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GEOLOGY AND COAL RESOURCES OF THE MINOT REGION NORTH DAKOTA

BY

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GEOLOGY AND COAL RESOURCES OF THE MINOT REGION, NORTH DAKOTA

By David A. Andrews

ABSTRACT

The Minot region includes about 2,800 square miles in north-central North Dakota, extending from the Souris River on the north to the Missouri River on the south and from the western border of Ward County on the west to Anamoose, Sheridan County, on the east.

The divide between the Souris and Missouri Rivers, which is also the divide between drainage to Hudson Bay and the Gulf of Mexico, follows a belt of hummocky topography which is about 20 miles wide and trends northwestward across the central part of the Minot region. The surface of the region southwest of the divide is a plateau trenched to a depth of 200 feet or more by the valleys of the Missouri River and its tributaries. The northeastern part of the region is a plain sloping gently to the northeast and bordered on the north by the valleys, 100 to 200 feet deep, of the Souris River and the Riviere des Lacs.

About 250 feet of soft buff to gray sandstones and shales of the lower part of the Fort Union formation, of Eocene (Tertiary) age, are exposed along the Missouri River and probably 150 feet or more of these sedimentary rocks are exposed at places in the higher parts of the area. The Fort Union is also exposed in places along the Souris River, the Riviere des Lacs, and some of their deeper tributaries. Pleistocene glacial deposits, 1 to 200 feet thick, form a widespread surface cover in the high central part of the region and consist of sand, gravel, boulders, and clay. Similar deposits of the same age with a somewhat smaller thickness, 10 to 50 feet, cover most of the northern part of the region.

The hummocky divide in the central part of the region is formed by the Altamont moraine, of late Wisconsin (Pleistocene) age. The interstream divides of the country southwest of the Altamont moraine are covered with a thin veneer of drift of earlier than late Wisconsin age and late Wisconsin outwash. The present course of the Missouri River in this portion of the Minot region was established and incised in the Missouri Plateau in Pleistocene time. The sloping plain on the northeast side of the Altamont moraine marks the site of the southwest margin of the glacial Lake Souris. The history of this lake as recorded in the northeast corner of the Minot region is revealed by beaches at levels of 2,100 down to 1,600 feet above sea level, by deltas, and by intricate abandoned channels that drained the lake.

During the higher stages of Lake Souris the beaches followed the front of the Altamont moraine and probably extended from the vicinity of Dogden Butte northwestward beyond the northern border of North Dakota, but at the low stages the lake was confined to the lower levels of Souris Valley and extended northward from the vicinity of Drake and Minot to the junction of the Souris and Assiniboine Rivers, in Manitoba.

Coal of lignite rank is found at several horizons in the Fort Union formation. Although several of these coal beds were found and measured, only six are of sufficient thickness and persistence to trace consistently along the outcrop and to trace by means of records of the deep wells that have been drilled in the region. These six coal beds average more than 4 feet in thickness; the Coteau bed, in the northeastern part of the region, is 13 feet thick for considerable distances; the Burlington bed, in the northwestern part of the region, and the Garrison Creek bed, in the southwestern part, attain thicknesses of 10 feet in some places. Several localities are indicated where stripping of the Coteau bed, the Garrison Creek bed, and the Minter bed (in the southwestern part of the region) may be commercially feasible. The estimated reserves of coal in the Minot region are 18,094,592,000 tons.

A test well drilled for oil near Des Lacs and another well just outside the southeast corner of the region were reported to have obtained showings of oil and gas but failed to obtain commercial production. The rocks in the region are practically flat-lying, and no indication of structural features favorable for oil accumulation was found.

INTRODUCTION

LOCATION AND EXTENT OF REGION

The Minot coal region includes most of Ward and McLean Counties and parts of Mercer, Sheridan, and McHenry Counties, in north-central North Dakota. It includes an area of approximately 2,800 square miles extending from the Riviere des Lacs and the Souris River on the north to the Missouri River on the south and from the vicinity of Berthold and Makoti, near the west border, to the vicinity of Drake and Anamoose, on the east border. The location of the Minot region is shown on figure 11.

Coal fields whose locations are shown on figure 11

No.	Field	Bulletin	No.	Field	Bulletin
1	Minot	906-B.	20	Miles City	341-A.
2	Washburn	381-A.	21	Marmarth	775.
3	New Salem	726-A.	22	Tullock Creek	749.
4	Cannonball River	541-G.	23	Bull Mountain	647.
5	Standing Rock and Cheyenne River.	575.	24	Sheridan	341-B.
			25	Powder River	381-B.
6	Fort Berthold	381-A, 471-C.	26	Little Powder River	471-A.
7	Fort Berthold	726-D.	27	Gillette	796-A.
8	Williston	531-E.	28	Northward extension of Sheridan.	806-B.
9	Sentinel Butte	341-A.			
10	Northwestern South Dakota	627.	29	Ashland	831-B.
11	Culbertson	471-D.	30	Rosebud	847-B.
12	Scobey	751-E.	31	Forsyth	812-A.
13	Fort Peck	381-A.	32	Richey-Lambert	847-C.
14	Sidney	471-D.	33	Mizpah	906-C.
15	Glendive	471-D.	34	Pine Ridge	541-H.
16	Terry	471-D.	35	Nesson Anticline	691-G.
17	Baker	471-D.	36	McCone County	905.
18	Ekalaka	751-F.	37	Big Horn County	856.
19	Little Sheep Mountain	531-F.			

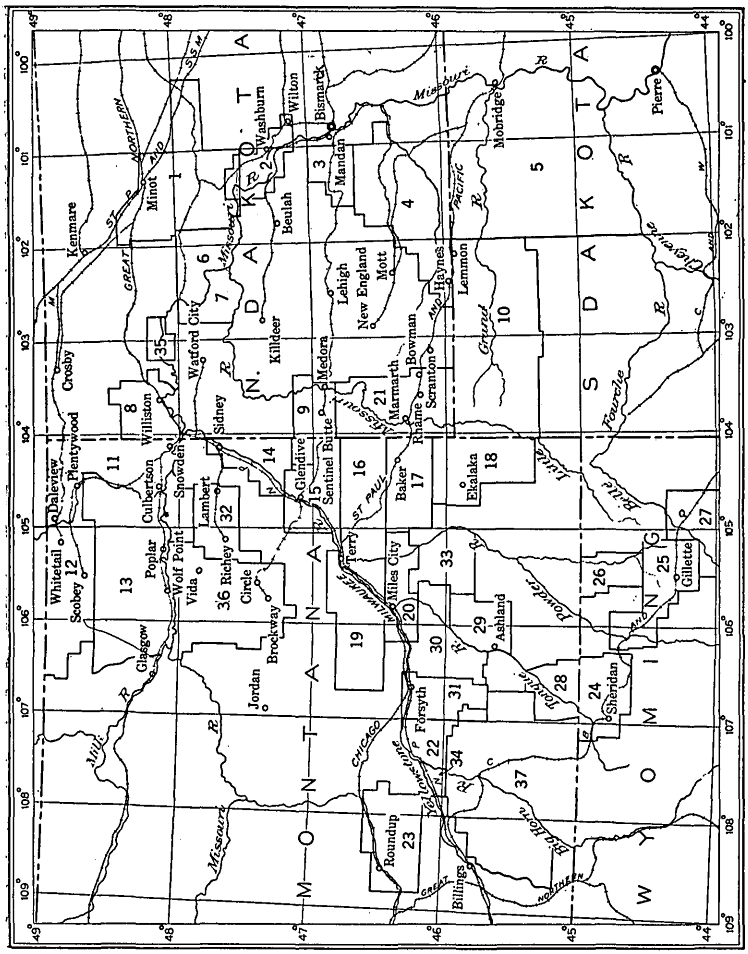

FIGURE 11.—Index map of western North Dakota and adjacent States showing location of the Minot region (No. 1) and other areas described in published reports.

FIELD WORK

The field investigations for this report were conducted by the United States Geological Survey during the summer and early fall of 1934 in consequence of an allotment of funds from the Public Works Administration. The writer, who had charge of the investigations, was assisted by R. B. Simpson, F. R. Waldron, and L. E. Holmgren. Topographic maps of the Minot, Sawyer, Benedict, Kongsberg, Balfour, Drake, Garrison, and Coleharbor 15-minute quadrangles were used as base maps for mapping the geology of the eastern part of the region. Those portions of the region along the Missouri and Souris Rivers and the Riviere des Lacs not covered by the topographic maps were mapped by plane table and telescopic alidades; altitudes were determined by measuring vertical angles with the alidade, beginning with benchmarks on the topographic maps; numerous land corners were located to determine the location of land lines. In the western part of the region, where no coal crops out, the township plats published by the General Land Office were used as base maps, and locations were determined by compass direction and speedometer measurements of distances; altitudes were determined by aneroid barometers. In most places these traverses followed section-line roads. The use of the automobile traverse method of mapping permitted rapid mapping of a large area where there are no rock outcrops and where the location and altitude of wells and the distribution of glacial deposits comprised the principal data to be obtained. The areas mapped by the different methods are shown on figure 12.

PREVIOUS INVESTIGATIONS

That portion of the Minot region included in Ward and McLean Counties has been described by Wilder and Wood,[1] who gave an extended description of the known lignites in Ward County. Wilder [2] has briefly discussed the coals along the Missouri River in the southern part of the region. Later the known coal outcrops were briefly described and an estimate made of the reserves of coal in North Dakota by Leonard, Babcock, and Dove.[3] Willard and Erickson [4] described the hummocky central portion of the region, known as the Coteau du Missouri, and presented a detailed map of a part of the Coteau. Several references to the glacial features of Lake Souris were made by Upham [5] but he did not describe in detail any of the

[1] Wilder, F. A., and Wood, L. H., Lignite deposits of McLean County and preliminary report on Ward County: North Dakota Geol. Survey 2d Bienn. Report, pp. 74-141, 1901-1902.

[2] Wilder, F. A., The lignite of North Dakota and its relation to irrigation: U. S. Geol. Survey Water-Supply Paper 117, pp. 34-35, 1905.

[3] Leonard, A. G., Babcock, E. J., and Dove, L. P., The lignite deposits of North Dakota: North Dakota Geol. Survey Bull. 4, pp. 111-131, 146-152, 1925.

[4] Willard, D. E., and Erickson, M. B., Survey of the Coteaus of the Missouri: North Dakota Agr. College Survey 2d Bienn. Rept., for 1903-4, pp. 17-27, 1904.

[5] Upham, Warren, The glacial Lake Agassiz: U. S. Geol. Survey Mon. 25, 1896.

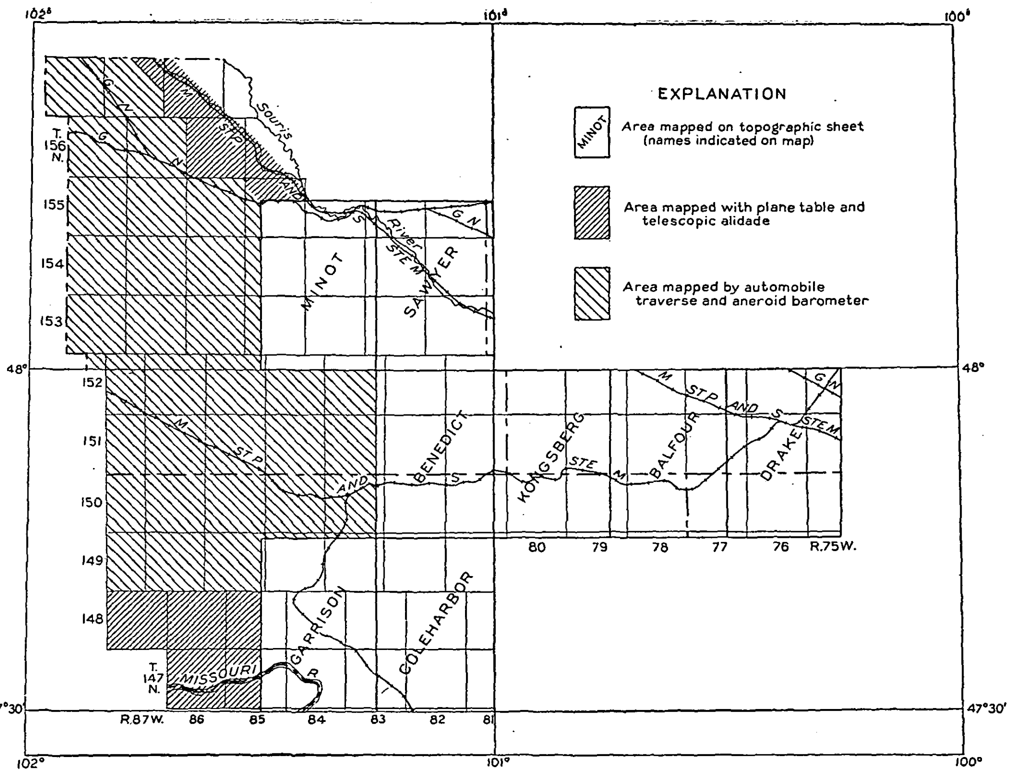

FIGURE 12.—Index map of the Minot region, North Dakota, showing areas in which different methods of mapping the geologic features were used.

features that are found in this part of North Dakota. Simpson [6] briefly described the general features of the geology of North Dakota and included a detailed description of artesian water by counties.

The Minot region was briefly described in a preliminary report by the writer,[7] and an abstract by him describing the features of glacial Lake Souris has also been published.[8]

The geology and coal resources of an area on the west were described in a preliminary report by Smith [9] and more fully described in a later report by Pishel.[10] The adjoining area on the south has also been described by Smith.[11] Other reports describing the geology and coal resources of nearby areas in North Dakota, South Dakota, eastern Montana, and Wyoming are indicated on figure 11.

ACKNOWLEDGMENTS

The writer wishes to express his appreciation to his assistants, Messrs. Simpson, Waldron, and Holmgren, for their industry and efficient service during the field work. He also wishes to express his gratitude for the cooperation of the many inhabitants who gave information about their wells, of the well drillers, who supplied much additional information, and of the coal-mine operators, who gave freely of their time to assist in the study of their mines. Mr. E. A. Whitman, chief engineer of the Minneapolis, St. Paul & Sault Ste. Marie Railroad, supplied detailed logs of the wells drilled by that railroad. H. D. Miser, under whose direction this work was done, and A. A. Baker, both of the United States Geological Survey, gave many helpful suggestions during the preparation of this report.

