sandy sediments and lignite beds, and by scattered red clinker beds formed by the baking of the rocks during the burning of the underlying lignite beds.

SENTINEL BUTTE SHALE MEMBER

The Sentinel Butte shale member of the Fort Union formation comformably overlies and is gradational with the Tongue River member (Brown, 1948, p. 1265–1274). It consists mainly of dark sandy shale and clayey sandstone that contains many concretions and dark-brown ferruginous nodules. It also contains a few lignite beds, which locally attain minable thickness. It is as much as 350 feet thick in Slope County, where it is exposed around the base of H T Butte and the uplands to the east. In Slope County the contact between the Sentinel Butte shale member and the underlying Tongue River member is placed at the base of the H T Butte lignite bed—the highest persistent lignite bed in the area. The Sentinel Butte shale is the uppermost member of the Fort Union formation and is overlain unconformably by a massive sandstone of the White River formation.

Fossil bones were found by the writers in the Sentinel Butte shale about 15 feet below the contact with the White River formation in the SE¼SE¼ sec. 15, T. 134 N., R. 101 W., Slope County, N. Dak. These bones tentatively have been identified as remains of a fresh-water reptile, *Champsosaurus*, by J. R. Macdonald, curator of vertebrate paleontology at the museum of the South Dakota School of Mines and Technology (oral communication, 1954).

WHITE RIVER FORMATION

The White River formation is of Oligocene age, and consists mainly of white calcareous sandstones and shales, bentonite, and a few bentonitic clays (Clarke, 1948, p. 8–10, and Leonard, 1922, p. 218–222). The sandstone is locally conglomeratic and contains pebbles from 2 to 3 inches in diameter. These sediments total about 300 feet in thickness south of Amidon in the Chalky Buttes and in White Butte where they are best exposed. Remnants of White River sediments also lie atop Medicine Pole Hills in Bowman County and East and West Rainy Buttes in Slope County.

As described by Hares (1928, p. 40–41), the White River formation includes a basal massive, resistant, medium-grained unfossiliferous sandstone composed of quartz grains cemented by calcium carbonate and including small amounts of muscovite. This sandstone is 60 to 80 feet thick on H T Butte and presumably is the same sandstone that caps the Rainy Buttes about 20 miles northeast of H T Butte. The sandstone weathers to yellow brown and the exposed surface is locally pockmarked by differential erosion. Hares (1928, p. 41) classed this sandstone as Oligocene(?) because of the

"* * * striking contrast of its lithology with that of the underlying rocks; because of a probable erosional unconformity at its base suggested by marked local irregularities of thickness of the Sentinel Butte shale; and because of the apparent conformability of the sandstone with the normal White River Oligocene deposits that overlie it in White Butte, 6 miles southeast of H T Butte, and also in Sentinel Butte, in T. 139 N., R. 104 W. Fragments of white calcareous rock resembling normal White River material are present on the top of Bullion Butte, which is capped by the massive sandstone under discussion."

According to W. E. Benson (written communication, 1954), this same bed on Medicine Pole Hills in Bowman County and on West Rainy Butte in Slope County contains a fauna representative of the lower White River formation and is Chadron in age. On an eastern outlier of the Chalky Buttes in the NE¼SW¼ sec. 31, T. 134 N., R. 100 W., a fauna of late Oligocene age was collected in 1953 by J. R. Gill and R. C. Kepferle, and identified by Jean Hough of the Paleontology and Stratigraphy Branch. The beds containing the fauna correlate with the Brule formation in South Dakota and Nebraska.

TERRACE DEPOSITS AND RECENT ALLUVIUM

Gravel deposits lie in terrace remnants along the uplands bordering the Little Missouri River and its larger tributaries, such as Deep Creek and Sand Creek, and also along some of the eastward-flowing streams of the area. Some of the higher terrace remnants may be of Tertiary age, but most are of Quaternary age. These terraces are composed of pebbles of igneous rocks and clinker. They also contain a few bones, which probably were derived from the reworking of sediments of the White River formation. The deposits attain a thickness of at least 20 feet.

Alluvium of Recent age is present along the valleys of most of the creeks and rivers in the area, attaining a thickness of at least 20 feet in the flood plain of the Little Missouri River. This alluvium consists mainly of fine silt, clay, and sand, and locally contains gravel.

STRUCTURE

Slope and Bowman Counties lie on the southwestern flank of the Williston structural basin and are crossed in the extreme west by the Cedar Creek anticline, also called the Glendive anticline and the Baker-Glendive anticline, which extends N. 30° W. from near the northwestern corner of South Dakota to Glendive, Mont. Petroleum is being produced from the Montana part of this anticline; in the North Dakota part, wells have produced gas in western Bowman County, but as yet no oil has been found. The Cedar Creek anticline is asymmetrical. On the west flank the strata dip southwestward from 5° to 20°, and on the east flank, dip generally northeastward at about 3°. Eastward from the anticline, the strata are more nearly horizontal, and within the lignite-bearing area of Slope and Bowman Counties the regional dip is from 25 to 50 feet per mile northeastward and northward. Minor undulations of the strata cause local changes in the regional dip.

Although aerial photographs show what appears to be a fault scar on the west end of H T Butte in secs. 23 and 26, T. 134 N., R. 102 W., this evidence could not be corroborated during a cursory field examination of the locality, and no indication of faulting was found elsewhere in the area.

LIGNITE

PHYSICAL AND CHEMICAL CHARACTERISTICS

Fresh lignite in Slope and Bowman Counties is dark brown and has a brownish streak. A large part of it has a pronounced woody texture, and is exceedingly tough and resilient. When mined the lignite tends to break into irregular elongate or slablike pieces parallel to the bedding. Examination of the cross section of a bed at a fresh exposure shows that the lignite consists of alternating elongate, roughly parallel lenses of previtrain and attrital lignite with a few thin layers of black fusain. The previtrain, or woody textured, lenses usually range from a fraction of an inch to about 6 inches in thickness and are a few inches to several feet long. The lignite in places contains impurities: pyrite as fracture fillings or as desseminated masses (known as "sulfur balls"); gypsum as fracture fillings; clay in layers; and, rarely, silicified wood.

When the lignite is exposed to air, it loses moisture rapidly, cracks, and gradually breaks into small fragments. This characteristic of lignite, which is called slacking, is a disadvantage for those users who prefer lump lignite, but does not necessarily affect its industrial utility for those who use finely ground and pea-sized lignite.

Another important characteristic of lignite is the tendency to ignite spontaneously when stored in loose piles for long periods. Under these conditions, the heat generated by the oxidation of the small particles accumulates until the lignite becomes so hot that it starts smouldering, and it may eventually break into flame. The present practice of the railroads in North Dakota is to ship the lignite in open cars, for the lignite practically never catches fire during the few weeks that it is in the car. Lignite will not ignite spontaneously unless a good supply of oxygen is available. When lignite is to be stored for many months or years, the best method is to grind it into small sizes, and then place it in a pile layer by layer, compacting each layer as it is laid down. Other methods of storing lignite are to store it under water, in open pits, or in piles covered by road tar.

Analyses of 10 samples of the lignite in Slope and Bowman Counties are given in Table 3. Of these, nos. 10218, 10217, A45696, A45697, A45698, and D73701 are analyses of samples of the Harmon lignite bed taken from mines in the 2 strippable deposits described in this report. These 6 analyses show that the Harmon lignite in the deposits has an average heating value of about 6,300 Btu and an average moisture content of 42 percent, both on the "as received" basis—the as received basis being the equivalent of freshly mined lignite. This heating value is slightly less than the average of North Dakota lignites, and the moisture content is somewhat greater. The ash and sulfur content of the lignite is fairly low. The ash is of medium fusibility, for all the samples tested softened in the from 2200° F to 2600° F temperature range. Lignite is more reactive chemically than the higher rank coals and is well suited to the various processes for producing synthetic liquid fuels and other chemicals.

TABLE 3.—***Analyses of lignite from Slope and Bowman Counties, N. Dak.***

[By U. S. Bureau of Mines except where noted]

Type of sample: Dc, core sample from drill hole; M, sample from mine face; T, sample from tipple; Condition of sample: A, as received; B, moisture free; C, moisture and ash free.

Sample no. and date of analysis	Name and location of mine or prospect	Name and stratigraphic position of lignite bed	Type of sample	Condition of sample	Proximate analysis				Ultimate analysis					Heating value Btu
					Moisture	Volatile matter	Fixed carbon	Ash	Sulfur	Hydrogen	Carbon	Nitrogen	Oxygen	
D-68871 (1951)	Drill hole in NE¼NW¼ sec. 2, T. 130 N., R. 104 W., Bowman Co.	Harmon(?) bed, Tongue River member.	Dc	A	41.0	26.2	22.5	10.3	2.2	6.8	34.6	0.5	45.6	5,860
				B	--------	44.4	38.2	17.4	3.8	3.7	58.6	.9	15.6	9,930
				C	--------	53.8	46.2	--------	4.6	4.5	71.0	1.1	18.8	12,020
14857 (1912)	Durkin prospect, SW¼ sec. 34, T. 130 N., R. 103 W., Bowman Co.	T Cross bed, Ludlow member.	M	A	43.6	23.2	27.0	6.2	.7	--------	--------	--------	--------	5,830
				B	--------	41.2	47.8	11.0	1.2	--------	--------	--------	--------	10,340
[1] 10218 (1934)	Hallenbeck mine, sec. 1, T. 133 N., R. 102 W., Slope Co.	Harmon bed; Tongue River member.	M	A	42.5	27.2	24.0	6.3	1.4	--------	--------	--------	--------	5,952
[1] 10306 (1934)	Langer mine, sec. 12, T. 135 N., R. 101 W., Slope Co.	Unnamed bed (possibly H T Butte bed), Sentinel Butte shale member.	M	A	44.4	25.2	23.7	6.7	1.8	--------	--------	--------	--------	5,683
A-45696 (1928)	Halleck mine, SE¼ sec. 15, T. 132 N., R. 102 W., Bowman Co.	Harmon bed, Tongue River member.	M	A	41.1	25.6	27.5	5.8	.7	7.4	38.6	.6	46.9	6,680
				B	--------	43.5	46.7	9.8	1.3	4.8	65.6	1.0	17.5	11,330
				C	--------	48.2	51.8	--------	1.4	5.3	72.6	1.1	19.6	12,560
[1] 10217 (1934)	Bowman mine, sec. 14, T. 132 N., R. 102 W., Bowman Co.	do	M	A	43.0	27.3	25.3	4.4	.6	--------	--------	--------	--------	5,915
-------- (1946)	Twin Buttes mine, sec. 2, T. 131 N., R. 102 W., Bowman Co.	do	T	A	48.3	--------	--------	--------	--------	--------	--------	--------	--------	5,660
				B	--------	46.5	43.0	10.5	1.7	4.5	63.9	.9	18.5	10,940
A-45697 (1928)	Scranton Mine, SW¼ sec. 24, T. 131 N., R. 100 W., Bowman Co.	Harmon bed (upper bench), Tongue River member.	M	A	41.2	24.8	26.9	7.1	1.4	7.2	37.8	.6	45.9	6,510
				B	--------	42.2	45.8	12.0	2.4	4.5	64.3	1.0	15.8	11,070
				C	--------	47.9	52.1	--------	2.8	5.1	73.1	1.1	17.9	12,580
A-45698 (1928)	Buffalo Creek mine, SW¼ sec. 25, T. 131 N., R. 100 W., Bowman Co.	Harmon bed (lower bench), Tongue River member.	M	A	39.2	24.2	28.7	7.9	1.2	7.0	38.2	.6	45.1	6,620
				B	--------	39.8	47.3	12.9	2.0	4.3	62.9	.9	17.0	10,880
				C	--------	45.8	54.2	--------	2.3	5.0	72.2	1.1	19.4	12,500
D-73701 (1951)	Peerless mine, sec. 34, T. 131 N., R. 99 W., Bowman Co.	do	T	A	43.1	24.5	25.3	7.1	.8	--------	--------	--------	--------	6,110
				B	--------	43.0	44.6	12.4	1.4	--------	--------	--------	--------	10,740
				C	--------	49.1	50.9	--------	1.6	--------	--------	--------	--------	12,270

[1] Circular 8, University of North Dakota College of Engineering, 1934.

LEONARDITE

Leonardite is a colloidal material that can be extracted from weathered lignite by alkaline solutions. It is used in making wood stain and dye, and, having the property of swelling and forming a gel, as a stabilizing agent in well-drilling fluid. Weathered lignite has been mined intermittently since 1942 from pits at locations 62, 64, and 70 (pl. 16) and at the Peerless mine (location 93, pl. 19) and used for the extraction of this material.

Leonardite was named and described by Dove (1926, p. 33). It is a waxlike, black or brown, shiny, vitreous material formed by the oxidation of lignite, particularly the previtrain layers. Lavine (1939, p. 157) also attributes leonardite to humus materials of lignite that are changed by progressive oxidation to an alkali soluble form.

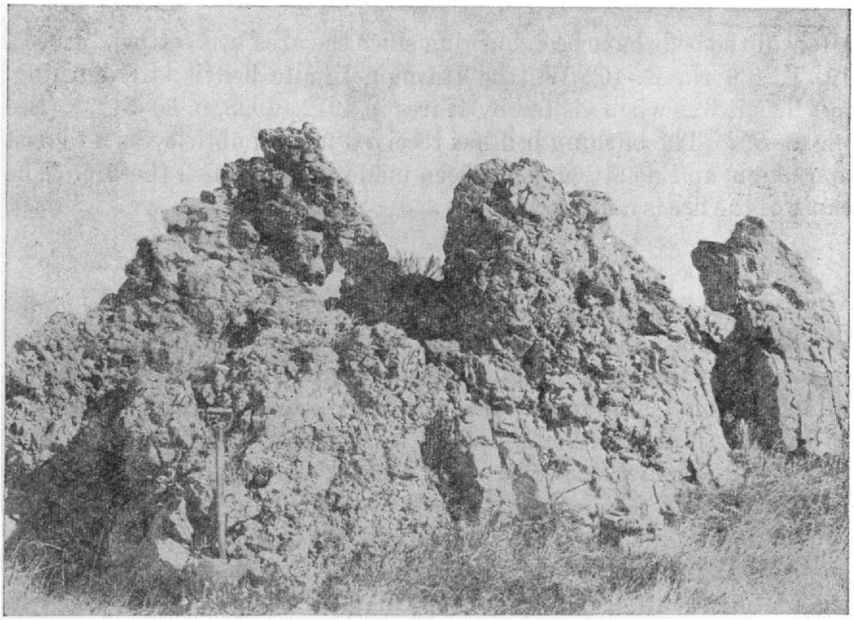
In the localities from which leonardite is mined, the lignite has been weathered under thin overburden, possibly by means of water percolating downward from the surface. At none of these localities was the leonardite seen in the form described by Dove, probably because it is disseminated throughout the lignite. Leonardite can be concentrated by solution and redeposition, and the waxlike, shiny, vitreous material described by Dove is probably leonardite that has been formed in this manner. At present, not enough is known about the environment under which it is formed to enable the ready location of minable quantities by means of surface exploration. The most likely localities are in the areas marked on the deposit maps as "Harmon lignite inferred to be weathered or partly weathered."

CLINKER AND ITS RELATION TO LIGNITE

The term clinker includes all the several types of rock that have been changed from their original composition, texture, or appearance by the heat of gases given off by the subsurface burning of coal beds. In Slope and Bowman Counties the clinker—locally called "scoria"—generally in the form of reddish fissile shale, is notably more indurated than the unaltered shale of the Fort Union formation. Locally, the original clay, sandstone, or shale of the overburden has been completely fused to form a brittle, resistant rock that now is exposed in huge, irregular masses (pl. 12–*A*) along the former outcrops of a few of the thicker lignite beds.

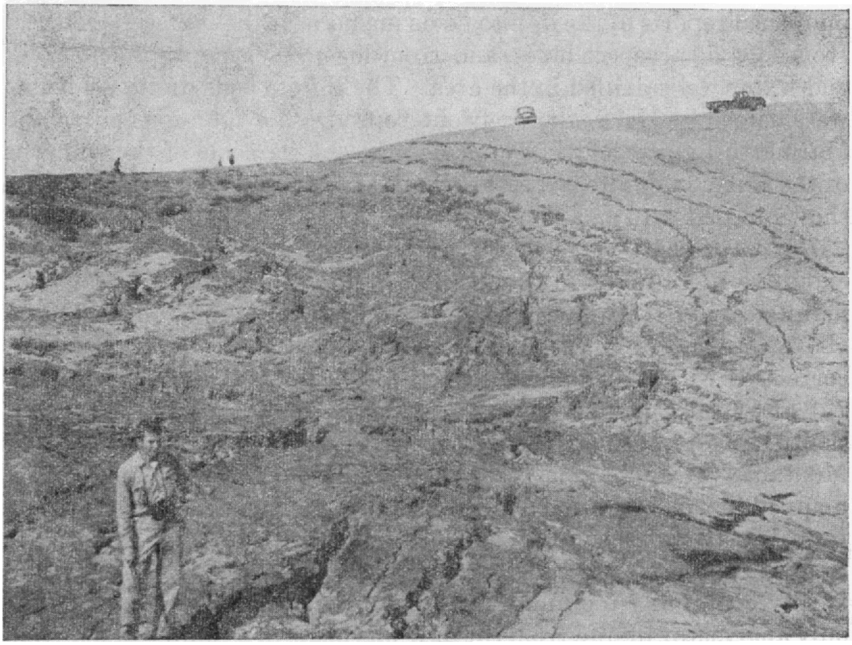
Some of the more brittle pieces of clinker were fashioned into knives, arrowheads and other implements by Indians who once roamed this region. The present use of clinker is all-weather-road surfacing in areas in which gravel is not readily available.

