DEPARTMENT OF THE INTERIOR
UNITED STATES GEOLOGICAL SURVEY
GEORGE OTIS SMITH, DIRECTOR

GEOLOGIC ATLAS
OF THE
UNITED STATES

BISMARCK FOLIO

NORTH DAKOTA

BY

A. G. LEONARD

SURVEYED IN COOPERATION WITH
THE STATE OF NORTH DAKOTA

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GEOLOGIC ATLAS OF THE UNITED STATES.

The Geological Survey is making a geologic atlas of the United States, which is being issued in parts, called folios. Each folio includes topographic and geologic maps of a certain area, together with descriptive text.

THE TOPOGRAPHIC MAP.

The features represented on the topographic map are of three distinct kinds—(1) inequalities of surface, called *relief*, as plains, plateaus, valleys, hills, and mountains; (2) distribution of water, called *drainage*, as streams, lakes, and swamps; (3) the works of man, called *culture*, as roads, railroads, boundaries, villages, and cities.

Relief.—All elevations are measured from mean sea level. The heights of many points are accurately determined, and those of the most important ones are given on the map in figures. It is desirable, however, to give the elevation of all parts of the area mapped, to delineate the outline or form of all slopes, and to indicate their grade or steepness. This is done by lines each of which is drawn through points of equal elevation above mean sea level, the vertical interval represented by each space between lines being the same throughout each map. These lines are called *contour lines* or, more briefly, *contours*, and the uniform vertical distance between each two contours is called the *contour interval*. Contour lines and elevations are printed in brown. The manner in which contour lines express altitude, form, and grade is shown in figure 1.

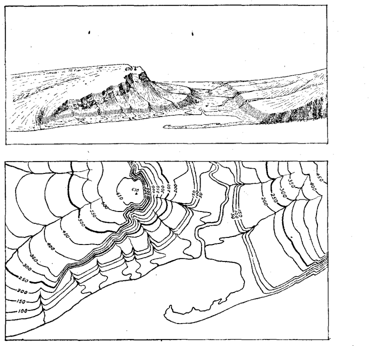


FIGURE 1.—Ideal view and corresponding contour map.

The sketch represents a river valley between two hills. In the foreground is the sea, with a bay that is partly closed by a hooked sand bar. On each side of the valley is a terrace. The terrace on the right merges into a gentle hill slope; that on the left is backed by a steep ascent to a cliff, or scarp, which contrasts with the gradual slope away from its crest. In the map each of these features is indicated, directly beneath its position in the sketch, by contour lines. The map does not include the distant portion of the view. The following notes may help to explain the use of contour lines:

1. A contour line represents a certain height above sea level. In this illustration the contour interval is 50 feet; therefore the contour lines are drawn at 50, 100, 150, and 200 feet, and so on, above mean sea level. Along the contour at 250 feet lie all points of the surface that are 250 feet above the sea—that is, this contour would be the shore line if the sea were to rise 250 feet; along the contour at 200 feet are all points that are 200 feet above the sea; and so on. In the space between any two contours are all points whose elevations are above the lower and below the higher contour. Thus the contour at 150 feet falls just below the edge of the terrace, and that at 200 feet lies above the terrace; therefore all points on the terrace are shown to be more than 150 but less than 200 feet above the sea. The summit of the higher hill is marked 670 (feet above sea level); accordingly the contour at 650 feet surrounds it. In this illustration all the contour lines are numbered, and those for 250 and 500 feet are accentuated by being made heavier. Usually it is not desirable to number all the contour lines. The accentuating and numbering of certain of them—say every fifth one—suffices and the heights of the others may be ascertained by counting up or down from these.

2. Contour lines show or express the forms of slopes. As contours are continuous horizontal lines, they wind smoothly about smooth surfaces, recede into all reentrant angles of ravines, and project in passing around spurs or prominences. These relations of contour curves and angles to forms of the landscape can be seen from the map and sketch.

3. Contour lines show the approximate grade of any slope. The vertical interval between two contours is the same, whether they lie along a cliff or on a gentle slope; but to attain a given height on a gentle slope one must go farther than on a steep slope, and therefore contours are far apart on gentle slopes and near together on steep ones.

A small contour interval is necessary to express the relief of a flat or gently undulating country; a steep or mountainous country can, as a rule, be adequately represented on the same scale by the use of a larger interval. The smallest interval used on the atlas sheets of the Geological Survey is 5 feet. This is in regions like the Mississippi Delta and the Dismal Swamp. For great mountain masses, like those in Colorado, the interval may be 250 feet and for less rugged country contour intervals of 10, 20, 25, 50, and 100 feet are used.

Drainage.—Watercourses are indicated by blue lines. For a perennial stream the line is unbroken, but for an intermittent stream it is broken or dotted. Where a stream sinks and reappears the probable underground course is shown by a broken blue line. Lakes, marshes, and other bodies of water are represented by appropriate conventional signs in blue.

Culture.—The symbols for the works of man and all lettering are printed in black.

Scales.—The area of the United States (exclusive of Alaska and island possessions) is about 3,027,000 square miles. A map of this area, drawn to the scale of 1 mile to the inch would cover 3,027,000 square inches of paper and measure about 240 by 180 feet. Each square mile of ground surface would be represented by a square inch of map surface, and a linear mile on the ground by a linear inch on the map. The scale may be expressed also by a fraction, of which the numerator is a length on the map and the denominator the corresponding length in nature expressed in the same unit. Thus, as there are 63,360 inches in a mile, the scale "1 mile to the inch" is expressed by the fraction $\frac{1}{63,360}$.

Three scales are used on the atlas sheets of the Geological Survey; they are $\frac{1}{250,000}$, $\frac{1}{125,000}$, and $\frac{1}{62,500}$, corresponding approximately to 4 miles, 2 miles, and 1 mile on the ground to an inch on the map. On the scale of $\frac{1}{62,500}$ a square inch of map surface represents about 1 square mile of earth surface; on the scale of $\frac{1}{125,000}$, about 4 square miles; and on the scale of $\frac{1}{250,000}$, about 16 square miles. At the bottom of each atlas sheet the scale is expressed in three ways—by a graduated line representing miles and parts of miles, by a similar line indicating distance in the metric system, and by a fraction.

Atlas sheets and quadrangles.—The map of the United States is being published in atlas sheets of convenient size, which represent areas bounded by parallels and meridians. These areas are called *quadrangles*. Each sheet on the scale of $\frac{1}{250,000}$ represents one square degree—that is, a degree of latitude by a degree of longitude; each sheet on the scale of $\frac{1}{125,000}$ represents one-fourth of a square degree, and each sheet on the scale of $\frac{1}{62,500}$ one-sixteenth of a square degree. The areas of the corresponding quadrangles are about 4000, 1000, and 250 square miles, though they vary with the latitude.

The atlas sheets, being only parts of one map of the United States, are not limited by political boundary lines, such as those of States, counties, and townships. Many of the maps represent areas lying in two or even three States. To each sheet, and to the quadrangle it represents, is given the name of some well-known town or natural feature within its limits, and at the sides and corners of each sheet are printed the names of adjacent quadrangles, if the maps are published.