GEOGRAPHY

SURFACE FEATURES

Most of the Minot region lies on the northeast margin of the Missouri Plateau, an extensive plateau area, now considerably dissected, extending eastward from the northern Rocky Mountains. The northeastern part of the plateau has been severed from the main part by the Missouri River, which has been entrenched 200 to 300 feet below the general plateau level of the immediately adjacent country. The Missouri River cuts across the southeast corner of the region and forms the northeastern boundary of the Missouri Plateau. The Coteau du

[6] Simpson, H. E., Geology and ground-water resources of North Dakota: U. S. Geol. Survey Water-Supply Paper 598, 1929.

[7] Andrews, D. A., Geology and coal resources of the Minot area, North-central North Dakota: U. S. Dept. Interior Press Mem., Aug. 5, 1935.

[8] Andrews, D. A., Early stages of glacial Lake Souris, North Dakota: Washington Acad. Sci. Jour., vol. 25, no. 12, pp. 568–569, 1935.

[9] Smith, C. D., The Fort Berthold Indian Reservation lignite field, North Dakota: U. S. Geol. Survey Bull. 381, pp. 30–39, 1909.

[10] Pishel, M. A., Lignite in the Fort Berthold Indian Reservation, North Dakota, north of Missouri River: U. S. Geol. Survey, Bull. 471, pp. 170–186, 1912.

[11] Smith, C. D., The Washburn lignite field, North Dakota: U. S. Geol. Survey Bull. 381, pp. 19–29, 1909.

Missouri is bounded on the south and west by the Missouri River and on the northeast by the Riviere des Lacs and Souris River, which border the Minot region on the north. The altitudes along the Missouri River range from 1,675 to 1,720 feet in the Minot region, and the altitudes along the Souris River and Riviere des Lacs range from 1,520 to 1,640 feet. On each side of these rivers the surface rises gently as a regular plain toward the interstream divide, which is a hummocky strip extending southeastward across the central part of the Minot region. A few local hills along this divide have altitudes slightly more than 2,300 feet above sea level.

A fairly steep northward-facing escarpment 100 to 200 feet high, here called the Altamont escarpment (see pl. 11) follows an approximately straight line extending from the northwest corner of the Minot region southeastward through Kongsberg to the southeastern part of the region. The general surface of the part of the region northeast of this escarpment is an even plain sloping 30 to 40 feet to the mile northeastward from altitudes of 1,900 to 2,100 feet above sea level at the escarpment to 1,600 to 1,800 feet above sea level at the border of the river valleys. The western and central part of the plains area is drained by numerous parallel streams flowing northeast to the major streams. That portion of the plain north and east of the vicinity of Butte is slightly irregular and uneven, and the relief is less than 100 feet; it is very poorly drained, although there are numerous abandoned stream valleys, now occupied by swamps, that are filled and clogged with irregular hummocks of sand and gravel or occupied by very weak sluggish drainage; it becomes more uneven toward the southeast corner and is surmounted by two rounded hills rising about 200 feet above the general level of the plain in T. 150 N., Rs. 75 and 76 W.

About 10 miles northeast of and more or less parallel to the Altamont escarpment, the plain is entrenched by the valleys of the Riviere des Lacs and the Souris River. The Riviere des Lacs, the smaller of the two, follows a meandering course through a flat-bottomed straight valley 150 to 250 feet deep from Carpio to Burlington, where it joins the Souris River. The markedly meandering Souris River flows southeastward from Burlington to Velva, where it turns northeastward just outside the Minot region, eventually flowing northward and northwestward around the west side of the Turtle Mountains before entering the Assiniboine River in Manitoba. The valley walls along the southwest side of the Souris Valley remain steep and high southeastward from Burlington, but the walls on the northeast side of the valley decrease in height toward the southeast, in consequence of which the northern walls southeast of Minot are in most places less than 100 feet high. The south wall of the Souris Valley from Minot to Velva is here called the Souris escarpment. From Velva the Souris

River flows northeastward in a shallow valley, but the Souris escarpment trends somewhat indistinctly southeastward and merges into the Altamont escarpment near Krueger Lake, in T. 150 N., R. 77 W. The Souris escarpment trends northwestward from Minot approximately parallel to but a few miles east of the valley of the Souris River. In this part of the region its topographic expression becomes less and less distinct.

A belt of country about 20 miles wide that is characterized by innumerable hummocks and depressions lies southwest of the Altamont escarpment. The local relief at many places in this belt is 200 feet. There is no surface drainage from this part of the region, for most of the precipitation sinks into the underlying sand or gravel and the remainder gathers into more or less ephemeral lakes in the depressions. The drainage divide between the Souris River, which drains into Hudson Bay, and the Missouri River, which drains into the Gulf of Mexico, follows this belt.

The southwestern part of the Minot region, a portion of the Missouri Plateau, is bordered by the deep valleys of the Missouri River and its tributaries. The Missouri River Valley is about 3 miles wide and is bordered by walls that rise abruptly 200 feet to the plateau surface forming the divides between Douglas, Garrison, Snake, and Wolf Creeks.

The term "Coteau du Missouri" has long been applied to this portion of North Dakota, but considerable confusion has arisen as to the exact meaning of the term. It has been applied both to the Altamont and Souris escarpments and to various parts of the country bordered by these escarpments. However, the United States Geographic Board [12] defined the Coteau du Missouri as "the narrow plateau beginning in the northwest corner of North Dakota between the Missouri River and River des Lacs and Souris River and running southeast and south with its southern limit not well defined and its western escarpment forming the bluffs of the Missouri River." This definition clearly means that the Coteau du Missouri is that portion of the Missouri Plateau province lying north and east of the Missouri River, but it is perhaps a broader application than that intended by Catlin, [13] who first described the coteaus and referred only to that part of the hilly hummocky divide between the Missouri River and the Souris River. (See fig. 13.)

[12] U. S. Geographic Board 6th Rept., 1890–1932, p. 238, 1933.

[13] Catlin, G., Account of a journey to the Coteau des Prairies, with a description of the Red Pipe Stone quarry and granite boulders found there: Am. Jour. Sci., 1st ser., vol. 38, pp. 138–146, 1840.

DRAINAGE AND WATER SUPPLY

The northern part of the region is drained by the Souris River and by the Riviere des Lacs, which joins the Souris River at Burlington. Both streams are perennial. The Souris River flows southeastward across the northern part of the Minot region but near Velva turns northeastward and flows in a northerly direction to the Assiniboine River in Manitoba. The northern plains area is drained by straight, parallel northeastward-trending tributaries of the Souris River and the Riviere des Lacs.

The southwestern part of the region is drained by the Missouri River, a tributary of the Mississippi, and by short tributaries—Douglas Creek (West Fork, Middle Fork, and East Fork), Garrison, Snake, and Wolf Creeks—that join the Missouri. These small streams do not carry water except after rains or thaws, but they have marshy stretches that are fed by seeps or springs from the coal beds.

The southeastward-trending belt of country, 20 miles wide, that follows the divide between the Missouri and the Souris Rivers has no outflowing surface drainage. This belt is underlain by deposits of gravel, sand, and silt as much as 200 feet in thickness, and in consequence most of the precipitation sinks into the ground, although small lakes and marshes hold water for part of the year. Much of the water lost reappears at the surface, either as seeps at the contact of the gravel with bedrock or as springs or seeps in the coal beds on each side of the divide.

CLIMATE AND VEGETATION

The climate of the Minot region is semiarid. The average annual precipitation at four United States Weather Bureau observation stations ranges from 15.65 to 17.71 inches, but the departures from this average may be large in any year. More than half of the rainfall occurs during the summer. During 1934 the temperature ranged from −34° to 106° F. The following table summarizing the climatic data obtained at four stations in the region has been compiled from the records of the United States Weather Bureau:

Climatic data for the Minot region, North Dakota

[From U. S. Weather Bureau reports]

	Date or length of record (years)	January	February	March	April	May	June	July	August	September	October	November	December	Annual
Dogden Butte, McLean County (altitude, 1,880 feet)														
Lowest precipitation ... inches	1934	0.16	Tr.	0.59	0.37	0.42	2.72	1.87	1.31	1.31	0.04	0.22	0.08	9.09
Highest precipitation ... do	1928	.11	Tr.	.30	.99	3.33	7.25	7.85	3.76	.18	.21	Tr.	.30	24.24
Average precipitation ... do	9	.15	.44	.37	1.23	4.01	3.50	2.72	2.26	1.01	1.13	.52	.37	17.71
Mean temperature, 1934, °F	--------	17.2	19.8	26.8	44.5	63.0	63.0	71.0	67.4	52.4	49.8	33.6	12.8	43.4
Near Foxholm, Ward County (altitude, 1,657 feet)														
Lowest precipitation ... inches	1934	0.23	0.09	0.38	0.05	0.08	1.81	0.43	1.07	1.40	0.08	0.21	0.52	6.35
Highest precipitation ... do	1927	.41	.27	1.27	1.84	6.29	2.34	2.55	3.84	.23	1.83	.85	.45	22.19
Average precipitation ... do	14	.33	.57	.67	1.35	1.97	3.09	2.23	1.74	1.56	1.10	.67	.61	15.65
Garrison, McLean County (altitude, 1,901 feet)														
Lowest precipitation ... inches	1874	0.02	Tr.	0.42	0.48	1.15	1.51	0.41	3.19	0.54	0.02	0.10	0.02	7.81
Highest precipitation ... do	1882	.43	.54	2.05	3.25	2.49	5.61	4.34	.21	2.56	2.82	.74	.70	25.74
Average precipitation ... do	58	.42	.50	.93	1.22	2.23	3.42	2.26	2.02	1.44	.90	.55	.55	16.38
Mean temperature, °F	--------	7.6	10.9	23.8	42.3	52.7	62.2	68.2	66.1	54.9	42.7	26.3	13.7	39.3
Minot, Ward County (altitude, 1,557 feet)														
Lowest precipitation ... inches	1934	0.21	0.10	0.42	0.16	0.24	2.45	1.09	0.41	1.32	0.07	0.25	0.41	7.13
Highest precipitation ... do	1899	.30	.15	.80	1.40	5.31	6.07	2.30	5.20	.80	1.35	.55	.04	24.27
Average precipitation ... do	39	.38	.47	.69	1.23	2.04	3.22	1.87	2.01	1.61	.98	.67	.48	15.65

The vegetation[14] in the Minot region is typical of the vegetation of the northern Great Plains. Grass is abundant and consists principally of grama, needle, wheat, and prairie June grasses, although nigger wool and bluestem grasses are common in the morainal hills. Trees grow naturally only along the stream courses; ash, boxelder, and cottonwood are the common varities. Wheat is the principal cultivated crop, although other small grains—oats, flax, barley, and rye—are extensively grown. Corn and alfalfa are also important crops particularly along the valleys.

POPULATION

The population of the Minot region is 42,550. According to the 1930 census there are 17 towns or villages in this region with a population of more than 100, but about half of the population is distributed through the rural districts. Minot, with a population of 16,099 in 1930, is the third largest city in North Dakota; it is on the main lines of two transcontinental railroads and is the principal shipping point and business center for most of the northwestern part of North Dakota and adjacent parts of Canada. Farming is the principal industry in the region, although coal mining is also an important industry.

ACCESSIBILITY

The main lines of two railroads, the Minneapolis, St. Paul & Sault Ste. Marie and the Great Northern, cross the Minot area. The main line of the Minneapolis, St. Paul & Sault Ste. Marie Railway between Milwaukee and Regina, Saskatchewan, on the Canadian Pacific Railway, follows the valley of the Riviere des Lacs and Souris River from the northern border of the region, at Carpio, through Minot to Velva, 4 miles east of Sawyer, where it leaves the valley of the Souris River and continues southeastward through Balfour, Drake, and Anamoose to the east boundary of the region. A spur line of this railway runs westward from Drake to Max, whence it goes south and southeast through Garrison and Coleharbor and connects with the Northern Pacific Railway at Bismarck, 75 miles south of Coleharbor. Another spur line continues west from Max through Douglas, Ryder, and Makoti to Sanish, on the Missouri River 40 miles west of Makoti. Another spur of this railway runs northeast from Drake. The main line of the Great Northern Railway, between St. Paul, Minn., and Seattle, Wash., crosses the northern part of the region through Berthold, Minot, and Surrey. A spur line of this railway extends northwestward from Berthold, and the "Surrey cut-off" extends southeastward from Surrey and crosses the corner of the region

[14] Aldous, A. E., and Deeds, J. F., Land classification of the northern Great Plains, Montana, North Dakota, South Dakota, and Wyoming, U. S. Geol. Survey, 1929.

northeast of Drake. No part of the region is more than 25 miles from a shipping point on one of the railways.

Two interstate highways cross the Minot region. A paved highway, U. S. 2, follows the route of the main line of the Great Northern Railway. A graveled highway, U. S. 83, extends south through Minot, Coleharbor, and Bismarck, 75 miles south of this region. Other improved highways give ready access to other parts of the region; N. Dak. 23 trends east through Ryder, Max, and Drake; N. Dak. 37 trends east through Garrison; N. Dak. 28 trends south across the western part of the area, crossing the Missouri River by ferry south of Garrison; N. Dak. 41 trends south through Ruso; N. Dak. 9 is paved and follows approximately the route of the main line of the "Soo" Railway. Scheduled bus service is available on U. S. 2 and N. Dak. 9 across North Dakota and on U. S. 83 between Minot and Bismarck. Local bus service is available on a number of other highways that have contract mail service. Roads that can be traveled with an automobile follow most of the section lines, so that practically all parts of this region are readily accessible.

The Missouri River is a navigable stream but is little used. Two grain elevators have been built on the banks of the river, one on the north side and one on the south side in the southwestern part of the Minot region, and grain is sometimes shipped from these points.

STRATIGRAPHY

GENERAL FEATURES

The sedimentary rocks exposed in the Minot region comprise the Fort Union formation, of Eocene (Tertiary) age, glacial deposits of Pleistocene age, and Recent alluvium. The Fort Union formation is well exposed along the valley of the Missouri River, but north of this valley it is extensively covered by glacial drift. Some information concerning the rocks older than the Fort Union is available from the log of a deep well and also from their outcrops in western North Dakota. The distribution of the formations is shown on the geologic map (pl. 11).

ROCKS NOT EXPOSED

PRE-LANCE FORMATIONS

The following log of a well drilled by the Des Lacs Western Oil Co. in the southwest corner of sec. 4, T. 155 N., R. 85 W., in the northwestern part of the Minot region, supplies a description of the rocks underlying the region to a depth of nearly 4,000 feet. This log was published by Simpson,[15] who used the log furnished by the driller and the interpretation of the rocks by J. B. Reeside, Jr., and W. T. Thom, Jr. The interpretation of the contact between the Lance formation and the Fort Union formation is that of the writer. The

[15] Simpson, H. H., Geology and ground water resources of North Dakota: U. S. Geol. Survey Water-Supply Paper 598, pp. 252–253, 1929.

earlier interpretation placed this contact at a depth of 920 feet in the well.