Although most of the burning of the lignite beds appears to have occurred many years ago—some of it as early as Pleistocene time—



A. MASS OF CLINKER FORMED AROUND A VENT FOR HOT GASES GIVEN OFF DURING BURNING OF HARMON LIGNITE BED

Less resistant clinker has been removed by erosion. View northeast in the SW¼ sec. 18, T. 133 N., R. 101 W., Slope County.



B. SLUMPED SURFACE AND FISSURES CAUSED BY BURNING OF THE HARMON LIGNITE BED

View west in the southwest corner of sec. 12, T. 136 N., R. 101 W., Slope County.

a few of the beds have been burning since the area was settled. In sec. 12, T. 136 N., R. 102 W., the Harmon lignite bed is still burning, much as it was when visited by Hares in 1912 (1928, p. 50–51). (See pl. 12–*B*). The burning bed has received much publicity as a tourist attraction, and no attempt has been made to extinguish the fire. The cause of the fire is not known.

PRINCIPAL LIGNITE BEDS

The lignite beds that contain strippable or possible strippable deposits described in this report are the T Cross bed of the Ludlow member, the Hansen and Harmon beds of the Tongue River member, all in the Fort Union formation. Six other beds in this area are known to attain a maximum thickness of at least 5 feet. Two, the H T Butte bed of the Sentinel Butte shale member and an unnamed bed possibly correlative with the Garner Creek bed of the Tongue River member, exceed 10 feet in thickness. The H T Butte bed crops out on the slopes of H T Butte and two smaller buttes to the east, as well as along the foot of the western slope of the Chalky Buttes, and the other bed crops out in the hills in Tps. 132 and 133 N., R. 101 W. (See pp. 161, 165, and 166.) The stratigraphic relation of these beds within the Fort Union formation is shown by generalized columnar sections in plate 14. These sections were compiled from information contained in published reports of the lignite fields in and near the investigated area, from logs of prospect holes, and from logs of seismograph shotholes and water wells drilled in the area. The lignite beds discussed below were named by Hares and their outcrops are shown on his map of the Marmarth lignite field (1928, pl. 14), except for some of the outcrops of the Harmon lignite bed east of the Marmarth lignite field, which are shown in plates 16 and 19 of this report.

T Cross lignite bed.—The T Cross lignite bed is one of the most extensive lignite beds in Slope and Bowman Counties. It crops out mainly east of the Little Missouri River and lies from 40 to 100 feet above the base of the Ludlow member. The T Cross bed has been correlated with the Giannonatti bed (Winchester and others, 1916, p. 73) of South Dakota and has been traced from T. 20 N., R. 8 E., in South Dakota through Bowman and Slope Counties, N. Dak., to Montana (Hares, 1928, p. 47). Possible strippable deposit 3 is mapped in this bed where the thickness of the bed reaches 24 feet and probably averages 15 feet. The bed is notably irregular from place to place, however, generally ranging from 3 to 9 feet in thickness and locally containing too many partings to be of commercial use. The only analysis of lignite from this bed was made of a sample taken from the Durkin prospect, now abandoned, in the SW¼ sec. 34, T. 130 N.,

R. 103 W., Bowman County, N. Dak. (See analysis 14857, table 3.) No lignite is now mined commercially from the T Cross bed.

Hansen lignite bed.—The Hansen lignite bed crops out along both sides of the uplands between Deep Creek and the Little Missouri River in Tps. 133 to 136 N., Rs. 103 and 104 W., and along the eastern side of Deep Creek in Tps. 132 to 136 N., R. 102 W. It also underlies a few of the high, isolated hills in Bowman County. The Hansen bed lies from 45 to 90 feet stratigraphically above the base of the Tongue River member and is from 5 to 60 feet below the Harmon bed. The bed is fairly persistent over a wide area. It ranges in thickness from 2.5 to 13.7 feet at measured exposures, but commonly is from 3 to 7 feet thick. Possible strippable deposit 4 is in the Hansen lignite in T. 133 N., Rs. 102 and 103 W. (fig. 28), where logs of water wells and seismograph shotholes indicate that the bed averages 15 feet in thickness over an area of about 12 square miles and reaches a maximum of 25 feet in thickness. No lignite is now mined in commercial quantities from the Hansen bed, although it is still mined from small open pits by some ranchers to satisfy their requirements. No analyses of samples of lignite from the Hansen bed are available. According to Mr. B. Meggers, a mine operator, local residents prefer lignite from the Hansen bed to that of the other beds in the area because of its excellent burning properties.

Harmon lignite bed.—The Harmon lignite bed is the thickest bed in Slope and Bowman Counties and is one of the thickest and most extensive lignite beds in North Dakota. It lies from 100 to 140 feet above the base of the Tongue River member and crops out mainly along the uplands bordering the Little Missouri River, Deep Creek, and Sand Creek. Clinker on slopes and hilltops in western Slope and Bowman Counties at the stratigraphic horizon of the Harmon bed indicate that the bed once occupied a much greater area than it does now. The Harmon bed extends northward into Billings and Golden Valley Counties, N. Dak., where it correlates with bed A of the Sentinel Butte lignite field (Leonard and Smith, 1909, p. 24–25), and thence westward into Wibaux, Richland, and Dawson Counties, Mont., where it correlates with bed G of the Sidney lignite field (Stebinger, 1912, p. 288). In the vicinity of Bowman the Harmon bed has been known as the Bowman bed (Leonard, 1925, p. 62–67), and in the vicinity of Scranton it has been called the Scranton bed (Leonard, 1925, p. 59–62, and Brant, 1953, p. 46). Hares (1928, p. 94) states that he traced the Harmon bed from outcrops in T. 132 N., R. 102 W. to the vicinity of Scranton with a fair degree of certainty. The investigations of the writers indicate that Hares' correlation was probably correct. In the vicinity of Scranton the Harmon bed is present in two benches, that locally coalesce to one bed. The lower bench may be considered a separate bed, possibly the Haynes bed, in Adams County to the east.

The Harmon bed in Slope and Bowman Counties ranges from 3 to 37 feet in thickness where measured by the writers and averages more than 20 feet in thickness over an area of at least 50 square miles. It generally is free of partings. Analyses of samples from the bed are presented in table 3. Within the 2 strippable deposits described in this report the bed contains a total of 1,370 million short tons, with an additional 310 million tons in 4 possible strippable deposits. Thus, a total of 1,680 million tons, or nearly 10 percent of the estimated remaining reserves of the Harmon lignite bed in Slope and Bowman Counties (Brant, 1953), are in the strippable or possible strippable deposits described in this report.

HISTORY OF MINING

Commercial mining in Slope and Bowman Counties did not begin until after the railroad was built in 1907. Although there were always a few mines operating at other localities, Scranton, from the first, was the center of mining in the area, because of the thick lignite underlying the town and because it was on the main line of the railroad. The Scranton mines provided fuel for the many homesteaders who came into the area, and after 1910 increasingly larger amounts of lignite were shipped out. The peak year for production of lignite was 1927, when 60,346 tons were produced in Bowman County from 4 mines (table 4), 3 in the vicinity of Scranton—2 underground mines and 1 strip mine. Lignite from the mines furnished fuel for a large power plant; a briqueting plant was operating at full capacity; and a specially designed rotary drying plant was being planned. The depression of the 1930's, however, ended the mining prosperity of the area, and the large mines began to cease operations. Locally, farmers opened up smaller mines to supply neighboring families, but the production of lignite continued to decrease to reach a low of 5,121 tons for Bowman County in 1945. Production continued low until 1950, when the Knife River Coal Co. took over the Gascoyne mine (in sec. 34, T. 131 N., R. 99 W.), renamed it the Peerless mine, and began shipping the lignite to thermal power plants in South Dakota and Minnesota. In 1952 the total production of lignite in Slope and Bowman Counties was 144,873 tons, of which 99 percent came from the Peerless mine.

TABLE 4.—*Lignite produced in Slope and Bowman Counties, N. Dak., from 1925 through 1952*

[From annual reports of the North Dakota State Coal Mine Inspection Department]

Year	Bowman County		Slope County		Year	Bowman County		Slope County	
	Production (short tons)	Number of mines	Production (short tons)	Number of mines		Production (short tons)	Number of mines	Production (short tons)	Number of mines
1925	41,144	5	45	1	1940	8,766	4	2,293	5
1926	55,286	4	880	4	1941	9,214	4	2,182	3
1927	60,346	4	405	1	1942	10,497	5	1,790	8
1928	45,411	5	384	1	1943	11,620	2	2,192	4
1929	39,876	5	450	2	1944	10,500	2	966	3
1930	28,589	4	378	1	1945	5,121	1	500	2
1931	21,035	6	20	1	1946	6,366	2	132	2
1932	19,240	6	65	1	1947	7,384	3	560	2
1933	19,943	6	219	1	1948	5,186	3	--------	1
1934	16,983	9	209	1	1949	5,379	2	225	1
1935	15,202	4	790	4	1950	11,326	2	340	1
1936	9,513	7	700	3	1951	84,689	2	400	1
1937	11,376	5	2,704	6	1952	144,188	2	685	1
1938	8,275	5	3,054	11					
1939	7,024	5	2,114	4	Total	719,479	--------	24,682	--------

Although Slope County contains about 3 times as much lignite as Bowman County—20,091 million tons as compared with 7,021 million tons, according to an estimate by Brant (1953)—the production of lignite from Slope County has always been small, never exceeding more than a few thousand tons a year. The reason is clear: the main routes of transportation pass through Bowman County, consequently the Slope County mines could not compete with the Bowman County mines except for local trade.

The mining methods in Slope and Bowman Counties have changed radically. In the early days practically all the lignite was produced from underground mines. As better earth-moving equipment was developed, however, strip mining became more popular, and gradually supplanted underground mining. Since 1946 all mining has been by strip-mining methods.

In 1952 only one mine was operating in Slope County—the Gress mine in sec. 24, T. 136 N., R. 102 W. This mine operates only during the fall and winter and supplies lignite to the nearby farmers. Of the 2 mines operating in Bowman County in 1952, the Lamb mine (in sec. 25, T. 132 N., R. 105 W.), also has a small production and operates seasonally. The other mine, the Peerless, operates throughout the year. At the Peerless mine the overburden is loosened by light blasting, and a bulldozer scrapes it from the surface. The lignite is loaded into 10-ton trucks by a small diesel-powered shovel (pl. 13) and is hauled three-fourths of a mile to the tipple, where it is crushed, screened, and loaded into open railroad cars for shipment.

LOADING LIGNITE FROM THE LOWER BENCH OF THE HARMON BED AT THE PEERLESS MINE

View northeast in sec. 34, T. 131 N., R. 99 W., Bowman County, N. Dak. The weathered upper bench is about 7 feet thick and is separated from the main bench of the Harmon bed by about 15 feet of clay.

UTILIZATION

In 1952 about 20 percent of the North Dakota lignite production of 3 million tons was used for domestic purposes, about 65 percent, for the generation of electric power, and the rest, for industries, such as sugar refineries (A. Burr, oral communication, 1953). The briqueting of lignite increases the heating value and does away with the tendency to slack and to ignite spontaneously when stored, but lignite briquets have not been able to compete with oil and gas in the domestic market, and the industrial user finds it more economical to use lignite as mined. At present the largest use of lignite is in the generation of electric power; lignite from this area is being shipped to South Dakota and Minnesota for that purpose. The out-of-state market is limited, however, because of transportation costs, and competition from the higher rank coal from the midwestern fields. Industries coming into this area, however, would find that lignite is a cheap and abundant fuel.

An increase in competition from petroleum and natural gas in this region may be expected in the near future as a result of the newly discovered oil fields in western North Dakota and eastern Montana, and the completion, late in 1954, of a natural gas plant and three petroleum refineries, as well as pipelines transporting crude petroleum and petroleum products.

The most promising use of lignite in the future, in addition to its use as an industrial fuel, is as a raw material in the production of synthetic liquid fuels and chemicals. Lignite is well suited to the production of synthetic liquid fuels, and the tremendous reserves of lignite in this region provide a valuable resource, should the supply of liquid fuel from other sources run short. Production of other types of chemicals, however, show more promise for the immediate future. Two processes that appear to be well suited for the extraction of chemicals from lignite are gas synthesis and carbonization. The gas synthesis process, in which lignite is burned in the presence of steam, produces hydrogen and carbon monoxide. These gases can be used locally to make other chemical products, of which ammonia, for the manufacture of nitrate fertilizers and explosives, has the greatest present potential market. The carbonization process, in which lignite is heated in the absence of air, produces aromatic chemicals and tars. These products are used in the manufacture of a variety of other materials, including plastics, synthetic fibers, and sulfa drugs. In addition, the solid residue, or char, can be used as fuel. This process is being developed at the present time at Rockdale, Tex., where the Aluminum Co. of America will carbonize lignite to produce a char to be used in generating electricity and will sell the other products to the chemical industry.

SCOPE AND METHOD OF INVESTIGATION

The purpose of this investigation was to find large deposits of lignite that could be developed economically by strip-mining methods and to collect sufficient data on the thickness and depth of these lignite deposits so that the reserves of lignite under specified thicknesses of overburden could be calculated. The first step in accomplishing this purpose was to adopt uniform criteria for selection of deposits that can be considered economically strippable. These criteria may not conform to those of some strip-mine operations, because operating costs and market conditions differ from place to place. They are based, however, upon stripping practices of the coal industry of Montana and North Dakota during 1951, with allowance for future advances in strip-mining methods.

CRITERIA FOR SELECTION OF STRIPPABLE DEPOSITS

Of the many factors that affect the value of a deposit of strippable coal, those judged to be within the scope of this investigation were:

thickness of the lignite bed, thickness of the overburden, location, reserves, weathering of the lignite bed, partings in the lignite bed, and shape of the deposit. The criteria discussed below are similar to those used in other strip coal investigations of the U. S. Geological Survey (Brown and others, 1954; Culbertson, 1954; May, 1954; Kepferle, 1954). A few of the criteria have been modified to allow for special conditions in Slope and Bowman Counties.

Thickness of lignite.—The minimum thickness of lignite that can be strip mined economically depends on local conditions. In most parts of North Dakota a bed thickness of 5 feet is generally considered to be the minimum. In Slope and Bowman Counties, however, so much of the reserves are in beds more than 10 feet thick—nearly two-thirds of the total reserves according to a recent estimate (Brant, 1953, p. 45)—that it is unlikely that any beds less than 10 feet thick would be strip mined on a large scale in the forseeable future. Consequently, a bed thickness of 10 feet was adopted as the minimum for strippable deposits in this investigation. The term "bed thickness" as used in this report refers to the thickness of lignite only and does not include the thickness of partings.

Thickness of overburden.—In conformity with earlier investigations of deposits of strippable coal, an overburden thickness of 120 feet was considered to be the maximum for a strippable deposit in Slope and Bowman Counties. Each deposit was subdivided into three categories according to thickness of overburden—less than 60 feet, 60 to 90 feet, and 90 to 120 feet—to accommodate the various types of stripping equipment now in use or that may be in use in the near future, and to accommodate the various thicknesses of lignite beds that are found in a large deposit. For greatest economy the power shovel or drag line should be able to remove all the overburden by casting it directly on the spoil pile without rehandling. The capacity of most equipment now in use for this type of operation is from 50 to 60 feet of overburden, and this is considered to be a rough maximum for ordinary bed thicknesses. If more than 60 feet thick the overburden becomes increasingly difficult to remove, and the extra expense of rehandling usually is not justified unless the lignite bed is exceptionally thick. The strip mine at Colstrip, Mont., for example, which mines a 25-foot bed of subbituminous coal, regularly strips 80 feet—sometimes 90 feet—of overburden, and on one occasion stripped 145 feet of overburden to remove a small hill (Coal Age, March 1949, p. 98–102). It is doubtful, however, if more than 120 feet of overburden will be stripped as a regular practice in the near future, even in the Slope and Bowman County area where the beds range from 10 to 40 feet in thickness.

A stripping ratio, or ratio of the thickness of overburden to the thickness of the coal bed, is often used by strip miners to express the maximum thickness of overburden that can be stripped economically from a coal bed of a given thickness. In North Dakota a strip ratio of 10 to 1 is sometimes mentioned as the maximum for a profitable operation, but this ratio probably applies only to beds less than about 8 feet thick. Where the bed thickness exceeds 8 feet, the rapidly increasing cost of removing the overburden of necessity decreases the maximum acceptable strip ratio. In this area, where the beds are as much as 40 feet thick, a single maximum stripping ratio could not be applied to the entire area. Consequently a stripping ratio was not used in selecting deposits in this investigation.

By way of comparison, it may be mentioned that in 1952 North Dakota strip mines stripped an average of 38.2 feet of overburden from lignite beds that averaged 9.4 feet thick, which is a strip ratio of about 4.1 to 1 (Young and Anderson, 1952, p. 13). In the two deposits described in this report the strip ratio is about 2.7 to 1 for beds that average about 24 feet thick.

