

DESCRIPTION OF THE BISMARCK QUADRANGLE.

By Arthur G. Leonard.^a

INTRODUCTION.

LOCATION AND AREA.

The Bismarck quadrangle is bounded by parallels 46° 30' and 47° and meridians 100° 30' and 101° and thus covers one-fourth of a square degree, in that latitude an area of about 820 square miles. The quadrangle lies in central North Dakota and includes parts of Burleigh, Morton, and Emmons counties, with a very little of Oliver County. (See fig. 1.) Missouri

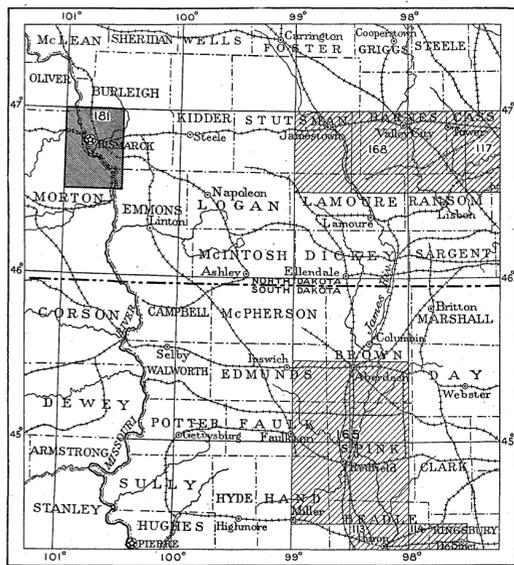


FIGURE 1.—Index map of parts of North and South Dakota. The location of the Bismarck quadrangle is shown by the darker ruling (No. 181). Published folios describing other quadrangles, indicated by lighter ruling, are as follows: Nos. 118, Huron; 114, De Smet; 117, Casselton-Fargo; 165, Aberdeen-Redfield; 108, Jamestown-Tower.

River flows diagonally across the quadrangle from northwest to southeast and divides it into two nearly equal parts. The principal towns are Bismarck, the State capital, on the east side of the river, and Mandan, nearly opposite on the west side.

GENERAL GEOGRAPHY AND GEOLOGY OF THE REGION.

In its geographic and geologic relations the Bismarck quadrangle forms a part of the Great Plains province. It lies near the eastern margin of that province, in the broad indefinite zone where it merges gradually into the Glaciated Plains province, which includes the prairie region of the upper Mississippi Valley. Nearly all parts of the Great Plains have similar topographic features, are alike in geologic structure, and have had a common geologic and physiographic history.

The surface of the country is flat or gently rolling, with a general though very slight eastward slope from an altitude of about 6000 feet at the base of the Rocky Mountains to the Mississippi Valley, but diversified here and there, especially in the western part, by buttes and pinnacles of more resistant rock that rise prominently above the plains. Farther east there are extensive areas of sand hills, and along the eastern margin lie irregular accumulations of glacial material.

In the eastern part of the province the valleys are broad and shallow, but toward the west side, where the land is higher and the streams are smaller and swifter, the valleys are narrower and deeper, with steep slopes and numerous cliffs. In semiarid regions of soft rocks, especially in northwestern South Dakota and adjacent parts of North Dakota, Montana, and Wyoming, the particular type of topography known as badlands is characteristically displayed.

Within the United States all of the Great Plains except its extreme southern part drains into the Mississippi through numerous tributaries, especially Missouri and Arkansas rivers and their branches. All the larger rivers rise in the Rocky Mountains and flow entirely across the Great Plains, as a rule with gentle slopes and sluggish currents.

The hard rocks of the Great Plains are all sedimentary, chiefly shale and sandstone, with some limestone. Many of the beds most recently deposited are still unconsolidated sand and clay, with widespread areas of volcanic ash and of gravel. The materials of the rocks were derived chiefly from the waste

^aThe Bismarck quadrangle was surveyed in cooperation with the North Dakota Geological Survey, Arthur G. Leonard, State geologist.

of the land farther west in the Rocky Mountain region. The older strata were deposited in marine waters, but the later sediments were laid down in lakes or spread by streams upon the flat surface of the land. The rocks range in age from Cambrian to Quaternary, those older than Cretaceous being displayed only along the western margin of the province, at the base of the Rockies, or exposed by erosion in a few areas of local uplift and in the deeper valleys along the east side of the plains.

Except in small areas of local uplift and folding the strata have been very little deformed since their deposition, and they now lie nearly horizontal but with a slight general dip eastward away from the mountains. The upturned edges of Paleozoic strata are exposed along the base of the Rockies, where they were involved in the Rocky Mountain uplift, but farther east the great central area of the Plains is occupied by practically horizontal rocks of Cretaceous and Tertiary age.

TOPOGRAPHY OF THE QUADRANGLE.

RELIEF.

The Bismarck quadrangle lies at the eastern margin of the Great Plains province, in the elevated region of western North Dakota known as the Coteau du Missouri. The area included in the quadrangle presents two topographic types—the upland plain, with its rolling or rough surface, and the more level valley lowlands along the Missouri and its larger tributaries.

Upland.—The altitude of the upland ranges from less than 1900 feet to about 2250 feet, though a few small areas rise to 2300 feet above sea level. The streams have deeply trenched the surface in many places and it is now broken by wide valleys. As a result of the extensive and long-continued erosion only scattered remnants of the plateau now remain. One of the largest of these remnants is the interstream area between Little Heart River and the headwaters of Rice and Chanta Peta creeks, which includes the highest land in the quadrangle. In the vicinity of Parkin there are several areas at 2250 to 2300 feet above sea level. Little Heart Butte, a small but conspicuous hill visible from the most distant parts of the quadrangle, rises abruptly to a height of 150 feet above the adjoining upland surface, or 2239 feet above the sea. Another extensive upland tract lies in the northern part of the quadrangle, at an altitude of 2000 to 2200 feet. The surface of this tract has been dissected by Burnt Creek and by tributaries of Apple Creek into a large number of irregular hills and ridges, most of them having altitudes of 2000 feet or more and some of them being several miles from the main upland, from which they have been separated by erosion. A massive sandstone 20 to 50 feet thick caps many of the higher ridges and buttes and outcrops in many places about their summits.

The surface of the upland in some places, as in the vicinity of Sather, is rough and hilly; in others it is more or less rolling. Much of it, particularly in the higher parts, is thickly strewn with glacial boulders.

Custer Flats is a detached upland area between Heart and Little Heart rivers. Its level or gently rolling surface has an altitude of 1900 feet or more.

Valley lowlands.—The valley lowlands occupy a considerable part of the area, by far the most extensive being those along the alluvial plain of the Missouri. In many places these lowlands merge by gently rising slopes into the upland, so that it is impossible to draw any sharp line between the two, but elsewhere the lowland and the upland are separated by abrupt slopes. A large part of the quadrangle is occupied by the slopes between the upland areas and the valley lowlands.

The most conspicuous topographic feature of the region is the valley of Missouri River, which crosses the quadrangle from northwest to southeast. The river has cut a great trench 400 to 600 feet deep and 2 to 3 miles wide at the bottom. The area of this nearly level valley bottom within the quadrangle is between 90 and 100 square miles. On the west the valley is bordered almost continuously by bluffs rising 300 to 600 feet above the river. On the east the bluffs are not so high or continuous, being interrupted in places and reaching an elevation of only 75 to 200 feet. The highest and most commanding escarpment is on the west side of the valley in the vicinity of Sugarloaf Butte, several miles below the mouth of Little Heart River. The steep grass-covered slope, deeply furrowed by many gulches, rises 600 feet above the bottom land. In the southeastern part of the quadrangle the valley is bordered on the west for 4 or 5 miles northward from Corner Butte by bare bluffs of shale and sandstone rising abruptly nearly 300 feet above the river.

The "first bottom" or flood plain of the Missouri lies 12 to 15 feet above the normal stage of the river. A large part of this bottom land is a natural meadow on which great quantities of wild hay are cut. Other parts are covered with a thick growth of brush and timber. In the Bismarck quadrangle the flood plain lies between 1600 and 1650 feet above sea level, the 1650-foot contour marking approximately the outer boundary of the alluvial bottom. A small terrace lying 6 feet above the flood plain, or 21 feet above the normal stage of the river, is present at some localities.

The principal terrace, 45 feet above the normal water level of the river, is well developed at several points in the Missouri Valley. Part of Bismarck is built upon this terrace, which extends from the railroad bridge across the Missouri southeastward past the city to and beyond Fort Lincoln. The main wagon road to the fort traverses this terrace. The face of this terrace is in most places marked by the 1650-foot contour. A terrace at approximately the same altitude extends almost continuously along the west side of the valley from a point opposite Fort Lincoln to the south side of the quadrangle. Livona, in the southeast corner of the quadrangle, is located on a well-developed terrace which extends southward from Devils Gulch at an altitude of 60 feet above the Missouri and has an average width of about half a mile. Traces of still other terraces are to be found at intervals along the valley. These benches or terraces are in part cut in the bedrock, in part built of gravel, sand, and river silt.

Heart River has cut a valley 250 feet deep and averaging three-fourths of a mile wide at the bottom. Gravel and sand terraces occur at many points and are prominent features of this valley. There is a lower terrace about 70 feet and an upper one about 110 feet above the river. The lower terrace is especially well shown on the south side of the valley about 3 miles west of Mandan, where it is nearly half a mile wide and is traversed for more than a mile by a wagon road. The upper terrace, which has been much eroded, appears south of the river opposite Mandan.

The valley of Little Heart River below its confluence with Southeast Branch is comparatively narrow and deep and bordered by steep slopes. Above the confluence the valley is broad, with relatively gentle slopes, and includes the Little Heart Flats, a level area which extends westward beyond the quadrangle and is between 8 and 9 miles long. The flats include not only the alluvial bottom of Little Heart River, which is of small extent, but also the broad valley bottoms of Southeast Branch and South Branch. These merge with the flood plain of the main stream, the width of the flats being thus much increased. The flats include also the gently sloping and slightly rolling surface with which the Little Heart alluvial plain merges on the south. Some portions of the flats are thus 50 feet or more above the river and are not a part of its flood plain.