Generalized record of the Des Lacs Western Oil Co.'s well, in the SW¼ sec. 4, T. 155 N. R. 85 W.

Age	Formation	Character of strata penetrated	Depth (feet)
Pleistocene	Glacial drift		0-50
Tertiary (Eocene)	Fort Union formation.	Gray, rather calcareous sandy clay, with streaks of limestone, sandstone, and lignite. Hard layer, with show of gas beneath, reported by driller at 210 feet.	60-590
		Lignite	590-598
Upper Cretaceous	Lance formation	Sandy clay, in part calcareous	598-900?
		Fine quartz sand, reported by driller to show oil	900?-920
		Dark sandy calcareous shale, containing lignite and fragments of limestone.	920-960
		Gray muddy shale	960-1,050
		Gray sandy clay, with some carbonaceous matter.	1,050-1,075
		Gray gumbo, with fragments of light-colored limestone.	1,075-1,125
		Gray fine-grained shaly sandstone	1,125-1,160
		Gray soft sticky shale	1,160-1,300
	Fox Hills sandstone	No cuttings; reported by driller as sandstone, with good show of oil and gas.	1,300-1,340
	Pierre shale	Light-gray shale, with calcareous layers	1,340-1,900
		No cuttings; reported by driller as "limestone, with good show of oil."	1,900?-1,905
		Gray shale	1,905-1,960
		Light-gray shaly limestone, with fragments of fossils.	1,960-1,980
		Gray shale, with calcareous layers	1,980-?
		Whitish clay	?-2,165
		Gray, rather calcareous shale	2,165-2,300
		Gray calcareous shale and limestone. According to driller's report there is sandy shale and sandstone, showing 1 to 10 barrels of oil a day, between 2,300 and 2,310 feet, which may correspond to the gas sand of the gas field at Glendive, Mont.	2,300-2,320
		Gray calcareous shale; fragments of fossils at 2,650 feet.	2,320-2,800
		Gray shaly limestone, with *Ostrea* and *Inoceramus*.	2,820-2,830
		Whitish shaly limestone	2,830-2,833
		Gray crumbly shale	2,833-2,878
		Blue limestone with *Inoceramus* and *Ostrea congesta;* probably corresponds to Eagle sandstone of Montana.	2,878-2,900
		Dark crumbly calcareous shale. Blue limestone containing pyrite and fossils at 2,995-3,030 feet. Driller reports sandstone showing 1 to 10 barrels of oil a day at 3,040-3,043 feet. This unit probably corresponds to Telegraph Creek formation of southern Montana.	2,900-3,133
	Niobrara formation	Blue limestone with *Baculites, Inoceramus,* and *Ostrea.*	3,133-3,140
		Dark-blue to black calcareous shale and limestone, with *Ostrea congesta* and abundant fragments of thick-shelled *Inoceramus.*	3,140-3,400
	Benton shale	Dark gummy, somewhat calcareous shale	3,400-3,476
		Dark-gray, rather splintery shale; fragments of fossils.	3,476-3,500
		Dark, rather gummy shale. According to driller, limestone and limy shale at 3,460-3,560 feet.	3,500-3,650
		Dark hard massive, fairly calcareous shale	3,650-3,856
		Gray limestone	3,856-3,860
		Dark massive shale	3,860-3,880
		Massive gray limestone	3,880-3,890
		Dark hard shale and limestone with *Inoceramus*	3,890-3,909
		Quartz sand; may correspond to Muddy sand or Newcastle sandstone of Wyoming called Dakota sandstone by driller.	3,909-3,924
		Hard dark, rather calcareous shale, with *Inoceramus.*	3,924-3,980

LANCE FORMATION

The Lance formation, of Upper Cretaceous age, does not crop out in the Minot region. In the central and southern part of North Dakota the Lance formation is about 650 feet thick and is divided into a lower member about 350 feet thick and the overlying Cannonball marine member, about 300 feet thick, or the Ludlow lignitic member, a lateral equivalent of the Cannonball.[16] The Cannonball marine member crops out along the Missouri River at Stanton, less than 15 miles south of the Minot region; its practically flat-lying position suggests that it is probably not more than 50 feet below the surface in the valley of the Missouri River in the southern part of the Minot region. This member "is composed predominantly of dark sandy shale or shaly sandstone with a subordinate amount of dark-yellow and gray sandstone. It also contains some thin limestones. All the strata are lenticular in character, and individual beds can be followed for only short distances."[17]

According to Thom's interpretation of the log of the well drilled by the Des Lacs Western Oil Co. (p. 13) in the northwestern part of the region, the top of the Lance is 920 feet below the surface (altitude about 1,100 feet). The writer, however, would place the top of the Lance about 300 feet higher, at the base of the 8-foot coal bed at a depth of 598 feet (altitude about 1,400 feet), because his correlations of higher coal beds indicate that the rocks in the western part of the Minot region are nearly horizontal and that the altitude of the top of the Lance along the Missouri River is about 1,600 feet. Thus 200 feet of irregularity of the Lance-Fort Union contact between the Missouri and the Des Lacs well is more consistent than the irregularity of about 500 feet that is required if this contact is placed at a depth of 920 feet in the Des Lacs well. In addition, according to the writer's interpretation, the thickness of the Lance in the Des Lacs well would be about 700 feet, which agrees closely with the measured thickness of about 650 feet at surface outcrops in southwestern North Dakota.

The Lance has not been recognized in the northeastern part of the Minot region nor in the valley of the Souris River in North Dakota; consequently the Fort Union has been mapped as resting directly upon the Pierre shale, of Upper Cretaceous age, along the valley of the Souris River northeast of the region.[18] It is possible that the Lance formation is present in this part of North Dakota but has not been recognized at the few localities where the bedrock is not covered by glacial drift. It is also possible that marine sedimentation resulting in the

[16] Lloyd, E. R., and Hares, C. J., The Cannonball marine member of the Lance formation of North and South Dakota and its bearing on the Lance-Laramie problem: Jour. Geology, vol. 23, pp. 523-547, 1915.

[17] Stanton, T. W., The fauna of the Cannonball marine member of the Lance formation: U. S. Geol. Survey Prof. Paper 128, p. 7, 1921.

[18] Leonard, A. G., The geological map of North Dakota: North Dakota Univ. Quart. Jour., vol. 4, p. 4, 1913.

deposition of beds to which the name Pierre is applied continued without any interruption in the Minot region until Fort Union time; if so, this means that the nonmarine Lance of western North Dakota is represented in the eastern part of the State by marine deposits that have not been or cannot be separated from the Pierre.[19]

ROCKS EXPOSED

TERTIARY SYSTEM

EOCENE SERIES

Fort Union formation.—The Fort Union formation is well exposed along the Missouri River and its tributaries in the southwestern part of the region. Along the Riviere des Lacs and the Souris River and some of their northeastward-flowing tributaries, there are small isolated outcrops of the Fort Union formation; but a coal bed was followed intermittently for a distance of 35 miles from the vicinity of Kongsberg northwestward to a point 10 miles south of Minot. The part of the formation exposed in the Minot region consists of light-colored tan and gray sandstones alternating with darker-gray and buff shales, with complete gradation between the shales and sandstones. It contains iron-stained concretionary layers and coal beds that range in thickness from an inch to 14 feet or more. The coal beds are more persistent than any other beds in the Fort Union and are the only key beds that can be traced. The following partial section of the Fort Union formation measured along the Missouri River is typical of the lithology of the formation:

Section of Fort Union formation measured in SE¼ sec. 33, T. 147 N., R. 84 W.

		Ft.	In.
	Top concealed		
1.	Shale and sandy shale, dull gray, tan, and buff	43	
2.	Coal } Garrison Creek coal bed	2	6
3.	Brown carbonaceous shale } Garrison Creek coal bed		½
4.	Coal } Garrison Creek coal bed	1	11
5.	Sandstone, light gray, poorly consolidated, evenly bedded	20	
6.	Shaly sandstone and sandy shale, light gray, with layers of brown iron-stained sandstone concretions	30	
7.	Shaly sandstone and sandy shale, light gray	18	
8.	Black carbonaceous shale	1	3
9.	Coal, dirty		3
10.	Shale and sandy shale, like bed 1	20	6
11.	Shaly sandstone and sandy shale, like bed 6	23	
12.	Coal		6

[19] Lloyd, E. R., and Hares, C. J., op. cit., p. 541. Andrews, D. A., Suggested Lance-Fort Union correlations in adjacent parts of Montana, North and South Dakota: Washington Acad. Sci. Jour. vol. 26, pp. 387-388, 1936.

Section of Fort Union formation measured in SE¼ sec. 33, T. 147 N., R. 84 W.—Continued

		Ft.	In.
13.	Shaly sandstone and sandy shale, like bed 6	33	
	Lower part of section measured in the northern part of sec. 27, T. 147 N., R. 84 W.:		
14.	Coal (Wolf Creek coal bed)	2	10
15.	Clay, gray (Wolf Creek coal bed)	1	
16.	Coal (Wolf Creek coal bed)	4	2
17.	Shaly sandstone and sandy shale, like bed 6	23+	
18.	Coal	2+	
	Water level in Missouri River.		
	Total	227+	

The Minter coal bed is about 50 feet above the top of this section. In the central part of the Minot region coal-bearing rocks are found in drilled wells 150 feet above the Minter bed. The sum of these measurements gives an approximate measure (50+227+150=427 feet) of the thickness of the Fort Union rocks exposed in the area. If the base of the Fort Union is about 50 feet below water level where the section given above was measured along the Missouri River, the total thickness of the Fort Union formation in the Minot region is about 475 feet.

QUATERNARY SYSTEM

PLEISTOCENE SERIES

Glacial drift caps the hills and divides between most of the tributary streams to the Missouri River in the southern part of the region. These deposits, which have an average thickness of 20 feet or less, are not shown on the geologic map. The drift is composed of sand and gravel, scattered boulders, and minor amounts of clay and silt, unstratified and unconsolidated, and was deposited by pre-Wisconsin glaciers, probably of Illinoian or Iowan age.[20]

The Altamont moraine, deposited by a glacier of late Wisconsin age,[21] caps the divide between the Souris River and the Missouri River. It consists of unconsolidated gravel, sand, and abundant boulders, largely of granitic materials, with minor amounts of finer sediments. This morainal material ranges from a few feet to 200 feet or more in thickness. In some places it rests directly on the Fort Union; in others a layer of pre-late Wisconsin drift or till probably lies between them.

All of the region north and east of the Altamont moraine is covered by glacial drift, which is overlain in most places by a thin veneer of sediments laid down or reworked by the glacial Lake Souris, except small areas where stream erosion has exposed the underlying Fort

[20] Alden, W. C., Physiography and glacial geology of eastern Montana and adjacent areas: U. S. Geol. Survey Prof. Paper 174, pp. 75-78, 1932. Leonard, A. G., The pre-Wisconsin drift of North Dakota: Jour. Geology, vol. 24, pp. 521-532, 1916.

[21] Chamberlin, T. C., Preliminary paper on the terminal moraine of the second glacial epoch: U. S. Geol. Survey 3d Ann. Rept., p. 388, 1883. Upham, Warren, The glacial Lake Agassiz: U. S. Geol. Survey Mon. 25, p. 139, 1896.

Union formation. The lake sediments are composed largely of sand, silt, and clay that fill the depressions of the lake floor or form a thin veneer over the drift deposited by the late Wisconsin and earlier glaciers. No attempt has been made by the writer to differentiate between the lake sediments and the underlying drift of this region, for their combined thickness does not average more than 30 feet. (See pl. 13, *B*.)

Terraces along the Missouri River are floored by sand, gravel, and silt from a few feet to 75 feet or more thick. Some of the highest of these terraces are at a level comparable with those along the Missouri River in the Fort Berthold Indian Reservation,[22] which occur 30 to 80 feet above the present river level and which Alden [23] discusses as follows:

> It should be noted that not all the stream deposits in the abandoned channels or on the cut terraces cited above are known to be either pre-Iowan or not glacial outwash. Further study may show that at least some of them are not to be correlated with No. 3 bench.

However, he believes that at least some of the terraces at this level are equivalent to the No. 3 bench mapped along the Missouri and Yellowstone Rivers in Montana and states that

> there is conclusive evidence that No. 3 bench was completed as early as the oncoming of the Wisconsin stage of glaciation.

No evidence was found during this investigation concerning the age of these terraces, but it is probable that some of the higher terraces are pre-Wisconsin and post-Kansas, [24] although it is equally probable that some of the lower and intermediate terraces are of late Wisconsin or even post-Wisconsin age.

RECENT SERIES

Alluvium is present along the courses of the Missouri and Souris Rivers, the Riviere des Lacs, and some of their major tributaries. Because the alluvium occupies so narrow a belt along the tributaries, it was mapped by the writer only along the major streams. No direct evidence of its thickness was obtained along the Missouri River except in a few places along the banks where less than 50 feet of alluvium overlies the Fort Union exposed in the stream channel. At Minot drilled wells have penetrated 142 feet of sand and gravel in the valley of the Souris River before encountering bedrock.[25] However, a part of the sand and gravel should probably be classed as Pleistocene.

[22] Pishel, M. A., Lignite in the Fort Berthold Indian Reservation, North Dakota, north of Missouri River: U. S. Geol. Survey Bull. 471–C, p. 4.

[23] Alden, W. C., Physiography and glacial geology of eastern Montana and adjacent areas: U. S. Geol. Survey Prof. Paper 174, p. 59, 1932.

[24] Alden, W. C., op. cit. p. 58.

[25] Simpson, H. E., Geology and ground-water resources of North Dakota: U. S. Geol. Survey Water-Supply Paper 598, p. 255, 1929.

The Missouri River flows between banks which are at most places a quarter of a mile to a mile apart. Although the river at normal stages occupies only a part of this flood plain, the remainder of the area between the banks is covered with sand, gravel, and silt and lies only a few feet above water level; it is covered in part or wholly by practically all high stages of the river. The banks that confine the normal flood channel of the river are generally not less than 10 feet high and do not exceed 40 feet, averaging about 20 feet. Bordering this flood channel on both sides of the river are deposits of sand and silt with some gravel, 20 feet or more thick, whose surface lies 10 to 40 feet above the normal river level. This alluvium is normally flooded during the heavy spring floods. Rising above this alluvium is the alluvial terrace 10 to 20 feet higher, whose thickness may in places exceed 50 feet. This terrace may be of Pleistocene age. It is the highest alluvial terrace found along the Missouri River in the Minot region.