Location.—For low cost development a strippable deposit should be as near as possible to the market or point of utilization, or at least be near a good means of transportation to these points. In Slope and Bowman Counties the main line of the Chicago, Milwaukee, St. Paul, and Pacific Railroad was considered to be the only feasible way at present to transport a large amount of lignite to its ultimate point of use. Thus, nearness to the railroad was an important consideration in selecting a deposit of strippable lignite for detailed investigation.

Reserves.—Because of the abundance of strippable lignite in western North Dakota, only the larger deposits were considered in the present investigation. A reserve of at least 10 million tons of lignite should be available under less than 60 feet of overburden to make it profitable to move heavy stripping equipment into an area, by present-day stripping practices.

Weathering of the lignite bed.—In North Dakota strip mines, weathered lignite generally is discarded because the weathering process causes the lignite to break down into small flakes and particles that are difficult to handle as fuel, and that have a reduced heat content because of oxidation. Consequently, a lignite bed in this area was considered suitable for stripping only if it was unweathered or if not more than the top 20 percent to 25 percent of the bed was affected by weathering.

Partings in the lignite bed.—Partings of clay or other mineral matter, if not removed, decrease the value of a lignite bed by increasing its ash content. As the cleaning of lignite is extremely difficult and correspondingly expensive, lignite beds that are free of partings are much preferred. In this investigation, only those lignite beds were considered strippable which were free of partings or in which

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the partings are so few or thin that the ash content is not increased significantly thereby, or in which the partings are so thick that they can readily be removed in a normal stripping operation.

Shape of deposit.—A strippable deposit should be relatively wide in proportion to its length in order to allow flexibility in planning the stripping operation and to minimize the waste along the outcrop caused by weathering of the lignite. Most deposits that are narrow and sinuous can not be stripped as advantageously as can the wider deposits, because of the high cost of the initial cut in relation to the subsequent cuts, and because of the smaller number of subsequent cuts available in a long narrow deposit.

PRELIMINARY INVESTIGATION

The preliminary investigation began with a study of the published reports on the lignite in Slope and Bowman Counties for the purpose of locating areas underlain by thick lignite and eliminating from further investigation those that were definitely unsuitable for strippable deposits. This study showed, for example, that the eastern and north-central parts of the area contains the thickest lignite beds and that the far western part contains no lignite beds of commercial thickness (fig. 19). For some parts of Slope and Bowman Counties, however, little or no information on the lignite appears in published reports, so an extended reconnaissance of the area was made to gather the considerable amount of information that was available locally. The main sources of this information were water-well drillers, farmers whose water wells reached the lignite beds, mine owners, and geophysical companies that were drilling seismograph shotholes throughout the area. Reports from these sources, together with the published data, indicated that several areas contain thick lignite under thin overburden. Of these areas, that north of Bowman and that east of Scranton were chosen for detailed investigation.

DETAILED INVESTIGATION

The detailed investigation of the specific areas consisted of determining the thickness of the lignite, and locating and plotting on aerial photographs the lignite bed outcrop and the three lines outlining thickness of overburden. These lines bound the three subdivisions of the strippable deposit: lignite under less than 60 feet of overburden, under 60 to 90 feet of overburden, and under 90 to 120 feet of overburden. These data were then transferred from the photographs to a base map made from General Land Office plats. Isopach lines were drawn for the strippable lignite from the thickness information available, and, finally, the reserves of lignite and the approximate stripping ratio were calculated.

DETERMINATION OF THICKNESS OF THE LIGNITE

The writers added to the data obtained in the preliminary investigation by logging some of the holes that were being drilled by shothole drillers and by drilling additional holes with a power auger mounted on a pickup truck. An effort was made to place the power-auger holes so that the results therefrom would complement less reliable data on thickness, and so that no part of the strippable deposit would be more than a mile from a point of thickness information.

Of the several kinds of information about the thickness, the detailed measurement of an exposure of the bed is the most accurate. Only a few measurements of exposures are used in this report, however, for the complete thickness of a strippable bed is rarely exposed in this area. Much of the information about thickness of the lignite was obtained by some type of drilling. Because of the toughness of the lignite as compared with the usual soft clays, shales, and sandstones in this area, the lignite beds are readily noted in drilling operations, even by those drillers who ordinarily would not be interested in lignite. The precision of the various drilling methods does not differ significantly, but the reliability of the reports depends chiefly upon the interest of the driller in recording the thickness of the lignite bed. In two types of drilling, the auger holes and prospect drilling by coal-mining companies, the primary object is to measure the thickness of the lignite bed. In the other two types, water-well drilling and seismograph-shothole drilling, lignite thickness is only of minor interest. Accordingly, measurements of thickness from water wells or seismograph shotholes were used only where they were verified by measurements from a power-auger hole nearby, or where they were logged by a driller who, to the writers' knowledge kept a reliable log. This kind of information was used also in a few places where there was no other reliable information for the immediate vicinity, but where the thickness and depth reported for the lignite bed conformed closely to the thickness and depth inferred for that point from nearby measurements.

The precision of the four types of drilling is inferred to be as follows: In most power-auger holes, the thickness of the bed could be determined to within 1 or 2 feet and the thickness of clay partings to within a few inches. Partings less than 2 inches thick, however, may not have been recognized. The prospect holes of the coal mining companies, though drilled with different equipment, probably measured the lignite with similar precision. Water-well drillers probably recorded the true thickness within an accuracy of about 2 feet, but may not have recorded partings of less than a foot or two. Seismograph shothole drillers probably measured the lignite with the least accuracy, because of the speed of their drilling operations. On the average, the bed thickness reported from shotholes are probably accurate to within about 3 feet, although partings may not have been recognized or recorded if they were less than 1 or 2 feet thick. Inasmuch as the Harmon lignite bed was found to be free from partings at most localities investigated by the writers, the fact that thin partings were not recorded by water well and seismograph-shothole drillers probably does not affect the value of their logs significantly.

After all thickness data were gathered and evaluated, the average thicknesses were calculated, and an isopach, or thickness, map was made of the strippable lignite deposits.

PLOTTING OF OUTCROP AND OVERBURDEN LINES

The line of outcrop of the strippable lignite was first located in the field, and then plotted on aerial photographs printed at a scale of 1:20,000. The line of outcrop of the other lignite beds shown on the Bowman deposit map were either located by reconnaissance methods in the field, or were taken directly from the map of the Marmarth lignite field (Hares, 1928, pl. 14), modified in part by the use of aerial photographs.

Next, the 60-foot, 90-foot, and 120-foot overburden lines (imaginary lines on the ground, every point of which is the same height above the bed of strippable lignite) were added to the photographs. These lines were located by reconnaissance methods, in which differences of elevation were found by use of the surveying altimeter and hand level, and horizontal distances by measurements from aerial photographs. The altimeter traverses were based on true elevation taken from U. S. Coast and Geodetic Survey benchmarks, or from seismograph shotholes at which the elevation had been determined by geophysical crews using plane table and alidade.

Because the points at which information was obtained are scattered and because of the reconnaissance method of mapping, the overburden lines are, of necessity, somewhat generalized. Before any mining operations are started, therefore, the deposit should be mapped and drilled in detail sufficient to permit accurate calculation of the total yardage of overburden and tonnage of lignite.

ESTIMATION OF STRIPPABLE RESERVES

After the field mapping was completed, the lines on the aerial photographs were transferred to a map base drawn from General Land Office plats. On this map the acreage underlain by strippable lignite, excluding any area in which the lignite bed had been mined out or is inferred to be weathered, was measured with a planimeter. The acreage was then multiplied by the average thickness of the lignite bed to obtain the volume of lignite in acre-feet, the volume in turn was multiplied by 1,750 tons per acre-foot, the average density of lignite in North Dakota and eastern Montana (Brant, 1953, p. 4), to get the remaining reserves in short tons.

The reserves in each deposit are tabulated in table 1 according to the three categories: less than 60 feet, 60 to 90 feet, and 90 to 120 feet of overburden. The reserves that would actually be recovered from these deposits are somewhat less than the amount shown, for some coal is always lost in the mining process. Because of the high efficiency of strip mining, however, the amount lost by this method usually is comparatively small. The large strip mine at Colstrip, Mont., for example, recovers nearly 95 percent of the coal in a bed 25 feet thick (Styles, 1951, oral communication).

The reliability of the reserve figures in table 1 can be inferred from the spacing of the points at which data on thickness was obtained and from the persistence of the lignite bed. They are so spaced that about 90 percent of the total reserves are within one mile and about 75 percent of the reserves under less than 60 feet of overburden are within half a mile of such a point. As the Harmon lignite bed is one of the most persistent beds in the United States (Hares, 1928, p. 49), and all the reserves are within 1½ miles of such a point, the reserve figures in table 1 are considered reliable enough to fall within the indicated category of the reliability classification of lignite reserves of North Dakota (Brant, 1953, p. 8).

ESTIMATION OF STRIPPING RATIO

A stripping ratio is the ratio between the thickness of the overburden on a lignite bed to the thickness of the bed itself. Strip ratios are widely used in the coal mining industry to evaluate deposits of coal and for that reason an attempt was made to calculate the stripping ratios for the two deposits described in this report. An accurate determination of stripping ratio was not possible because of the lack of precise information on the variation of the thickness of overburden. It was possible, however, to obtain an approximate stripping ratio for each deposit or deposit subdivision by taking a weighted average of overburden thicknesses in each of the three categories of thickness of overburden, as estimated from the writers' knowledge of the topography of the area, and comparing it with the average thickness of lignite as previously determined. These strip ratios, which are presented in table 1, are average ratios, however, and cannot be applied to small parts of the deposits with assured accuracy.

DEPOSITS OF STRIPPABLE LIGNITE

BOWMAN DEPOSIT

The Bowman deposit—the larger of the two deposits of strippable lignite described in this report—has an areal extent of nearly 40 square miles, and contains indicated reserves of 1,099 million short tons of strippable lignite in one continuous bed. (See table 1 and pls. 15 and 16.) It lies in Tps. 132 to 135 N., Rs. 101 and 102 W., Slope and Bowman Counties, N. Dak. Bowman, the county seat and largest town in Bowman County, is about 4 miles south of the deposit and is served by the main line of the Chicago, Milwaukee, St. Paul and Pacific Railroad and by U. S. Highways 12 and 85. Amidon, the county seat of Slope County, lies about 2 miles east of the northern part of the deposit. The deposit is accessible by means of gravel-surfaced, graded U. S. Highway 85, which crosses the deposit between Bowman and Amidon, and by the many graded county roads that serve the areas on either side of the highway.

A 44,000 volt power transmission line that roughly parallels U. S. Highway 12 is the nearest source of electric power. The nearest accessible water supply is the Little Missouri River at Marmarth, 31 road miles west of Bowman. Water in quantities sufficient to supply the needs of large-scale industry is available from the Missouri River at Mobridge, S. Dak., 170 miles southeast of Bowman, and from the Yellowstone River at Fallon, Mont., about 115 miles northwest of Bowman by way of the railroad.

Because it is large, the Bowman deposit will be discussed in four parts in the following order: northern part, which includes all the deposit within T. 135 N., Rs. 101 and 102 W.; north-central part, which includes all the deposit within T. 134 N., Rs. 101 and 102 W.; south-central part, which includes all the deposit within T. 133 N., Rs. 101 and 102 W.; and southern part, which includes all the deposit within T. 132 N., Rs. 101 and 102 W.

NORTHERN PART

The northern part of the Bowman deposit (pl. 15) is in secs. 13, 25, and 36, T. 135 N., R. 102 W., and secs. 17 to 21 and 28 to 34, T. 135 N., R. 101 W., Slope County, N. Dak.

TOPOGRAPHY AND LAND USE

The northern part of the Bowman deposit is drained by Sand Creek, which lies to the west. This creek flows in a well-defined channel that meanders along a fairly flat, alluvial-filled valley bottom from one-eighth to one-fourth of a mile wide. The sides of the valley rise abruptly for 20 to 60 feet and form typical breaks against the generally smooth slopes back from the valley. These smooth slopes are modified by the U-shaped valley of Hay Creek—a major tributary—and the V-shaped valleys of the minor tributaries, and by the rounded ridges that extend from the high divide to the east. Gravel-capped terraces are conspicuous north of Hay Creek and east of Sand Creek to the south. The maximum relief within the mapped area is about 250 feet.

Most of the gently sloping land is farmed. The steep slopes of the uplands and the flat creek bottoms are covered with grass, which is cut for hay or used as pasture. Some low brush and a few trees border Sand Creek.

HARMON LIGNITE BED

The Harmon lignite bed ranges in thickness from 12 to 40 feet in the northern part of the Bowman deposit and probably averages 25.8 feet; it is thickest in the southwestern corner of T. 135 N., R. 101 W. (See map, pl. 15). The information about the bed was derived from 8 seismograph shotholes, 4 power-auger holes, 1 water well, and 2 exposures (graphic sections nos. 1 through 15, pl. 17). Of the seismograph shotholes, those at locations 11 and 14 were logged by one of the writers. These observations show that the Harmon bed consists of clean lignite, except for a clay parting 2 to 3 feet thick that lies 3 to 5 feet below the top of the bed at locations 10, 11, 12, and 13. This same parting is visible where the top 5 or 6 feet of the bed is exposed along the bank of Sand Creek about half a mile south of location 13. The two exposures at locations 10 and 12 were measured by Hares (1928, pl. 13). When visited by the writers only the upper bench and the upper part of the lower bench were visible, the rest having been covered by slump since the bed was last mined. The base of the Harmon bed is exposed just north of the reservoir in sec. 31, T. 135 N., R. 101 W. Elsewhere in the mapped area the former outcrops of the Harmon bed is marked mainly by clinker produced by the burning of the bed.

Water was found near the base of the Harmon bed in the hole drilled at location 4, and water in standing pools along Sand Creek in sec. 31, T. 135 N., R. 101 W., probably comes from the Harmon bed.

The Harmon bed dips northward about 40 feet per mile in the northernmost part of the deposit, and, as the bed is above the main drainage channels, draining water from strip pits would not be very difficult in this area. Southward, however, pumping probably would be necessary to rid the strip pits of water because the direction of dip changes from northward to east-northeastward, which is almost directly opposed to the general land drainage.

OVERBURDEN AND FLOOR ROCK

The lowest 30 feet of overburden of the Harmon lignite bed in the northern part of the Bowman deposit is predominantly clay. At location 12, this clay contains abundant leaf imprints. Above the clay, the overburden is mainly a light-yellow massive to crossbedded fine- to medium-grained sandstone that is composed chiefly of quartz grains cemented loosely with calcium carbonate. Locally this sandstone is cemented more firmly forming a resistant calcareous sandstone. Much of it is water bearing, particularly in the valley of Hay Creek. Small iron sulfide concretions that alter to limonite on exposure are fairly common throughout the sandy sediments. The sandstone may be interbedded with thin beds of clay and lignite.

In sec. 19, T. 135 N., R. 101 W., a lignite bed crops out about 30 feet above the Harmon bed. This bed is reported to be 5 feet thick at a depth of 80 feet in a seismograph shothole drilled half a mile east of location 4, and is 8 feet thick at a depth of 110 feet in a similar hole a mile east of location 11. Clinker of another bed about 60 feet above the Harmon bed is present at location 1, and bloom from this bed is visible at various points along the contour line marking 60 feet of overburden in sec. 13, T. 135 N., R. 102 W., and in adjacent sec. 18 of the township to the east. Gravel deposits attain a thickness of 15 feet where they cap the terraces on the east side of Sand Creek.

The Harmon bed is underlain by clay in the northern part of the Bowman deposit.

RESERVES AND STRIPPING RATIO

The northern part of the Bowman deposit contains reserves of 183 million tons, of which 70 million tons, or about 38 percent, are beneath less than 60 feet of overburden, and about 72 percent are beneath less than 90 feet of overburden. (See table 1.) The stripping ratio averages 2.7 feet of overburden to each foot of coal, although it is probably as much as 8 to 1 near the contour line bounding 120 feet of overburden in the extreme north, where the Harmon bed thins to less than 15 feet in thickness.

The Harmon bed contains additional reserves of lignite in the area to the north of the Bowman deposit, but the available time was insufficient to allow the drilling and mapping necessary to determine the average thickness of the bed and the location of the overburden lines. These reserves, however, are farther from existing transportation facilities.

NORTH-CENTRAL PART

The north-central part of the Bowman deposit lies in secs. 1, 2, 12, 13, 14, 22, 23, 25, 26, 27, 35, and 36, T. 134 N., R. 102 W., and secs. 4 to 9, 16, 17, 18, 30, 31, and 32, T. 134 N., R. 101 W., Slope County, N. Dak. (pl. 15).

TOPOGRAPHY AND LAND USE

The most prominent feature in the area, H T Butte, locally called Black Butte, lies in secs. 19 and 30, T. 134 N., R. 101 W., and secs. 23, 24, and 25, T. 134 N., R. 102 W., and rises about 500 feet above the surrounding countryside. The divide between Sand Creek and Deep Creek extends northward from the west end of H T Butte and southeastward from the east end of the butte along a rolling grass-covered upland. Sand Creek on the east side of the divide receives most of the drainage from the deposit north of the butte. Sand Creek is a perennial stream in the township to the north, but flows only intermittently in this area of the deposit. The channel of Sand Creek is made up of well-sorted quartz sand derived from the erosion of the rocks of White River age that are exposed in White Butte just east of the mapped area. Sand Creek flows in a flat flood plain as much as a third of a mile wide, but its tributaries occupy V-shaped valleys. The relief of these valleys is as little as 30 feet near their confluence with the main creek valley but increases greatly as the valleys encroach upon the slopes of H T Butte and its associated uplands.