A number of partly buried morainic hills rise through the alluvial deposits in the valley of Southeast Branch, some of them just appearing, like islands, above the level valley floor. Southeast Branch winds about over its plain and among the morainic hills in a shallow V-shaped trench 8 to 10 feet deep in its upper part. South Branch flows for miles in an even shallower and more poorly defined trench.

In the southern part of Apple Creek Township and the adjoining part of Manning Township there is an area of some 8 or 10 square miles which is very sandy, the sand in many places having been heaped by the wind into dunes. These dunes are irregular in shape and height, some of the largest being 50 to 100 feet high. Most of them are covered with grass, which keeps the sand from shifting.

DRAINAGE.

The entire quadrangle is drained by the Missouri and its tributaries. The chief tributaries from the east are Apple and Burnt creeks, with Long Lake Creek just appearing in the southeast corner; those from the west are Heart and Little Heart rivers and Rice and Square Butte creeks. Chanta Peta Creek, which drains the central southern part of the quadrangle, joins Cannonball River, a tributary of the Missouri, a few miles south of the quadrangle boundary.

The Missouri has a total length within the quadrangle of 61.6 miles, in which distance it falls 42.8 feet, an average fall of 8 1/2 inches to the mile. Heart River, the largest of the tributaries, rises over 120 miles to the west. Apple Creek, though much smaller than the Heart, ranks next in size and drains a considerable area both inside and outside of the quadrangle.

The width of its valley is strikingly disproportionate to the present size of the stream, and it doubtless once had a much greater volume.

The only stream whose drainage area lies almost wholly within the quadrangle is Rice Creek, which enters the Missouri near the southern border. The divide separating the creek from the river has a very steep escarpment on the east, toward the river, and a relatively gentle slope on the west. Owing to the wash of the rain and the constant slumping of the eastern bare clay slope the divide is slowly migrating westward where the gentle slope will not favor rapid erosion.

All the larger streams meander widely on their flood plains, and Apple Creek especially incloses several islands formed by the dividing of the stream channel. There are many islands in the channel of the Missouri, and others are formed by abandoned meanders which are still joined at both ends to the main stream. Other abandoned meanders now form backwaters. Lakes Robinson and Wilde occupy such depressions in the flood plain of the Missouri.

The lower courses of several of the streams are peculiar in that after entering the valley of the Missouri they flow for miles nearly parallel to the main stream before joining it. Apple Creek turns abruptly southward not far from the State penitentiary and flows more than 8 miles in that direction before joining the Missouri. Heart and Little Heart rivers and Burnt and Square Butte creeks behave in a similar manner. These peculiar courses are probably due to the slight slope of the Missouri flood plain away from the river, which prevents the junction of the streams until the Missouri swings to the side of the valley along which the tributary flows.

CULTURE.

The Bismarck quadrangle, which lies in an agricultural region, is rather uniformly though sparsely settled. Bismarck and Mandan are the only towns of any considerable size. The main line of the Northern Pacific Railway crosses the quadrangle from east to west, and a branch line along the west side of the Missouri Valley crosses the quadrangle from south to north. The Bismarck line of the Minneapolis, St. Paul & Sault Ste. Marie Railway enters from the southeast, runs to Bismarck, and leaves the quadrangle on the north. The quadrangle is everywhere traversed by highways, largely though not wholly laid out along section lines.

DESCRIPTIVE GEOLOGY.

STRATIGRAPHY.

The rocks of the Bismarck quadrangle consist of stratified deposits of Cretaceous and Tertiary age and surficial deposits of Quaternary age. The former underlie the whole area of the quadrangle but do not outcrop extensively except in the bluffs along the streams and about the margins of the higher upland areas. The surficial deposits consist in part of glacial materials, in part of recent alluvium and wind-blown sand. The rock formations will be described in the order of their age, beginning with the oldest.

CRETACEOUS SYSTEM.

FOX HILLS SANDSTONE.

Name and character.—The only formation of undisputed Cretaceous age in the Bismarck quadrangle is the Fox Hills sandstone, the latest of the marine formations in the Great Plains province. After its deposition the sea receded finally from the region. The formation takes its name from Fox Ridge, in South Dakota, where it is typically developed. The small area occupied by it in the Bismarck quadrangle is part of a much larger one extending down the valley of the Missouri into South Dakota, where it is found both east and west of the river.

The Fox Hills sandstone is exposed on Cannonball River, which flows east and joins the Missouri about 5 miles south of the quadrangle, for 12 or 14 miles above its mouth. At many points along its valley the formation occurs in cliffs rising from the water's edge to an altitude of 80 to 90 feet above the river, or approximately 1680 feet above sea level. As better opportunity for the study of the sandstone is afforded by the exposures along the Cannonball, a description of these exposures, which show the general character of the beds throughout the region, will be given here.

The unweathered rock is gray with yellow patches, but weathered outcrops are yellowish or brownish. The sandstone is rather fine grained and for the most part so soft and friable that it can be crumbled in the hand. Cross lamination is very common, and the rock contains great numbers of large and small ferruginous sandstone nodules, many of these also showing cross lamination. The nodules appear to be due to the segregation of the iron in irregular patches, cementing the sand into firm masses that are considerably harder than their matrix. In many places the iron has impregnated certain layers and formed indurated ledges which resist weathering and therefore project beyond the softer portions. The nodules range in diameter from an inch and less to 6 and 8 feet.

Small, irregular, stemlike or twisted concretionary forms are abundant at many points. In some portions these brown ferruginous nodules are so numerous that they constitute the bulk of the rock and the gray, loosely cemented sandstone forms a sort of matrix in which they are embedded. On weathering they project beyond the surface of the softer and less coherent rock, and weathered-out nodules are exceedingly abundant at the bases of slopes and scattered over the surface in many places. Where the iron is not so much segregated and the nodules are therefore scarce, the sandstone has a yellow color, due to disseminated iron oxide. Where the nodules are abundant the rest of the rock is gray in consequence of the iron having been largely leached from it and concentrated in them. Cannonball River was named from the great abundance in its valley of large spherical nodules weathered out from these beds.

Fossils.—At several localities in the valleys of Cannonball River and Long Lake Creek, just south of the southeastern part of the quadrangle, the following fossils, identified by T. W. Stanton, were collected:

Avicula linguiformis E. and S.	Maetra? sp.
Avicula nebrascana E. and S.	Ostrea pellucida M. and H.
Chemnitzia cerithiiformis M. and H.?	Protocardia subquadrata E. and S.
Callista deweyi M. and H.	Scaphites cheyennensis Owen.
Cinulia concinna M. and H.?	Tancredia americana M. and H.
Dentalium gracile M. and H.	Tellina scitula M. and H.
Maetra warrenana M. and H.	

In the Cannonball Valley, south of the quadrangle, on a slope a few feet below the top of the formation, two teeth were found. C. W. Gilmore, of the National Museum, has identified one of these as the tooth of a large fish, the other as that of some *Mosasaurus*, "remains of which do not occur above the Pierre." Although these teeth were not found in place, it was evident from their position that they must have come either from beds of the Fox Hills formation or from the overlying Lance formation ("Ceratops beds"). It would appear to be impossible for the tooth of the *Mosasaurus* found at this locality to have been derived from beds of Pierre age, for the nearest outcrop of the Pierre is 15 miles to the south, along the Missouri.

Thickness and relations.—As the base of the Fox Hills sandstone is not exposed in the Bismarck quadrangle, its thickness can not be determined in that area, but in northern South Dakota it is known to reach 200 feet. In the valley of the Cannonball the top of the formation is marked by a light-gray, almost white cross-bedded sandstone, the laminae being one-fourth to one-half inch thick. This bed is from 12 to 18 inches in thickness. The overlying Lance formation rests in apparent conformity upon the top of the Fox Hills.

Occurrence and distribution.—The area occupied by the Fox Hills sandstone in the Bismarck quadrangle is confined to the southeast corner, where it outcrops in a narrow strip along the base of the bluffs on each side of the Missouri Valley and for some distance up the valleys of tributary streams.

On the west side of the Missouri the formation extends along the bluffs from the southern margin of the quadrangle to a point north of Fort Rice, and up the valley of Rice Creek for about 2 miles. It is well exposed at the bridge where the river road crosses Rice Creek, forming a cliff 30 feet high that rises abruptly from water level. It is also exposed about half a mile upstream, near the northwest corner of sec. 15, T. 135 N., R. 79 W., and again in the low cliff, 30 or 40 feet high, overhanging the river just below the mouth of Rice Creek. The Missouri, swinging against the cliff at this point, is undermining it, and the harder layers form projecting ledges.

On the east side of the river the formation extends as far north as Lake Wilde, near which it passes below river level. It is well shown in the vertical cliff which rises from the water's edge at the bend of the river south of Lake Wilde, and which is formed almost wholly of Fox Hills sandstone, here exposed for 50 feet above the normal stage of the river. South of the ravine in sec. 7, T. 135 N., R. 78 W., the river bluff is grassed over as far as the valley of Long Lake Creek, and the sandstone outcrops only at a point just southwest of Livona.

Long Lake Creek, which joins the Missouri just south of the quadrangle, barely crosses its southern margin in two places. The Fox Hills was traced up the valley of this stream for 4 miles from its mouth. For many miles beyond the last outcrop seen there are no exposures, so that the extent of the formation in that direction could not be determined. About one-fourth mile above the bridge where the Fort Yates stage road crosses the creek, half a mile south of the quadrangle, there is an outcrop in which the sandstone extends at least 60 feet above the creek.

CRETACEOUS OR TERTIARY ROCKS.

LANCE FORMATION.