STRUCTURE

Although the rocks in eastern North Dakota dip gently westward, the rocks in central and western North Dakota, which includes the Minot region, are generally horizontal. (See fig. 13.) In continental sediments of the type found in the Minot region, where bedding is irregular, difficulty is encountered in tracing key horizons to work out the structure. In this region the additional handicap of having few and poor exposures, except along the Missouri River, renders the problem even more difficult. Coal beds are the only beds that can be traced with assurance.

Although there are minor wrinkles and irregularities in the attitude of the beds, the flat-lying beds have no apparent regional dip. The Garrison Creek coal bed, which can be followed for more than 25 miles across the southern part of the region at altitudes of 1,800 to 1,870 feet above sea level, is tentatively correlated by the writer with the Coteau bed, which crops out extensively in the northeastern part of the region at 1,830 to 1,910 feet above sea level. Although the base of the Fort Union has been interpreted by the writer as lying about 1,600 feet above sea level along the Missouri River in the southern part of the region and about 1,400 feet above sea level in the well of the Des Lacs Western Oil Co. near Lonetree, in the northern part of the region, both of these assignments are interpretations and may be subject to error. This variation could easily be accounted for by a transgression of the formational boundary. Similar transgressions have been noted in many places along the surface outcrop in eastern Montana.[26]

There are three small structural features of interest. A shallow syncline with a maximum depth of less than 100 feet and a maximum

[26] Andrews, D. A., Suggested Lance-Fort Union correlations in adjacent parts of Montana, North and South Dakota: Washington Acad. Sci. Jour. vol. 26, pp. 387-388, 1936.

width of about 1½ miles trends north-south along the Middle Fork of Douglas Creek in the western part of Tps. 147 and 148 N., R. 85 W. A displacement of about 80 feet is suggested in the southeast corner of T. 152 N., R. 81 W., where the Coteau bed southeast of that locality crops out at an altitude of 1,910 feet in sec. 36 and at about 1,830 feet in sec. 26, to the northwest. No direct evidence of the manner of this displacement was found in the field, but it is assumed to be a bending rather than faulting of the beds. A slight downwarp between Carpio and Foxholm, in adjacent corners of Tps. 50 and 51 N., Rs. 80 and 81 W., has carried the Burlington bed below the alluvial level of the Riviere des Lacs in this vicinity. The Burlington bed crops out from 5 to 40 feet above the level of the alluvium east of Foxholm and west of Carpio.

GEOMORPHOLOGY

The Minot region is crossed by the boundary between the Central Lowland and Great Plains provinces.[27] (See fig. 14.) The northeastern part of the region lies in the western lake section of the Central Lowland province and is characterized by undissected drift-covered plains. The central and southwestern parts of the region lie in the glaciated Missouri Plateau section of the Great Plains province and are characterized by dissected and glaciated plateaus. The boundary between these two provinces is the Souris escarpment, at the northeastern limit of the Missouri

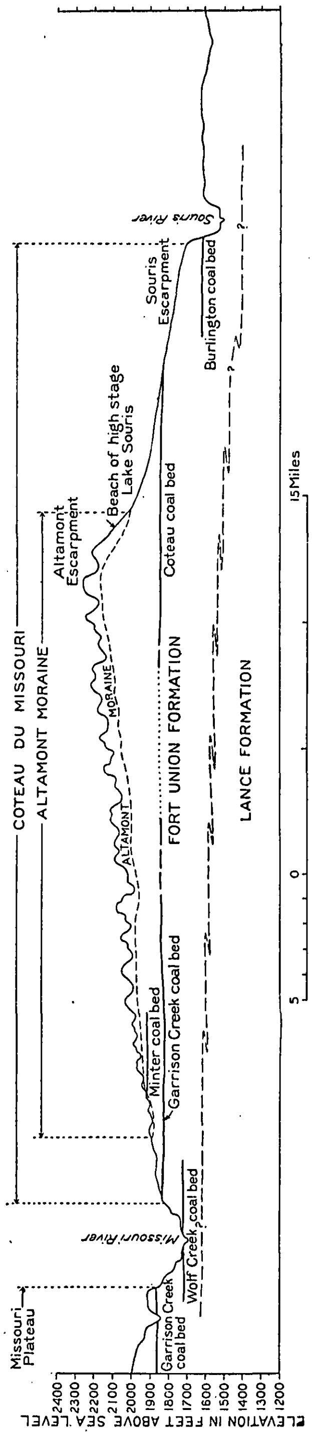

FIGURE 13.—Diagrammatic section north-south across Minot region showing position of coal beds, rock formations, and other geologic features. (Note: The coal beds are not all encountered in one section but have been shown in their relative positions.)

[27] Fenneman, N. M., Physiographic divisions of the United States: Assoc. Am. Geographers Annals, vol. 18, no. 4, pp. 314-317, 322-323, 1928.

Plateau. The escarpment trends diagonally across the region in a northwesterly direction; it coincides with the south sides of the valleys of the Souris River and the Riviere des Lacs on the west and follows closely the northeast boundary of the Altamont moraine on the east. That portion of the Missouri Plateau section northeast of the Missouri River is referred to as the Coteau du Missouri.[28]

Although Leonard [29] thought that the major drainage patterns of North Dakota were formed in Tertiary time, prior to the Pleistocene glaciation, later workers as well as some of the earlier students have ascribed the present course of the Missouri River and other major drainage features of the part of North Dakota that includes the Minot region to the influence of Pleistocene glaciation.[30] Todd [31] concluded that the Missouri and Yellowstone drained northward to the Hudson Bay prior to Pleistocene time and did not flow through the part of North Dakota included in the Minot region. He also concluded that the Little Missouri River (see pl. 12 and fig. 14) flowed along what is now the Missouri River from the present confluence of the Little Missouri and Missouri Rivers to the mouth of Snake Creek and continued northeastward along the valleys of Snake Creek and the Turtle Creek spillway to the present course of the Souris River in the vicinity of Velva. This course of the Little Missouri along Snake Creek and the Turtle Creek spillway may have been abandoned during one of the earlier glacial advances but was almost obliterated by deposits of the Wisconsin glacier. Such a course can be followed south of the Altamont moraine, but in and north of the Altamont moraine, where there was much deposition of material, this course cannot be followed unless the spillway of the highest stage of glacial Lake Souris from the vicinity of Ruso southward to Turtle Lake was localized along this old channel. Filling may not have completely obliterated the topography of this old valley.

Alden [32] concludes that—

the diversion [of the upper Missouri River from its course to the Hudson Bay along a channel running northward from Williston 80 miles west of the Minot region to the present site] was undoubtedly due to the advance of one of the early ice sheets from the Hudson Bay region to the Coteau du Missouri, at either the Nebraskan or the Kansan stage of glaciation * * * Evidently the Missouri was sufficiently intrenched along its new course in North and South Dakota by the end of the Kansan stage of glaciation to maintain that course after the ice had melted away.

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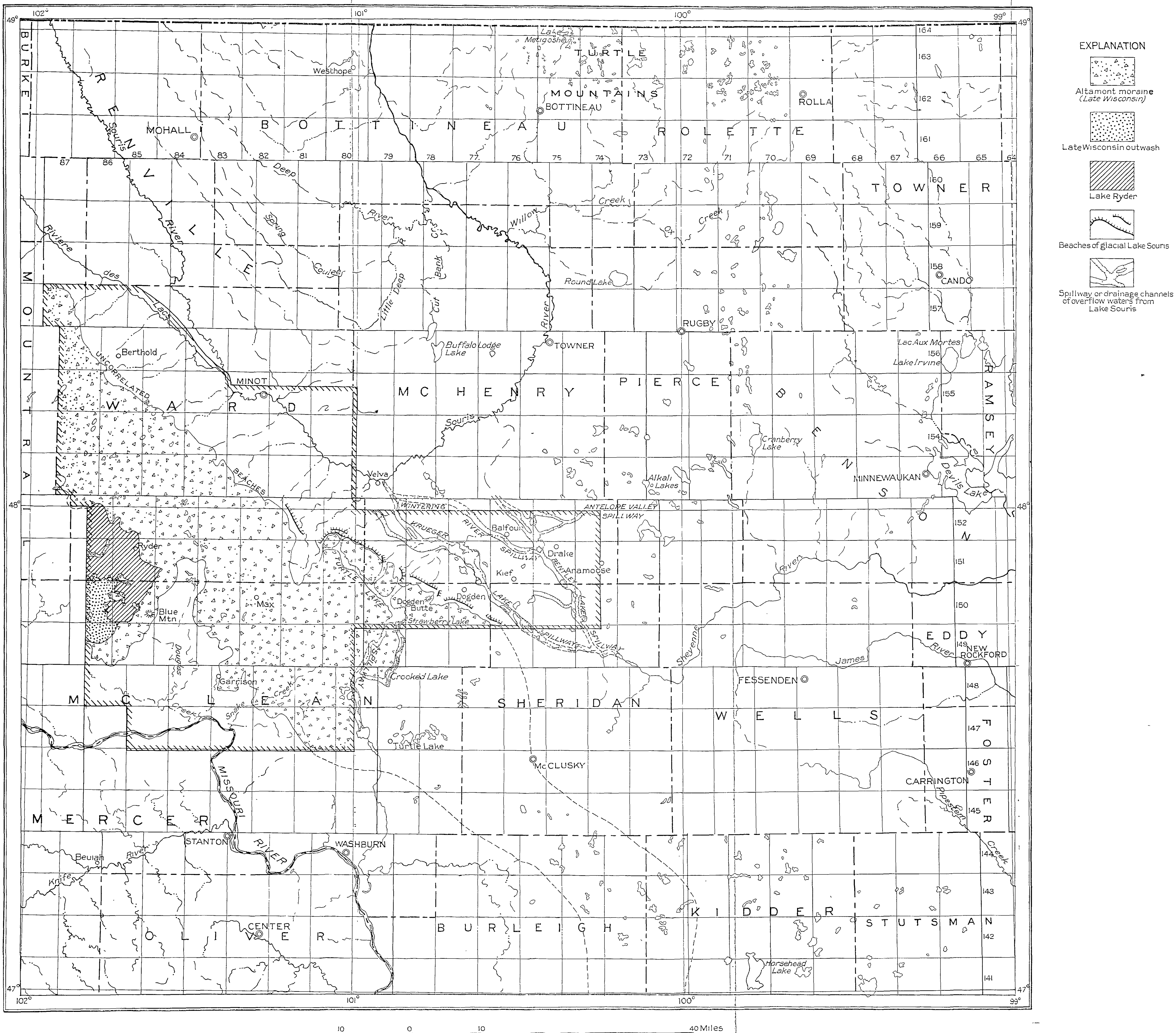
[28] U. S. Geographic Board 6th Rept., p. 238, 1933.

[29] Leonard, A. G., Pleistocene drainage changes in western North Dakota: Geol. Soc. America Bull., vol. 27, pp. 295-304, 1916.

[30] Warren, G. K., On certain physical features of the upper Mississippi River: Am. Naturalist, vol. 2, pp. 497-502, 1868. Todd, J. E., Is the channel of the Missouri River through North Dakota of Tertiary origin?: Geol. Soc. America Bull., vol. 34, pp. 469-493, 1923. Alden, W. C., Physiography and glacial geology of eastern Montana and adjacent States: U. S. Geol. Survey Prof. Paper 174, p. 58, 1932.

[31] Todd, J. E., op. cit., fig. 1, p. 471.

[32] Alden, W. C., op. cit., p. 58.



MAP OF NORTH-CENTRAL NORTH DAKOTA SHOWING PLEISTOCENE FEATURES OF THE MINOT REGION AND THEIR RELATION TO SURROUNDING AREAS.

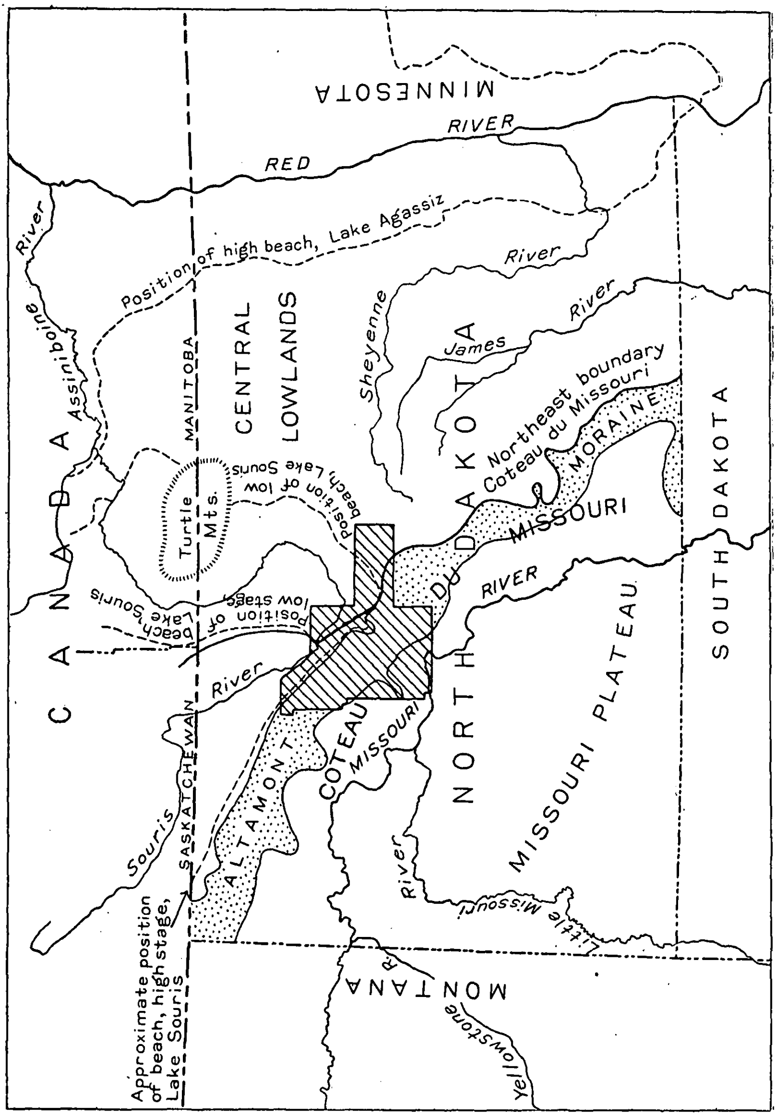


FIGURE 14.—Sketch map of North Dakota and adjacent areas showing major geographic and physiographic features.

Alden would correlate with the No. 3 bench in Montana some of the terraces along the Missouri River in the Fort Berthold Indian Reservation that are undoubtedly equivalent to some of the terraces along the Missouri River in the Minot region 30 to 80 feet above the present river level. In this connection he states [33] that "there is conclusive evidence that No. 3 bench was completed as early as the oncoming of the Wisconsin stage of glaciation."