Flat-topped ridges capped by remnants of terrace gravel extend northward from H T Butte in secs. 8, 17, and 18, T. 134 N., R. 101 W. Similar, though less dissected, terraces border the uplands of White Butte just east of the mapped area and extend northwestward into secs. 4, 5, 6, 9, and 16 of the same township. On the deposit map (pl. 15) the rough outline and lineation of these terraces are indicated by the contour line for 120 feet of overburden.

West and south of H T Butte the deposit is drained by Deep Creek, which flows northward to the Little Missouri River. From H T Butte a gently sloping surface extends for about a mile to the west and about a mile and a half to the south. This surface is broken only by a few terracelike ridges and, to the south, by a westward-trending, intermittent stream that has incised a channel to a depth of about 30 feet. Most of the area is grass-covered pasture land, although some of the rolling land north of H T Butte is farmed. A few trees and shrubs grow along the creek bottoms as well as on the rough slopes of H T Butte.

HARMON LIGNITE BED

The Harmon lignite bed in the north-central part of the Bowman deposit ranges from 15 to 40 feet in thickness, and averages 28.3 feet. The thickness data in this part of the deposit were derived from 10 prospect holes drilled with a power auger and from 11 seismograph shotholes, of which those at locations 18, 23, 25, 28, 30, and 33 were logged by the writers (Graphic sections nos. 16 through 36, pl. 17).

The strippable lignite seems to be the thickest along the channel of Sand Creek in the three northern tiers of sections in T. 134 N., R. 102 W.; the thinnest part of the strippable bed is along the outcrop. Because of uncertainty as to the thickness of lignite penetrated at location 16, the bed is considered to constitute a thickness of not less than 21 feet of clean lignite nor more than 31 feet of lignite containing a few thin partings near the base. A seismograph shothole logged by the writers at location 25 gave similarly inconclusive results within the thickness range of from 32 to 42 feet. The graphic sections (pl. 17) show no partings at locations 16 and 25, and the average thickness shown by these sections, 26 and 37 feet, respectively, are the thicknesses used in calculating the reserves in the immediate vicinity of the holes. At location 33 the bed was penetrated for 13 feet without reaching the bottom, and at location 34 the top part of the bed was eroded, apparently before or during the deposition of the thin gravel deposit that overlies it. Clay partings ranging from 2 inches to 2 feet in thickness lie from 2 to 4 feet below the top of the Harmon bed at locations 19, 21, and 31. The Harmon lignite has been mined at an opencut at location 27 near the west end of H T Butte and has been reached by wells in the west half of secs. 23 and 26, T. 134 N., R. 102 W. The top of the bed is exposed in the channel of Sand Creek just south of the township line in sec. 6, T. 134 N., R. 101 W.

At location 18, in a seismograph shothole logged by the writers, clinker totaling 15 feet in thickness immediately overlies 22 feet of lignite. As clinker is not exposed at the surface around this hole, the extent to which the Harmon lignite has burned in this area is not known. The unburned lignite beneath should be of good quality, and therefore is included in the strippable reserves. Unburned lignite beneath clinker indicates that oxygen was not available to the lower part of the bed at the time of burning—possibly because the lower part was saturated with water.

The bed dips northeastward from 20 to 40 feet a mile throughout most of T. 134 N., Rs. 101 and 102 W., increasing to about 60 feet a mile just south of H T Butte. At location 25, a structural anomaly in the lignite bed is indicated by a somewhat lower altitude for the top of the bed than is suggested by the regional dip that persists in the surrounding locations. The lignite bed is higher than the drainage level throughout most of the north-central part of the deposit, except east of Sand Creek and south of H T Butte.

OVERBURDEN AND FLOOR ROCK

South of H T Butte the overburden on the Harmon bed in the north-central part of the Bowman deposit is predominantly clay for as much as 90 feet above the lignite, but becomes more sandy above this distance. North and east of H T Butte the overburden is clayey only within 20 to 30 feet above the Harmon bed and is predominantly sandy above 30 feet. A lignite bed not more than 2 feet thick was found about 35 feet above the Harmon bed at location 33. A lignite bed 5 feet thick was logged at about 60 feet above the Harmon bed in the hole drilled at location 28. No trace of either of these beds was found at the surface. Gravel deposits 5 to 15 feet thick cap the ridge-like terrace remnants that extend northward into the deposit in secs. 17 and 18, T. 134 N., R. 101 W. Gravel deposits also underlie the surface of the terraces that border the east side of Sand Creek and the south side of H T Butte. A few of the ridges that rise to slightly more than 120 feet above the general land surface impart a sinuous outline to the deposit. Inasmuch as these ridges are extremely narrow, they probably would be removed rather than bypassed by any stripping operation that was removing as much as 120 feet of overburden.

The rock beneath the Harmon bed is clay in this part of the deposit, except at location 30, where sand was found.

RESERVES AND STRIPPING RATIO

The remaining reserves of strippable lignite in the north-central part of the Bowman deposit total 299 million tons, of which 107 million tons, or 35 percent, lie beneath less than 60 feet of overburden, and 63 percent lies beneath less than 90 feet of overburden. (See table 1.) The average stripping ratio for this part of the Bowman deposit is less than that for any other part of the deposit. It averages 2.4 to 1 throughout and ranges from an average of 1.5 to 1 in the category of less than 60 feet of overburden, to 2.4 to 1 in the category of 90–120 feet of overburden.

SOUTH-CENTRAL PART

The south-central part of the Bowman deposit lies in secs. 1, 12, 13, 24, and 25, T. 133 N., R. 102 W., and secs. 4 to 11, and 14 to 33, T. 133 N., R. 101 W., Slope County, N. Dak. (pl. 16).

TOPOGRAPHY AND LAND USE

In this area, the high divide between southeastward-flowing Cedar Creek on the east and northward-flowing Deep Creek on the west borders the eastern edge of the strippable deposit. This divide follows the tops of rolling hills that are about 200 feet high in the north to as low as 60 feet in the central part, and rise to more than 150 feet above the surrounding countryside in the south. These hills are generally grass covered near their tops but are farmed along the more gentle slopes near their bases. Three roughly parallel ridges extend northwestward into the deposit from this main divide. One, in the southern third of T. 133 N., R. 101 W., is about 2 miles long and has a maximum relief of about 100 feet; another, near the center of the same township, is about 5 miles long and has a maximum relief of about 150 feet; the third, near the northern boundary of the township, is about 2 miles long and extends westward from a small butte on the line between secs. 4 and 5. Three major tributaries to Deep Creek receive most of the drainage of the township. The northernmost of these is the largest and drains most of the north half of the area, flowing westward into Stewart Lake and thence into Deep Creek. Stewart Lake is the only perennial lake in the area; it is supplied not only from runoff but also by many springs, some issuing from the Harmon lignite bed. The valley in which Stewart Lake lies is as much as a mile wide and is fairly mature. Gravel-covered terrace remnants rise to about 75 feet above the present stream bottom on the north side of the valley, and the stream channel is entrenched 10 to 20 feet below the level of the main valley floor.

This valley is unusual among those of the deposit area in that it broadens headward, due mainly to the low relief of the Cedar Creek-Deep Creek divide to the east. This headward broadening combined with a flattening of the already low dip of the strippable lignite provides a large area in which the Harmon lignite lies beneath more than 60 and less than 120 feet of overburden. The two main Deep Creek tributaries that drain the southern half of the south-central part of the deposit are fairly short. The flat valley bottom of the more northern of these two tributaries is at least half a mile wide, whereas, the other is much narrower. Except in the immediate vicinity of the farmsteads, the area is practically treeless. Approximately half of the area is farmed, the rest is grass covered.

HARMON LIGNITE BED

The Harmon lignite bed in the south-central part of the Bowman deposit thickens from east to west from 16 to 37 feet (pl. 16). The average thickness of the bed is 22.5 feet. The sources of thickness information are 12 holes drilled with a power auger, reports from 2 water wells, and 13 seismograph shotholes, of which those at locations 47, 50, 54, and 61 were logged by the writers (graphic sections, nos. 37 through 63, pl. 18). One of the writers was also present when the well at location 39 was drilled. A third well, about two-thirds of a mile east of location 39, entered lignite presumed to be the Harmon bed at a depth of 72 feet, but did not transect the complete thickness of the bed. Other wells in the area are reported to have reached the Harmon bed, but have been drilled so long ago that the present resident of the farmstead has no recollection of the depth or thickness of the bed.

The thickest lens of the Harmon lignite bed in this area centers around location 58, where 37 feet of lignite was penetrated in drilling. A clay parting 6 inches thick was found 2½ feet below the top of the bed at location 37, and a similar parting was found 5 feet below the top of the bed at location 41. A bed that appears to be an upper bench of the Harmon lignite bed is 3 feet thick at location 50 and is separated from the lower bench of 18 feet of lignite by a parting of shale and clay 14 feet thick. A seismograph shothole about one mile east of location 55 reached a bed of lignite 4 feet thick that may be the upper bench of the Harmon bed. This hole, however, passed through 21 feet of sediments below this bench without reaching any other lignite. Two miles east of location 55 a seismograph shothole passed through 3 feet of lignite, 5 feet of clay, and 8 feet of lignite. The 16 feet of lignite and clay was assumed to be the Harmon bed. The top of the Harmon bed seems to have been eroded at location 38.

The Harmon bed has been mined from several small openings, that most recently operated being at location 62 where the National Aluminate Co. has mined weathered lignite for use in making dye. Other openings are the Hallenbeck mine in the SE¼ sec. 1, T. 133 N., R. 102 W., where the bottom part of the bed was being mined by the local ranchers as recently as 1940, and in the NW¼ sec. 19, T. 133 N., R. 101 W., where Hares (1928, p. 89) reported that 5½ feet of lignite was exposed, but that the bottom part of the bed was covered by water. An analysis of a sample of lignite from the Hallenbeck mine is given in table 3.

OVERBURDEN AND FLOOR ROCK

Gray to yellow clay and shale constitute most of the overburden within 50 feet of the top of the Harmon bed in the south-central part of the Bowman deposit. Above 50 feet, the overburden is increasingly sandy and contains at least three thin lignite beds. Two of these thin beds have burned along parts of their outcrops and can be traced by the resulting clinker. Clinker from a bed about 90 feet above the Harmon bed crops out along the ridge just south of Stewart Lake and is also conspicuous just east of the section corner to the east. Clinker from this bed and from a bed 30 to 45 feet higher crop out in several places along the upland slopes of the high ridges in the area and indicate that these beds are fairly persistent. A third bed, 50 to 60 feet above the Harmon lignite bed, has burned to form clinker along the slopes of the ridge about half a mile east of location 51. Clinker at this same stratigraphic position was also found in a seismograph shothole drilled at location 61. This same bed is 2, 10, 11, and 9 feet thick where it was reached in holes drilled respectively at location 43, one mile west of location 43, location 56, and 2 miles east of location 61. Silicified tree stumps and other silicified wood in association with a discontinuous quartzitic layer are scattered along the top of the ridge in the SE¼ of sec. 33, T. 133 N., R. 101 W., at about 180 feet above the Harmon bed.

The rock beneath the Harmon bed is mainly clay, although holes drilled at locations 43, 47, 54, 61, and 63 entered shale, and holes drilled at locations 50 and 59 entered sandstone just under the lignite.

RESERVES AND STRIPPING RATIO

The remaining reserve of strippable lignite in the south-central part of the Bowman deposit total 389 million tons, of which 152 million tons, or 39 percent, lie beneath less than 60 feet of overburden, and 72 percent lie beneath less than 90 feet of overburden (table 1). The stripping ratio for this part of the deposit is greater than that for any other part. It averages 3.1 to 1 in all 3 categories of thickness of overburden and ranges from an average of 1.7 to 1 in the category of less than 60 feet of overburden to an average of 4.9 to 1 in the category of 90–120 feet of overburden. The south-central part of the deposit in the west overlaps an area in which lignite from the underlying Hansen bed could be obtained by removing an additional 40 to 60 feet of sandstone, shale, and clay which lie beneath the Harmon bed. The Hansen bed in this area is more than 10 feet thick and contains possible strippable reserves totalling about 200 million tons (fig. 27).

SOUTHERN PART

The southern part of the Bowman deposit (pl. 16) lies in secs. 1, 2, 11 to 16, and 22 to 25, T. 132 N., R. 102 W., and secs. 7, 18 to 21, 27 to 30, and 32 to 34, T. 132 N., R. 101 W., Bowman County, N. Dak.

TOPOGRAPHY AND LAND USE

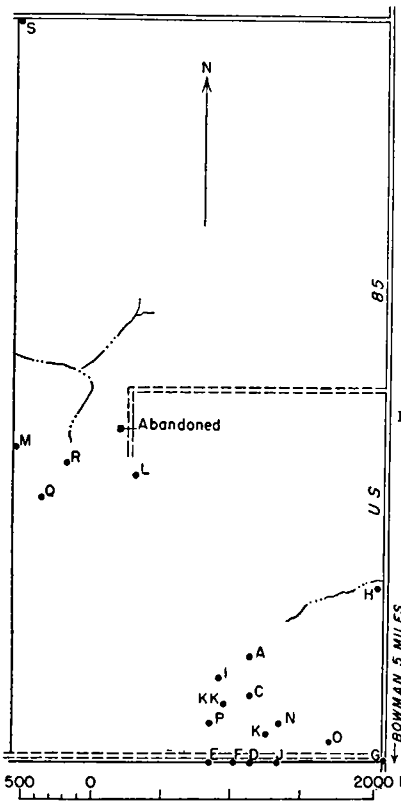
The drainage divide between the Little Missouri River and the Missouri River passes southward along the range line common to Rs. 101 and 102 W., in T. 132 N. Deep Creek drains the land west of the divide. Cedar Creek and Buffalo Creek drain the land east of the divide, their drainage basins being separated by a ridge that extends eastward from the S½ sec. 19, T. 132 N., R. 101 W. Most of the hills are low, fairly rounded, and slightly elongated in a northwesterly direction. The gentle low slopes are farmed, but the steeper, high slopes are left in grass. The western part of the mapped area has a fairly low relief except where hummocks and ridges capped with clinker have resisted the levelling effects of erosion.

Twin Buttes form a conspicuous landmark just south of the mapped area in secs. 35 and 36, T. 132 N., R. 102 W., and adjoining secs. 1 and

2 of the township to the south. These buttes rise to about 150 feet above the Harmon lignite bed and are capped by a slabby layer of quartzite.

HARMON LIGNITE BED

The Harmon lignite bed in and near the southern part of the Bowman deposit ranges in thickness from a reported 38 feet at location 67, to 5 feet at location 78. Information about the thickness of the Harmon bed in this area is derived from 9 power-auger holes, 2 well reports, 1 report from an abandoned mine, and 3 prospect holes drilled by the Bowman Holding Co. (graphic sections nos. 64 through 78, pl. 18). In 1925 this company drilled 20 prospect holes which are shown in figure 20, but only the three shown at locations 69, 71, and 73 on plate 16 were found in the field. The logs that are presented with



Hole — LOG *

- A. 31 feet of sand, 1 foot of soft coal, 6 feet of blue clay, 33 feet of hard coal, 2 feet below coal.
- B. 18 feet of clay, 6 feet of slack, 26 feet of hard coal, 3 feet below coal. (Location unknown).
- C. 23 feet of clay, 2 feet of slack, 29 feet of hard coal, 2 feet below coal.
- D. 21 feet of clay, 2 feet of red clay and sand, 4 feet of slack, 15 feet of hard coal, 5 feet below coal.
- E. 35 feet of clay, 1 foot of slack, 4 feet of hard coal, 6 feet below coal.
- F. 38 feet of clay, 3 feet of scoria, 6 feet of clay, no coal.
- G. 30 feet of clay, 2 feet of slack, 31 feet of hard coal, 2 feet below coal.
- H. 48 feet of clay, 1 foot of slack, 33 feet of hard coal, 3 feet below coal.
- I. 18 feet of clay, 6 feet of slack, 21 feet of hard coal, 3 feet below coal.
- J. 34 feet of clay, 8 feet of scoria, 8 feet of clay.
- K. 31 feet of clay, 9 feet of slack, 4 feet of mixed hard coal, 3 feet below coal.
- KK. 20 feet of clay, 10 feet of slack, 18 feet of hard coal, 2 feet below coal.
- L. 16 feet of clay, 4 feet of slack, 23 feet of hard coal, 3 feet below coal.
- M. 14 feet of clay, 3 feet of slack, 1 foot of clay, 33 feet of hard coal, 4 feet below coal.
- N. 20 feet of clay, 7 feet of slack, 21 feet of hard coal, 3 feet below coal.
- O. 16 feet of clay, 18 feet of slack, 9 feet of hard coal, 2 feet below coal.
- P. 18 feet of clay, 9 feet of slack, 18 feet of hard coal, 2 feet below coal.
- Q. 18 feet of clay, 10 feet of sand, 4 feet of clay 6 feet of scoria, 4 feet mixed.
- R. 20 feet clay, 10 feet slack, 8 feet of hard coal, 2 feet below coal.
- S. 4 feet of clay, 35 feet of sand, 17 feet of clay, 2 feet of slack, 32 feet of hard coal, 2 feet below coal.