THE GEOLOGIC MAPS.

The maps representing the geology show, by colors and conventional signs printed on the topographic base map, the distribution of rock masses on the surface of the land and, by means of structure sections, their underground relations, so far as known and in such detail as the scale permits.

KINDS OF ROCKS.

Rocks are of many kinds. On the geologic map they are distinguished as igneous, sedimentary, and metamorphic.

Igneous rocks.—Rocks that have cooled and consolidated from a state of fusion are known as *igneous*. Molten material has from time to time been forced upward in fissures or channels of various shapes and sizes through rocks of all ages to or nearly to the surface. Rocks formed by the consolidation of molten material, or magma, within these channels—that is, below the surface—are called *intrusive*. Where the intrusive rock occupies a fissure with approximately parallel walls it is called a *dike*; where it fills a large and irregular conduit the mass is termed a *stock*. Where molten magma traverses stratified rocks it may be intruded along bedding planes; such masses are called *sills* or *sheets* if comparatively thin, and *laccoliths* if they occupy larger chambers produced by the pressure of the magma. Where inclosed by rock molten material cools slowly, with the result that intrusive rocks are generally of crystalline texture. Where the channels reach the surface the molten material poured out through them is called *lava*, and lavas often build up volcanic mountains. Igneous rocks that have solidified at the surface are called *extrusive* or *effusive*. Lavas generally cool more rapidly than intrusive rocks and as a rule contain, especially in their superficial parts, more or less volcanic glass, produced by rapid chilling. The outer parts of lava flows also are usually porous, owing to the expansion of the gases originally present in the magma. Explosive action, due to these gases, often accompanies volcanic eruptions, causing ejections of dust, ash, lapilli, and larger fragments. These materials, when consolidated, constitute breccias, agglomerates, and tuffs.

Sedimentary rocks.—Rocks composed of the transported fragments or particles of older rocks that have undergone disintegration, of volcanic ejecta deposited in lakes and seas, or of materials deposited in such water bodies by chemical precipitation are termed *sedimentary*.

The chief agent in the transportation of rock débris is water in motion, including rain, streams, and the water of lakes and of the sea. The materials are in large part carried as solid particles, and the deposits are then said to be mechanical. Such are gravel, sand, and clay, which are later consolidated into conglomerate, sandstone, and shale. Some of the materials are carried in solution, and deposits of these are called organic if formed with the aid of life, or chemical if formed without the aid of life. The more important rocks of chemical and organic origin are limestone, chert, gypsum, salt, iron ore, peat, lignite, and coal. Any one of the kinds of deposit named may be separately formed, or the different materials may be intermingled in many ways, producing a great variety of rocks.

Another transporting agent is air in motion, or wind, and a third is ice in motion, or glaciers. The most characteristic of the wind-borne or eolian deposits is loess, a fine-grained earth; the most characteristic of glacial deposits is till, a heterogeneous mixture of bowlders and pebbles with clay or sand.

Sedimentary rocks are usually made up of layers or beds which can be easily separated. These layers are called *strata*, and rocks deposited in such layers are said to be stratified.

The surface of the earth is not immovable; over wide regions it very slowly rises or sinks, with reference to the sea, and shore lines are thereby changed. As a result of upward movement marine sedimentary rocks may become part of the land, and most of our land areas are in fact occupied by rocks originally deposited as sediments in the sea.

Rocks exposed at the surface of the land are acted on by air, water, ice, animals, and plants, especially the low organisms known as bacteria. They gradually disintegrate and the more soluble parts are leached out, the less soluble material being left as a *residual* layer. Water washes this material down the slopes, and it is eventually carried by rivers to the ocean or other bodies of water. Usually its journey is not continuous, but it is temporarily built into river bars and flood plains, where it forms *alluvium*. Alluvial deposits, glacial deposits (collectively known as *drift*), and eolian deposits belong to the *surficial* class, and the residual layer is commonly included with them. Their upper parts, occupied by the roots of plants, constitute soils and subsoils, the soils being usually distinguished by a notable admixture of organic matter.

Metamorphic rocks.—In the course of time, and by various processes, rocks may become greatly changed in composition and in texture. If the new characteristics are more pronounced than the old such rocks are called *metamorphic*. In the process of metamorphism the constituents of a chemical rock may enter into new combinations and certain substances may be lost or new ones added. A complete gradation from the primary to the metamorphic form may exist within a single rock mass. Such changes transform sandstone into quartzite and limestone into marble and modify other rocks in various ways.

From time to time during geologic ages rocks that have been deeply buried and have been subjected to enormous pressures, to slow movement, and to igneous intrusion have been afterward raised and later exposed by erosion. In such rocks the original structures may have been lost entirely and new ones substituted. A system of planes of division, along which the rock splits most readily, may have been developed. This structure is called *cleavage* and may cross the original bedding planes at any angle. The rocks characterized by it are *slates*. Crystals of mica or other minerals may have grown in the rock in such a way as to produce a laminated or foliated structure known as *schistosity*. The rocks characterized by this structure are *schists*.

As a rule, the oldest rocks are most altered and the younger formations have escaped metamorphism, but to this rule there are many important exceptions, especially in regions of igneous activity and complex structure.

FORMATIONS.

For purposes of geologic mapping rocks of all the kinds above described are divided into *formations*. A sedimentary formation contains between its upper and lower limits either rocks of uniform character or rocks more or less uniformly varied in character, as, for example, an alternation of shale and limestone. Where the passage from one kind of rocks to another is gradual it may be necessary to separate two contiguous formations by an arbitrary line, and in some cases the distinction depends almost entirely on the contained fossils. An igneous formation contains one or more bodies of one kind, of similar occurrence, or of like origin. A metamorphic formation may consist of rock of uniform character or of several rocks having common characteristics or origin.

When for scientific or economic reasons it is desirable to recognize and map one or more specially developed parts of a varied formation, such parts are called *members*, or by some other appropriate term, as *lentils*.

AGES OF ROCKS.

Geologic time.—The time during which rocks were made is divided into *periods*. Smaller time divisions are called *epochs*, and still smaller ones *stages*. The age of a rock is expressed by the name of the time interval in which it was formed.

The sedimentary formations deposited during a period are grouped together into a *system*. The principal divisions of a system are called *series*. Any aggregate of formations less than a series is called a *group*.

Inasmuch as sedimentary deposits accumulate successively the younger rest on those that are older, and their relative ages may be determined by observing their positions. In many regions of intense disturbance, however, the beds have been overturned by folding or superposed by faulting, so that it may be difficult to determine their relative ages from their present positions; under such conditions fossils, if present, may indicate which of two or more formations is the oldest.