It seems fairly conclusive, then, that the present major drainage pattern of that part of North Dakota embracing the Minot region was established in Pleistocene time prior to the Wisconsin advance of the glacier, probably by the end of the Kansan stage, although there may have been considerable modification of the Souris River drainage after the withdrawal of the Wisconsin glaciers.

The glacial deposits south and west of the Altamont moraine are thin and have not been entirely differentiated on the geologic map (pl. 11). They consist of glacial drift, less than 20 feet thick in most places, capping the level divides between the tributary streams of the Missouri River of pre-Wisconsin time; probably some of the isolated exposures of morainal material in the western part of the region south of Ryder should be classed as of early Wisconsin age; [34] probably some of the unmapped glacial material as well as some of the material mapped as morainal should also be classed as outwash.

The glacial deposits left by the late Wisconsin glacier are the most conspicuous in the Minot region as well as in the remainder of North Dakota, not only because they obscure much of the material deposited by earlier glaciers but also because weathering and erosion have scarcely affected them since the withdrawal of the ice. The Altamont moraine, which marks the farthest advance of the ice front, forms a belt of hummocky topography about 20 miles wide, trending northwestward across the region and forming the divide between the Hudson Bay and Gulf of Mexico drainage systems. A moraine extending southwestward from the vicinity of Douglas through Blue Mountain to the southern part of T. 149 N., R. 87 W., may be earlier than late Wisconsin; also the isolated exposures of moraine west of this one may be of the same age, but they are here grouped with the late Wisconsin moraine, although considered to have been formed during the earliest part of the advance of the Wisconsin ice.

Beaches at two levels along the moraine, in the vicinity of Ryder and Makoti and in the western part of T. 150 N., R. 86 W., show that a small body of water, here named Lake Ryder, was formed by a dam between the front of the Altamont moraine and the northwest side of the moraine extending through Blue Mountain. The maximum depth of the lake probably did not greatly exceed 50 feet. At a high

[33] Alden, W. C., op. cit., p. 59.
[34] Alden, W. C., op. cit., fig. 6, p. 76.

stage of this lake some water drained westward through a small stream channel across the outwash plain in the southern part of T. 150 N., R. 87 W., but the channel through which Lake Ryder was completely drained must be somewhere west of the Minot region.

As the glacier melted and retreated from the Altamont moraine water accumulated in the area dammed between the moraine and the front of the ice. This dam has been accounted for by postulating a retreat of the ice from the moraine in the region northwest of Dogden Butte while the ice retained its position against the moraine in the region southeast of Dogden Butte.[35] This body of water has been named Lake Souris. A low stage was described by Upham.[36] Sediments deposited in Lake Souris and the glacial materials reworked by the lake waters formed an even floor, which is now a smooth plain sloping 30 to 40 feet to the mile toward the northeast. The slope of this plain probably represents approximately the slope of the pre-Wisconsin surface. A series of beaches between altitudes of 2,000 and 2,120 feet which mark the water level of the highest stage of Lake Souris are present intermittently near the northeast edge of the Altamont moraine. Beaches northwest of T. 152 N., R. 82 W., have not been accurately traced and correlated and are shown on plate 11 as a series of uncorrelated beaches.

Beaches at lower levels representing successively lower stages of Lake Souris were formed at altitudes of 1,900 and 1,800 feet. Deltas and beaches along the Souris River from Minot eastward and in the northeastern part of the region mark a stage of the lake when the water level was at an altitude between 1,620 and 1,560 feet; this stage is the lowest recorded in the Minot region.

The glacial Lake Souris at its highest stage, marked by the beaches at altitudes near 2,120 feet, drained to the Missouri River by way of Horseshoe Valley and Turtle Lake, here called the Turtle Lake spillway, which was eroded to a maximum depth of about 80 feet in the region between Ruso and Strawberry Lake. As the glacier front continued to withdraw other and lower outlets were uncovered and there were stages of the lake marked by beaches at 2,000, 1,900, and 1,800 feet above sea level. The outlets or spillways controlling these lake levels are probably south and east of the Minot region. Thus the Turtle Lake spillway ceased to function as soon as an outlet at a lower level was formed, each successive lower spillway causing an abandonment of the previous higher spillway.

The low stage of Lake Souris at altitudes of 1,620 to 1,560 feet probably covered far more area than the higher stages, because the ice front was farther to the north and probably had a much longer

[35] Andrews, D. A., Early stages of glacial Lake Souris, North Dakota: Washington Acad. Sci. Jour., vol. 25, no. 12, pp. 568-569, 1935.

[36] Upham, Warren, The glacial Lake Agassiz: U. S. Geol. Survey Mon. 25, p. 255, 1895 [1896].

duration. At any rate, the history of this low stage present in the Minot region is much more intricate than that of the higher stages. The Krueger Lake spillway,[37] which extends from the vicinity of Velva southeastward to the vicinity of Butte, includes Krueger Lake and is joined in T. 149 N., R. 75 W., by the Bentley Lake spillway, extending southward from Bentley Lake 3 miles west of Drake. These two spillways drained Lake Souris when the water stood at 1,620 feet above sea level. They lowered the surface of the water to about 1,580 feet as the valleys were eroded down. A minor tributary heading about 2 miles west of Kief has a well-developed valley that carried some of the overflow at this stage.

In a reconnaissance study of the area south and east of the Minot region it was apparent that the combined Krueger-Bentley Lake spillway drained at first through a now abandoned channel to Pipestem Creek, a tributary of the James River, which joins the Missouri River in the southeast corner of South Dakota. While water was still flowing through the Krueger-Bentley Lake spillway, however, the lower reaches of this spillway were captured in T. 148 N., R. 73 W., by the Sheyenne River, which joins the Red River at Fargo, N. Dak., in the bed of glacial Lake Agassiz. This capture could have been effected during the early stages of glacial Lake Agassiz, because the highest level of that lake was about 1,100 feet above sea level, or nearly 500 feet lower than the altitude of Lake Souris at the 1,620-foot stage. The retreat of the front of the Wisconsin glacier and the formation of Lake Agassiz gave a much steeper gradient to those streams flowing to Lake Agassiz than to the streams flowing southward to the Missouri River, so that the Sheyenne River worked headward and captured the headwaters of the James River drainage.

At a later time, when the level of Lake Souris had been lowered 20 to 40 feet by the erosion of the Krueger and Bentley Lake spillways, the retreat of the ice front uncovered the Wintering River spillway, which was low enough to serve as a drainage channel, causing the abandoning of the Krueger and Bentley Lake spillways. At first the waters draining through the southern part of the Wintering River spillway flowed eastward to the Sheyenne River through the Antelope Valley spillway, and later with still further retreat of the glacier the drainage was northward through the Wintering River spillway to the present course of the Souris River. When the Wintering River and Antelope Valley spillways began to carry the drainage from the lake, the stream flowing through the Bentley Lake Valley became sluggish and was choked by dams of heavily laden ice. When the icebergs in

[37] In order to facilitate discussion of the history of Lake Souris, those valleys formed by the drainage of the lake are called spillways, and the best-known geographic feature in or along each valley is attached to identify that particular spillway for convenience in reference. Most of the spillways are now completely abandoned; some of them have hardly been altered since Wisconsin time, but others have been slightly modified by post-Wisconsin changes of drainage.

the Bentley Lake spillway melted and deposited their load of material the valley was left half filled with hummocks of drift and depressions.[38]

An interesting feature is the northwest-southeast alinement of the glacial deposits in the vicinity of Drake and Balfour. This alinement is further emphasized by the straight symmetrical ridges in the vicinity of Balfour.[39] Although these straight ridges have been interpreted as beach ridges by Upham,[40] the writer believes that they are very similar to the features described by Tyrrell [41] as ispatinows and that they represent fillings in longitudinal cracks near the front of the waning glacier. The remarkably even crests of the ridges probably indicate that the depth of filling of the cracks was controlled by the level of Lake Souris at the time of their formation. Their similarity to the features described by Tyrrell is supported by their straightness, symmetry, length, and even crest. This would indicate, then, that although the regional advance of the Wisconsin glacier was southwestward, an arm of the glacier advanced southeastward along the valley of the Souris River in the late stages of the late Wisconsin advance.[42]

COAL BEDS

All the coal that crops out in the Minot region is in the Fort Union formation. The deep well of the Des Lacs Western Oil Co., drilled near Lonetree, also encountered some coal in the underlying Lance formation. Coal beds crop out extensively along the valleys of the Missouri River and its tributaries, but in most of the region the coal-bearing rocks are concealed by a mantle of glacial deposits, and the coal beds appear at the surface only where post Pleistocene stream erosion has exposed the underlying rocks. Such erosion has been particularly effective in exposing coal beds along the valley of the Souris River and the Riviere des Lacs northwest from Minot and near the head of the tributary streams northwest from Kongsberg. Outcrops of the coal beds have been extensively prospected, and much of the information concerning the coal beds of the Minot region was obtained from prospect and mine openings. Some information concerning the thickness and altitude of coal beds in the drift-covered areas was obtained from the records of drilled water wells, but the records of a great many wells were incomplete or not available and therefore supplied little or no information concerning the coal.

Sections of the coal beds were measured at numbered localities indicated on plate 11, and graphic sections with corresponding locality numbers appear in figures 15, 16, 17, and plates 14 and 15. Thick-

[38] See topographic map of Drake quadrangle, U. S. Geol. Survey, 1930.

[39] See topographic map of Balfour quadrangle, U. S. Geol. Survey, 1929.

[40] Upham, Warren, The glacial Lake Agassiz: U. S. Geol. Survey Mon. 25, p. 255, 1896.

[41] Tyrrell, J. B., Report of the country between Athabasca Lake and Churchill River: Canada Geol. Survey Ann. Rept., new ser., vol. 8, p. 23D, 1897.

[42] Andrews, D. A., op. cit., p. 569.

nesses and depths of coal beds encountered in the wells are plotted on plate 11.

BURLINGTON BED

The Burlington bed is recognized only in the part of the Minot region north and west of Minot. This bed was discussed by L. H. Wood,[43] who described the mines and the coal beds of Ward County in 1902. Later this coal bed was described in a general report discussing the lignite of North Dakota, in which it was called the Burlington bed.[44]

Glacial drift and the deposits of Lake Souris cover practically all of the part of the region north and west of Minot. The Burlington bed, however, crops out intermittently beginning at a point 3 miles west of Minot and extending northwestward along the valleys of the Souris River and the Riviere des Lacs to the northern border of the region. Its outcrops are from 5 to 40 feet above the alluvial floors of these valleys, but between Foxholm and Carpio the coal bed dips a few feet below the level of the alluvium. Northwest from Burlington there are no outcrops of this coal bed on the northeast side of the river, but mine openings expose the coal in the southwest corner of sec. 15, T. 157 N., R. 85 W., and at two localities in the SW¼ sec. 1, T. 156 N., R. 85 W. Few wells have been drilled deep enough to encounter the horizon of the Burlington bed in the northwest corner of the region, and no idea of its extent can be ascertained from the wells. To judge from its lateral extent along the outcrop, however, it probably extends 10 miles southwest of Burlington under cover of 200 to 500 feet. According to the writer's interpretation of the log of the Des Lacs Western Oil Co.'s well near Lonetree the altitude of the base of the Fort Union in that well is about 1,420 feet and the Burlington bed is about 200 feet higher.

Measured sections of the Burlington bed are shown in figure 15. It is 2½ to 3 feet thick in the vicinity of Carpio. At Foxholm there are two benches, an upper bench 4 feet 8 inches thick and a lower bench 6 inches thick separated by 10 inches of clay. From Lloyd Coulee southeastward through Burlington it averages about 9 feet in thickness, but it thins to 5 feet 10 inches at locality 16, in the South Branch of Gassman Coulee. The thickest observed section of the Burlington bed is at locality 10, in the NW¼ sec. 3, T. 155 N., R. 84 W., where there is an upper bench 9 feet 4 inches thick and a lower bench 1 foot 6 inches thick, separated by a clay parting 2 inches thick. In the vicinity of Burlington, where the coal is thick, it characteristically has a clay parting about 1½ feet above the base of the coal. Elsewhere the partings are more irregular.

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43 Wood, L. H., Preliminary report on Ward County and adjacent territory with special reference to the lignite: North Dakota Geol. Survey 2d Bienn. Rep., pp. 84–146, 1902.

44 Leonard, A. G., and others, The lignite deposits of North Dakota: North Dakota Geol. Survey Bull. 4, pp. 146–153, 1925.

LOCAL BED ABOUT 75 FEET ABOVE BURLINGTON BED

A local bed 1,685 feet above sea level and about 75 feet above the Burlington bed crops out at an abandoned strip mine in the NE ¼ sec. 35, T. 155 N., R. 84 W. The base of the coal is below water, and the top of the coal bed has been eroded, but the incomplete section

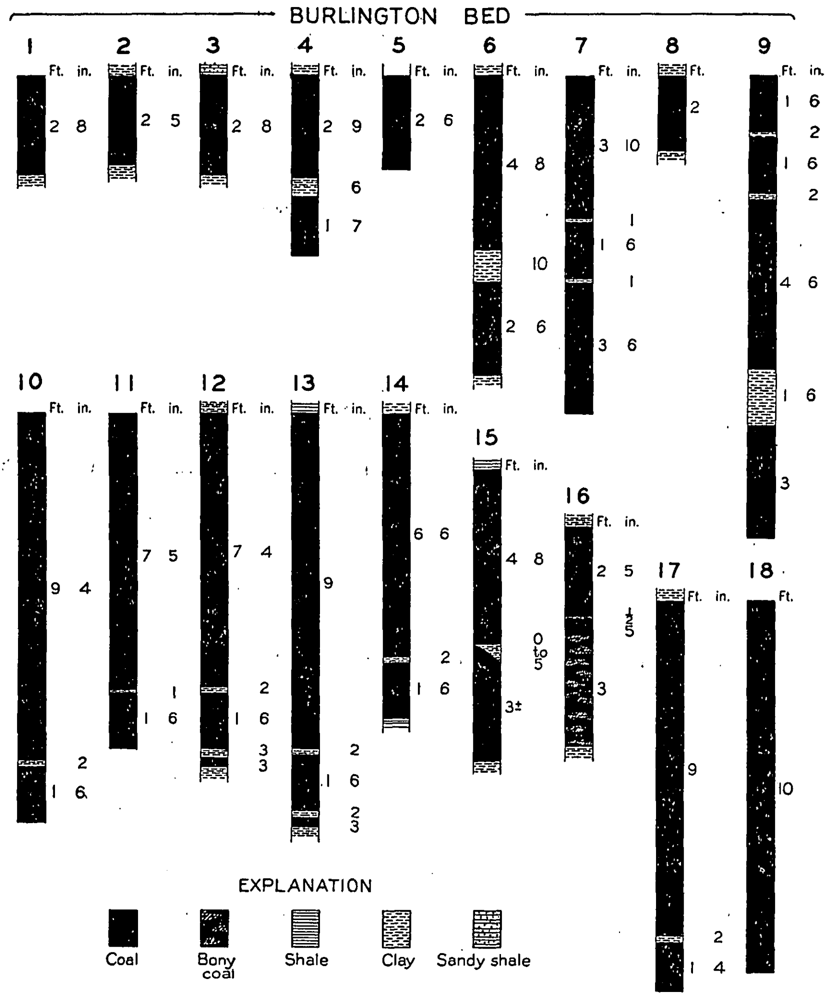

FIGURE 15.—Sections of the Burlington coal bed.

measured 3 feet 10 inches. No other outcrops of this coal were found, but a coal was encountered in several wells near this horizon southeastward as far as sec. 20, T. 154 N., R. 83 W., at an altitude of 1,655 to 1,686 feet.