* The last item indicates depth drilled after passing through last coal bed. Lithology not recorded.

Figure 20.—Map of the east half of sec. 24, T. 132 N., R. 102 W., Bowman County, N. Dak., showing location of prospect holes drilled in 1925 by the Bowman Holding Co.

the map indicate that the Harmon bed penetrated by the prospect holes has a much greater range in thickness within the SE¼ sec. 24 than is shown by the isopach lines on plate 16. This may be explained in part by the fact that normal local variations in thickness are not shown by the isopach lines, and in part by the indication that the lignite at locations D, E, K, and R, may be eroded. The logs (fig. 20) also show that many of the holes were drilled where the Harmon bed has weathered under a fairly thin overburden. Holes at locations F, J, and Q (fig. 20) penetrated only clinker ("scoria") indicating that the Harmon bed has been burned beneath some of the area.

The thickness or isopach map of the Bowman deposit (pl. 16) shows that the thickest lignite lies in the west of the southern part. East of secs. 27 and 34, T. 133 N., R. 101 W., the lignite becomes too thin to be considered economically strippable. At the Halleck mine (location 67, pl. 16) the lignite is reported by Leonard (1925, p. 64) as being from 30 to 38 feet thick. Other reports that the lignite in this mine is 60 feet thick are not considered valid, because holes drilled near the mine at locations 66 and 68 show that the bed is 31 feet and 27 feet thick, respectively, at these locations. The writers were unable to confirm a report that a 35-foot thickness of the Harmon bed was entered at a depth of about 55 feet by a well drilled in the NE corner of the S½ sec. 19, T. 132 N., R. 101 W. The lignite at location 72 appears to be eroded at the top. At all but two locations the Harmon bed is free from partings: at location 76 a clay parting 1 foot thick, lies 1 foot below the top of the bed; and just outside the strippable area at location 78 the top 1 foot of the lignite bed is separated from the lower 4 feet by a parting of sand and clay 10 feet thick. South of location 78 an additional prospect was drilled that showed the bottom bench had thinned to less than 2 feet thick. A report from the well at location 75 indicates that the Harmon bed there is only 9 feet thick. Analyses of samples from the Halleck mine (location 67) and the Bowman mine (near location 68) are presented in table 3.

Because the outcrop of the Harmon lignite bed is only slightly above the main stream valleys, and because the strata dip northeastward from 25 to 50 feet per mile, pumping would be necessary to drain the pits of water, unless special care is taken to lay out the pits parallel to the strike of the lignite bed.

OVERBURDEN AND FLOOR ROCK

The overburden of the Harmon lignite bed in the southern part of the Bowman deposit appears to be mainly light gray to yellow shale and clay, with sand in increasing amounts in the overburden more than 50 feet above the lignite. Two fairly persistent lignite beds were found at 80 to 90 feet and at 120 to 135 feet above the Harmon bed. The higher of the two is more conspicuous, and its outcrop trace is marked by clinker in secs. 18 and 19, T. 132 N., R. 101 W. These beds are exposed in several road cuts along U. S. Highway 85. The lower of the two beds was mined at one time from an exposed bank about half a mile east of location 75, where it was reported to be 5 or 6 feet thick. One of these beds is reported to attain a thickness of 15 feet in the N½ sec. 27, T. 132 N., R. 101 W.

An abundance of mollusks were found within a layer of sand on top of a small knoll along the south line of sec. 34, T. 132 N., R. 101 W., about 30 feet above the inferred base of the Harmon lignite bed.

Clay constitutes the floor rock of the Harmon bed in the southern part of the Bowman deposit.

RESERVES AND STRIPPING RATIO

The remaining reserves in the southern part of the Bowman deposit total about 228 million tons. Fifty-five percent of this amount, 126 million tons, lies beneath less than 60 feet of overburden. This percentage of reserves in the category of less than 60-feet of overburden is greater than for any other part of the Bowman deposit. (See table 1.) The average stripping ratio for this part of the deposit is 2.7 to 1, and ranges from 1.6 to 1 in the category of less than 60 feet of overburden to 4.3 to 1 in the category of 90–120 feet of overburden.

SCRANTON DEPOSIT

The Scranton deposit (pl. 19) is the smaller of the two strippable lignite deposits described in this report. It contains reserves of 273 million short tons of lignite (table 1) and underlies about 10.4 square miles in secs. 13, 14, 23, 24, and 25, T. 131 N., R. 100 W., secs. 18 to 23, 25 to 30, and 32 to 36, T. 131 N., R. 99 W., and secs. 1 and 2, T. 130 N., R. 99 W., Bowman County, N. Dak.

The main line of the Chicago, Milwaukee, St. Paul and Pacific Railroad and paved U. S. Highway 12 parallel the deposit on the south, and pass through the small towns of Scranton and Gascoyne. In addition to sidings at these two towns, the railroad also has a siding at the tipple of the Peerless mine about 1½ miles east of Gascoyne, as most of the lignite from this mine is shipped by rail to markets in the eastern part of North and South Dakota and southern Minnesota. By rail, the deposit is 150 miles west of the Missouri

River at Mobridge, S. Dak., is 45 miles east of the Little Missouri River at Marmarth, N. Dak., and is about 127 miles southeast of the Yellowstone River at Fallon, Mont.

TOPOGRAPHY AND LAND USE

The entire runoff of the area of the Scranton deposit is received by Buffalo Creek, which parallels the deposit on the south and is a southeastward-flowing intermittent tributary to the Grand River. The deposit lies along the southern slopes of the uplands which parallel the deposit to the north and form the divide between Buffalo Creek and Cedar Creek. A southwestward trending ridge extends into the northwestern part of the area from this high divide, and in the SW¼ sec. 13 is surmounted by Scranton Butte, which rises about 160 feet above the strippable lignite bed. For the most part, however, the land surface over the deposit is gently rolling. The valley bottom of Buffalo Greek is fairly flat and is generally about half a mile wide. From this bottom, the surface rises fairly steeply for 20 to 40 feet on either side, then flattens out to form a low rolling bench that extends as much as three miles back from the bottom and is modified only by low ridges and the slightly entrenched channels of southeastward-flowing intermittent tributaries to Buffalo Creek. Northwest of Gascoyne one of these tributaries has been dammed, forming a perennial reservoir fed in part by springs and in part by runoff. The uplands are fairly rounded. At their highest point within the mapped area they rise about 185 feet above the strippable lignite bed. The maximum relief in the mapped area is about 250 feet. Most of the land underlain by the Scranton deposit is farmed, the rest is grass covered and devoid of trees or shrubs.

HARMON LIGNITE BED

Thickness data obtained from 1 seismograph-shothole drill report, 7 power-auger holes, 3 exposures, and 16 prospect reports of the Knife River Mining Co., indicate that the strippable lignite in the Scranton deposit ranges from 10 to 32 feet in thickness (graphic sections 79 through 105, pl. 20). Throughout most of the deposit area, the Harmon bed occurs in two benches, which in the central part of the deposit at location 90 converge to form 31 feet of solid lignite. The upper bench of the Harmon bed ranges from 4 to 20 feet in thickness and contains clay partings from 6 inches to 2 feet thick at locations 80, 81, and 86. Only the upper bench was penetrated at locations 79, 80, 81, 84, 85, 86, 99, 103, 104, and 105. The lower bench ranges in thickness from 7 to 23 feet and contains a parting 1½ feet thick at location 93, and 8½ feet thick at location 97. Only the lower bench was penetrated at locations 98 and 101. The upper bench and part of the lower bench are exposed at location 100 and both benches were penetrated at locations 82, 83, 87 to 97, and 102 (pl. 19).

In the western half of the deposit, only the upper bench is considered strippable, partly because the thickness of the parting between the two benches exceeds 5 feet, and partly because insufficient thickness information precludes making reliable estimates of the extent and thickness of the lower bench. In the central part of the deposit, where the two benches converge or are separated by a parting less than 5 feet thick, both benches are considered strippable. In the eastern part of the deposit, where the parting increases to more than 5 feet thick, only the thick lower bench or, at location 97, the upper part of the lower bench is considered strippable. The thin upper bench is excluded in the eastern part of the deposit because of its nearness to the surface and the resulting extent to which it is weathered back from the outcrop precludes making an estimate of the minable reserves it contains without additional prospecting and mapping. Additional unweathered reserves from the upper bench probably could be recovered by any operation strip mining the lower bench of the Harmon lignite bed. The isopach lines on plate 19 indicate only the thickness of the strippable lignite as described above.

Westward from Scranton the upper bench of the Harmon bed thins, and is only 4½ feet thick at an abandoned opening near the NE corner of sec. 17, T. 131 N., R. 100 W. Lack of thickness information northeast of Scranton precludes extending the deposit northward beyond the limits indicated on the map (pl. 19). Further prospecting may disclose additional reserves of thick lignite beneath the valley of the creek to the north. The Harmon bed is partly exposed at locations 81, 83, 84, and 100, as well as at the opencuts of the abandoned mines in and near Scranton. In addition, the top of the bed is visible at several openings along the east margin of the reservoir northwest of Gascoyne, and in several of the road cuts of both the railroad and the highway between the Adams County line and Scranton. These exposures all show some weathering; the only fresh exposure of the bed was at the Peerless mine (location 93), where a detailed megascopic examination was made of the upper part of the lower bench. In this examination, one-third of the measured section consisted of identifiable previtrain in lenses more than one-fourth of an inch thick. The rest was predominantly attrital with a few disseminated flecks of pyrite and some thin veinlets of fusain. Clinker formed by burning of the Harmon bed is conspicuous along the highway and railroad.

Water is found near the base of the lignite bed at almost every point of information. Because the bed dips northeast 20 to 25 feet per mile and the land surface slopes in the opposite direction, the accumulated water probably could be drained from the pits only by pumping.

Three samples of the Harmon bed in the Scranton deposit have been analyzed by the U. S. Bureau of Mines (table 3). One of these samples was taken from the Peerless mine; another was taken from the now-abandoned strip mine southeast of Scranton; and the third was taken from the now-abandoned underground mine near location 83.

OVERBURDEN AND FLOOR ROCK

The rocks overlying the Scranton deposit consist of poorly indurated sandstone, shale, and a few isolated lenses of fresh-water limestone. At the Peerless mine, clay predominates in the overburden for about 30 feet above the Harmon bed. Above 30 feet the sediments become increasingly sandy. Minor constituents in the overburden are small iron sulfide concretions, which on exposure weather to limonite; gypsum crystals, which are particularly large and abundant just above the lignite bed at location 84; petrified tree stumps as large as 3 feet in diameter, which are scattered over the surface in the S½ sec. 27, north of the Peerless mine; and lenses of dense, gray fresh-water limestone, which are 3 to 5 feet thick, and 15 to 20 feet in diameter, and contain carbonized plant stems and leaves. Several of these limestone lenses are interbedded with clay in the 20-foot section between the top bench and the main bench of the Harmon bed at the Peerless mine. A conglomerate compoted of quartz sand and well-rounded pebbles of igneous rocks imbedded in a limy matrix tops Scranton Butte. This conglomerate is about 6 feet thick, slabby, and probably a remnant of a terrace formed during the erosion of White River sediments, remains of which surmount the uplands of east-central Slope County to the north.

The floor rock at every point of information consists of clay.

RESERVES AND STRIPPING RATIO

The remaining reserves of strippable lignite in the Scranton deposit total 273 million tons, or about one-fifth of the total remaining reserves in the Bowman and Scranton deposits. (See table 1.) Of the total reserves in the Scranton deposit, 140 million tons, or 51 percent, is in the category of less than 60 feet of overburden. The stripping ratio in this category of reserves averages 1.9 to 1. The average stripping ratio for the Scranton deposit is 2.6 to 1.

POSSIBLE DEPOSITS OF STRIPPABLE LIGNITE

At least four other deposits in Slope and Bowman Counties possibly contain large reserves of strippable lignite. Four deposits—arbitrarily numbered 1, 2, 3, and 4 and described below—were located by means of data from seismograph shothole logs, water-well logs, or by reports of thick lignite by Hares (1928). Either because of insufficient field time, or because the deposits are too far from transportation to be of commercial importance at the present, the writers made no attempt to verify the indicated thickness of the lignite bed or to map thickness-of-overburden lines in detail. The reliability of the data, for the most part, are unknown and they are considered to be no more than a fair indication of the true thickness of the bed. However, the data may be of value to anyone making further investigations in this area. Therefore a map of each deposit was made (figs. 21, 23, 25, and 27), and on each map is shown the probable line of outcrop of the strippable bed (modified after Hares, 1928, pl. 14), and the probable location of the 120-feet-of-overburden line, as well as the location of all available thickness information. These maps are merely sketch maps and do not show the outcrops of clinker or of other lignite beds in the area.

Reports of thick coal in other parts of the area for which no geologic maps have been published indicate that there may be other deposits of lignite which may be strippable. The following information is given as an aid to future investigation: (1) Seven seismograph shotholes drilled a mile apart along the east line of secs. 19, 30, and 31, and the south line of secs. 32 to 36, T. 134 N., R. 100 W., indicate that a lignite bed under from 29 to 120 feet of overburden ranges from 7 to 27 feet in thickness; (2) in the four sections adjoining the township corner common to Tps. 133 and 134 N., Rs. 98 and 99 W., seismograph-shothole logs indicate that a lignite bed ranges from 10 to 20 feet in thickness and lies beneath overburden from 20 to 85 feet thick; and (3) at the SW corner of sec. 15, T. 133 N., R. 99 W., a lignite bed that appears to be the same bed as that mentioned in (2) above is reported to attain a thickness of 30 feet below a depth of 4 feet, in a seismograph shothole.

DEPOSIT 1

Possible strippable deposit 1 occupies about 7½ square miles in secs. 17, 20, 21, and 28 to 33, T. 136 N., R. 102 W., and secs. 5 to 9, 16, 17, 20, 21, and 22, T. 135 N., R. 102 W., Slope County, N. Dak. (fig. 21).

The northern tip of the deposit is just half a mile south of the Great Bend in the Little Missouri River; the southern tip lies 8 miles west of the village of Amidon, reached by a graded, gravel-surfaced county road. The deposit underlies the northern part of the uplands which form the north-trending divide between Sand Creek and Deep Creek. These uplands generally present a smooth and fairly rolling surface, except along their margins where the slopes are steep and dissected.

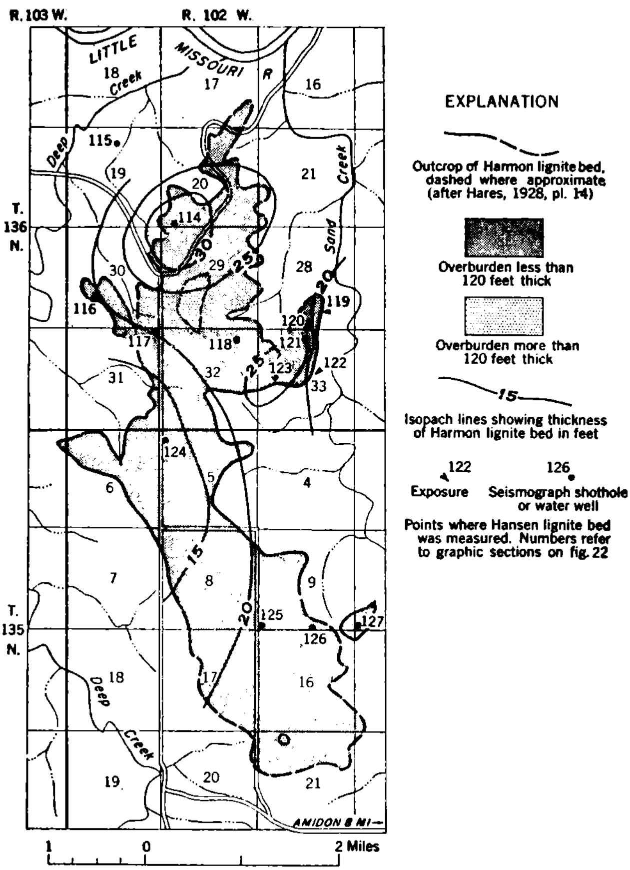


FIGURE 21.—Sketch map of possible strippable deposit in 1 in Harmon lignite bed, Slope County, N. Dak.

A few pines and cedars grow on these dissected slopes. Most of the land in the southern part of the deposit is farmed; the northern part of the deposit is mainly grass-covered pasture land.