Name and general distribution.—The Lance formation, which rests in apparent conformity on the Fox Hills sandstone and is overlain by the Fort Union formation, is named from Lance Creek, Converse County, Wyo., where it is typically exposed, with its characteristic dinosaurian remains. This for-

mation, which has been variously designated the "Hell Creek beds," "Converse County beds," "Somber beds," "Ceratops beds," and "dinosaur-bearing beds," occupies all of the Bismarck quadrangle except the small area of the Fox Hills sandstone in the southeast corner and the areas of the Fort Union formation near the northern border. It forms part of a much larger area which extends from a point in South Dakota northward almost to Washburn, N. Dak., and from a few miles to 60 or 70 miles east and west of the Missouri. Beds of the same formation occupy extensive areas in southwestern North Dakota, eastern Montana, South Dakota, Wyoming, and Canada.

Character and thickness.—The Lance formation is composed of shale and sandstone of prevailing dark colors, dark gray, brown, and black being most common. Much of the sandstone is soft, the sand grains being but loosely cemented. Where exposed in the vicinity of Bismarck and Mandan the formation is composed largely of shale cut by numerous joints. In color the beds are strikingly different from the overlying yellow beds of the Fort Union, and it is generally not difficult to distinguish between the two. The rocks of the Fort Union formation are buff and light ash-gray, as contrasted with the dark colors of the Lance. It is on account of their dark and somber aspect that the latter have sometimes been designated "Somber beds."

Although only thin seams of lignite appear in the sections given below, the formation contains good workable beds of lignite at many localities in North Dakota, Montana, and elsewhere, and there is at least one such bed in the Bismarck quadrangle. This is exposed at several points on Little Heart River and its tributaries and has a thickness of 5 feet. It is described more in detail under the heading "Economic geology."

If, as appears to be the case, the yellow beds of the Fort Union formation are absent from the hilltops in the southern part of the quadrangle, the thickness of the Lance formation is at least 650 to 700 feet.

Fossils.—Fossils occur only sparingly in the Lance formation in this area. The distal end of a tibia of *Triceratops* (?), identified by C. W. Gilmore, was found 2½ miles northeast of Lake Wilde, in the NE. ¼ sec. 33, T. 136 N., R. 78 W., at an altitude of 1790 feet above sea level, or about 160 feet above the Fox Hills sandstone. In 1908 T. W. Stanton collected dinosaur bones a few miles north of the mouth of the Cannonball, not far from the southern border of the quadrangle. These were identified in part as *Trachodon* and in part as dinosaurs of the order Ceratopsia and came from beds approximately 100 feet above the Fox Hills sandstone.⁴

Stanton also collected the following plants from strata a few feet above the highest observed dinosaur bones:

Taxodium sp.	Sassafras sp.
Populus amblyrhyncha Ward.	Ficus n. sp.?
Sapindus affinis Newberry.	Ficus n. sp.
Quercus sp.	

F. H. Knowlton^b obtained the following plants near the base of the bluff 1½ miles above the mouth of Apple Creek:

Adiantum? sp.	Ficus sp.
Salix sp.	Laurus sp.
Quercus sp.	Carpites sp.

Occurrence and distribution.—The outcrops of the Lance formation are confined almost wholly to the bluffs along the Missouri and to the valley of Heart River, although there are small exposures on the Little Heart and other streams. The most extensive outcrops are found in the bare escarpment bordering the valley of the Missouri on the west from Corner Butte northward for 4 or 5 miles. The formation is also well exposed in the bluffs near Square Butte, 2½ miles southeast of Sugarloaf Butte, and in the bluff just north of the point where Little Heart River enters the Missouri Valley. On the east side of the Missouri Valley the beds are exposed in the steep slopes in T. 136 N., R. 78 W., in the bluffs bordering the flood plain in Manning Township, and for several miles above the mouth of Apple Creek. They also outcrop at the east end of the railroad bridge over the Missouri and again about 2 miles north of the bridge. Other good exposures are found in the cuts along the Minneapolis, St. Paul & Sault Ste. Marie Railway north of Bismarck.

Exposed sections.—The character of the Lance formation is well shown in the following sections:

Section of Lance formation 3 miles northwest of old Fort Rice, in the NW. ¼ sec. 21, T. 136 N., R. 79 W.

	Ft. in.
Unexposed to top of bluff.....	15
Clay shale, gray.....	6 6
Shale, brown, carbonaceous, with 1-inch seam of lignite at top and 2-inch seam at bottom.....	1 6
Shale, brown and gray, with some sandy layers.....	13
Lignite, with brown carbonaceous clay below.....	6
Shale, brown, carbonaceous, with sandstone and sandy shale toward top.....	15
Sandstone, yellow and gray, soft.....	28
Sandstone, soft and loosely cemented, very ferruginous and brown, with impure limonitic concretions arranged mostly in two bands, 2 to 4 inches thick.....	6

^a Proc. Washington Acad. Sci., vol. 11, No. 3, 1909, p. 250.

^b Idem, p. 200.

	Ft. in.
Shale, dark colored, almost black when moist; brown in places.....	6
Sandstone, massive; shows cross lamination; rather coarse, gray; forms vertical cliffs.....	44
Shale, sandy in some layers, and sandstone, soft, gray; contains dark-brown ferruginous concretions at several horizons, one near the top, but these concretionary layers are not persistent.....	32
Sandstone and shale, gray, in alternating layers.....	16
Sandstone, soft, gray, with several thin brown carbonaceous layers.....	22
Sandstone, gray, and sandy shale, in alternating layers.....	4
Unexposed to river.....	150
	354

The base of the above section, the lower 150 feet of which is concealed, can not lie far above the Fox Hills sandstone, which outcrops only about 4 miles to the southeast.

The base of the Lance formation and the underlying Fox Hills sandstone are exposed on Cannonball River 7 or 8 miles south of the quadrangle, in sec. 28, T. 134 N., R. 80 W., where the following section is found:

Section on Cannonball River.

	Feet.
Drift gravel and sand (Quaternary).....	2
Lance formation:	
Shale, dark colored.....	27
Sandstone, soft, with many thin brown carbonaceous laminae.....	11
Sandstone, soft, yellow.....	16
Shale, brown, carbonaceous, with two lignite beds, one near the base, 2 to 3 inches thick and passing in places into black shale; the upper bed 2 feet below top of the shale and 6 to 8 inches thick, containing good lignite.....	8
Shale, gray.....	3
Sandstone, gray.....	8
Shale, gray.....	4
Shale, brown, carbonaceous.....	3
Sandstone and shale in alternating layers, the former predominating. Shale is in thin beds, for the most part several inches to 3 or 4 feet thick, dark gray, brown, and yellow. On weathered slope beds are light and dark gray.....	57
Shale, dark gray, with a few brown layers, (probably Lance formation).....	22
Fox Hills sandstone. Sandstone, shows cross lamination; contains numerous ferruginous nodules. At the top, at its contact with the overlying Lance formation, is a light-gray, almost white sandstone ledge which exhibits cross lamination clearly, the laminae being one-fourth to one-half inch thick. This layer is firmly cemented, hard sandrock, and is 12 to 18 inches thick. The sandstone contains shells near the middle and also about 10 feet below top. Exposed above the river.....	80
	241

The contact of the two formations is well exposed here for a distance of more than one-eighth of a mile and the beds appear perfectly conformable. All the strata above the white cross-laminated sandstone except the upper 2 feet are regarded as belonging to the Lance.

The next section is exposed in the steep bluff on the east side of Apple Creek, in sec. 26, Lincoln Township, 5 miles south of Bismarck.

Section of Lance formation on Apple Creek.

	Ft. in.
Sand, fine grained.....	12
Sandstone, yellow, and gray shale, in alternating layers.....	27
Lignite.....	6
Shale, gray, with carbonaceous streaks.....	3
Shale, brown, carbonaceous.....	2
Shale and sandstone in alternating layers.....	10
Shale, dark gray to black, weathers to a very sticky clay.....	22
Shale, sandy, chocolate-brown, carbonaceous.....	1
Sandstone, argillaceous, gray.....	10
Sandstone.....	1
Shale, sandy, gray.....	3
Sandstone, gray, coarse grained.....	20
Shale, gray.....	5
Sandstone, coarse grained, gray, with several thin shale layers, exposed above creek.....	30
	142 11

There is a good exposure of the Lance formation at the east end of the railroad bridge over the Missouri. The upper beds of the section are excellently shown in the deep cut made by the railroad in its approach to the bridge.

Section at bridge near Bismarck.

	Ft. in.
Drift, resting on the eroded surface of the Lance formation.....	15-20
Lance formation:	
Shale, dark gray to black, with thin light-gray streaks. Many joint cracks a few inches apart cut the shale in many directions; the faces of the joints are stained brown by iron.....	42
Shale, sandy, black.....	1
Shale, black.....	3
Sandstone, dark gray to black.....	1
Shale, black.....	2
Sandstone, yellow.....	4
Shale, dark gray to black, and yellow fine-grained sandstone and sandy shale, in alternating layers.....	22
Shale, black.....	30
Unexposed to river.....	15
	141

A little over 2 miles north of the bridge, near the line between secs. 13 and 24, T. 139 N., R. 81 W., the following section appears:

Bismarck.

Section on Burnt Creek.

	Ft. in.
Drift.....	10
Lance formation:	
Sandstone, gray and yellow, with large concretions.....	22
Shale, sandy, light colored, containing gypsum.....	22
Shale, black, some layers sandy, jointed, contains considerable gypsum.....	30
Shale, gray.....	5
Shale, black, sandy below.....	5
Sandstone, black and yellow.....	5
Shale, black, alternating with yellow sandstone.....	12
Unexposed to river.....	25
	137

The three following sections are exposed on Heart River in the vicinity of Mandan. The first is near the city limits and just above the railroad bridge across the river.

Section of Lance formation near Mandan.