Many stratified rocks contain *fossils*, the remains or imprints of plants and animals which, at the time the strata were deposited, lived in bodies of water or were washed into them, or were buried in surficial deposits on the land. Such rocks are called fossiliferous. By studying fossils it has been found that the life of each period of the earth's history was to a great extent different from that of other periods. Only the simpler kinds of marine life existed when the oldest fossiliferous rocks were deposited. From time to time more complex kinds developed, and as the simpler ones lived on in modified forms life became more varied. But during each period there lived peculiar forms, which did not exist in earlier times and have not existed since; these are *characteristic types*, and they define the age of any bed of rock in which they are found. Other types passed on from period to period, and thus linked the systems together, forming a chain of life from the time of the oldest fossiliferous rocks to the present. Where two sedimentary formations are remote from each other and it is impossible to observe their relative positions, the characteristic fossil types found in them may determine which was deposited first. Fossil remains in the strata of different areas, provinces, and continents afford the most important means for combining local histories into a general earth history.

It is many places difficult or impossible to determine the age of an igneous formation, but the relative age of such a formation can in general be ascertained by observing whether an associated sedimentary formation of known age is cut by the igneous mass or is deposited upon it. Similarly, the time at which metamorphic rocks were formed from the original masses may be shown by their relations to adjacent formations of known age; but the age recorded on the map is that of the original masses and not that of their metamorphism.

Symbols, colors, and patterns.—Each formation is shown on the map by a distinctive combination of color and pattern and is labeled by a special letter symbol.

Patterns composed of parallel straight lines are used to represent sedimentary formations deposited in the sea, in lakes, or in other bodies of standing water. Patterns of dots and circles represent alluvial, glacial, and eolian formations. Patterns of triangles and rhombs are used for igneous formations. Metamorphic rocks of unknown origin are represented by short dashes irregularly placed; if the rock is schist the dashes may be arranged in wavy lines parallel to the structure planes. Suitable combination patterns are used for metamorphic formations known to be of sedimentary or of igneous origin. The patterns of each class are printed in various colors. With the patterns of parallel lines, colors are used to indicate age, a particular color being assigned to each system.

The symbols consist each of two or more letters. If the age of a formation is known the symbol includes the system symbol, which is a capital letter or monogram; otherwise the symbols are composed of small letters.

The names of the systems and of series that have been given distinctive names, in order from youngest to oldest, with the color and symbol assigned to each system, are given in the subjoined table.

Symbols and colors assigned to the rock systems.

	System.	Series.	Symbol.	Color for sedimentary rocks.
Cenozoic	Quaternary	Recent Pleistocene	Q	Brownish yellow.
	Tertiary	Pliocene Miocene Oligocene Eocene	T	Yellow ocher.
Mesozoic	Cretaceous		K	Olive-green.
	Jurassic		J	Blue-green.
	Triassic		TR	Peacock-blue.
Paleozoic	Carboniferous	Permian Pennsylvanian Mississippian	C	Blue.
	Devonian		D	Blue-gray.
	Silurian		S	Blue-purple.
	Ordovician		O	Red-purple.
	Cambrian		Є	Brick-red.
	Algonkian		A	Brownish red.
	Archean		AR	Gray-brown.

SURFACE FORMS.

Hills, valleys, and all other surface forms have been produced by geologic processes. For example, most valleys are the result of erosion by the streams that flow through them (see fig. 1), and the alluvial plains bordering many streams were built up by the streams; waves cut sea cliffs and, in cooperation with currents, build up sand spits and bars. Topographic forms thus constitute part of the record of the history of the earth.

Some forms are inseparably connected with deposition. The hooked spit shown in figure 1 is an illustration. To this class belong beaches, alluvial plains, lava streams, drumlins (smooth oval hills composed of till), and moraines (ridges of drift made at the edges of glaciers). Other forms are produced by erosion. The sea cliff is an illustration; it may be carved from any rock. To this class belong abandoned river channels, glacial furrows, and peneplains. In the making of a stream terrace an alluvial plain is first built and afterward partly eroded away. The shaping of a marine or lacustrine plain is usually a double process, hills being worn away (*degraded*) and valleys being filled up (*aggraded*).

All parts of the land surface are subject to the action of air, water, and ice, which slowly wear them down, and streams carry the waste material to the sea. As the process depends on the flow of water to the sea, it can not be carried below sea level, and the sea is therefore called the *base-level* of erosion. Lakes or large rivers may determine local base-levels for certain regions. When a large tract is for a long time undisturbed by uplift or subsidence it is degraded nearly to base-level, and the fairly even surface thus produced is called a *peneplain*. If the tract is afterward uplifted, the elevated peneplain becomes a record of the former close relation of the tract to base-level.

THE VARIOUS GEOLOGIC SHEETS.

Areal geology map.—The map showing the areas occupied by the various formations is called an *areal geology map*. On the margin is a *legend*, which is the key to the map. To ascertain the meaning of any color or pattern and its letter symbol the reader should look for that color, pattern, and symbol in the legend, where he will find the name and description of the formation. If it is desired to find any particular formation, its name should be sought in the legend and its color and pattern noted; then the areas on the map corresponding in color and pattern may be traced out. The legend is also a partial statement of the geologic history. In it the names of formations are arranged in columnar form, grouped primarily according to origin—sedimentary, igneous, and crystalline of unknown origin—and within each group they are placed in the order of age, so far as known, the youngest at the top.

Economic geology map.—The map representing the distribution of useful minerals and rocks and showing their relations to the topographic features and to the geologic formations is termed the *economic geology map*. The formations that appear on the areal geology map are usually shown on this map by fainter color patterns and the areas of productive formations are emphasized by strong colors. A mine symbol shows the location of each mine or quarry and is accompanied by the name of the principal mineral mined or stone quarried. If there are important mining industries or artesian basins in the area special maps to show these additional economic features are included in the folio.

Structure-section sheet.—In cliffs, canyons, shafts, and other natural and artificial cuttings the relations of different beds to one another may be seen. Any cutting that exhibits those relations is called a *section*, and the same term is applied to a diagram representing the relations. The arrangement of rocks in the earth is the earth's *structure*, and a section exhibiting this arrangement is called a *structure section*.

The geologist is not limited, however, to natural and artificial cuttings for his information concerning the earth's structure. Knowing the manner of formation of rocks and having traced out the relations among the beds on the surface, he can infer their relative positions after they pass beneath the surface and can draw sections representing the structure to a considerable depth. Such a section is illustrated in figure 2.

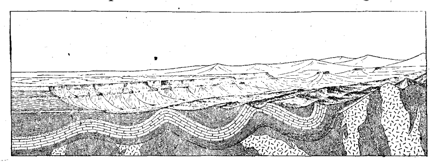


FIGURE 2.—Sketch showing a vertical section at the front and a landscape beyond.

The figure represents a landscape which is cut off sharply in the foreground on a vertical plane, so as to show the underground relations of the rocks. The kinds of rock are indicated by appropriate patterns of lines, dots, and dashes. These patterns admit of much variation, but those shown in figure 3 are used to represent the commoner kinds of rock.