In addition to three exposures, thickness information was provided by logs of 11 seismograph shotholes, of which those at locations 117 and 125 were logged by the writers. These data (graphic sections nos. 114–127, fig. 22) indicate that the Harmon bed ranges from 10

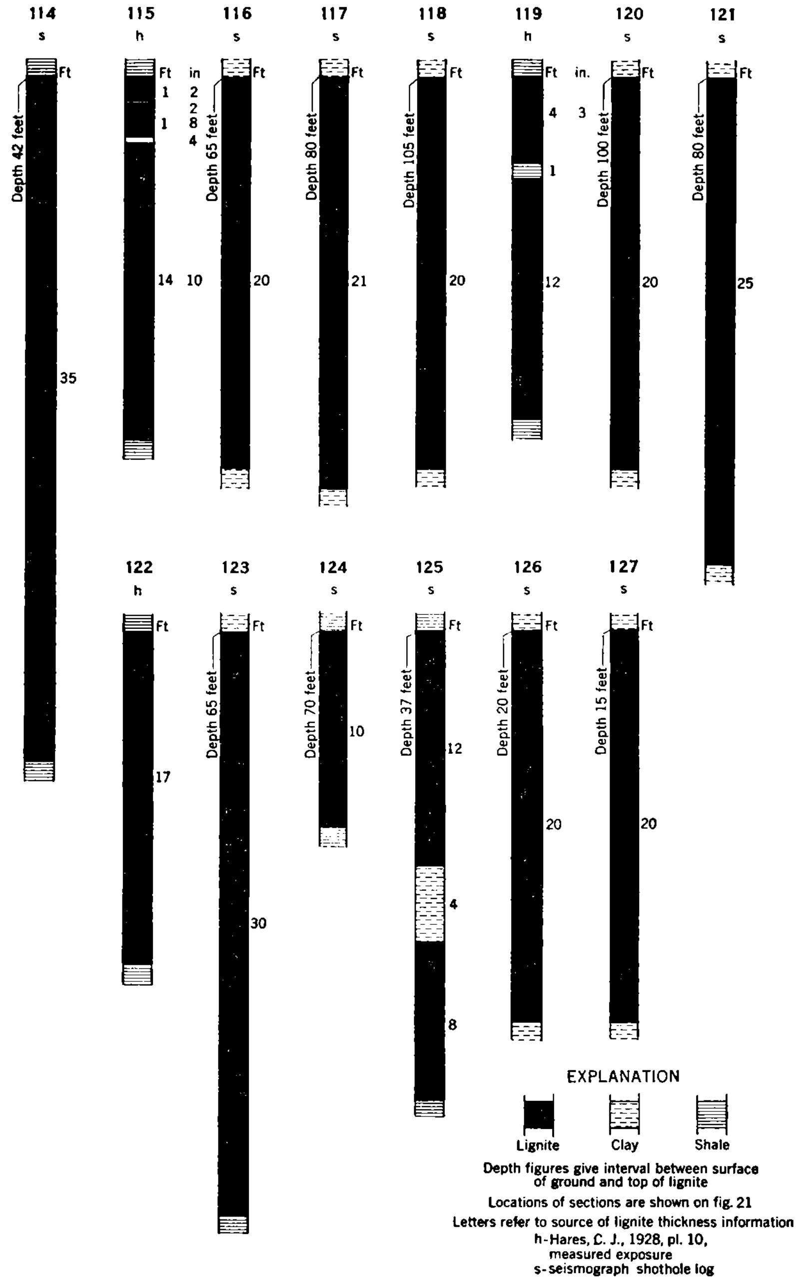


FIGURE 22.—Sections of Harmon lignite bed in and near possible strippable deposit 1, Slope County, N. Dak.

to 35 feet in thickness and probably averages at least 20 feet thick. Thus, the deposit is inferred to contain possible strippable reserves of about 170 million tons of lignite.

The overburden consists mainly of clay, shale, and soft sandstone. The thickness of the overburden is greatest in sec. 29, T. 136 N., R. 102 W., where the summit of a hill is about 150 feet above the lignite bed. The average thickness of the overburden in the northern part of the deposit is probably about 70 feet. In the central part of the deposit the thickness of the overburden does not exceed 80 feet, and probably averages about 60 feet. At the extreme southern tip of the deposit, in the NE¼ sec. 21, T. 135 N., R. 102 W., the summit of a hill is about 130 feet above the lignite, but elsewhere the thickness of the over-

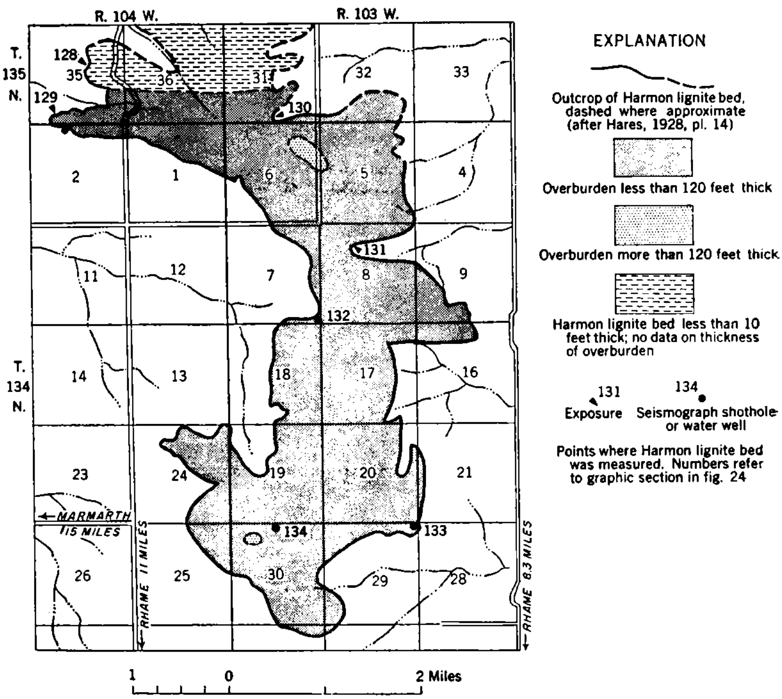


FIGURE 23.—Sketch may of possible strippable deposit 2 in Harmon lignite bed, Slope County, N. Dak.

burden probably averages about 40 feet. The lignite bed dips northward and northeastward from 20 to 40 feet per mile. The bed lies entirely above the main drainage channels of the area.

DEPOSIT 2

Possible strippable deposit 2 (fig. 23) occupies about 8½ square miles in secs. 5 to 9, 16 to 21, and 29 to 32, T. 134 N., R. 103 W.; secs. 1, 2, 24, and 25, T. 134 N., R. 104 W.; secs. 31 and 32, T. 135 N., R. 103 W.; and secs. 35 and 36, T. 135 N., R. 104 W., Slope County, N. Dak. The deposit underlies part of the uplands which form the north-trending divide between Deep Creek on the east and the Little Missouri River on the west. The village of Rhame lies south of the deposit and is accessible by means of gravel-surfaced county roads. Marmarth, on the Little Missouri River, is 16 road-miles to the southwest. Only about one-fifth of the land is under cultivation, the rest being treeless, grass-covered pasture. This area was once farmed extensively, but as most of the land is submarginal, the Federal Government has purchased it and reseeded it with grass.

Four exposures measured by Hares (1928) and one seismograph-shothole log indicate that the Harmon bed in the northern part of

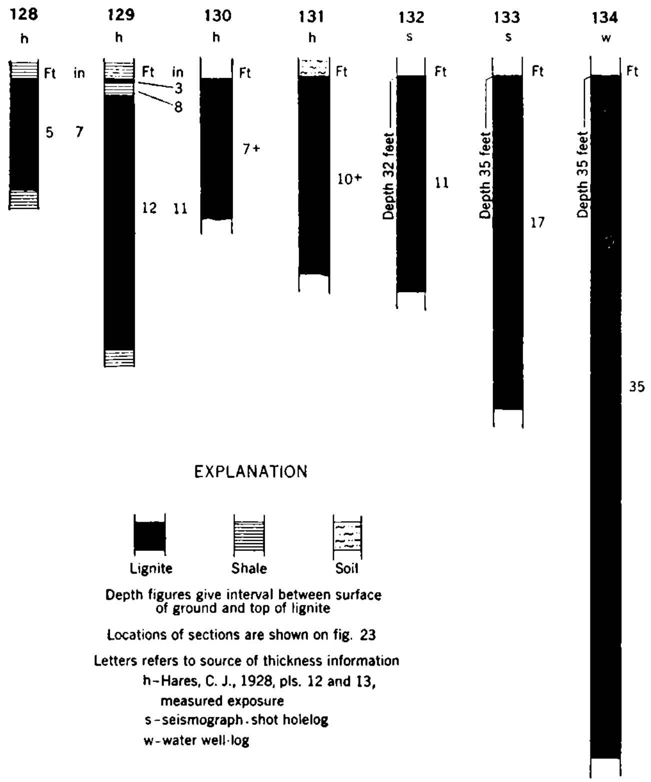


FIGURE 24.—Sections of Harmon lignite bed in and near possible strippable deposit 2, Slope County, N. Dak.

the deposit ranges from 5 feet 7 inches to 12 feet 11 inches in thickness, and a seismograph shothole and a water-well log indicate that the bed in the southern part of the deposit may thicken to 35 feet (fig. 24). If an average thickness of 15 feet is assumed, the reserves of lignite under less than 120 feet of overburden are about 140 million tons. The Harmon bed in this area dips northeastward at about 20 feet per mile. Because the lignite lies well above the main drainage channels of the area, water may be disposed of easily.

The overburden consists mainly of soft sandstone, shale, and clay. The terraces that border the eastern margin of the deposit are capped by gravel. Except where modified by stream valleys, the land rises fairly steeply along the margin of the deposit; hence, the overburden throughout the deposit probably averages about 75 feet in thickness.

DEPOSIT 3

Possible strippable deposit 3 comprises about 9 square miles in secs. 16, 17, 20, 21, 22, 23, and 26 to 36, T. 133 N., R. 104 W., Slope County, and partial secs. 4 and 6, T. 132 N., R. 104 W., and partial sections 1 and 2, and sections 11 and 12, T. 132 N., R. 105 W., Bowman

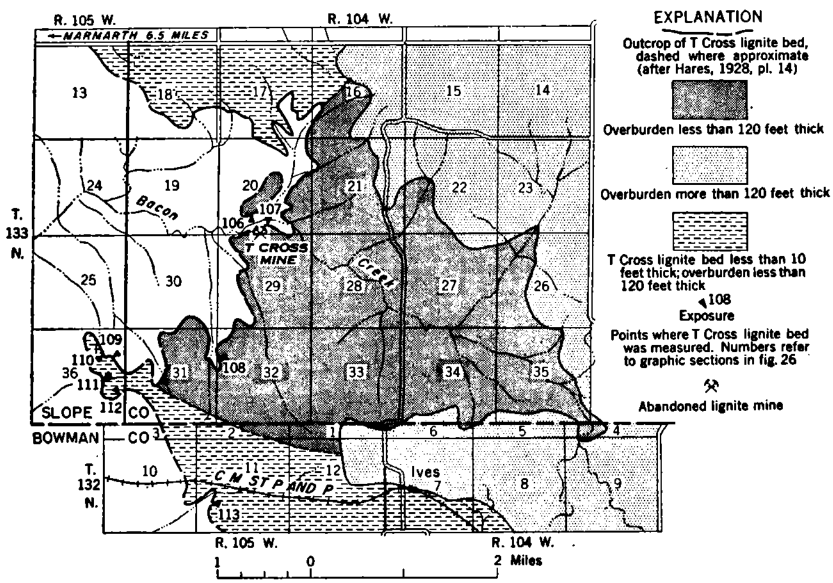


FIGURE 25.—Sketch map of possible strippable deposit 3 in the T Cross lignite bed, Slope and Bowman Counties, N. Dak.

County, N. Dak. (fig. 25). The deposit is in the T Cross lignite bed of the Ludlow member, and occupies the headward part of the valley formed by westward-flowing Bacon Creek, an intermittent tributary of the Little Missouri River. The land surface in the western part of the deposit is gently rolling and much of it is farmed. The surface in the eastern part of the deposit is characterized by steep slopes and is used mainly as pasture for livestock. Marmarth is 12.5 miles west from the deposit by way of the graded county road to the north, and is 11.3 miles to the west by way of the county road and paved U. S. Highway 12 to the south. Ives, a siding on the railroad, lies less than a miles south of the deposit, and the Little Missouri lies about 5 miles to the west.

The only thickness data available for the T Cross lignite bed in and near the deposit are exposures measured by Hares (1928). These measurements show that the bed ranges in thickness from 4 to 24 feet, and at location 106 contains many shale partings (fig. 26). The lignite bed is assumed to average 15 feet in thickness throughout the deposit. Thus, the deposit is inferred to contain about 150 million short tons of lignite beneath less than 120 feet of overburden. Because of the lack of thickness information throughout the deposit, and because of the indicated variations in the thickness and quality of the T Cross bed along the outcrop, extensive drilling would be necessary to determine more precisely the amount of reserves within the deposit.

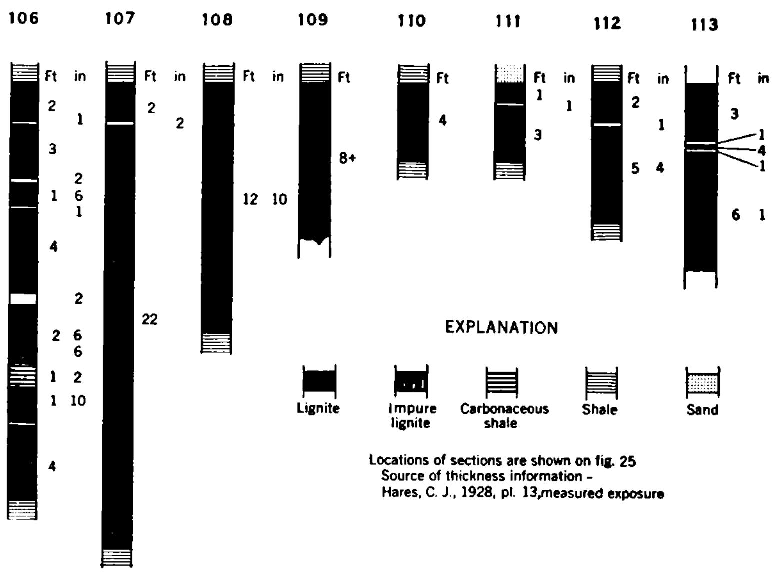


FIGURE 26.—Sections of T Cross lignite bed in and near possible strippable deposit 3, Slope and Bowman Counties, N. Dak.

A sample of lignite taken from the T Cross bed at the Durkin prospect has been analyzed by the U. S. Bureau of Mines (table 3).

The overburden consists mainly of shale and sandy shale with some sandstone. Gravel-capped terraces cover a wide area near the outcrop of the T Cross bed in the vicinity of the abandoned T Cross mine, and the Ives lignite bed lies 50 feet stratigraphically above the T Cross bed. The dip in this area is greater than in the eastern part of the county, owing to the proximity of the Cedar Creek anticline. Local dips of 5° and 3° to the northeast are reported by Hares (1928, p. 87) in the SE¼ sec. 26, T. 133 N., R. 104 W., but the general dip within the area is about 45 feet per mile to the northeast.

DEPOSIT 4

Possible strippable deposit 4 comprises about 12 square miles in secs. 17 to 21, 28, 29, 30, 32, and 33, T. 133 N., R. 101 W., and secs. 10 to 16 and 21 to 27, T. 133 N., R. 102 W., Slope County, N. Dak. (fig. 27). The deposit is in the Hansen lignite bed of the Tongue River member and underlies the low, rolling uplands of the upper tributaries of Deep Creek. Most of the land is farmed; the rest is grass covered and is used as pasture for livestock. The town of Bowman is about 8 miles

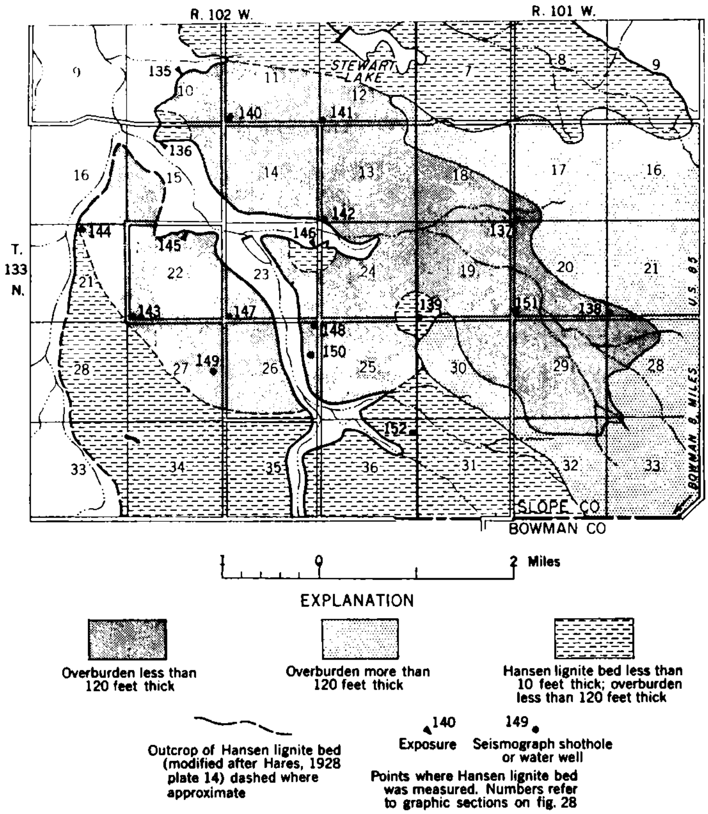


FIGURE 27.—Sketch may of possible strippable deposit 4 in Hansen lignite bed, Slope County, N. Dak.

south of the deposit and readily accessible by means of any of the three graded county roads which cross the area or by the all-weather, gravel-surfaced U. S. Highway 85, which passes along the eastern margin of the deposit.