	Ft. in.
Shale, black and gray, jointed irregularly, the joint cracks filled with gypsum; breaks into large, angular fragments. When weathered this shale has mottled appearance. To top of bluff.....	44
Sandstone, gray below and yellow above; contains many limonitic nodules.....	5
Shale, dark brown to black, carbonaceous, alternating with very fine grained, finely laminated soft yellow and gray sandstone. The sandstone layers grow thicker and more numerous toward the top of this member until they form the main bulk of the rock. The joint cracks are filled with gypsum.....	11
Sandstone, fine grained, yellow, soft.....	5
Shale, sandy, dark brown.....	3
Sandstone, soft, gray, with indurated ledge; the upper portion contains layers of black shale.....	5
Shale, black and carbonaceous, and fine-grained yellow and gray sand, in alternating layers.....	6-8
Sandstone, yellow, soft, fine grained, laminated.....	6-15
Shale, black, carbonaceous, alternating with layers of fine-grained yellow and gray sand.....	6
Sandstone, yellow, soft, fine grained.....	1
Shale, black and carbonaceous, alternating with layers of fine-grained gray and yellow sand, one half inch to 2 inches thick.....	15
Shale, sandy, dark gray to dark brown, with some layers of soft sandstone, to river level.....	8
	100 10

Section on the south side of the Heart River valley, in the NW. 1/4 sec. 22, T. 139 N., R. 81 W.

	Ft. in.
Quaternary:	
Soil, sandy.....	3
Sand (Pleistocene), argillaceous, fine grained, and firmly laminated, buff in color; maximum thickness in this locality.....	20
Unconformity.	
Lance formation:	
Shale, gray and black, mottled; much of the shale is arenaceous, the sand being very fine; some of the sandy layers have yellowish color. Some portions contain considerable carbonaceous material, giving the rock its black color. Shale cut by systems of joints running irregularly in many directions but in general steeply inclined. The joint cracks are filled with gypsum and the sides are stained with iron oxide. Shale breaks into large angular blocks several inches in diameter. When moist this shale is not plastic like that below. The mottled character shows on the weathered face of the bluff, where there are large blotches of black on the gray surface; it also appears on the small fragments.....	28
Shale, dark gray and yellow, some layers sandy; more thinly bedded than overlying shale.....	7
Sandstone, soft, fine grained, gray and yellow.....	7
Sandstone, argillaceous, fine grained; forms hard projecting ledge.....	2
Shale, dark gray to black, alternating with bands of finely laminated and fine-grained yellow sand.....	3
Shale, dark gray to almost black when moist, bluish gray when dry. When wet forms a plastic clay. Contains several layers of fine sand 2 to 3 inches thick.....	9
Sandstone, soft, loosely cemented, yellow.....	1
Unexposed to river level.....	27
	108 6

Section on the north side of the Heart River valley, in the SW. 1/4 sec. 19, T. 139 N., R. 81 W., about half a mile below the railroad bridge.

	Ft. in.
Quaternary:	
Soil.....	1
Clay, washed from slopes above.....	6-15
Gravel and sand.....	1
Lance formation:	
Shale, sandy, dark gray, jointed.....	6
Sandstone, argillaceous, forming ledge.....	5
Shale, sandy, dark gray to black, jointed; contains large sandstone concretions near top.....	22
Shale, black, crumbles into small flakes.....	2
Shale, dark colored to black when moist, bluish gray when dry; jointed, more thinly laminated toward the base.....	28
Sandstone, soft and unconsolidated, brown and ferruginous below, yellow above.....	3
Shale, black, and yellow sand in alternating beds.....	2
Sandstone, dark colored below and yellow above, soft, fine grained.....	16
Shale, indurated, forming stony ledge.....	15
Shale, blue, exposed above river.....	4
	107 1

Relations, age, and correlation.—The Lance formation lies at the horizon separating the Cretaceous and the Tertiary and it is difficult to determine to which of these systems it should be referred. At most places in the Bismarck area where the contact has been observed the Lance seems to rest conformably on the Fox Hills sandstone, as it apparently does in Cannonball Valley, and it everywhere passes conformably into the Fort Union above. In many localities in Wyoming, Montana, and

South Dakota, however, where the contact has been observed the Lance formation rests unconformably on the Fox Hills sandstone, so that on stratigraphic grounds it appears to be more closely related to the overlying Fort Union, with which it is always conformable, than to the underlying Fox Hills sandstone.

Knowlton states that 193 forms of plants have been found in the Lance formation, and that of the number 84 species have been positively identified. As the greater number (61) of these species are common to the Fort Union formation he considers the Lance formation to be the lower member of the Fort Union and therefore of Tertiary age. The present writer now holds the same view. But the vertebrate fauna, consisting of dinosaurs and mammals, afford considerable ground for the belief, held by Stanton and others, that the Lance formation should be regarded as of Cretaceous age.

The Lance formation of the Bismarck quadrangle is the approximate equivalent not only of the "Ceratops beds" of Wyoming but of the "Hell Creek" beds of Montana. It also appears to occupy the stratigraphic position of beds in other areas which have been assigned to the Laramie formation, at least in that it lies above the Fox Hills sandstone and beneath the Fort Union formation.

TERTIARY SYSTEM.

EOCENE SERIES.

FORT UNION FORMATION.

Name and general distribution.—Resting conformably on the Lance formation are the light-colored shales and sandstones of the typical Fort Union. As already stated, some geologists regard the Lance formation ("Ceratops beds") as the lower member of the Fort Union, but on account of the difference of opinion regarding its age it is here treated separately, and the Fort Union formation is considered to include only those beds above the Lance.

The name Fort Union was first used by F. V. Hayden in 1861 to designate the group of strata containing lignite beds in the country about Fort Union, at the mouth of the Yellowstone, and extending north into Canada and south to old Fort Clark, a few miles below the mouth of Knife River. The formation is known to occupy a large part of western North Dakota and eastern Montana and adjoining areas in South Dakota, Wyoming, and Canada. The Fort Union in the Bismarck quadrangle is a part of this larger area.

Character and thickness.—The formation consists of light ash-gray and yellow sandstone and shale, with beds of lignite that range in thickness from a few inches to 35 feet, beds 5 to 10 feet thick being of common occurrence. Many of these beds have burned out extensively along their outcrop, and the heat thus produced has baked and in places fused the overlying clays, changing their color to red and pink. This burned clay or clinker is a conspicuous feature of the formation.

The maximum exposed thickness of the Fort Union in the Bismarck quadrangle is probably not much over 200 feet, but in western North Dakota, where the total thickness is displayed, it is approximately 1000 feet.

Fossils.—From several exposures of the Fort Union in the Bismarck quadrangle the following species of fossil plants and shells have been obtained:

Aralia notata Lesquereux.	Viburnum sp.
Euonymus sp.	Campeloma multilineata M. and H.
Grewiopsis populifolia Ward.	H.
Platanus haydenii Newberry.	Campeloma producta White.
Platanus nobilis Newberry.	Corbula maclintockii M. and H.
Populus amblyrhyncha Ward.	Viviparus retusus M. and H.
Populus cuneata Newberry.	Viviparus trochiformis M. and H.
Populus daphnogenoides Ward.	H.
Populus sp.	Unio sp., fragments.

The Fort Union formation contains, altogether, a flora of 400 species. The invertebrate fauna comprises many species of fresh-water shells, but vertebrate fossils are rare in this formation. In western North Dakota the bones of fishes, turtles, and the aquatic reptile *Champsosaurus laramiensis* have been found in undoubted Fort Union strata.

Occurrence and distribution.—The Fort Union formation is present in the Bismarck quadrangle only in the northern townships—Burnt Creek, Crofte, Cromwell, Frances, Glenview, Naughton, and Riverview—and in a few small areas west of the Missouri. The beds occur only on the higher upland areas, the base of the formation lying between the 1950-foot and 2000-foot contours, or between 300 and 350 feet above the Missouri. The strata have been extensively eroded, Burnt Creek and the tributaries of Apple Creek having cut broad valleys through them into the underlying Lance formation. Hence the outline of the main area is exceedingly irregular, and there are numerous small detached areas, some of them at a distance of several miles from the main mass, as, for example, the outliers in Frances Township.

So far as known the only areas of Fort Union on the west side of the Missouri within the quadrangle are on the high divide northwest of Mandan, except one small area in the southeast corner of Oliver County, at the northwest corner of the quadrangle. The uppermost beds on the divide northwest

of Mandan are made up of yellow clay shale resembling the typical Fort Union and yielded several of the species of shells given in the list of fossils.

In Oliver County, beyond the northern border of the quadrangle, beds of Fort Union age are exposed near the top of a high ridge in the N. $\frac{1}{4}$ sec. 20, T. 141 N., R. 81 W. The section at this locality is as follows:

Section of Fort Union formation in N. $\frac{1}{4}$ sec. 20, T. 141 N., R. 81 W.

	Ft.	in.
Shale, yellow	20	
Coal	10	
Shale, chocolate-brown, carbonaceous layers alternating with gray beds	15	
Sandstone, gray, coarse grained (Lance formation?), exposed	15	

This outcrop is not far from the contact of the Fort Union and the Lance and the sandstone at the base of the section may belong to the latter formation.

On the east side of the Missouri the best exposure of the Fort Union is 2 miles northwest of Sather, in the SW. $\frac{1}{4}$ sec. 1, T. 140 N., R. 81 W.

Section of Fort Union formation northwest of Sather.

	Ft.	in.
Unexposed to top of hill	28	
Sandstone, very soft, containing many gastropods with a few unios	1	
Sandstone, very soft, ash-gray, very fine grained	15	
Shale, limonitic, yellow	4-6	
Shale, ash-gray	16	
Coal	1	6
Sandstone, soft, very fine grained, ash-gray and yellow	2	
Shale, yellow	2	6
Sandstone, very fine grained, soft, ash-gray and yellow, exposed	13	
	79	6

The ash-gray and yellow shales and soft sandstones of this section are very typical of the Fort Union formation. Some of the fossil shells given in the list of fossils were collected at this place.

A yellow and gray sandstone, at least 50 feet thick, with some soft and some hard layers, outcrops at the top of the high, flat-topped butte in the SE. $\frac{1}{4}$ sec. 30, T. 141 N., R. 80 W., and has yielded several of the species of fossils named in the list.