LOCAL BED 23 FEET BELOW WOLF CREEK BED

The lowest coal bed found along the Missouri River crops out at water level at locality 103, near the center of sec. 27, T. 147 N.,

R. 84 W. This bed is 23 feet below the Wolf Creek bed and about 60 feet above the base of the Fort Union formation. This interpretation does not indicate, however, that this local bed is lower than the Burlington bed, because according to the writer's interpretation the base of the Fort Union transgresses downward about 200 feet from north to south across the Minot region. Only 2 feet of the top part of this bed was exposed above water level, and this part is exposed only during low-water stages of the Missouri River. This is probably the same coal that is mined on the west bank of the Missouri River 2 miles south of the Minot region, where it is 7 to 8½ feet thick.[45]

WOLF CREEK BED

The Wolf Creek coal bed, about 80 feet above the base of the Fort Union formation, crops out along the base of the steep escarpment on the east side of the Missouri River through secs. 15, 22, 27, 33, and 34,

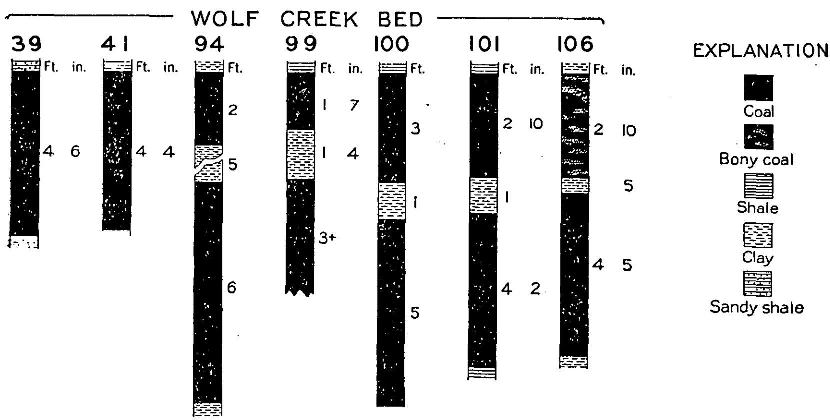

FIGURE 16.—Sections of the Wolf Creek coal bed.

T. 147 N., R. 84 W. It is here named from its exposures along the mouth of Wolf Creek. North and south of that vicinity and on the west side of the Missouri River it is concealed by terrace gravel. This bed was described by L. P. Dove.[46] Measured sections (see fig. 16) show a lower bench ranging from 3 feet at locality 99 to 6 feet at locality 94 and an upper bench ranging from 1 foot 7 inches at locality 99 to 3 feet at locality 100, with the clay parting between the benches only 5 inches thick at locality 106 and 5 feet at locality 94.

A coal bed that is probably the Wolf Creek bed crops out along the Missouri River in T. 147 N., R. 86 W. It is 4 feet 6 inches thick at locality 39 and 4 feet 4 inches thick at locality 41. This coal bed is bed 1–A of the Fort Berthold Indian Reservation.[47]

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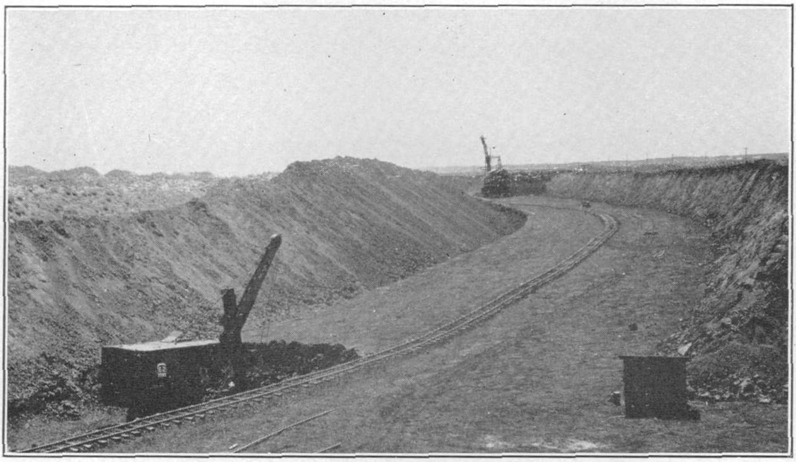
[45] Leonard, A. G., and others, The lignite deposits of North Dakota: North Dakota Geol. Survey Bull. 4, p. 122, 1925.

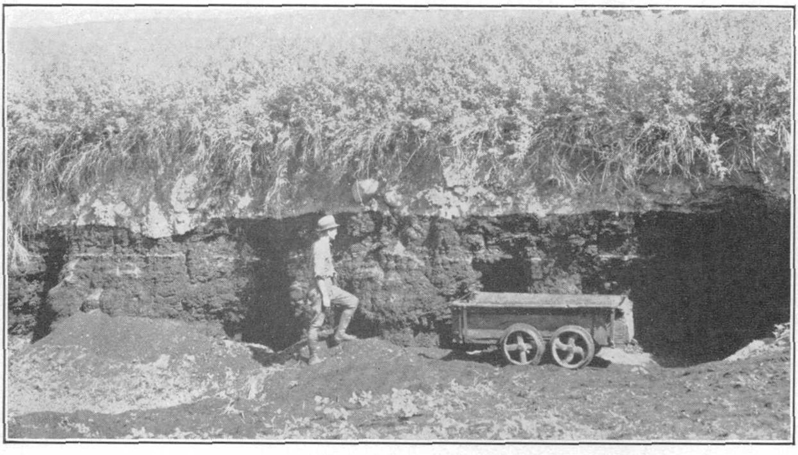
[46] Idem, pp. 121–122.

[47] Pishel, M. A., Lignite in the Fort Berthold Indian Reservation, North Dakota, north of Missouri River: U. S. Geol. Survey Bull. 471, pp. 179–180, 1912.

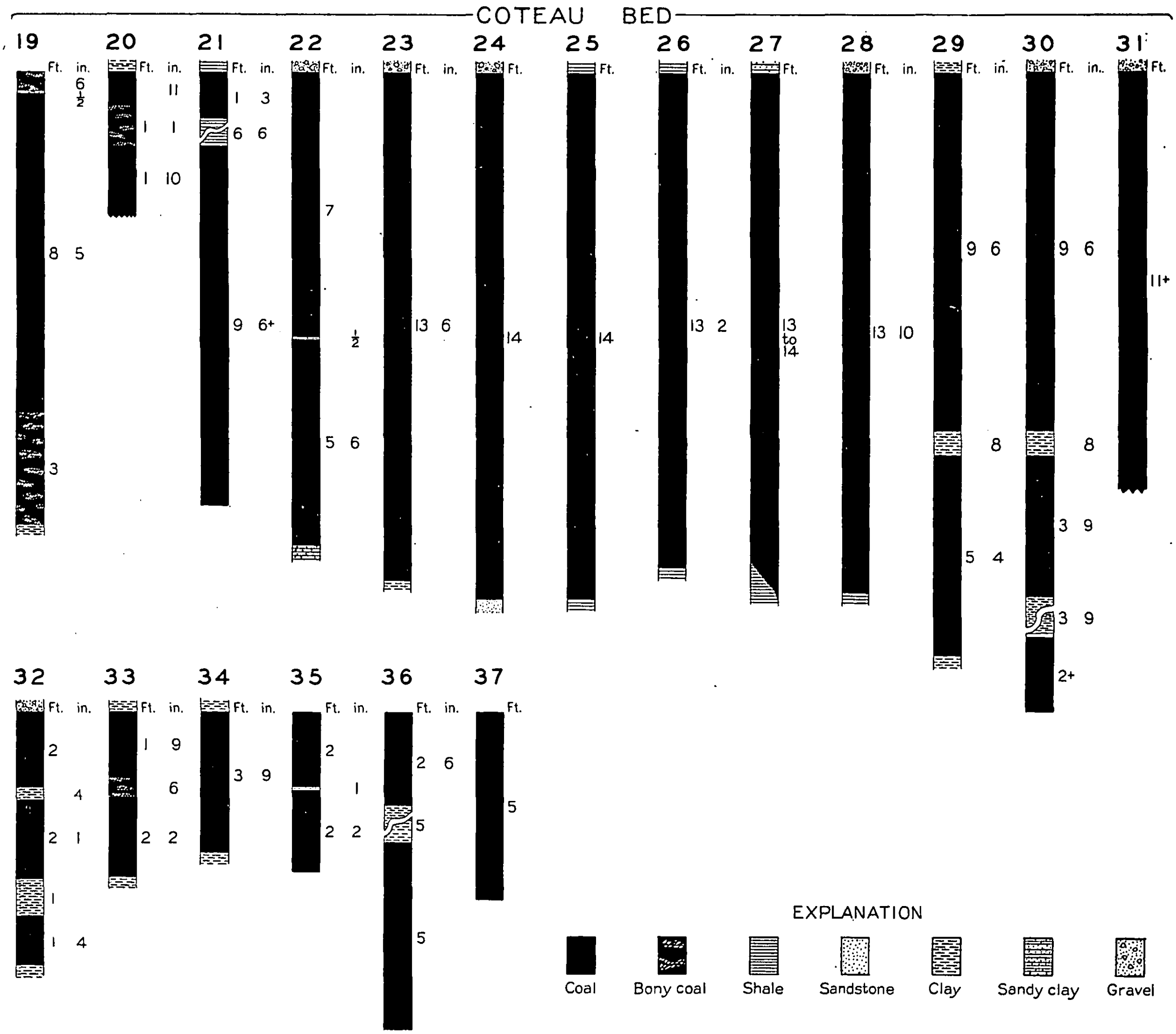


A. COTEAU COAL BED IN STRIP PIT OF TRUAX-TRAER LIGNITE COAL CO. IN SEC. 35, T. 152 N., R. 81 W.

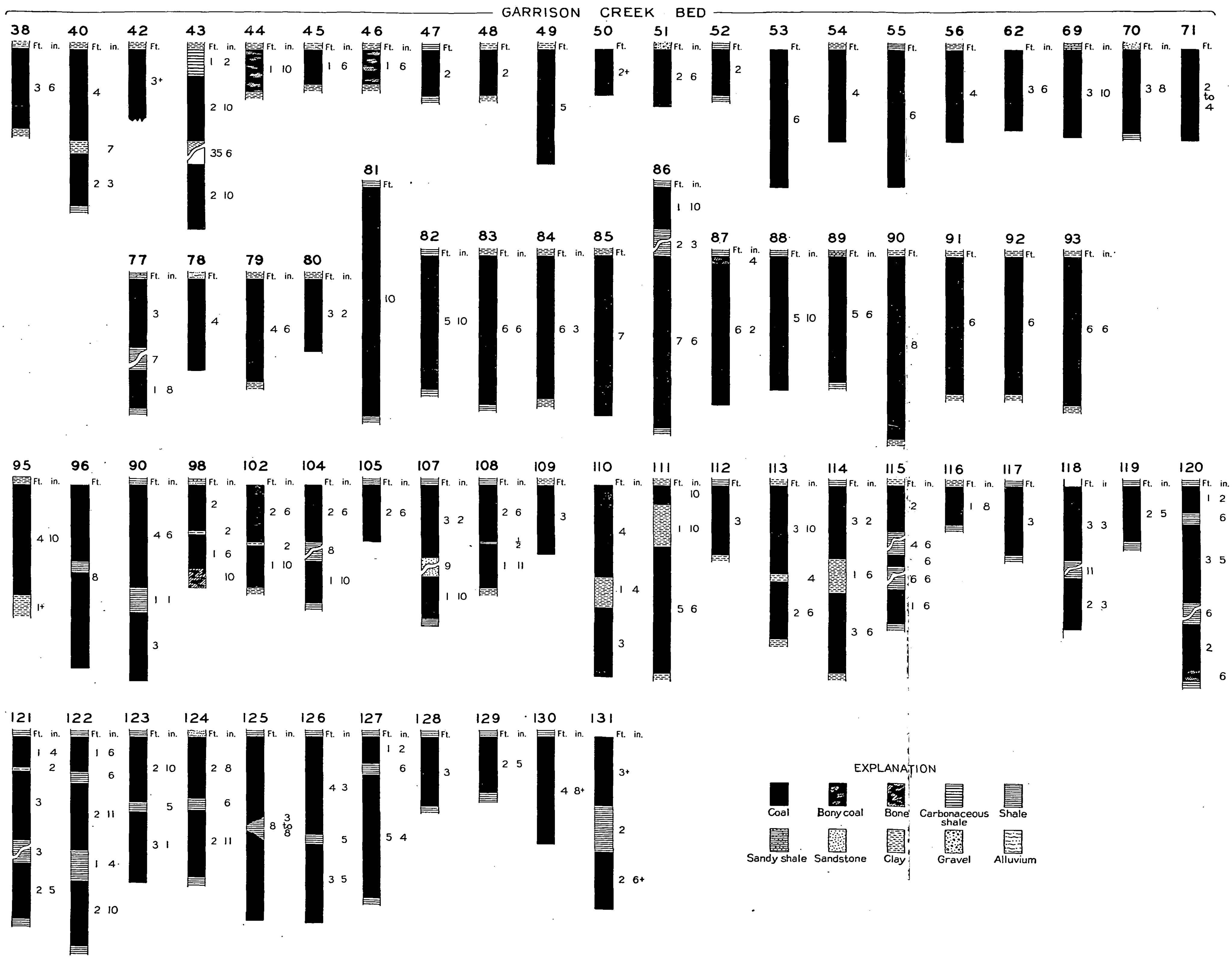
Coal bed is 14 feet thick; cover, 30 feet. Courtesy of Truax-Traer Lignite Coal Co.