The Hansen lignite bed in and near the deposit, as measured at the outcrop by Hares (1928), ranges from 6 feet 8 inches to 10 feet 7 inches in thickness, and at locations 145 and 146 contains a 2-inch parting of shale 2 feet above the base of the bed. Additional thickness data are furnished by 3 water wells and 11 seismograph shotholes, of which those at locations 138, 139, and 152 were logged by the writers (fig. 28).

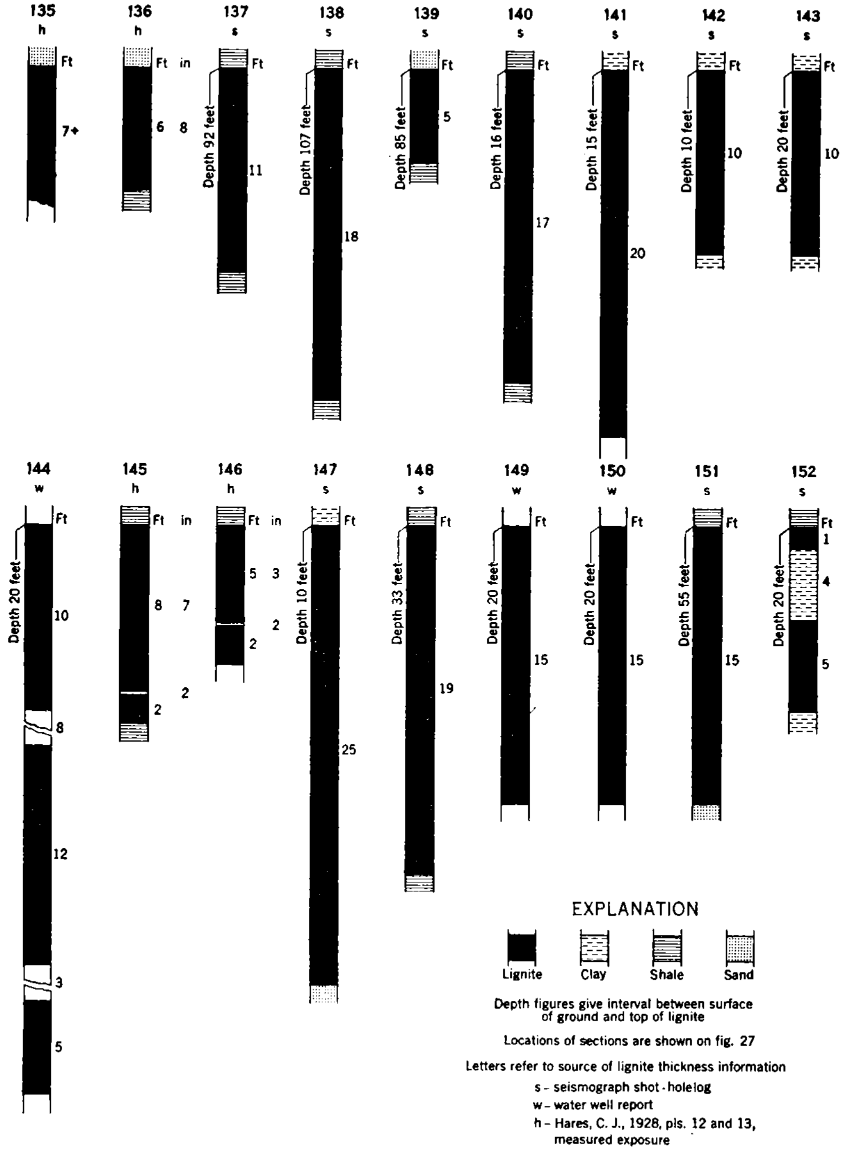


FIGURE 28.—Sections of Hansen lignite bed in and near possible strippable deposit 4, Slope County, N. Dak.

These additional measurements indicate that the bed attains a maximum of 25 feet in thickness at location 147—the greatest known thickness of the Hansen bed in Slope and Bowman Counties. Within the deposit the Hansen bed probably averages 15 feet in thickness. In this average are included the thickness of the top 2 of the 3 benches of lignite that are reported in the log from a water well drilled at location 144. The 3 benches at location 144 and the unusual thickness of lignite at location 147 indicate that the Hansen bed may coalesce with the underlying H bed in this area. The indicated reserves within the deposit total about 200 million short tons of lignite. No allowance is made for weathered lignite in these reserves, although as much as 10 percent of the reserves may be weathered along the outcrop where the overburden is thin.

The overburden consists mainly of poorly indurated calcareous sandstone, clayey shale, and clay. The Harmon lignite bed and clinker from the burned Harmon bed lie from 40 to 60 feet above the Hansen bed and are mapped in detail as part of the Bowman deposit (pl. 16) The contour line outlining 60 feet of overburden in the Bowman deposit approximates the 120 feet-of-overburden contour of deposit 4.

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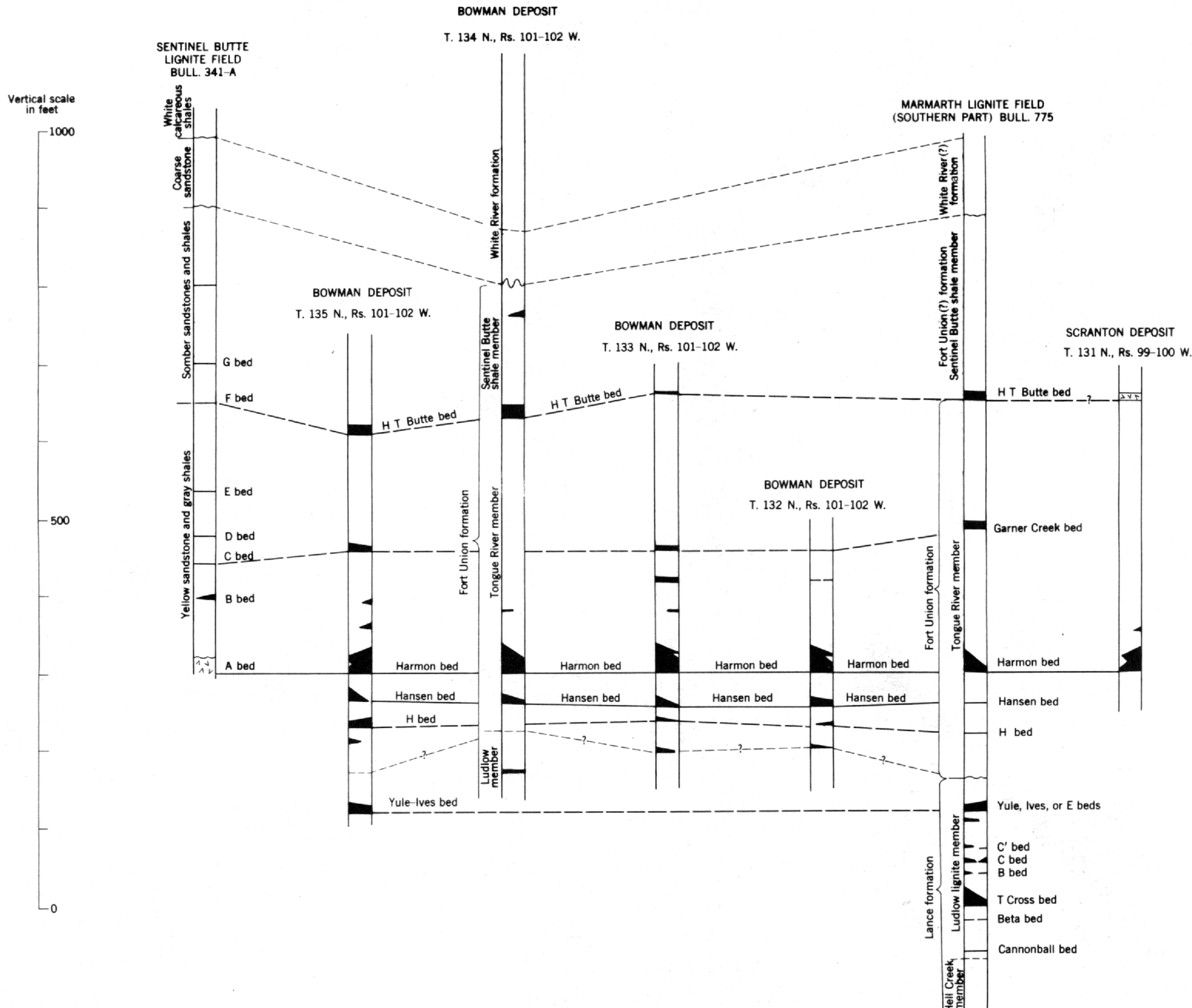

Compiled by R. C. Kepferle, 1952

GENERALIZED COLUMNAR SECTIONS SHOWING STRATIGRAPHIC POSITION AND SUGGESTED CORRELATION OF MAIN LIGNITE BEDS IN SLOPE, BOWMAN, AND GOLDEN VALLEY COUNTIES, NORTH DAKOTA

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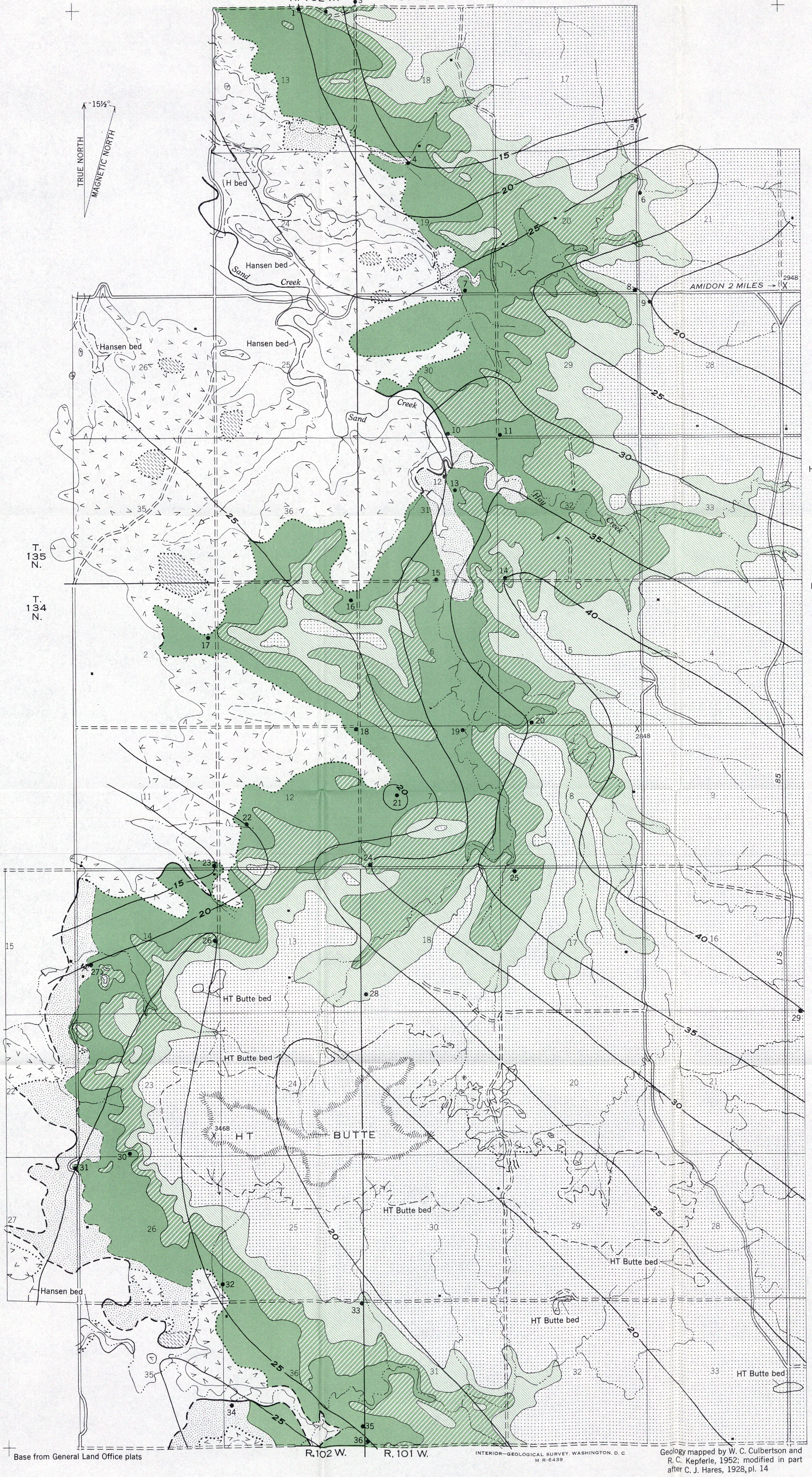


EXPLANATION

Outcrop of Harmon lignite bed, dashed where inferred

Hansen bed
Outcrop of other lignite beds, dashed where inferred

Clinker. Dotted line shows inferred contact with lignite

—30—
Isopach lines showing thickness of Harmon lignite bed in feet

•29
Points where Harmon lignite bed was measured. Numbers refer to graphic section in pl. 17

Abandoned lignite mine

3468 X
U. S. C. and G. S. bench mark, with elevation above sea level

STRIPPABLE LIGNITE (HARMON BED)

Overburden less than 60 feet thick

Overburden 60 to 90 feet thick

Overburden 90 to 120 feet thick

HARMON LIGNITE NOT CONSIDERED STRIPPABLE

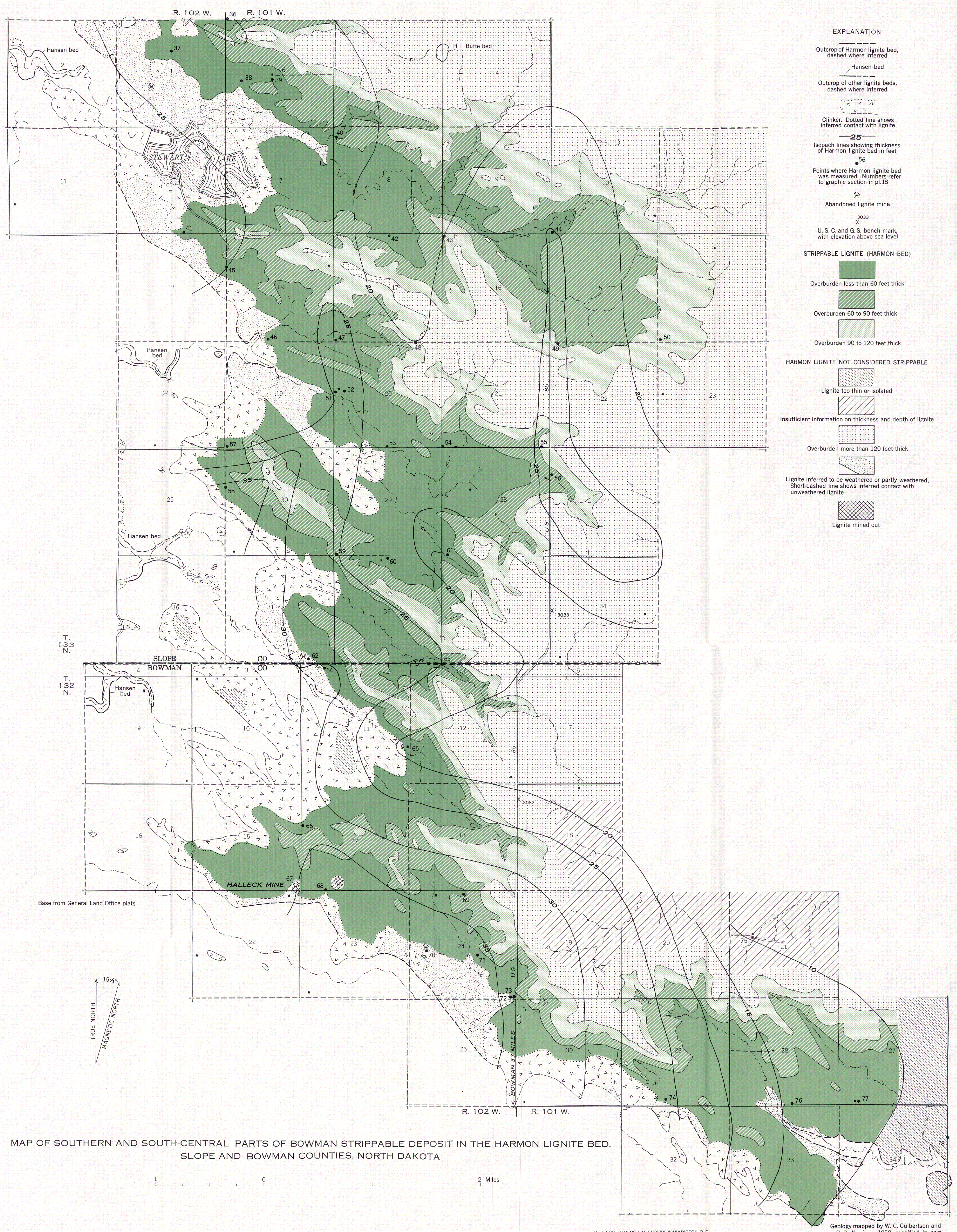
Lignite too thin or isolated

Overburden more than 120 feet thick

Lignite inferred to be weathered or partly weathered. Short-dashed line shows inferred contact with unweathered lignite