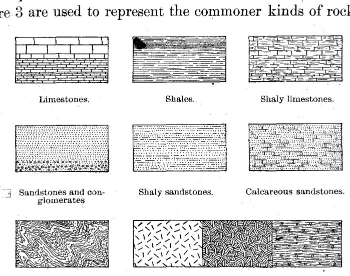


FIGURE 3.—Symbols used in sections to represent different kinds of rocks.

The plateau shown at the left of figure 2 presents toward the lower land an escarpment, or front, which is made up of sandstones, forming the cliffs, and shales, constituting the slopes. The broad belt of lower land is traversed by several ridges, which are seen in the section to correspond to the outcrops of a bed of sandstone that rises to the surface. The upturned edges of this bed form the ridges, and the intermediate valleys follow the outcrops of limestone and calcareous shale.

Where the edges of the strata appear at the surface their thickness can be measured and the angles at which they dip below the surface can be observed. Thus their positions underground can be inferred. The direction of the intersection of a bed with a horizontal plane is called the *strike*. The inclination of the bed to the horizontal plane, measured at right angles to the strike, is called the *dip*.

In many regions the strata are bent into troughs and arches, such as are seen in figure 2. The arches are called *anticlines* and the troughs *synclines*. As the sandstones, shales, and limestones were deposited beneath the sea in nearly flat sheets, the fact that they are now bent and folded is proof that forces have from time to time caused the earth's surface to wrinkle along certain zones. In places the strata are broken across and the parts have slipped past each other. Such breaks are termed *faults*. Two kinds of faults are shown in figure 4.

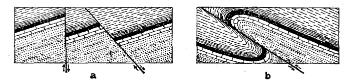


FIGURE 4.—Ideal sections of strata, showing (a) *normal* faults and (b) a *thrust* or *reverse* fault.

At the right of figure 2 the section shows schists that are traversed by igneous rocks. The schists are much contorted and their arrangement underground can not be inferred. Hence that portion of the section delineates what is probably true but is not known by observation or by well-founded inference.

The section also shows three sets of formations, distinguished by their underground relations. The uppermost set, seen at the left, is made up of sandstones and shales, which lie in a horizontal position. These strata were laid down under water but are now high above the sea, forming a plateau, and their change of elevation shows that a portion of the earth's mass has been uplifted. The strata of this set are parallel, a relation which is called *conformable*.

The second set of formations consists of strata that have been folded into arches and troughs. These strata were once continuous, but the crests of the arches have been removed by erosion. The beds, like those of the first set, are conformable.

The horizontal strata of the plateau rest upon the upturned, eroded edges of the beds of the second set shown at the left of the section. The overlying deposits are, from their position, evidently younger than the underlying deposits, and the bending and eroding of the older beds must have occurred between their deposition and the accumulation of the younger beds. The younger rocks are *unconformable* to the older, and the surface of contact is an *unconformity*.

The third set of formations consists of crystalline schists and igneous rocks. At some period of their history the schists were folded or plicated by pressure and traversed by eruptions of molten rock. But the pressure and intrusion of igneous rocks have not affected the overlying strata of the second set. Thus it is evident that a considerable interval elapsed between the formation of the schists and the beginning of deposition of the strata of the second set. During this interval the schists were metamorphosed, they were disturbed by eruptive activity, and they were deeply eroded. The contact between the second and third sets is another unconformity; it marks a time interval between two periods of rock formation.

The section and landscape in figure 2 are ideal, but they illustrate actual relations. The sections on the structure-section sheet are related to the maps as the section in the figure is related to the landscape. The profile of the surface in the section corresponds to the actual slopes of the ground along the section line, and the depth from the surface of any mineral-producing or water-bearing stratum that appears in the section may be measured by using the scale of the map.

Columnar section.—The geologic maps are usually accompanied by a *columnar section*, which contains a concise description of the sedimentary formations that occur in the quadrangle. It presents a summary of the facts relating to the character of the rocks, the thickness of the formations, and the order of accumulation of successive deposits.

The rocks are briefly described, and their characters are indicated in the columnar diagram. The thicknesses of formations are given in figures that state the least and greatest measurements, and the average thickness of each formation is shown in the column, which is drawn to scale. The order of accumulation of the sediments is shown in the columnar arrangement—the oldest being at the bottom, the youngest at the top.

The intervals of time that correspond to events of uplift and degradation and constitute interruptions of deposition are indicated graphically and by the word "unconformity."

GEORGE OTIS SMITH,
Director.

May, 1909.

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 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.

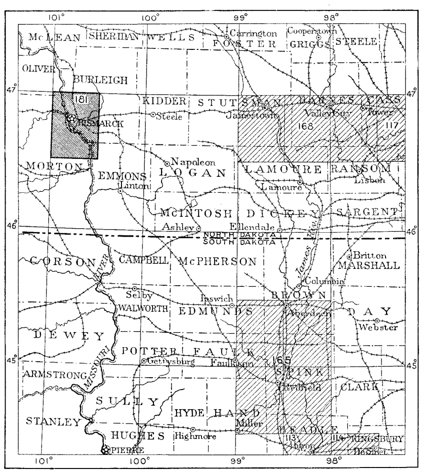


FIGURE 1.—Index map of parts of North and South Dakota.

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. 113, Huron; 114, De Smet; 117, Casselton-Fargo; 165, Aberdeen-Redfield; 168, Jamestown-Tower.

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 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.

[a] The Bismarck quadrangle was surveyed in cooperation with the North Dakota Geological Survey, Arthur G. Leonard, State geologist.

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 bowlders.

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 $8\frac{1}{3}$ 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 ot 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 linguæformis E. and S.	Mactra ? sp.
Avicula nebrascana E. and S.	Ostrea pellucida M. and H.
Chemnitzia cerithiformis 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.
Mactra 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 laminæ 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 formation, 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 prevailingly 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.[a]

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 laminæ	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 laminæ 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	6
Sandstone, argillaceous, gray	10	
Sandstone	1	6
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	6
Sandstone, dark gray to black	1	
Shale, black	2	6
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:

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	6
Shale, black, sandy below	5	
Sandstone, black and yellow	5	6
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	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. ¼ sec. 32, 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	6
Sandstone, soft, fine grained, gray and yellow	7	6
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	6
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. ¼ 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	6
Sandstone, argillaceous, forming ledge	5	4
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.
Euonymus sp.
Grewiopsis populifolia Ward.
Platanus haydenii Newberry, young leaf.
Platanus nobilis Newberry.
Populus amblyrhyncha Ward.
Populus cuneata Newberry.
Populus daphnogenoides Ward.
Populus sp.

Viburnum sp.
Campeloma multilineata M. and H.
Campeloma producta White.
Corbula mactriformis M. and H.
Viviparus retusus M. and H.
Viviparus trochiformis M. and H.
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. ½ sec. 20, T. 141 N., R. 81 W. The section at this locality is as follows:

Section of Fort Union formation in N. ½ 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. ¼ 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. ¼ 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. ¼ 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 bowlders, (*b*) till, or bowlder clay, and (*c*) stratified silt, sand, and gravel.

GLACIAL BOWLDERS.

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 bowlders alone. In many places these glacial bowlders, 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 bowlders touch one another.