In the vicinity of Sather, especially west and northwest of the post office, most of the hills reaching altitudes of 2000 feet or more are capped with ledges of indurated sandstone, generally outcropping about the summits. Fragments broken from these ledges are scattered down the slopes. The sandstone has retarded the erosion of the hills and has to a large extent determined their present height. As there are many sandstones in the Fort Union at several horizons, separated by no great thicknesses of shale, it is difficult to determine whether the ledges capping the hills are all at the same horizon. It is perhaps more probable that they should be referred to several, not very widely separated.

Other thick sandstones of the Fort Union are well exposed in Naughton Township, where they appear at the summits of the ridges and buttes. They are particularly well shown in secs. 7, 10, 16, 18, 22, and 23. In the NW. $\frac{1}{4}$ sec. 33, Crofte Township, 30 feet of yellow and gray sandstone outcrops, and there are several other exposures of a similar sandstone in sec. 36 of the same township. To judge from these outcrops and from well records the Fort Union of Naughton and adjoining townships is composed largely if not wholly of sandstone throughout a thickness of 100 to 200 feet.

QUATERNARY SYSTEM.
PLEISTOCENE SERIES.

The Pleistocene deposits are very different in origin from those thus far considered. Instead of being marine or ordinary fresh-water sediments they have been formed through the agency of the vast continental glaciers which once covered the region. They present a marked contrast to the Cretaceous and Tertiary formations not only in origin but in appearance and mode of occurrence. The deposits were formed long after the beds of the Fort Union formation were laid down and they overlie the earlier formations without regard to altitude, forming a thin veneer over part of the area. In only a few places are they of sufficient thickness to modify to a notable degree the preglacial topography.

The Pleistocene deposits include (a) glacial boulders, (b) till, or boulder clay, and (c) stratified silt, sand, and gravel.

GLACIAL BOULDERS.

Although the Bismarck quadrangle lies outside of the outermost (Altamont) moraine formed by the Dakota lobe of the Wisconsin glacier it is well within the limits of the glaciated area. But, though the region was covered by an ice sheet, the drift deposited by it is for the most part not very thick, and throughout much of the area it is represented by boulders alone. In many places these glacial boulders, most of which are granite, thickly cover the surface, there being little or no drift clay associated with them, so that they now lie directly on the Cretaceous and Tertiary formations. In such localities

they are not scattered loosely over the ground but form a bed or pavement of rock in which many of the boulders touch one another.

These boulder beds are especially noticeable on the tops of divides and on upland areas. They occur on the uplands about Parkin, on those east of the Southeast Branch of Little Heart River, on those south of the South Branch of the same river, on Custer Flats, on the divide northwest of Mandan, and on portions of the uplands in Naughton Township and elsewhere. The boulder-covered areas are not separately shown on the map, partly because the boulders occur in nearly every part of the quadrangle and partly because the areas where they are particularly thick are small and have no very definite boundaries.

The boulders range from 6 inches to several feet in diameter, large ones 8 or 10 feet across being occasionally found. Although the boulder beds are commonly on the upland areas, scattered boulders are found in all parts of the quadrangle and at all altitudes, from the valley bottoms, 1650 feet or less above sea level, to the tops of the highest divides, 2300 feet above sea level and 700 feet above the Missouri. Boulders are reported to have been encountered in two wells at Bismarck 125 feet below the surface, or 1545 feet above sea level.

Just north of the point where the valley of Little Heart River joins that of the Missouri the gentle slope from the bluff to the larger stream is broken by low knolls thickly dotted with good-sized granite boulders. Similar boulders are also found in the gravel terraces of Missouri and Heart rivers.

GLACIAL TILL.

With the exception of the marginal moraines of the Little Heart River basin very little till is now found west of the Missouri within the limits of the quadrangle. This absence of the finer materials of the drift is perhaps due to erosion that has carried them away and left behind only the boulders and coarse glacial gravel, which may thus represent a residual deposit. The boulders in most places rest directly on the bedrock. At some points residual gravels are found and their presence is probably to be explained in the same way. The region is one of considerable relief and has apparently been subjected to much erosion since this older drift was deposited.

The morainic hills of the Little Heart basin are perhaps best shown near the head of Southeast Branch, where the moraines cross the valley bottom at several points and also lie about its margins near the base of the slopes. In the S. $\frac{1}{4}$ sec. 4, T. 135 N., R. 81 W., the morainic belt crosses the upper valley of Southeast Branch, some of the hills resting on the slopes east of the valley and others rising from the flat. Above the moraine the valley is narrow and has almost no flood plain, but below the moraine the valley is two-thirds of a mile wide. The drift hills shut in the upper valley so that the plain beyond can not be seen, and the creek winds about among the hills, which rise 20 to 40 feet above the surrounding surface.

The morainic belt continues unbroken along the south side of the valley of South Branch to and beyond the western border of the quadrangle. It is particularly well developed in secs. 31 and 32, T. 136 N., R. 81 W., where the hills, as usual, occur near the base of the slope. The moraine crosses the upper valley of South Branch, which is completely shut in by the hills, about on the western line of T. 136 N., R. 81 W. The road leading north from the southwest corner of this township passes between two pairs of morainic hills, one pair on each side of the creek, and between a third pair just north of the forks of the road.

Morainic hills are also present on the north side of the broad valley of South Branch, where they extend as far northwest as sec. 23, T. 136 N., R. 82 W. The road along the north side of sec. 32, T. 136 N., R. 81 W., traverses a typical morainic belt thickly strewn with boulders and lying on the slope 50 feet or more above the valley plain. The moraine continues around to the west side of the valley of Southeast Branch and extends north along the slope as far as the deep ravine near the north line of sec. 20, T. 136 N., R. 81 W. Beyond this point no drift hills were observed.

On the east side of the valley there are few morainic hills north of the center of sec. 21. A cluster of them about the house on the north line of sec. 28 lies in the valley and covers some 40 acres. Here the moraine is nearly half a mile wide and extends a short distance up the slope. Farther south it is broken by the deep ravine in secs. 33 and 34, but it reappears in the eastern part of sec. 34 and in sec. 3, T. 135 N., R. 81 W., as a wide belt of irregular hills, their sides thickly strewn with boulders.

In addition to the scattered drift hills rising above the valley plain there are three clearly defined moraines crossing the valley bottom of Southeast Branch with a northeast-southwest trend. One extends from the Harm place, in the SW. $\frac{1}{4}$ sec. 4, T. 135 N., R. 81 W., to the northeast corner of the same section. A second crosses the valley in the W. $\frac{1}{4}$ sec. 33, T. 136 N., R. 81 W. The creek has cut a postglacial valley through both these moraines. The third moraine, which forms the divide between the two branches of the Little Heart, is in

the northwest corner of sec. 32, T. 136 N., R. 81 W. Several kettle holes, characteristic of moraines, are to be found here among the hills.

The soil of these morainic hills is too stony for cultivation and the wheat fields of the plain extend only to their bases, so that the knolls with their many boulders present a striking contrast to the surrounding fields of grain.

There are morainic hills also on the north side of the main valley of the Little Heart, where they lie on the slope, in one place as much as 150 feet above the flats. The hummocky knolls, thickly strewn with boulders, extend from the western boundary of the quadrangle eastward into sec. 28, T. 137 N., R. 81 W. Several morainic hills are present also east of the river, in the E. $\frac{1}{4}$ sec. 28. The hill in the NW. $\frac{1}{4}$ sec. 30 is formed in part at least of drift, and is crowned by several low, irregular knolls carrying great numbers of large boulders.

Just west of the quadrangle is an area of morainic hills with an altitude of nearly 100 feet above Little Heart Flats, which surround it on all sides. Its rough, hummocky surface, consisting of many low knolls, is almost paved with boulders. This area has a length east and west of $1\frac{1}{2}$ miles and a width of 1 mile. The wagon road from Mandan to Flasher crosses its east end.

These moraines of the Little Heart basin appear to be marginal accumulations of drift about an ice lobe which occupied the basin for a considerable period after the continental glacier had retreated some distance from its extreme western limit in this region. This limit was 40 or 50 miles farther west, as indicated by the presence of numerous glacial boulders, though no till or boulder clay is found west of the Little Heart area. The ice was several hundred feet thicker in the Little Heart basin than over the surrounding uplands, and therefore seems to have occupied this depression for some time after it had disappeared from the highlands.

The boulder clay forming the highest of these morainic hills probably is 40 to 60 feet or more thick. Good outcrops showing the till are, however, very rare. The best one is in a cut bank on the north side of the valley of Little Heart River, just below the mouth of Southeast Branch, where 10 feet of boulder clay, gravel, and sand are exposed. Till also appears along the road on the opposite side of the valley, just east of the bridge across Southeast Branch. This latter area is too small to be shown on the geologic map.

There appears to be more boulder clay east of the Missouri, but even here it forms only a thin veneer over the underlying rocks, in few places exceeding 8 or 10 feet in thickness. The till on this side of the river is in most places so thin and patchy, being entirely absent in large areas, and outcrops are so few, that it is not possible to map it even approximately. For this reason even the areas of boulder clay that are mentioned in the text are not shown, because either their extent is not known or else they are too small to be mapped.

In the bluffs of the Missouri 3 miles northwest of Bismarck 10 feet of till is exposed, and in the cut at the east end of the railroad bridge across the river there is a thickness of 15 to 20 feet, with several good-sized boulders at the base of the till. Boulder clay appears in a number of the cuts along the Minneapolis, St. Paul & Sault Ste. Marie Railway north of Bismarck, generally associated with water-laid drift. Near the north line of sec. 15, Hay Creek Township, the following section is found:

Section near north line of sec. 15, Hay Creek Township.