B. COTEAU COAL BED OVERLAIN BY PLEISTOCENE GRAVEL AT REED MINE IN SW¼ SEC. 27, T. 153 N., R. 82 W.



SECTIONS OF THE COTEAU COAL BED.



SECTIONS OF THE GARRISON CREEK COAL BED.

The Wolf Creek coal bed is found at 1,744 to 1,766 feet above sea level in eight wells as far north as sec. 1, T. 148 N., R. 83 W., and as far east as sec. 4, T. 147 N., R. 81 W., under cover of about 200 feet. Beyond these points wells do not reach the horizon of this bed, and it may extend many miles farther.

COTEAU BED

The Coteau bed crops out intermittently for a distance of about 35 miles from the western part of T. 153 N., R. 82 W., to the northwestern part of T. 150 N., R. 87 W. It is exposed only where stream erosion has removed the covering of glacial drift and lake sediments. This bed was briefly described by Wood [48] and later described and named by Leonard.

Northwest of the Truax-Traer mine, in the southern part of T. 152 N., R. 81 W., the Coteau bed crops out in nearly every stream at altitudes of 1,830 to 1,840 feet above sea level. (See pl. 13, *A* and *B*.) At the northwestern outcrops of this bed in T. 153 N., R. 82 W., it is 250 to 270 feet above the horizon of the Burlington bed. Southeast of the Truax-Traer mine, in the northeastern part of T. 151 N., R. 81 W., a coal bed was found at two localities at 1,910 feet above sea level. This coal was mapped for about 3 miles, and although no evidence was found indicating appreciable dips, it probably represents the Coteau bed. There are no outcrops between these localities and sec. 32, T. 151 N., R. 79 W., where the Coteau bed crops out at 1,850 feet above sea level. From that locality it can be traced southeastward to the east side of Dogden Butte.

The thickness of the Coteau bed is shown by graphic sections in plate 14. Northwest from the Truax-Traer camp it has an average thickness of about 13 feet 6 inches; at most localities the coal is clean and free from partings, but at localities 29 and 30 it has an 8-inch parting 9½ feet below the top of the bed. The bed at an altitude of 1,910 feet southeast of the Truax-Traer mine and probably equivalent to the Coteau bed was measured only at locality 31, where 11 feet of coal, with the base concealed, is exposed in an abandoned mine. The coal was reported to have an equal thickness 1 mile northwest of locality 31. In the vicinity of Kongsberg and Dogden Butte the Coteau bed is much thinner than it is to the northwest; the thickness ranges from a maximum of 5 feet at localities 36 and 37 to a minimum of 3 feet 9 inches at locality 34.

The Coteau [49] bed is thought to underlie the country as far south as Strawberry Lake and Benedict and west to and including T. 151 N.,

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[48] Wood, L. H., Preliminary report on Ward County and adjacent Territory with special reference to the lignite: North Dakota Geol. Survey 2d Bienn. Rept., pp. 132-134, 1901-1902.

[49] Leonard, A. G., and others, The lignite deposits of North Dakota: North Dakota Geol. Survey Bull. 4, pp. 148-153, 1925.

R. 83 W. The well information supplying the data for this area is meager, and the correlation of the coals in the wells is somewhat doubtful. The Coteau bed is found at altitudes of 1,827 to 1,870 feet above sea level in this area and is tentatively correlated with the Garrison Creek bed, which is widespread in the area to the southwest.

GARRISON CREEK BED

The Garrison Creek bed, here named from its exposures along Garrison Creek, crops out extensively along both sides of the Missouri River and its tributaries in the southwestern part of the Minot region. The Garrison Creek bed is bed 2 of the Fort Berthold Indian Reservation,[50] where it is known to extend westward to the vicinity of Elbo Woods, 24 miles west of the Minot region. The occurrence of this bed in the vicinity of Garrison [51] has been briefly described.

The coal crops out at 1,780 to 1,830 feet above sea level in the western part of the Minot region on both sides of the Missouri River and from 1,850 to 1,880 feet above sea level in the eastern part of its outcrop. In the western part of the region the Garrison Creek bed is generally less than 5 feet thick, although measured sections show 6 feet of coal at localities 53 and 55, in sec. 31, T. 148 N., R. 86 W., and sec. 24, T. 148 N., R. 87 W. (pl. 15). The coal bed is 10 feet thick at locality 81, in sec. 5, T. 148 N., R. 85 W.; it averages 6 feet east of this point. Along Wolf Creek and the Missouri River this bed ranges in thickness from 2½ feet at locality 105 to 7½ feet in two benches at localities 96 and 97. South of the Missouri River it is generally present in two or three benches. The maximum measured thickness of the lower bench is 5 feet 6 inches at locality 111 and 5 feet 4 inches at locality 127, and that of the upper bench is 4 feet 3 inches at locality 126 and 4 feet at locality 110.

From a study of the drilled wells the Garrison Creek bed can be followed along the southern margin of the region to the eastern border at 1,820 to 1,860 feet above sea level. About 5 miles east of Garrison this bed has an altitude of 1,875 feet in the mines and wells. It can be followed fairly consistently northeastward to Benedict at altitudes of 1,840 to 1,885 feet, although the bed at 1,800 to 1,820 feet at the head of Snake Creek may be the Garrison Creek bed also. This bed is encountered as far west as the East Branch of Douglas Creek, but its surface outcrop can be followed northward along Douglas Creek. Northwest from Garrison the horizon of the Garrison Creek bed is far below most of the wells, although it may be represented by the 4-foot bed at 1,859 feet above sea level in the well at Douglas and the 6-foot bed at an altitude of 1,826 feet in the well at Ryder.

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[50] Pishel, M. A., Lignite in the Fort Berthold Indian Reservation, North Dakota, north of Missouri River: U. S. Geol. Survey Bull. 471, p. 180, 1912.

[51] Leonard, A. G., and others, The lignite deposits of North Dakota: North Dakota Geol. Survey Bull. 4, pp. 122–123, 1925.

MINTER BED

The Minter coal bed, here named from its exposure at the Minter mine, in sec. 12, T. 149 N., R. 85 W., crops out intermittently along Douglas Creek. It is bed 3 of the Fort Berthold Indian Reservation [52] and lies 60 to 70 feet above the Garrison Creek bed. Although this bed is variable it averages 5 feet in thickness over a considerable extent of its outcrop. Measured sections of this bed are shown in figure 17. The variability can be noted by comparing the section measured by the writer in 1934 at locality 75 with the following section measured by Dove in the mine at the same locality a few years earlier.[53]

Section of Minter coal bed at locality 75

	Feet	Inches
Glacial gravel	5	
Clay, blue	1	3
Lignite	6	6
Clay seam, not persistent	1	
Lignite, good	1	6
Clay, blue, reported.		

The Minter bed is found in many wells in T. 149 N., R. 84 W., at 1,940 to 1,982 feet above sea level. Coal is found at this horizon in two wells northeast of Benedict and in four wells in T. 152 N., R. 84 W. Coal is also found at this horizon along the western margin of the Minot region northward from the vicinity of Makoti to T. 155 N., R. 87 W.

COAL BEDS IN THE COVERED PORTION OF THE REGION

The coal beds in the Fort Union formation are good aquifers, and many of the wells in the region obtain water from them. In this investigation about 90 percent of the farms were visited in an attempt to obtain information about the coal beds encountered in drilling their wells. On the several hundred farms visited, definite information was obtained at about 350 wells. Altitudes of the wells were determined by aneroid barometers in that part of the country not covered by topographic maps.

The wells that are known to have encountered coal are plotted on the geologic map (pl. 11), with the surface altitude of the well and the altitude of the top of any coal found in the well. The altitude of each coal bed is followed by a dash and the thickness of the coal bed, if known, and preceded by a letter symbol indicating the bed if it can be correlated.

About 50 feet above the Minter bed is the C bed, unknown from surface outcrops but found in the vicinity of Douglas in several wells

[52] Pishel, M. A., Lignite in the Fort Berthold Indian Reservation, North Dakota, north of the Missouri River: U. S. Geol. Survey Bull. 471, p. 181, 1912.

[53] Leonard, A. G., and others, The lignite deposits of North Dakota: North Dakota Geol. Survey Bull. 4, p. 24, 1925.

at 1,980 to 2,010 feet above sea level. North of Max this bed is found at 2,000 to 2,015 feet; near Ryder at 2,010 to 2,030 feet; and again near Makoti at 1,980 to 1,990 feet. Above the C bed and 90 to 100 feet above the Minter bed, extending southeast from Douglas to the border of the field, is the B bed, at 2,040 to 2,060 feet above sea level. This bed also extends northwest from Douglas to Rice

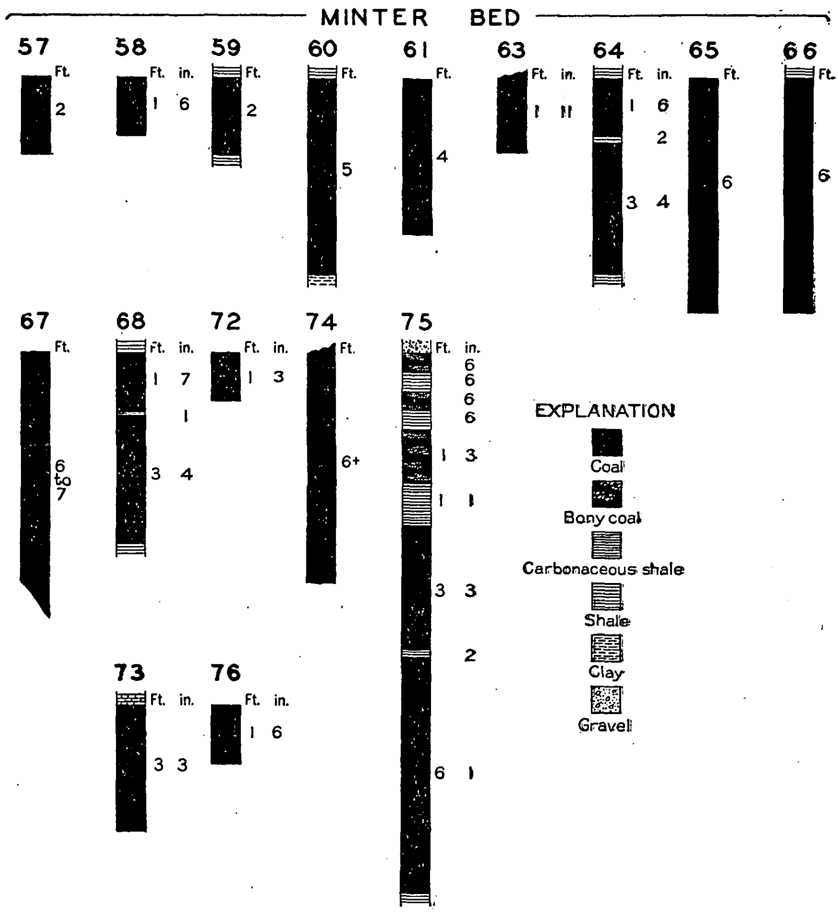

FIGURE 17.—Sections of the Minter coal bed.

Lake at similar altitudes. Along the western border of the field south from Ryder are a few wells that encounter a higher coal, the A bed at 2,100 to 2,125 feet above sea level. This is the highest bed found in this region and is about 150 feet above the Minter bed.

Along the north border of the field between the Altamont moraine and the Riviere des Lacs, the deep wells are more closely spaced than in the morainal area, but many of these wells are so old that the records have been lost and the data on them are dependent entirely on the memory of the owners. There is much greater difficulty in correlating the coal in these wells than elsewhere in the area. Northeast of Berthold coal is found in two wells at 1,670 and 1,698 feet above sea level and in four others at 1,765 to 1,790 feet above sea level. Northwest of Berthold a coal is found in several of the wells at 1,910 to 1,955 feet above sea level, that may represent the Minter coal bed found a few miles to the south at 1,945 to 1,985 feet. The lower altitude of the coal near Berthold may be a result of the small downwarp noted in the surface outcrops between Carpio and Foxholm. Coals are present at other horizons in the vicinity of Berthold, but they do not seem to be persistent. South of Lonetree, however, coal is found at 1,850 to 1,885 feet above sea level, extending about 15 miles to the southeast.

CHARACTER OF COAL

Physical properties.—The coal in the Fort Union formation in the Minot region is of lignitic rank. It is a tough brown fibrous coal which contains many carbonized plant remains. The coal does not break readily, although it splits easily along the bedding. On exposure to the air it slacks rapidly. Carbonized logs, which do not appreciably affect the quality of the coal, are found at many places in the field. Many silicified logs are found at the top of the Garrison Creek coal bed, and occasionally a log is found carbonized at one end and silicified at the other end.

Chemical properties.—Three samples of coal were collected by the writer in the Minot region and were analyzed by the United States Bureau of Mines. The analyses are given in the following table, together with analyses of three samples previously collected from this region and of two coals from other areas for comparison. The analyses are presented in three forms—A, as received; C, moisture-free; D, moisture- and ash-free.