MAP OF NORTHERN AND NORTH-CENTRAL PARTS OF BOWMAN STRIPPABLE DEPOSIT IN THE HARMON LIGNITE BED, SLOPE COUNTY, NORTH DAKOTA

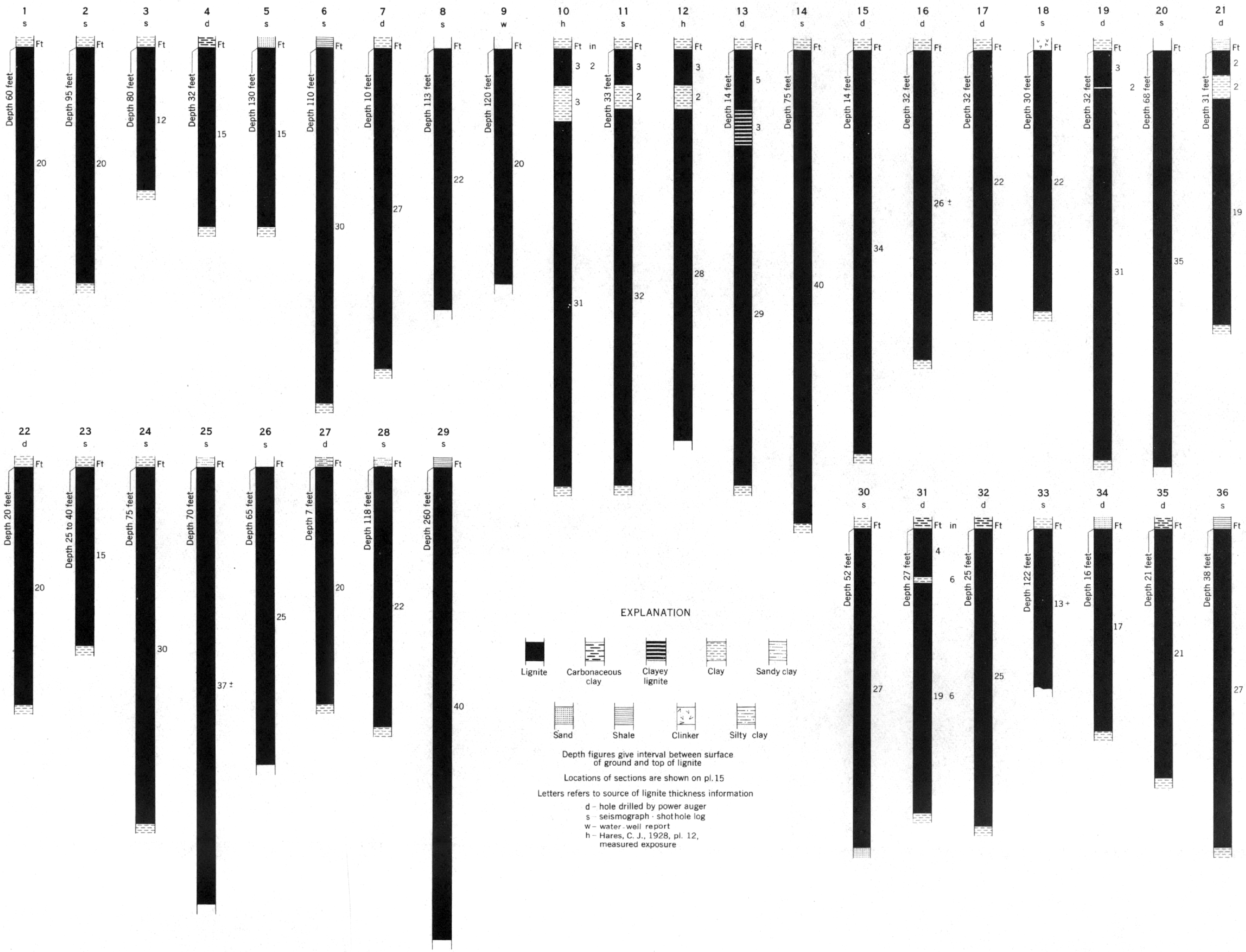
1 0 2 Miles



MAP OF SOUTHERN AND SOUTH-CENTRAL PARTS OF BOWMAN STRIPPABLE DEPOSIT IN THE HARMON LIGNITE BED, SLOPE AND BOWMAN COUNTIES, NORTH DAKOTA

INTERIOR—GEOLOGICAL SURVEY, WASHINGTON, D. C.
M 8-6439

Geology mapped by W. C. Culbertson and R. C. Kepferle, 1952; modified in part after C. J. Hares, 1928, pl. 14



SECTIONS OF THE HARMON LIGNITE BED IN NORTHERN AND NORTH-CENTRAL PARTS OF BOWMAN STRIPPABLE DEPOSIT, SLOPE COUNTY, NORTH DAKOTA

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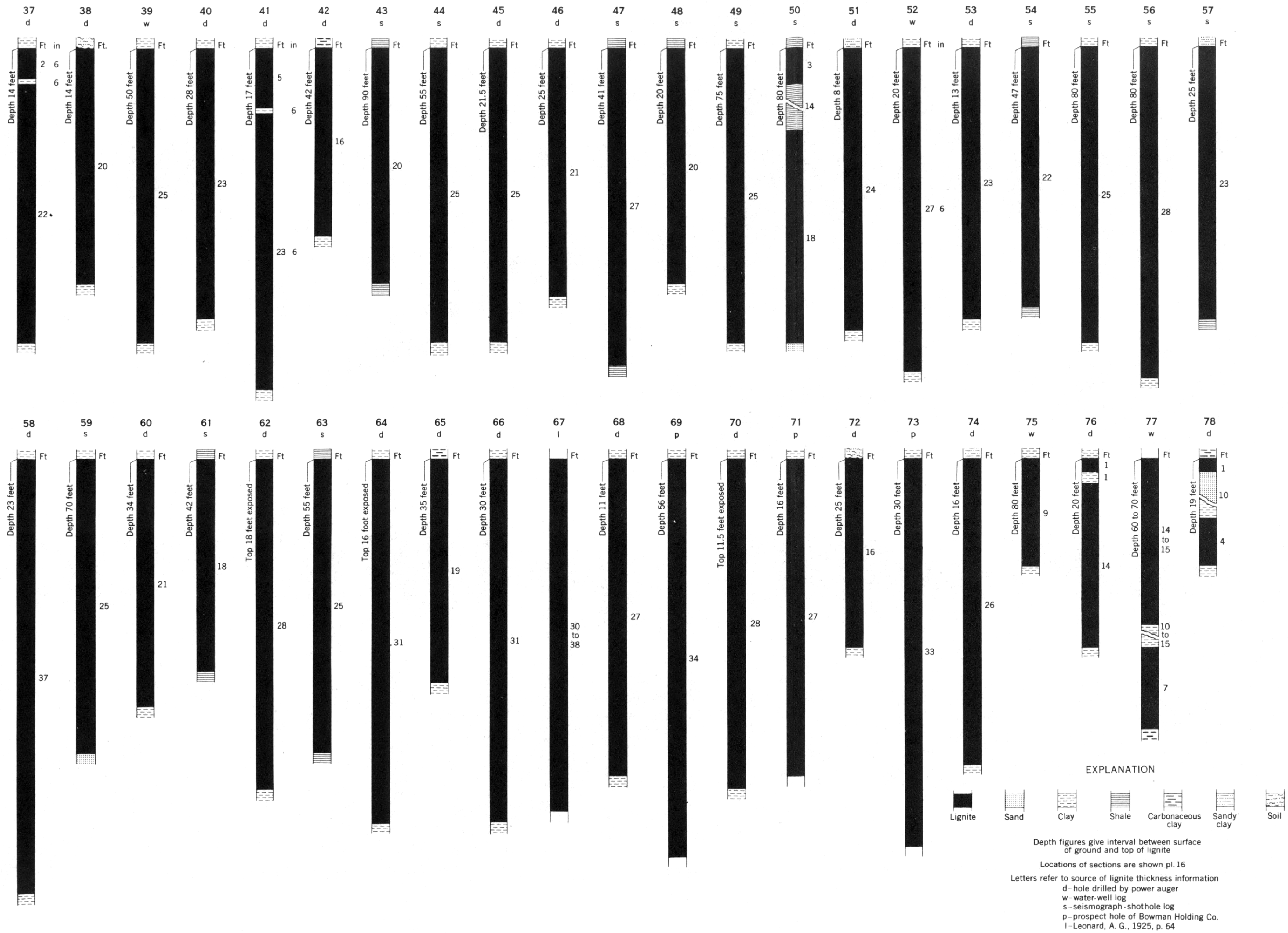

SECTIONS OF THE HARMON LIGNITE BED IN NORTHERN AND NORTH-CENTRAL PARTS OF BOWMAN STRIPPABLE DEPOSIT, SLOPE COUNTY, NORTH DAKOTA

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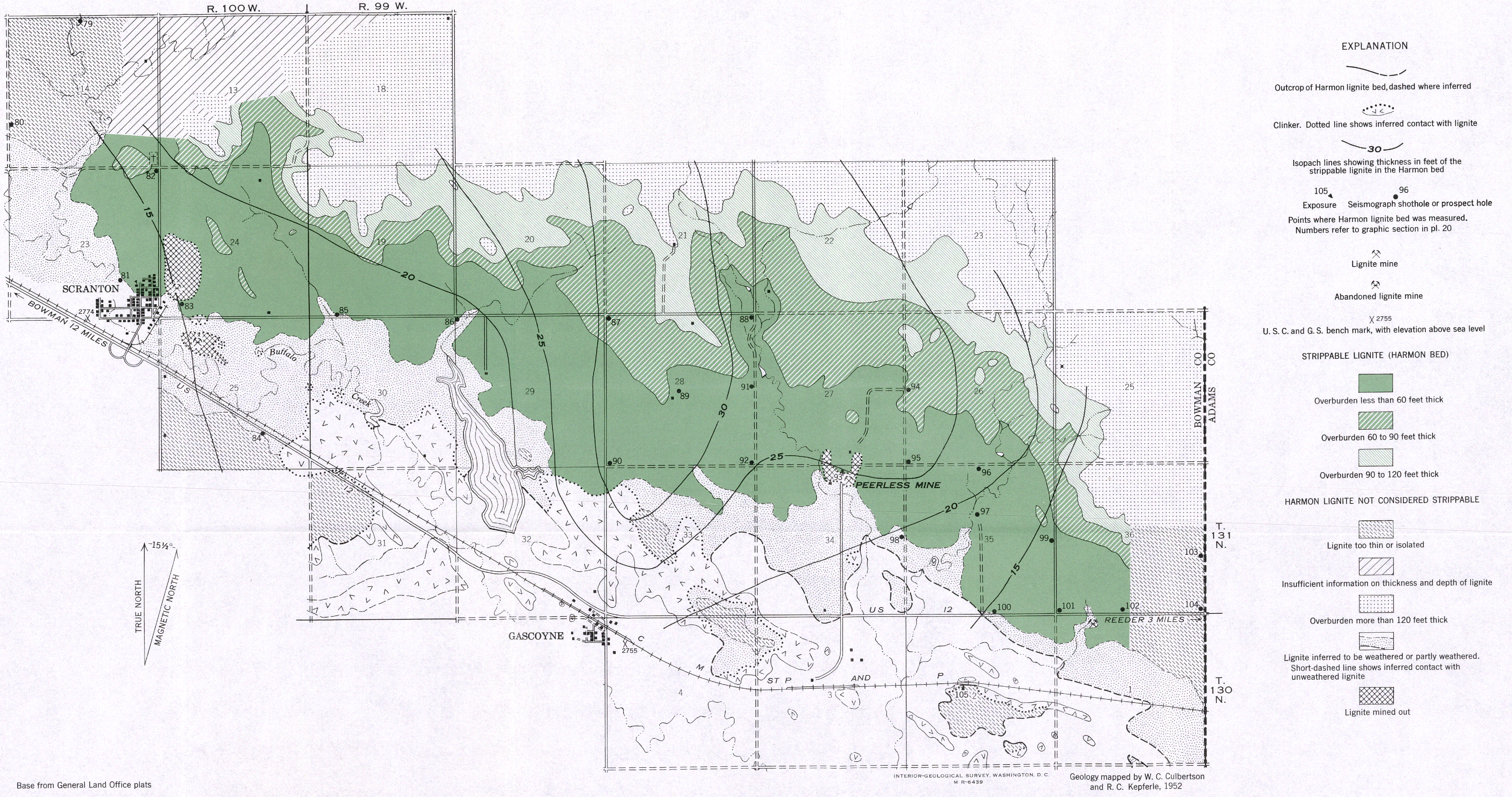
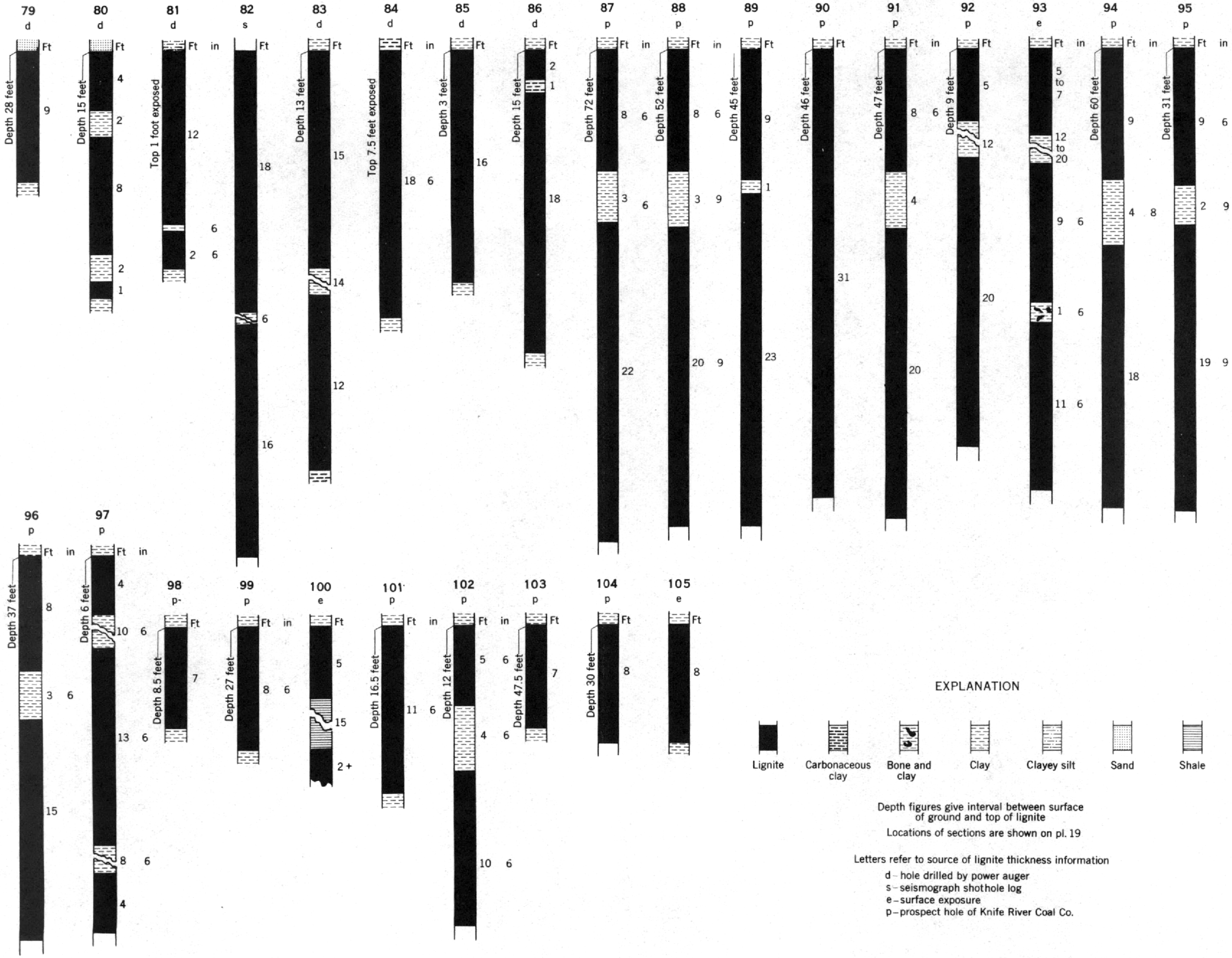


Base from General Land Office plats

Geology mapped by W. C. Culbertson and R. C. Kepferle, 1952

MAP OF SCRANTON STRIPPABLE DEPOSIT IN THE HARMON LIGNITE BED, BOWMAN COUNTY, NORTH DAKOTA

1 0 2 Miles



EXPLANATION

Lignite — Carbonaceous clay — Bone and clay — Clay — Clayey silt — Sand — Shale

Depth figures give interval between surface of ground and top of lignite

Locations of sections are shown on pl. 19

Letters refer to source of lignite thickness information
- d – hole drilled by power auger
- s – seismograph shothole log
- e – surface exposure
- p – prospect hole of Knife River Coal Co.

SECTIONS OF THE HARMON LIGNITE BED IN SCRANTON STRIPPABLE DEPOSIT, BOWMAN COUNTY, NORTH DAKOTA