These bowlder 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 bowlder-covered areas are not separately shown on the map, partly because the bowlders 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 bowlders range from 6 inches to several feet in diameter, large ones 8 or 10 feet across being occasionally found. Although the bowlder beds are commonly on the upland areas, scattered bowlders 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. Bowlders 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 bowlders. Similar bowlders 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 bowlders and coarse glacial gravel, which may thus represent a residual deposit. The bowlders 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. ½ 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 bowlders 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 bowlders.

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. ¼ sec. 4, T. 135 N., R. 81 W., to the northeast corner of the same section. A second crosses the valley in the W. ½ 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 bowlders 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 bowlders, 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. ½ sec. 28. The hill in the NW. ¼ sec. 30 is formed in part at least of drift, and is crowned by several low, irregular knolls carrying great numbers of large bowlders.

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 bowlders. This area has a length east and west of 1½ 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 bowlders, though no till or bowlder 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 bowlder 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 bowlder 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 bowlder 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 bowlder 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 bowlders at the base of the till. Bowlder 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.

	Feet.
Soil	2½–4
Gravel and bowlders, large and small; in places this member consists largely of bowlders	2
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 bowlders. In sec. 22 of Hay Creek Township an outcrop shows 7 feet of bowlder clay underlain by 3½ feet of shale. Near the northern border of the quadrangle, in the NW. ¼ 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.

Bowlder 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 bowlder 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 extramorainic 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 bowlders and gravel. As already stated, it has the appearance of having undergone much erosion, which has carried away most of the glacial débris and left behind only the coarser materials and the abundant bowlders. If, as seems probable, these are all that is left of a former sheet of till which once covered the glaciated region beyond the Altamont moraine, this would indicate that a considerable period of erosion has elapsed since the deposition of the extramorainic drift, and hence that it is an old drift. Whether it is Kansan or one of the other old drifts it is not possible to say at this time, but it may perhaps be referred provisionally to the Kansan. In the early work in this area these deposits were assigned to the Wisconsin, but evidence found later has led to the assignment of the drift to an earlier epoch.

STRATIFIED DRIFT.

Stratified drift, including gravel deposits, occurs along Burnt and Hay creeks and is exposed in cuts along the Minneapolis, St. Paul & Sault Ste. Marie Railway. In many of the cuts north of Arnold these glacial gravels rest on the Lance formation and have a thickness of 3 to 6 feet. Much of the gravel is very coarse, with many small bowlders 6 to 8 inches in diameter. In the vicinity of the State penitentiary 7 feet of gravel is exposed along the railroad, and in sec. 15, Hay Creek Township, in a ditch beside the track, is a deposit of gravel 4 feet thick containing bowlders. Stratified drift is exposed in the clay pit of the State brickyard, near the penitentiary, where 12 feet of clay and sand are seen, there being three beds of clay separated by two beds of fine-grained sand. In the extreme northeast corner of the quadrangle deposits of gravel occur along the West Branch of Apple Creek. None of the outcrops of stratified drift mentioned above are shown on the map, as either they are too small to be mapped or their extent is unknown on account of the scarcity of exposures.

While the Dakota lobe of the Wisconsin ice sheet was building the Altamont moraine one of the important outlets for the drainage from the melting ice was Apple Creek. During the long time that must have been required for the formation of this massive morainic belt, which is in places 20 miles wide, the silt-laden waters of Apple Creek were making deposits in the valley of that stream. Outcrops of stratified drift which probably represent this glacial silt appear in several cuts along the Northern Pacific Railway, where it follows the south side of the Apple Creek valley. In sec. 1, Apple Creek Township, 5 feet of shale is exposed, overlain by 3 to 4 feet of yellow, finely laminated sandy clay containing near its base pebbles and small bowlders of granite and other rock. In another cut 1 mile to the east 5 feet of water-laid drift appears. An outcrop in the NW. ¼ sec. 11 of the same township shows 12 feet of the Lance formation, overlain by 7 feet of yellow laminated sandy clay containing lime concretions. Resting on the clay is 1 foot of gravel at the top of the cut. In a deep railroad cut in sec. 7, Apple Creek Township, 20 feet of drift is exposed. The lower 15 feet is composed of finely laminated fine-grained sand containing pockets or patches of clay. The laminæ are much crumpled, broken, and folded as if the deposit had been subjected to considerable pressure. The upper 5 feet is unstratified clay. The stratified drift of the Apple Creek valley, which is shown in the outcrops just described, is represented on the map, together with a considerable area in Boyd Township, south of Menoken.

The glacial outwash in the Little Heart region forms the alluvial flats which have already been described under the heading "Topography." These flats were formed during the retreat of the ice sheet from the west side of the Missouri and are intimately related to the moraines of the Little Heart basin. These valley trains, which are shown on the map, are composed of fine sandy clay or silt.

GLACIAL TERRACE DEPOSITS.

The glacial terrace deposits are confined to the vicinity of the streams and in their formation the materials of the drift have been sorted by running water. In part, at least, the streams swollen by the drainage from the melting ice have been instrumental in their formation. Some of these deposits were perhaps laid down some time after the deposition of the till, but most of them are believed to have been deposited during the Pleistocene epoch.

Extensive gravel deposits form a terrace along the south side of the Heart River valley and are well shown in secs. 30, 33, and 34, T. 139 N., R. 81 W., and in sec. 25, T. 139 N., R. 82 W. The wagon road leading south from Mandan and crossing Heart River by the new bridge near the west line of sec. 34 passes through a cut just south of the bridge, where the gravel is well exposed. Here layers of gravel alternate with beds of coarse and fine sand, and large pebbles of granite and other igneous rocks are not uncommon, many having a diameter of 5 to 6 inches. An extensive exposure of the gravel occurs in the large pit in sec. 30, T. 139 N., R. 81 W., to which the spur track from the Northern Pacific Railway extends. The terrace here has an elevation of 70 feet above Heart River and is composed largely of very coarse gravel and bowlders 8 to 12 inches in diameter, with finer gravel and a little sand. The pebbles and bowlders are of glacial origin, a large proportion of the material being unlike the underlying rock and consisting of granite, gneiss, quartzite, etc., with some local rock most of which is from the harder sandstone beds of the Lance formation. A number of large glacial bowlders are scattered over the surface of the terrace and others are mingled with the gravel.

In the construction of the branch line of the Northern Pacific Railway north from Mandan a cut was made along the edge of the terrace bordering the Missouri, about a mile north of the town. In this cut the shale of the Lance formation appears at 35 to 40 feet above the river, overlain by very coarse gravel and sand having a maximum thickness of 12 feet. Mingled with these materials are granite bowlders 2 and 3 feet in diameter, some of them resting directly on the shale. Considerable coarse laminated sand is mixed with the gravel, and it is overlain in places by 6 to 8 feet of clay and fine sand, probably washed down from the higher slopes. The terrace gravels exposed in this cut form too small an area to be mapped.