Soil	Feet.
Gravel and boulders, large and small; in places this member consists largely of boulders	2-4
Till, light gray	6

About three-fourths mile farther south, in the same section, 8 feet of shale is exposed, overlain by 4 feet of gravel containing boulders. In sec. 22 of Hay Creek Township an outcrop shows 7 feet of boulder clay underlain by $3\frac{1}{2}$ feet of shale. Near the northern border of the quadrangle, in the NW. $\frac{1}{4}$ sec. 33, Crofte Township, sandstone of the Fort Union formation is overlain by 5 feet of gravelly till composed largely of local material but containing a few pebbles of granite and other igneous rock.

In the till of this locality and others along the railroad already mentioned Fort Union shells are embedded. They were doubtless incorporated in it along with the shale and sand of that formation, and large numbers of them have been remarkably well preserved.

Boulder clay appears at several points on Apple Creek. An outcrop in sec. 36, Gibbs Township, shows 11 feet of sandstone overlain by 12 feet of till, and about 4 miles below, near the line between secs. 3 and 4, Apple Creek Township, 10 feet of boulder clay is exposed near the top of a cut bank.

The glacial till of the Bismarck area, like that of much of the rest of western North Dakota, is extramrainic drift and lies outside of the outer (Altamont) moraine. This moraine is thought to mark approximately the western border of the Wisconsin drift sheet. The drift which occurs outside of it is thin and patchy and is represented in many places only by boulders and gravel. As already stated, it has the appearance of having

bordering land, but during the deposition of the intervening Niobrara the water was free from sediment and was inhabited by marine, lime-secreting organisms in countless numbers, the remains of which accumulated to form calcareous beds. During Fox Hills time the sea became shallower and strong currents sorted the materials, resulting in the formation of the cross-bedded sandstone of this formation, which overlies the Pierre shale.

After the Fox Hills sandstone had been deposited marine conditions came to an end and the sea withdrew finally from this region. The next sediments to be formed were those of the Lance formation, which were probably deposited in a freshwater lake or lakes. The coarse and fine materials deposited in these waters and resting upon the Fox Hills sandstones form the alternating sandstone and shale of the Lance. In certain localities there were marshes or swamps, formed doubtless through the filling of the lake basins with sediments, and the vegetation which grew in these places accumulated to form beds of lignite. At this time great land reptiles, such as dinosaurs, were abundant, especially the massive and clumsy *Triceratops*, which must have roamed in large numbers along the shores of lake and swamp.

TERTIARY PERIOD.

Deposition continued during Fort Union time, but a large part of the sediments then deposited may have been spread over the surface of the land by streams, instead of being laid down upon lake bottoms. In the one way or the other were deposited the sandstone, shale, and clay of the Fort Union formation. This time was particularly favorable for lignite formation, there being many extensive swamps in which grew and accumulated year after year the lignite-forming trees and other plants. As many as 400 species of plants are known to have been living at this time, among them being a *Sequoia* which is related to the giant redwood of California and the remains of which have been preserved in the rocks of the Fort Union formation.

At the close of Fort Union time deposition ceased in this region, although 100 miles to the west it continued into the Oligocene epoch and fluvialite and lacustrine sediments containing many remains of mammals were accumulated to a thickness of at least 300 feet. Throughout most of the Tertiary period the land was rising and was subjected to erosion, which removed hundreds of feet of strata over large areas and formed the broad valleys of the Missouri and its tributaries. During this period of erosion the Missouri cut its valley to a depth of nearly 800 feet below the present upland surface in the southern part of the quadrangle, and to a width ranging from 2 to 3½ miles. The topographic features of the region, including the high ridges and divides, the isolated buttes, the escarpments, and the stream valleys, were all formed by erosion chiefly in the later part of the Tertiary period. The surface of the greater part of the area was thus lowered 100 to 800 feet or more.

The climate during the Tertiary period is believed to have been much milder in high latitudes than at the present time, the fossil floras indicating a mild temperate climate even in the Arctic regions.

QUATERNARY PERIOD.

PLEISTOCENE EPOCH.

At the close of the Tertiary period the warmth of a temperate climate gave way to the rigors of an arctic cold. Great ice sheets or continental glaciers spread outward from several centers in Canada, until the northern part of North America was covered by a sheet of slowly moving ice hundreds or thousands of feet thick which advanced as far south as New York Bay and Ohio and Missouri rivers. At its greatest extent the ice covered all of North Dakota except the southwest corner.

The deep valley of the Missouri did not serve as a barrier to the onward movement of the ice, which extended some 60 miles farther west in the latitude of Cannonball River. The Missouri does not appear to have been forced to seek a new course for any great length of time, for that the present valley of the river was occupied by it previous to the glacial advance is clear from the fact that the present valley is filled to a depth of 100 feet or more by glacial deposits and late glacial or post-glacial gravels. The boulders encountered in wells at Bismarck at a depth of 125 feet and the borings for the piers of the Northern Pacific Railway bridge show that the valley was formerly 100 feet or more deeper than at present, with glacial deposits at that depth upon the preglacial surface. The filling is believed to have taken place chiefly since the Wisconsin ice invasion, though some of it may have been deposited during or after the earlier ice advance which left the sheet of extramainic drift over the whole region. This older drift has undergone so much erosion that in most places only boulders and residual gravel are left, the finer materials of the till having been swept away.

During the retreat of the earlier glacier an ice lobe of considerable size occupied the basin of Little Heart River long

enough for the deposition of the moraines already described. This basin lies 200 to 300 feet below the surrounding upland and the ice which filled it was presumably several hundred feet thicker than that lying over adjoining areas. The greater thickness of the ice in this depression probably accounts for the existence of the ice lobe with its consequent moraines. Wherever the end of the diminishing lobe remained stationary for a time terminal moraines were formed, as across the valley near the head of Southeast Branch. At the same time the silt-laden waters flowing from the ice deposited their sediment to form the gently sloping plains of the basin.

It seems probable that the drainage of the Little Heart basin was at one time carried southeastward by way of the valley now occupied by a tributary of Chanta Peta Creek, in the northeast corner of T. 135 N., R. 81 W. It is impossible to determine whether the divide between this tributary and the headwaters of South and Southeast branches is composed wholly of morainic material accumulated in a preglacial valley or is in part bedrock, but it is certain that the divide is in part, at least, formed by a moraine.

The northward retreat of the ice from the Little Heart area, with the formation of an ice-margin lake through the blocking of the former outlet by the moraine just mentioned, suggests itself as a possible explanation of the broad flats of the region. But no definite evidence of such a lake has been found, and the decided slope of the valley bottom, in places nearly 25 feet to the mile, is opposed to this hypothesis. The material composing the flats was apparently deposited by streams that flowed from the melting ice during the time when the moraines were being formed.

After the disappearance of the earlier ice sheet no part of the Bismarck quadrangle was again, so far as is known, covered by a glacier. The western margin of the Dakota lobe of the Wisconsin glacier approached within about 15 miles of the east side of the quadrangle and remained in that position for a time sufficient for the accumulation of the massive Altamont moraine, which has been traced a long distance through Canada, the Dakotas, Minnesota, and Iowa. The branches of Apple Creek, having their sources in or near the moraine, received the drainage of a large area of the melting ice. The greater part of the waterlaid drift of the quadrangle was deposited at this time.

The present valley of Apple Creek is broad and comparatively shallow with gently sloping sides, and the preglacial valley was doubtless much deeper. A deep well at the State penitentiary and another about 2 miles south of McKenzie, a town a few miles east of the quadrangle, each passed through about 200 feet of silt and struck a bed of glacial boulders resting on several feet of sand with fragments of lignite. This deep preglacial valley was filled with a great thickness of silt washed from the melting ice, and Apple Creek must at that time have been many times larger than it is to-day. In some places there are terraces that stand 45 feet above the creek, of which at least the upper portions are formed of gravel and sand.

The depressions in the vicinity of Menoken appear to be due to irregular deposition of this outwash material. The long, narrow one extending southeastward from the town is part of a large swampy tract, lying chiefly outside the quadrangle, in which one branch of Apple Creek has its source. Another depression, probably once occupied by a glacial stream, now vanished, joins the Missouri Valley at Lake Robinson and extends north and east near the Boyd School, about 9 miles of its length being in the Bismarck quadrangle.

It was probably during the glacial epoch that the lower course of Apple Creek was changed from its former position, when it flowed through the depression extending northward from Twin Buttes, to its present location along the base of the eastern bluff of the Missouri Valley. The sand which had accumulated in the old valley bottom was heaped into dunes by the wind and shifted a mile or so eastward.

The gravel terraces along the Missouri, Heart, and other streams were doubtless formed toward the close of the glacial epoch, when the streams were flooded by the melting of the ice and their swift currents carried much glacial gravel and deposited it along the valley bottoms. Subsequently the streams sunk their channels below their old flood plains, so that the latter were left as terraces many feet above the present bottom lands.

RECENT EPOCH.

Since the disappearance of the ice sheet the streams have spread alluvium upon their present flood plains, and the Missouri has deposited silt in its valley to a depth of more than 80 feet. It has also shifted its course from time to time, and portions of its abandoned channel are to be seen at several points along the valley. Much material has been washed down the slopes and spread out on the bottom lands. The soils have been formed in part by the weathering of shale and sandstone of the Lance and Fort Union formations, in part by the material washed down the slopes, and in part from the drift, both stratified and unstratified, all being intermingled with decayed material of vegetable origin.

ECONOMIC GEOLOGY.

The mineral resources of the Bismarck quadrangle consist of lignite, clay, gravel, and sand, and the surface and underground water and the soil.

LIGNITE.

Occurrence and distribution.—The Bismarck quadrangle lies near the eastern edge of the North Dakota lignite area, and there are several large mines within 6 to 12 miles of its western and northern boundaries. Most of the coal beds of the State are found in the Fort Union formation, but in the vicinity of Yule and elsewhere in southern Billings County there are several workable coal beds in the upper part of the Lance formation. It is in this formation that the lignite mined in this quadrangle is found. The only workable bed is the one exposed in the valleys of Little Heart River and its tributaries, in the eastern portion of T. 137 N., R. 81 W. The lignite lies about 100 feet above the Missouri, or a little more than 1750 feet above sea level. The 1750-foot contour therefore represents approximately the outcrop of this lignite bed, which has a maximum thickness where worked of 6 feet 7 inches, though in most places it is not over 5 feet thick.