Analyses of coal from Minot region and other areas in North Dakota and Montana

Location	Laboratory No.	Air-drying loss	Form of analysis	Proximate				Ultimate					Heating value	
				Moisture	Volatile matter	Fixed carbon	Ash	Hydrogen	Carbon	Nitrogen	Oxygen	Sulphur	Calories	British thermal units
Zook mine, Garrison, N. Dak., NE¼ sec. 17, T. 148 N., R. 48 W.	Composite, A99252 to A99255.	27.5	A	38.2	26.3	30.5	5.0	7.0	40.3	0.7	46.6	0.4	3,794	6,830
			C	--------	42.6	49.4	8.0	4.4	65.2	1.1	20.7	.6	6,144	11,060
			D	--------	46.3	53.7	--------	4.8	70.9	1.1	22.5	.7	6,683	12,030
Roseglen City Coal Co., Roseglen, N. Dak.	Composite, A99771 to A99774.	30.3	A	37.9	25.8	30.2	6.1	6.9	40.9	.6	44.9	.6	3,833	6,900
			C	--------	41.5	48.7	9.8	4.4	65.8	.9	18.2	.9	6,167	11,100
			D	--------	46.0	54.0	--------	4.9	72.9	1.0	20.2	1.0	6,839	12,310
Quality Lignite Co., Burlington, N. Dak., sec. 2, T. 155 N., R 84 W.	Composite, A 99902 to A 99905.	27.9	A	36.6	21.9	31.5	10.0	6.4	38.0	.6	44.9	.1	3,439	6,190
			C	--------	34.4	49.8	15.8	3.7	59.9	1.0	19.4	.2	5,422	9,760
			D	--------	40.9	59.1	--------	4.4	71.1	1.1	25.2	.2	6,433	11,580
Steven Bros. Coal Co., Garrison, N. Dak., sec. 19, T. 148 N., R. 84 W.	A 45983	11.9	A	33.1	29.6	32.7	4.6	6.7	43.6	.7	44.0	.4	4,128	7,430
			C	--------	44.3	48.3	6.9	4.6	65.2	1.1	21.6	.6	6,178	11,120
			D	--------	47.6	52.4	--------	4.9	70.1	1.2	23.2	.6	6,639	11,950
Conon mine, Burlington, N. Dak., sec. 12, T. 148 N. R. 84 W.	31705	30.1	A	36.93	24.92	27.72	10.43	6.39	37.36	.61	44.99	.22	3,339	6,010
			C	--------	39.51	43.95	16.54	3.63	59.23	.97	19.28	.35	5,294	9,529
			D	--------	47.34	52.66	--------	4.35	70.97	1.16	23.10	.42	6,343	11,417
Truax-Traer Coal Co., Velva, N. Dak., sec. 27, T. 152 N., R. 81 W.	A 45987	14.1	A	36.8	27.8	30.2	5.2	6.9	41.2	.7	45.6	.4	3,867	6,960
			C	--------	44.1	47.6	8.3	4.4	65.2	1.1	20.3	.7	6,122	11,020
			D	--------	48.0	52.0	--------	4.8	71.1	1.2	22.2	.7	6,672	12,010
Knife River Coal Min. Co., Beulah, N. Dak.	A 68042	--------	A	35.6	26.2	32.6	5.6	6.7	42.3	.6	44.1	.7	3,961	7,130
			C	--------	40.7	50.6	8.7	4.3	65.7	.9	19.3	1.1	6,144	11,060
			D	--------	44.6	55.4	--------	4.7	72.0	1.0	21.1	1.2	6,733	12,120
Northwestern Improvement Co., Colstrip, Mont.	A 46852	--------	A	25.6	27.2	40.2	7.0	6.3	51.5	.8	33.8	.6	4,939	8,890
			C	--------	36.5	54.1	9.4	4.7	69.2	1.1	14.8	.8	6,633	11,940
			D	--------	40.3	59.7	--------	5.2	76.4	1.2	16.4	.8	7,322	13,180

A99252 to A99255. Garrison Creek bed; composite of three samples taken at three fresh exposures in the underground mine in 1934.
A99771 to A99774. Minter bed; composite of three samples taken at three fresh exposures in underground mine in 1934.
A99902 to A99905. Burlington bed; composite of three samples taken at fresh exposures in underground mine in 1934.
A45983. Garrison Creek bed; sampled by Allport and Mather.
31705. Burlington bed; composite analyses of samples 31702–31704; sampled by J. G. Shoning.
A45987. Coteau bed; composite analyses of samples A45984–A45986; sampled by Allport and Mather.
A68042. composite analyses of samples A68037–A68041; sampled by M. M. Mounts.

MINING

Although the early history of mining in the Minot region is not readily traceable, there were many active mines at the beginning of the twentieth century,[54] and the history of mining undoubtedly extends back more than 60 years. Probably the first mine opened by white men was the mine on the Garrison Creek bed in the SW¼ sec. 35, T. 148 N., R. 85 W.,[55] that was worked by the men stationed at old Fort Stephenson, in sec. 10, T. 147 N., R. 85 W. Coal was mined about 2 miles south of Burlington at the old Colton mine in the 1880's. With the completion of the St. Paul, Minneapolis & Manitoba Railway from Minot to Great Falls, Mont., in 1887, a new demand for coal was created by the railway and by the new settlers that came in with its completion. From that time until after the World War the area around Burlington was the largest producer in the Minot region. In 1928 the Truax-Traer Co. opened a strip pit in sec. 26, T. 152 N., R. 81 E., and built a railroad connecting with the "Soo" Line, 5 miles to the northeast. Since that time the Velva district, largely from this one mine, has produced annually about 275,000 tons, about 15 percent of the total State production. According to the report of the State mining inspector for 1933,[56] there were 9 active mines in the district around Velva, 17 around Burlington, and 6 around Garrison. That report does not include mention of the many small local mines nor the large number of abandoned and idle openings. The following table, compiled from the annual report of the inspector, lists the production of coal in the Minot region since 1920.

Coal produced in North Dakota and in Minot region, since 1920, by districts, in tons

Year	State production	Burlington district	Velva district	Garrison district	Total Minot region
1920	878,969	65,906	9,645	20,169	95,720
1921	895,715	35,402	4,198	21,019	60,619
1922	1,057,823	36,025	6,004	60,145	102,174
1923	1,435,605	23,277	7,369	127,624	158,270
1924	1,029,449	40,442	2,892	40,175	83,509
1925	1,357,408	43,910	13,213	83,524	140,647
1926	1,385,362	29,518	15,221	73,995	118,734
1927	1,529,154	28,368	15,873	98,868	143,109
1928	1,783,624	27,480	246,025	69,018	342,523
1929	1,902,593	17,767	298,216	79,220	395,203
1930	1,849,144	29,866	345,628	85,833	461,327
1931	1,552,242	41,088	274,676	81,308	397,072
1932	1,743,053	51,341	275,309	81,626	408,276
1933	1,872,381	62,050	284,642	91,255	437,947

The mines of the Minot region may be grouped into three classes—open strip pits, entries or inclined shafts, and vertical shafts. The

[54] Wilder, F. A., and Wood, R. H., Report on lignite, by counties: North Dakota Geol. Survey 2d Bienn. Rept., pp. 56, 162, 1902.

[55] Wilder, F. A., The lignite of North Dakota and its relation to irrigation: U. S. Geol. Survey Water Supply Paper 117, p. 34, 1905.

[56] Olson, O. J., North Dakota Coal Mine Insp. Dept. 15th Ann. Rept., 1933.

Burlington bed, in the region northwest of Minot, is mined almost exclusively in entries or inclined shafts, and the coal is brought to the surface in the valley, where it is near the railroad for shipping or near the good highways for trucking. A few vertical-shaft mines have been opened from the top when the producers wanted to tap the vein farther from its outcrop. The Wolf Creek bed is mined solely by entry mines, because the cover is 200 feet or more; the coal is hauled by trucks. The largest mine on the Coteau bed is a strip mine of the Truax-Traer Co. (see pl. 13, *B*), which loads on a spur line of the railroad, but there are numerous other strip mines and entry mines along the coulees of the region which supply coal for transportation by trucks. The Garrison Creek bed is mined in strip pits along Garrison Creek, and the coal is loaded directly on spur lines of the railroad. Elsewhere the Garrison Creek bed is mined either in small strip pits along the outcrop or by slope entries where the cover ranges from 30 to 60 feet. The only large producing mine in the Minter bed is the Minter mine, a strip pit in sec. 14, T. 149 N., R. 85 W., although there are local strip pits elsewhere along the crop line of this bed.

In the Minot region the greatest hindrance to mining is the presence of water in the coal beds. Throughout most of the region where the coal is under considerable cover and is very far removed from the outcrop and from natural drainage lines, it usually carries water in appreciable quantities; consequently any shaft mining must have heavy pumping equipment. Such was the experience of two shafts that were sunk, one at Ruso and the other 2 miles northwest of Des Lacs, along the Great Northern Railway. In addition, the several hundred wells that have been drilled in this region show the presence of water in the coal beds.

Practically all the mining in this region has been done on or near the outcrop line of the coal, because the coal is exposed at the surface and can be easily prospected and economically mined on a small scale. Until coal is sufficiently valuable to overcome the heavy expense of the pumping of water, future mining is likely to be continued along the crop line, where there is good natural drainage. There are, however, large quantities of coal available by the present methods of mining. The entire area adjacent to the crop line of the Coteau bed from the central part of T. 153 N., R. 82 W., southwest to Dogden Butte, when sufficiently prospected, may disclose large stripping areas. Operations in these areas would necessitate the extension of a railroad. It may not be feasible to attempt strip mining of some areas along the coulees that have been extensively mined by underground methods. Of course, any area should be adequately tested for thickness of cover and extent and thickness of the coal before mining operations are begun.

There are numerous areas near the railway in the southwestern part of the region where stripping would be profitable. There remain considerable reserves along Garrison Creek, but these are being mined at the present time. Prospecting in the area 4 miles south of Garrison and 4 to 7 miles east of Garrison and along Wolf Creek for 3 or 4 miles west and northwest of Coleharbor would probably show areas that were suitable for stripping. In addition, the northwestern part of T. 149 N., R. 84 W., and the northeastern part of T. 149 N., R. 85 W., probably have areas underlain by the Minter bed that would justify a spur line of the railway and stripping. In parts of all these areas lignite of good quality and 5 to 14 feet thick may be expected under cover of less than 50 feet.

ESTIMATE OF RESERVES

The meager exposures of coal and the consequent meager knowledge of the extent and variation in thickness of the coal beds preclude an accurate estimate of the coal reserves in the Minot region. Furthermore, much of the district is undoubtedly underlain by coal beds in rocks older than any that crop out, but there are few available data concerning those beds, and no estimate can be made of the amount of coal that they contain. In computing the tonnage estimates presented in the following table well-log data were used to supplement information obtained at the outcrop, but in some parts of the region where the coal beds do not crop out and no information could be obtained from wells it was necessary to assume an arbitrary boundary for the limit of coal beds.

Estimated reserves in the principal coal beds in the Minot region

	Area (square miles)	Average thickness (feet)	Reserves (million tons)
Burlington bed	351½	6	2,429
Wolf Creek bed	193	4½	1,000
Coteau bed	337	9	3,494
Garrison Creek bed	919½	4	4,437
Minter bed	969	5	5,581
B bed	200	5	1,152
Total			18,094

OIL AND GAS

The Fort Union rocks, of Eocene age, that crop out in the Minot region and the underlying Lance formation, of Upper Cretaceous age, which together have a maximum thickness of about 1,000 feet, have nowhere been found to contain commerical quantities of oil or gas. The underlying Cretaceous rocks that yield oil and gas at many localities in Montana[57] and Wyoming[58] are more than 3,000 feet thick in the Minot region and are petroliferous in the well of the Des Lacs Western Oil Co., near Lonetree. Very little is known concerning the extent or possible petroliferous character of the older formations in this part of North Dakota.

The Fort Union and Cretaceous rocks and possibly the older formations are practically flat-lying in the Minot region, and structural features that usually control the accumulation of oil or gas in quantities of commercial importance are absent. Under such structural conditions there is little likelihood of notable accumulations of oil or gas.

The Des Lacs Western Oil Co. drilled a well in the SW¼ sec. 4, T. 155 N., R. 85 W., to a depth of 3,980 feet (p. 13). The well penetrated about 900 feet of Lance and Fort Union rocks and about 3,100 feet of older Cretaceous rocks. Shows of oil and gas were reported from Cretaceous rocks at depths of 900–920, 1,300–1,340, 1,900–1,905, 2,300–2,310, and 3,040–3,043 feet. About 2 miles southeast of the southeast corner of the Minot region a well has been drilled by local residents in the SE¼ sec. 3, T. 141 N., R. 81 W. This well is reported to be about 1,600 feet deep and to have encountered a show of oil; the bottom of the well is probably in the Pierre shale, of Upper Cretaceous age.

SALT DEPOSITS

Although no investigation was made of the salt deposits in the lakes of the Minot region, a recent report on the salt deposits in the northwestern part of North Dakota[59] shows that natural deposits of sodium sulphate (Glauber salt) are not uncommon in the Pleistocene lakes of North Dakota. The report cited describes deposits of sodium sulphate about 10 miles west of the Minot region. It is possible that some of the intermittent lake beds in the northeastern and central parts of the Minot area may contain sodium sulphate deposits of commercial rank.

ARTESIAN WATER

In an area extending southeastward from Berthold to the eastern part of T. 154 N., R. 83 W., about 8 miles south of Minot, and ranging in width from about 1 mile at each end to about 3 miles near Des

[57] Collier, A. J., The Kevin-Sunburst oil field and other possibilities of oil and gas in the Sweetgrass arch, Mont.: U. S. Geol. Survey Bull. 812, pp. 87–189, 1929. Reeves, Frank, Thrust faulting and oil possibilities in the plains adjacent to the Highwood Mountains, Mont.: U. S. Geol. Survey Bull. 806, pp. 185–190, 1928.

[58] Hewett, D. F., Geology and oil and coal resources of the Oregon Basin, Meeteetse, and Grass Creek Basin quadrangles, Wyoming: U. S. Geol. Survey Prof. Paper 145, pp. 71–91, 1926. Thom. W. T., Jr., and Spieker, W. M., The significance of geologic conditions in Naval Petroleum Reserve No. 3, Wyoming: U. S. Geol. Survey Prof. Paper 163, pp. 20–37, 1931.

[59] Lavine, Irvin, and Feinstein, Herman, Natural Deposits of Sodium Sulfate in North Dakota: Am. Inst. Min. Met. Eng. Contr. 97, 1936.

Lacs, most drilled wells obtain flowing water in coal beds or sandstone lenses of the Fort Union formation at depths of 100 to 550 feet. The outline of this area, described as the Des Lacs artesian area by Simpson,[60] is shown approximately on plate 11 by the distribution of the flowing wells. Although not all wells in this artesian area encounter flowing water, the water in most of the wells is under considerable pressure; the area in which the water is under some pressure usually extends 3 miles beyond the limits of the area in which flowing wells are obtained.

Simpson describes this type of artesian area, where the water comes from flat-lying beds in front of the terminal moraine, as the "escarpment type" of artesian system and says that—

> The water, which rises in wells to the surface in small weak flows, seems to derive its hydrostatic pressure more from the higher ground-water level beneath the escarpment, which causes a slow general downward percolation of the water, than from the elevation of water in the bed that is tapped.[61]

The flow of water in this area ranges from a few gallons an hour to 10 gallons a minute.

Artesian flow has also been obtained in a well in the SE¼ sec. 15, T. 151 N., R. 80 W.; water flows from a depth of 126 feet. Neighboring wells have water standing only a few feet below the surface.

A small area in the southeastern part of T. 150 N., R. 84 W., and the southwestern part of T. 150 N., R. 83 W., and the adjacent parts of the townships on the south has yielded flowing water at depths of 60 to 125 feet, with flows strong enough to meet all domestic needs.

Analyses of waters from this part of North Dakota[62] show that the water from the Fort Union formation has a hardness generally between 100 and 500 parts per million and dissolved solids about 2,000 parts per million. Practically all the artesian water of this region is suitable for domestic use.

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[60] Simpson, H. E., Geology and ground-water resources of North Dakota: U. S. Geol. Survey Water-Supply Paper 598, pp. 250–262, 1929.

[61] Simpson, H. E., op. cit., p. 51.

[62] Simpson, H. E., op. cit., pp. 272–307.

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