The terrace on the west side of the Missouri south of the Little Heart and also extending a few miles north of that stream consists in part of beds of the Lance formation overlain by glacial gravel and silt. These deposits are well exposed in some of the railroad cuts in the vicinity of Sugarloaf Butte and at a few points on the edge of the terrace. The following section, which is fairly representative, appears in one of the cuts:

Section in railroad cut near Sugarloaf Butte.

	Feet.
Glacial silt and wash from the bluffs	2–10
Glacial gravel	1– 5
Lance formation, exposed to bottom of cut	8–10

As shown in this exposure the gravel and silt are not of uniform thickness, but they appear to be generally present on this terrace, the silt everywhere being at the top.

RECENT SERIES.

ALLUVIUM.

Alluvium is found along practically all the streams of the area, notably Missouri and Heart rivers, but, except along the larger streams, it is too narrow to be represented on a map of the scale used in this folio. This recent deposit of the rivers is spread over the valley bottoms during floods, and in the Missouri Valley it has accumulated to a considerable depth. It is composed of sand, gravel, and a little clay, the upper 2 or 3 feet being commonly clay. The belt of alluvium along the Missouri has a maximum width of 3½ miles and an average width of about 2½ miles.

Most of the alluvium is believed to be of much more recent formation than the terraces of glacial gravel already mentioned, but some of the lower terraces along the Missouri and other streams are formed of recent alluvial deposits. This is doubtless true of the lower terrace between Fort Lincoln and the river, but the upper terrace, on which the fort is built, is probably Pleistocene.

Information regarding the thickness and character of the alluvium of the Missouri River valley is afforded by the records of borings made for the Northern Pacific Railway prior to the building of its bridge across the river at Bismarck. Through the kindness of the chief engineer the writer was allowed to examine these records, and the following, selected from 44 borings, are given as representative of the materials passed through:

Records of borings in channel of Missouri River near Northern Pacific Railway bridge at Bismarck.

Boring No. 21.

	Feet.
Sand, fine	47.4
Gravel, clear	2.2
(At this depth a hard bowlder was struck and the hole was abandoned).	

Boring No. 24.

	Feet.
Sand, fine	33
Sand, coarse, and gravel	11
Sand, fine, black	.5
Sand, coarse, and gravel	10
Clay (shale) penetrated	3.9
Total thickness of alluvium	54.5

Boring No. 34.

	Feet.
Sand, fine	22.5
Sand, fine, and lignite	7
Sand, coarse, and gravel	4
Gravel	2.5
Clay (shale), penetrated	5
Total thickness of alluvium	36

Boring No. 13.

	Feet.
Sand, fine	28
Gravel	2
Sand, fine, with a little lignite	19
Lignite and small balls of clay	.8
Sand, coarse, gravel, and lignite	10.2
Sand, fine, black	.2
Gravel, coarse, and fine sand	9.2
Clay (shale), blue, and sandstone, penetrated	15.4
Total thickness of alluvium	69.4

Boring No. 42.

	Feet.
Sand, fine, with gravel and lignite	36.2
Sand, coarse	11
Gravel	2.2
Clay, blue	.8
Sand, fine, dark	13
Sand, coarse	5.5
Gravel, coarse	3.2
Clay (shale), penetrated	6.5
Total thickness of alluvium	71.9

Boring No. 44.

	Feet.
Sand, fine	26.1
Coal	1.2
Sand, coarse, and pebbles	16.5
Sand, fine, and lignite	4.5
Sand, coarse, and pebbles	3.4
Clay, blue	.6
Sand, fine, dark	11
Sand, coarse, and gravel	9
Sand, fine, and lignite	6
Clay (shale), penetrated	1.5
Total thickness of alluvium	78.3

Boring No. 9.

	Feet.
Sand, fine, mixed with lignite and pebbles	59
Coal, mixed with lumps of clay and sand	3
Sand, coarse	3
Sand, fine, mixed with some lignite	18.8
Clay (shale), blue, penetrated	10.8
Total thickness of alluvium	83.8

The first three borings, Nos. 21, 24, and 34, are in the vicinity of the second pier from the east end of the bridge; the other four borings are near the west end. The greatest thickness of river silt penetrated in any of the 44 borings was 84 feet, the deposit thickening from 30 to 84 feet in a distance of 400 feet and being thickest at the west pier. It seems quite probable that the alluvium may extend to a considerably greater depth, as all the borings were made within 1200 feet of the east side of the valley and the opposite side is 2 miles beyond the west end of the bridge. It would be interesting to know how thick the alluvium is in that portion of the valley west of the present river channel and the bridge, as the borings show it to be thickening in that direction and it seems reasonable to assume that it reaches a greater thickness than 84 feet, perhaps 100 or 125 feet. Borings were also made along a line half a mile below the present bridge, but that site was rejected "because no hard material, suitable for the foundation of the piers, was found except at very great depth." The river silt was thus found to be thicker south of the bridge, but how much thicker is not stated.

Reference has previously been made to two wells at Bismarck which are reported to have struck bowlders at a depth of 125 feet. These were put down in the south edge of the city, which is built on the 45-foot terrace. The wells therefore penetrated 125 feet of river silt and gravel, much of which may have been deposited during the Pleistocene, when Apple Creek was carrying a heavy load of glacial débris. These bowlders, which rest on several feet of sand, mingled with fragments of lignite, were struck at an elevation of 1545 feet above sea level. The top of the shale was reached at 1541 feet in the deepest boring, near the west pier of the bridge.

There are a number of sand flats along the Missouri and shifting sand bars that are constantly forming and being washed away in its channel have much to do with making navigation difficult and dangerous.

Each overflow of the streams adds a little, often not more than a fraction of an inch, to the thickness of the alluvium, the materials thus deposited over the flood plains greatly increasing the fertility of these bottom lands.

DUNE SAND.

The area of sand dunes in Apple Creek and Manning townships has already been mentioned in the section on the topography of the quadrangle. Where the sand has been heaped into dunes by the wind it has a maximum thickness of nearly 100 feet. The area lies 5 or 6 miles east of the Missouri and several miles back from the bluffs bordering the valley. It does not seem at all probable that the source of the deposit was the sandy channel of the river, on account of the distance from that stream and the bluffs between. A broad, shallow depression, followed by the Minneapolis, St. Paul & Sault Ste. Marie Railway southeast of Bismarck, extends from a point near the railroad crossing over Apple Creek to the Missouri near Twin Buttes. This depression, lying just west of the dune area, is probably the abandoned valley of Apple Creek, which deposited the sand along its course, to be shifted later by the wind and spread over the area now covered by the dunes. The deposit rests on glacial drift and perhaps in places on the Lance formation.

STRUCTURE.

There is little to be said regarding structure in the Bismarck quadrangle. The strata are almost horizontal, dipping gently northward with an average slope of 10 feet or less to the mile. Owing to the scarcity of exposures and the lack of easily recognizable beds which could be traced for some distance, it is not known whether the dip is uniform or whether its uniformity is broken by minor undulations or possibly small faults, but nothing has been seen to indicate such minor deformations. The gentle northward tilt appears to be the result of continental uplift unaccompanied, at least in this region, by folding of the strata.