At the Kiponen mine, in the NE. ¼ sec. 25, T. 137 N., R. 81 W., the section of the lignite bed is as follows:

Section of lignite bed in Kiponen mine.

	Ft.	in.
Shale		
Lignite	2-3	
Clay	5	
Lignite	1	7
Clay	3-4	
Lignite	5	
Shale		

The lignite is mined by drifting in along the bed from the outcrop, the 5-foot seam and the overlying clay parting being removed and the 19-inch seam left to form the roof. Lignite has been mined from this opening for about four years and the drift is in over 300 feet, the lignite being run out on cars.

Farmers are reported to come to this mine for lignite from distances of 15 to 20 miles to the south and southwest. The lignite sells at the mine for \$1.25 a ton.

This bed has been mined by drifting into it in five or six other places along its outcrop in sec. 24 and 25, T. 137 N., R. 81 W. In the SE. ¼ sec. 24 the section of the bed is as follows:

Section of lignite bed in the SE. ¼ sec. 24, T. 137 N., R. 81 W.

	Ft.	in.
Shale		
Lignite	4	
Clay	7	
Lignite	7	
Clay	2	
Lignite	5	
Clay	7	
Lignite	4	5
Clay shale		

What is doubtless the same bed has been opened at several points along its outcrop in the ravine in the NE. ¼ sec. 26. The lignite is here thinner, ranging from 3½ to 4 feet, and the clay parting over the lower lignite bed is thicker. Lignite has also been mined in the NE. ¼ sec. 22 of the same township and range.

All the above localities are south of Little Heart River, but the same lignite bed has been opened in a number of places on the north side of the river, particularly in the S. ¼ sec. 14, T. 137 N., R. 81 W., where the bed is at least 3½ feet thick. It is being mined at present in the NE. ¼ sec. 14 and the drift runs back several hundred feet from the face of the outcrop. The coal is brought out on cars running on wooden rails faced with strap iron. The lignite bed is here 33 inches thick and 1 foot of overlying clay is removed to give more room for working. A prospect hole dug recently (1909) in sec. 12 shows 34 inches of lignite.

Where the bed has been prospected to the north and northeast it is found to be thinner and the lignite is split into several seams by partings of clay. It has been uncovered by stripping along its outcrop in sec. 7, T. 137 N., R. 80 W., where it measures only 1 foot in thickness. In the point of the bluff on which the triangulation station was established at the mouth of Little Heart River, the following thin beds appear, representing the workable bed found elsewhere.

Section in bluff at mouth of Little Heart River.

	Ft.	in.
Shale		
Lignite, shaly	4	
Clay	10	
Lignite	4	
Shale, brown, carbonaceous	17	
Lignite	9	
Shale, brown, carbonaceous, with 1 inch coal seam	3	
Shale and sandstone, to river level	120	

It will be seen from the above section that the lignite bed is here split into three layers, separated by seams of clay shale. The mines are worked only in the fall and winter. Little timbering is done except near the entrance.

The Little Heart lignite bed does not extend more than 1 or 2 miles north of the river, as it grows thinner in that direction and splits into several thin beds with clay seams between. The lignite bed has been extensively eroded in the valley of the Little Heart and its tributaries, the main valley having been cut to a depth of 50 to 100 feet below the lignite. South of the river it is known to extend into secs. 25 and 26, T. 137 N., R. 81 W., and how much farther has not been ascertained. The surface rises rather steeply to the upland level, where the lignite if present lies at a depth of 250 to 300 feet, and there are no well borings which have gone down to this depth. It is not improbable that the Little Heart lignite bed underlies the southwestern sections of T. 137 N., R. 80 W., and the southeastern sections of T. 137 N., R. 81 W. The best place to prospect for the lignite would be in the valley followed by the telegraph road down to the crossing of Little Heart River, or toward the base of the slope in sec. 27, T. 137 N., R. 81 W.

East of Missouri River in Emmons County a lignite bed is mined just beyond the border of the Bismarck quadrangle, in secs. 4 and 9, T. 135 N., R. 78 W. This mine is located within 2 miles of the outcrop of the Fox Hills sandstone along the river and the bed lies about 1850 feet above sea level, or not far from 200 feet above the Fox Hills. Lignite has been mined here since 1891. The bed varies in thickness from 2 to 3 feet. The lignite is of excellent quality and sells at the mine for \$2.50 a ton.

About 14 miles west of the Bismarck quadrangle a lignite bed 5 feet thick is exposed in the Heart River valley and in the valley of Sweet Brier Creek. Two or three miles west of the northwest corner of the quadrangle a 4-foot lignite bed has been mined at a number of points in the western part of T. 140 N., R. 82 W. The lignite occurs near the headwaters of one of the branches of Otter Creek and lies so near the surface that it is mined mostly by stripping off the cover. These lignite beds on Heart River and Otter Creek are stratigraphically much higher than the Little Heart lignite and probably occur in the Fort Union formation.

Because of the scarcity of timber in this general region lignite is almost the only fuel available at a reasonable price for domestic purposes. Some State institutions use lignite exclusively, and to supply this demand, together with a growing demand from manufacturing plants, several well-equipped mines are operated in different parts of the State.

The lignite in the Bismarck quadrangle and other parts of North Dakota will probably be used largely for generating power for pumping plants to irrigate lands along the larger streams. On the installation of a number of such plants great quantities of lignite would be required not only for their use but also to furnish settlers attracted by irrigated lands with a supply of fuel for domestic uses and to meet the demand of industries that would probably spring up with an influx of immigration.

East of the Missouri no lignite is mined in this quadrangle. A test pit put down near the east bank of the river at Bismarck, not far from the bridge, went through a lignite bed 2 feet thick at a depth of 44 feet. There are several large mines within 12 miles north of the quadrangle. The Washburn mine, at Wilton, produces more lignite than any other in the State. The Casino mine, about 9 miles north of Sather, has been worked for many years in a lignite bed 9 feet thick. The Yiengst mine, in sec. 34, T. 142 N., R. 79 W., is only 5 miles north of the quadrangle. The lignite at this mine is 6 feet thick, and under 60 feet of cover. The lignite of all these mines is believed to occur in the Fort Union.

Character of the lignite.—The lignite in the Bismarck quadrangle is dark brown in color, tough, and somewhat woody in structure, but the woody structure is not so common here as in beds higher in the geologic section, exposed in the western part of the State. The woody part is confined mostly to certain benches, the rest of the bed being composed of layers and pockets of nearly black textureless fuel which slacks more rapidly than the woody portions, as can be seen in natural exposures, where the woody parts, consisting usually of flattened tree trunks, protrude from the main body of the bed. In fact, some of the lignite of this area might almost be classed as subbituminous coal.

The visible impurities in the lignite consist mainly of sand and clay partings, which, on account of their friability, are difficult to separate from the fuel in mining. Mixtures of fine sand or clay and lignite, of irregular shape and extent, which seem to correspond to "bone coal" in higher grades of fuel, are at places found in the beds and are not easily detected without close examination, as they have the same appearance as the lignite. As a whole, however, the lignite contains no greater percentage of impurities than fuel of other grades.

When freshly mined the lignite is usually lusterless and massive, but on exposure it rapidly breaks down or "slacks" into small shiny cubical blocks, and this tendency is one of the greatest obstacles to be overcome if the fuel is to be consumed in plants so located as to necessitate long hauls by rail or mechanical handling of the material.

Chemical analyses and producer-gas, briquetting, and steaming tests.—The following analyses and producer-gas tests were

Bismarck.

made of samples taken from a mine near Wilton, a short distance north of the Bismarck quadrangle, but as the lignite in this quadrangle is not essentially different it is thought that these results will be of value in showing the general nature and composition of the fuel.

Analyses of lignite from Wilton, N. Dak.

	Mine samples.		
	Laboratory No. 1985.	Laboratory No. 1988.	Car sample, Laboratory No. 2048.
Air-drying loss.....	32.30	32.50	12.70
Proximate. { Moisture.....	40.53	41.88	35.96
{ Volatile matter.....	27.05	26.11	31.92
{ Fixed carbon.....	27.37	26.73	24.37
{ Ash.....	5.05	5.28	7.75
{ Sulphur.....	.76	.96	1.15
Ultimate. { Hydrogen.....			6.54
{ Carbon.....			41.43
{ Nitrogen.....			1.21
{ Oxygen.....			41.92
Calorific value determined:			
Calories.....	8,691		8,927
British thermal units.....	6,644		7,069

These analyses were made at the United States Geological Survey's fuel-testing plant in St. Louis from samples collected according to Survey regulations.^a

Another consideration that adds materially to the value of the lignite is its surprising success in producer-gas plants. The following statement^b has been made concerning the efficiency of North Dakota lignite in the gas producer and gas engine:

The result of the steam test was so unsatisfactory that there is nothing by which a direct comparison can be made of the efficiency of the fuel used in the producer-gas plant as compared with the efficiency developed in the steam plant. Nevertheless, a comparison of the results obtained on other coals under the steam boiler is instructive. The table shows that to produce one electrical horsepower hour in the producer-gas plant required 2.29 pounds of dry North Dakota lignite, whereas to produce the same result in the steam plant required 3.39 pounds of the best West Virginia coal. This means that North Dakota lignite, with the moisture eliminated, will do more work when used in a producer-gas plant than the best coal of the country will do in a steam plant.

A number of tests have been made recently by the fuel-testing plant of the Survey and by the Bureau of Mines to determine the best methods of briquetting North Dakota lignite. It has been found that the lignite can be briquetted, some of it without a binder, and that its efficiency is thereby materially increased. The briquetted product also stands weathering and handling much better than the raw material.

Steaming tests have also been made with specially constructed fire boxes and grates and the results are highly satisfactory, as the efficiency of this lignite when properly fired is so increased as to compare very favorably with that of fuel of higher grades.