GEOLOGIC HISTORY.

CRETACEOUS PERIOD.

During Cretaceous time the interior of the continent was depressed and the sea advanced over the land until the area now constituting North Dakota, along with the rest of the Great Plains region, was submerged. At first the water was shallow and the sediments were sorted and distributed by strong currents, resulting in the formation of the Dakota sandstone. Although this sandstone lies more than 2000 feet below the surface in this area it undoubtedly underlies all of the Bismarck quadrangle, for it is known to occur farther east and south, in North and South Dakota, where it is the source of artesian water.

The Cretaceous sea covered the region throughout Colorado and Montana time and in it were deposited the shale, chalk, and sandstone of the Benton, Niobrara, Pierre, and Fox Hills formations, with a total thickness between 1000 and 2000 feet. During the formation of the shale of the Benton and Pierre the rivers brought into the sea much clay and sand from the 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 fresh-water 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 fluviatile 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 postglacial gravels. The bowlders 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 extramorainic drift over the whole region. This older drift has undergone so much erosion that in most places only bowlders 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 bowlders 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. ½ 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 much handling of the material.

Chemical analyses and producer-gas, briquetting, and steaming tests.—The following analyses and producer-gas tests were 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. 1935.	Laboratory No. 1938.	Car sample, Laboratory No. 2243.
Air-drying loss		32.30	33.50	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	3,691		3,927
	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. ½ sec. 30, a spur track runs to a 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 bowlders. 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 bowlders which were encountered in sinking the wells. At the penitentiary this bowlder 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

[a] A more detailed account of the analyses can be found in Bull. U. S. Geol. Survey No. 290, 1905, pp. 138–139.

[b] Prof. Paper U. S. Geol. Survey No. 48, pt. 1, 1906, p. 111.

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. 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.

[a] Seventeenth Ann. Rept. U. S. Geol. Survey, pt. 2, 1896, p. 665.

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 bowlders, 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 are 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.

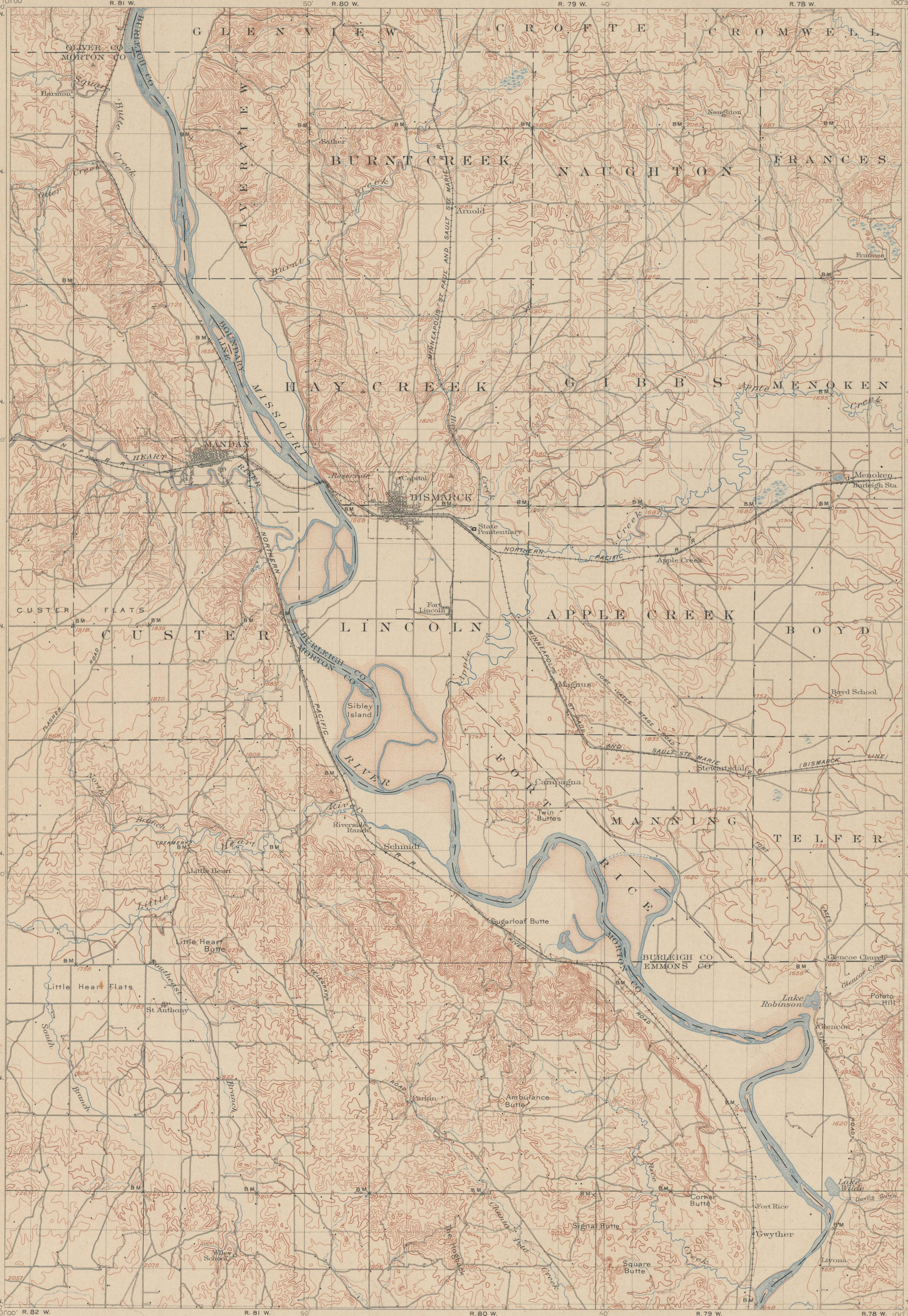
Reference has already been made to the dune area southeast of Bismarck, where the sand covers 8 or 10 square miles. The soil of this tract is thus composed almost wholly of quartz sand, which has accumulated to a considerable depth through the action of the wind.

June, 1911.

TOPOGRAPHY

U.S. GEOLOGICAL SURVEY
GEORGE OTIS SMITH, DIRECTOR

NORTH DAKOTA
BISMARCK QUADRANGLE



LEGEND

RELIEF
printed in brown

Figures *showing heights above mean sea level instrumentally determined*

Contours *showing height above sea, horizontal form, and steepness of slope of the surface*

Depression contours

Stream wash

DRAINAGE
printed in blue

Streams

Abandoned stream beds

Intermittent streams

Lakes and ponds

Fresh marshes

CULTURE
printed in black

Roads and buildings

Churches, school houses, and cemeteries

Private and secondary roads

Railroads

Bridges

Ferries

U.S. township and section lines

County lines

Township lines

Reservation lines

City, village, and borough lines

Triangulation stations

Bench marks

H. M. Wilson, Geographer.
Robert Muldrow, in charge of section.
Topography by Basil Duke and J. G. Staack.
Triangulation by Missouri River Commission.
Surveyed in 1905.
Northern Pacific railroad (Mandan south and north) added in 1911, without field examination, from plats supplied by the railroad company.

Scale $\frac{1}{125000}$

Contour interval 50 feet.
Datum is mean sea level.

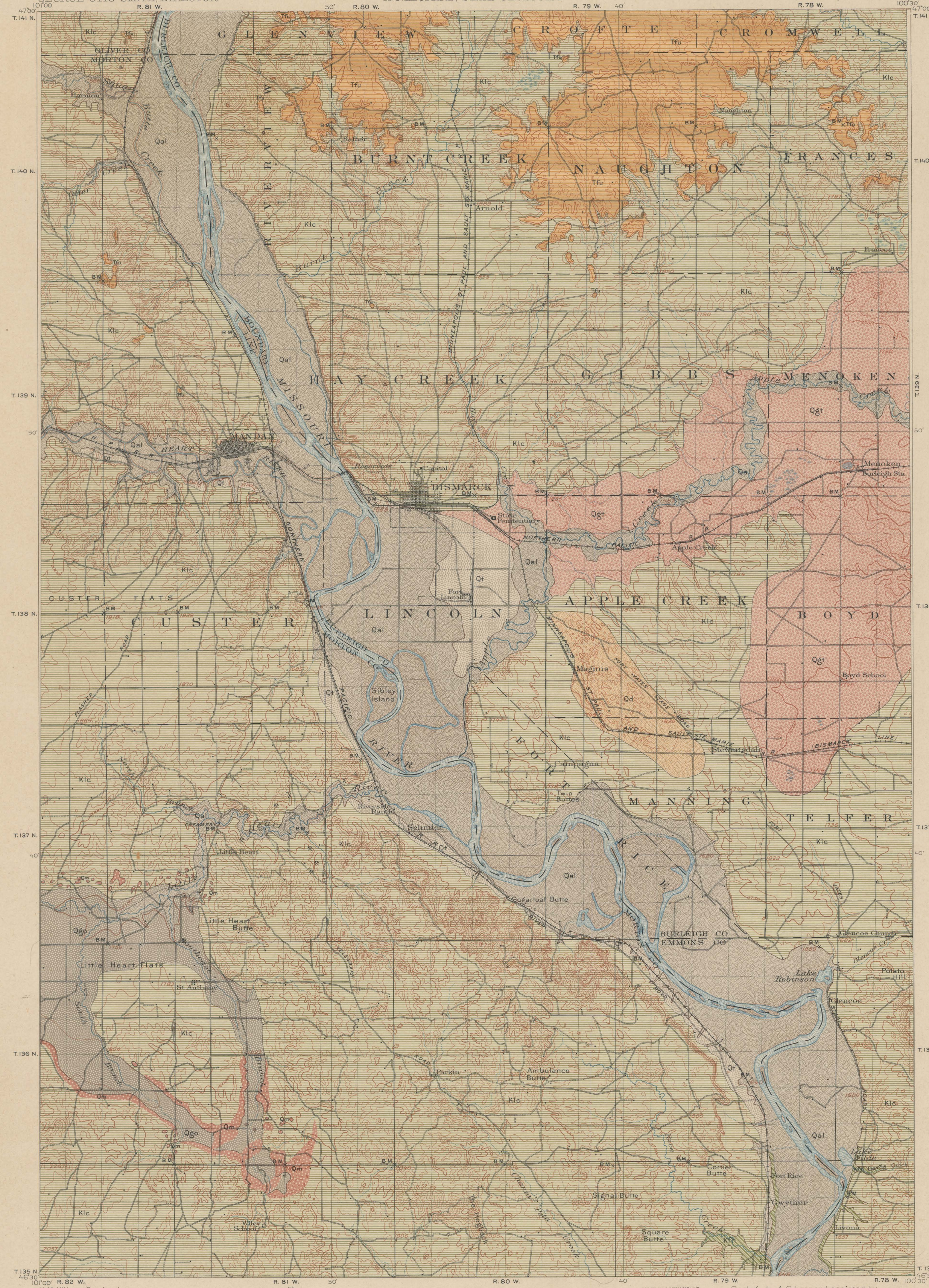
Edition of July 1907, reprinted Mar. 1911 with corrections.

U.S. GEOLOGICAL SURVEY
GEORGE OTIS SMITH, DIRECTOR

AREAL GEOLOGY

STATE OF NORTH DAKOTA
A.G. LEONARD, STATE GEOLOGIST

NORTH DAKOTA
BISMARCK QUADRANGLE



LEGEND

SEDIMENTARY ROCKS

(Areas of subaqueous deposits are shown by patterns of parallel lines; subaerial deposits by patterns of dots and circles)

QUATERNARY

Recent

Qd — Dune sand *(wind blown sand derived from old stream alluvium)*

Qal — Alluvium *(shown only in the larger valleys)*

Pleistocene

Qt — Glacial terrace deposits *(glacial gravel, sand, and silt on terraces of the Missouri River and larger tributaries; some later non-glacial terrace silts included in mapping)*

Qgo — Glacial outwash *(fine sandy clay or silt forming valley train in Little Heart Flats and vicinity)*

Qgt — Glacial till and stratified drift *(unstratified clay, sand, gravel, and bowlders, probably extra-morainic drift of early Wisconsin age, and stratified silt deposited by glacial streams)*

Qm — Morainic deposits *(hills of glacial drift generally covered with bowlders at surface)*

TERTIARY

Eocene

Tfu — Fort Union formation *(yellow and ash-gray shale and sandstone; overlaid in places by glacial bowlders and thin mantle of till)*

CRETACEOUS OR TERTIARY

Klc — Lance formation *(dark-colored shale and sandstone containing Dinosaur bones-"Ceratops beds"; overlaid in places by glacial till and bowlders)*

CRETACEOUS

Kfh — Fox Hills sandstone *(yellow to gray cross-bedded sandstone with many concretions)*

⚒ *Coal mines*
x *Coal prospects*

H. M. Wilson, Geographer.
Robert Muldrow, in charge of section.
Topography by Basil Duke and J.G. Staack.
Triangulation by Missouri River Commission.
Surveyed in 1905.

TRUE NORTH / MAGNETIC NORTH 14°
APPROXIMATE MEAN DECLINATION 1905.

Scale $\frac{1}{125000}$

1 ½ 0 1 2 3 4 5 Miles

1 ½ 0 1 2 3 4 5 Kilometers

Contour interval 50 feet.
Datum is mean sea level.
Edition of Mar. 1911.

DIAGRAM OF TOWNSHIP.

6	5	4	3	2	1
7	8	9	10	11	12
18	17	16	15	14	13
19	20	21	22	23	24
30	29	28	27	26	25
31	32	33	34	35	36

Geology by A.G. Leonard, assisted by W.H. Clark and R.L. Sutherland.
Surveyed in 1909-10.

SURVEYED IN COOPERATION WITH THE STATE OF NORTH DAKOTA.

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