The details of these tests are set forth in Bulletins 2 and 14 of the Bureau of Mines.

CLAY.

The clay and shale of the Fort Union formation are used in brickmaking in half a dozen places in North Dakota, and this formation contains extensive deposits which are suitable for high-grade front, fire, and ornamental brick. The large brick plants at Dickinson, Hebron, and Wilton employ these clays in the manufacture of their products, and some of the beds have been found suitable for table ware and pottery.

The Fort Union outcrops in only a few townships in this area and much of it is a soft sandstone, but it contains some clay which might be used for brick and other products.

Some layers of the Lance formation, which occupies so large a portion of the quadrangle, may contain shale adapted to the manufacture of brick, although so far as known no brick have been made from such shale.

The brick plant at Mandan, which is located near the bank of Heart River, uses alluvial clay in manufacturing hand-made brick. At the State brickyard, located near the penitentiary, a stratified drift clay is used, 12 feet of clay and sand being exposed in the pit, comprising three beds of clay, free from pebbles, separated by two layers of fine sand. The clay and sand are both used.

GRAVEL AND SAND.

Gravel and sand suitable for building and other purposes occur along many of the streams of the region, forming the terrace deposits already described. The most extensive deposits of these materials are probably those in the Heart River valley. They appear on the south side of the Heart opposite Mandan, where gravel and sand pits have been opened in the terrace at many points in secs. 33 and 34. About 2½ miles west of Mandan, in the S. ¼ sec. 30, a spur track runs to a

^aA more detailed account of the analyses can be found in Bull. U. S. Geol. Survey No. 290, 1905, pp. 138-139.

^bProf. Paper U. S. Geol. Survey No. 48, pt. 1, 1906, p. 111.

large pit where the railroad obtains gravel for ballast. Most of the gravel in this locality is very coarse, containing many small and some good-sized boulders. That there is a large supply of gravel here is shown by the fact that this terrace deposit extends along the valley for nearly 2 miles, having a width of over a quarter of a mile and a thickness of 40 to 50 feet. Near Bismarck an abundance of material for building purposes, for surfacing roads and streets, and for other uses is found in the terrace deposit of sand and gravel which extends west of town to the Missouri, and south to and beyond Fort Lincoln. The spur track to the steamboat landing runs near the edge of this terrace. Other deposits of gravel and sand lie along Apple, Burnt, and Hay creeks and in other places.

WATER RESOURCES.

SURFACE WATERS.

The surface waters of the quadrangle include streams, lakes, and springs. The area is well supplied with streams and these furnish water for stock throughout most of the year. The surface water is for the most part unfit for drinking, but Missouri River supplies Fort Lincoln and the cities of Bismarck and Mandan with excellent water.

With the exception of Chanta Peta Creek and some of the smaller creeks the streams flow throughout the year, being fed by both groundwater and rains. During the 17 years from 1892 to 1908 the average rainfall at Bismarck was 16.10 inches, the minimum being 13.67 inches (1898) and the maximum being 18.22 inches (1906).

Lakes Robinson and Wilde, with other smaller ones, on the flood plain of the Missouri, are the only lakes in the quadrangle. Springs are by no means common and are limited mostly to the bluffs along Missouri River.

SHALLOW DUG WELLS.

Shallow wells furnish sufficient water for farm and domestic use in many portions of the quadrangle, particularly in the southwest corner. These wells are supplied by water from the surface, which has soaked down through the superficial layers and as a rule has not traveled far before reaching the wells. West of the Missouri the water of these wells is found either in the Cretaceous shale and sandstone, or in the silt of the stream valleys. The water from the clay shale seeps slowly into the wells and if much is drawn off at one time it may require several hours for the water to reach its former level. If the water is in sandstone or silt it moves more freely and enters the well almost as fast as it is pumped out. Most of the wells located in the flood plain of the Missouri or its tributaries go down only 15 or 20 feet before reaching a good supply of water. In the extreme southeast corner of the quadrangle the wells are in the Fox Hills sandstone, which yields an abundance of pure water. The waters of the surface wells vary greatly in composition, but they are for the most part suitable for domestic purposes, except that many of them are rather hard and some are alkaline.

TUBULAR WELLS.

Bored or tubular wells with a depth of 75 to 250 feet are common in the area and form one of the principal sources of water supply. The wells of the electric-light plant and creamery at Bismarck are 130 feet deep and their water occurs in a bed of coarse sharp sand containing fragments of lignite. Resting on the sand is a bed of granite boulders which were encountered in sinking the wells. At the penitentiary this boulder bed was struck at 200 feet. The two wells which were bored some years ago at Fort Lincoln and which for a time furnished the water supply of the post had a depth of 98 feet and were 10 inches in diameter. They doubtless went down into the same sand bed at the base of the river silt as that encountered at Bismarck.

In that portion of the quadrangle lying north of the Northern Pacific Railway and east of the Missouri the bored wells range in depth from 150 to 240 feet, the water being found in a soft sandstone. The supply is abundant and the water is very soft. The well at Sather is 150 feet deep, and one 2 miles farther north, in sec. 5, T. 140 N., R. 80 W., on the upland, has a depth of 210 feet. A well in sec. 10, Naughton Township, reaches water at 112 feet, and another 2 miles to the south is 240 feet deep. In sec. 10, Apple Creek Township, water is found in one well at 90 feet. Many of the wells in the northeast corner of T. 137 N., R. 80 W., and the southeast corner of Lincoln Township have depths of 200 feet or more. A well 1½ miles west of Twin Buttes is 118 feet deep. The water of most of the tubular wells is found in the soft sandstones of the Lance formation at several horizons within 250 feet of the surface. It is generally soft and well suited to domestic use.

DEEP WELLS.

The only deep borings within the Bismarck quadrangle are those at Bismarck and Mandan. The well at Bismarck found no flows, though it is reported to have reached a depth of 1315 feet, passing through shale with a few thin limestone beds. It

fell far short of reaching the water-bearing beds of the Dakota sandstone. The deep well at Mandan went down 2000 feet but was apparently not quite deep enough to reach the Dakota sandstone. The only water obtained is a small flow from a depth of 357 feet, estimated at 3 gallons a minute, but it is soft and clear. At a depth of 410 to 470 feet, below the thin bed of loose sandstone which supplies this flow, another sand rock with a small flow was reported. This lower sandstone probably belongs to the Fox Hills formation. From 470 to 1500 feet the material was chiefly gray and blue shale, and from 1500 to 2000 feet the boring was mostly in shale, as near as could be learned.^a The Dakota sandstone in the Bismarck area therefore lies more than 2000 feet below the bottom of the Missouri River valley, or more than 354 feet below sea level.

SOILS.

Soils are produced by the breaking down of preexisting rocks, and their mineral constituents are mingled with the carbonaceous matter derived from the many generations of plants which have lived and died on the surface and thus contributed their organic material to the superficial layer.

The chief types of soil present in the Bismarck quadrangle are residual soils, rocky soils, glacial silt and drift soils, alluvial soils, and dune sand soils.

The residual soils are formed by the weathering and decomposition of the sandstone and clay shale of the Lance formation, and, to a less extent, of the Fort Union strata. These rocks break down readily to form a sandy clay or loam, which, mixed with decayed vegetation, produces a good deep soil.

^aSeventeenth Ann. Rept. U. S. Geol. Survey, pt. 2, 1896, p. 665.

Glacial débris from the continental ice sheet seems to have played very little part in the formation of this soil, though it occupies an area formerly covered by the moving ice. In localities where the bedrock is chiefly sandstone the soil is composed largely of sand and in localities underlain by shale the soil contains a large proportion of clay; but for the most part there is a mixture of sand and clay in varying proportions to form a loam.

These residual materials constitute the chief soils west of Missouri River, occupying practically all that region except the valley bottoms and certain small upland areas which are covered by the rocky soils mentioned below. Residual soils are also found over much of the upland east of the river, in Riverview, Burnt Creek, Naughton, and Frances townships, where they are derived mostly from the sandstone and shale of the Fort Union formation, though there is in places a small proportion of glacial débris with the local materials.

Rocky soils occupy many comparatively small areas on the uplands, particularly west of the Missouri. In such places the surface is thickly strewn with glacial boulders, chiefly granite, forming a soil which is much too rocky for cultivation. The land is, however, suitable for grazing and is commonly used for this purpose. Rocky soils occur in many places on the uplands south of Little Heart River, on Custer Flats south of Heart River, and in parts of Naughton and adjoining townships east of the Missouri.

East of the Missouri River valley the soils are largely of glacial origin except on the upland areas just mentioned, lying near the northern border of the quadrangle. During the formation of the massive Altamont moraine the margin of the

continental ice sheet lay only 10 or 15 miles east of the area and the waters flowing from the melting ice spread a layer of silt over a wide belt west of the moraine. These silt soils occur in the broad valley of Apple Creek, which was one of the chief outlets for the glacial drainage, and also cover extensive areas south of that creek. Silt of glacial origin is also found in the valleys of Burnt and Hay creeks. In other portions of the region east of the Missouri drift soils predominate, generally forming a more or less sandy loam. These soils occupy some areas north of Apple Creek.

Rich alluvial soils occur in the valley bottoms of all the larger streams, including not only the broad valley of the Missouri but also the smaller ones of Heart and Little Heart rivers and of Apple Creek. These alluvial soils consist in part of the flood-plain deposits formed by the streams in recent times and in part of the glacial gravel, sand, and silt laid down by the streams during the glacial period and forming terrace deposits which lie 15 to 50 feet above the present flood plains. In places these alluvial soils are very sandy, appearing as broad sandy flats along Missouri River, but for the most part they are composed of fine silt, which on the flood plain is being added to from time to time by the overflow of the river. The soils of the stream terraces generally have subsoils of gravel and sand.

Reference has already been made to the dune area southeast of Bismarck, where the sand covers 8 or 10 square miles. The soil of this tract is thus composed almost wholly of quartz sand, which has accumulated to a considerable depth through the action of the wind.

June, 1911.