DEPARTMENT OF THE INTERIOR
FRANKLIN K. LANE, SECRETARY
UNITED STATES GEOLOGICAL SURVEY
GEORGE OTIS SMITH, DIRECTOR

GEOLOGIC ATLAS
OF THE
UNITED STATES

MINNEAPOLIS-ST. PAUL FOLIO

MINNESOTA

BY

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WASHINGTON, D. C.
ENGRAVED AND PRINTED BY THE U. S. GEOLOGICAL SURVEY
GEORGE W. STOSE, EDITOR OF GEOLOGIC MAPS   S. J. KUBEL, CHIEF ENGRAVER
1916

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.

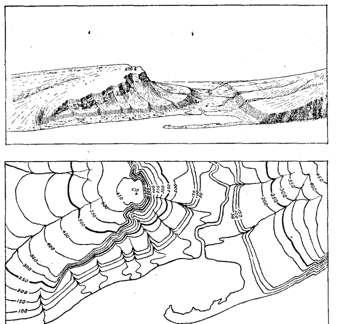


FIGURE 1.—Ideal view and corresponding contour map.

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		Ꞧ	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		Æ	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.

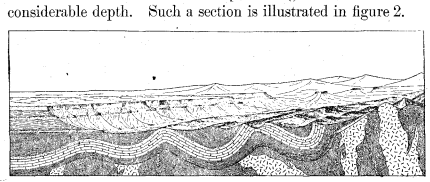


FIGURE 2.—Sketch showing a vertical section at the front and a landscape beyond.

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.

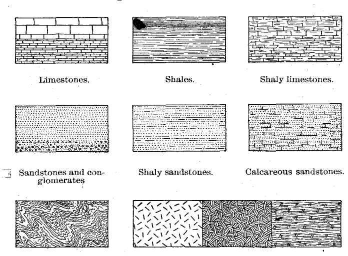


FIGURE 3.—Symbols used in sections to represent different kinds of rocks.

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.

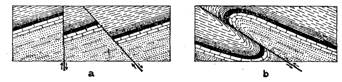


FIGURE 4.—Ideal sections of strata, showing (a) *normal* faults and (b) a *thrust* or *reverse* fault.

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 MINNEAPOLIS AND ST. PAUL DISTRICT.

By Frederick W. Sardeson.

INTRODUCTION.

LOCATION AND RELATIONS OF THE DISTRICT.

The district here described is bounded by parallels 44° 45′ and 45° 15′ and by meridians 93° and 93° 30′ and comprises the Anoka, White Bear, Minneapolis, and St. Paul quadrangles, an area of 846 square miles. It is in southeastern Minnesota (see fig. 1) and includes nearly the whole of Ramsey County, the greater part of Hennepin County, and smaller parts of Anoka, Dakota, Scott, and Washington counties. The city of Minneapolis stands near the center of the district, a part of it in each of the four quadrangles.

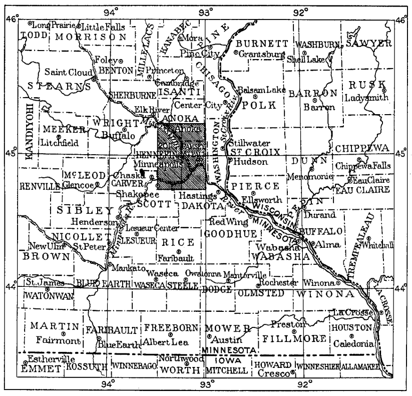


FIGURE 1.—Index map showing the location of the Minneapolis and St. Paul district (shaded area).

In its general geographic and geologic relations the district forms a part of the Glaciated Plains, which lie between the Appalachian province on the southeast, the Ozark province on the southwest, and the Laurentian upland on the north, and extend westward to merge into the Prairie Plains. It is situated near the northern margin of the Glaciated Plains, not far from the border of the southwestern extension of the Laurentian upland that is called "The Ranges," otherwise known as the Lake Superior highlands.

The Glaciated Plains province comprises five subprovinces: the Michigan syncline, lying between Lakes Huron, Erie, and Michigan; the Cincinnati anticline, extending southward across Indiana and western Ohio to northern Kentucky; the Central Mississippi basin, including Illinois, southern Iowa, and northern Missouri; the Upper Mississippi basin, including southern Wisconsin, the adjacent part of Illinois, northeastern Iowa, and southeastern Minnesota; and the Dakota subprovince, extending eastward from Missouri River, in North Dakota and South Dakota, to the western border of Minnesota and the Red River valley, and northward into Canada. The district described in this folio lies in the northwestern part of the Upper Mississippi basin subprovince and embraces the junction of the Mississippi and Minnesota valleys. (See fig. 2.)

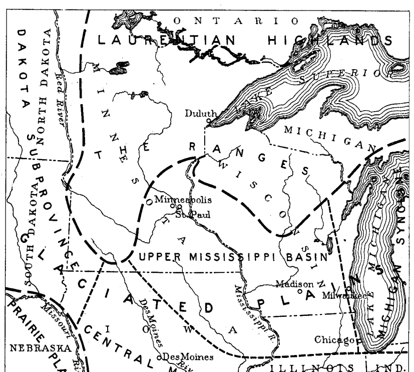


FIGURE 2.—Geographic provinces of Minnesota and adjacent region.
The Minneapolis and St. Paul district is entirely within the Upper Mississippi Basin.

OUTLINE OF THE GEOLOGY AND GEOGRAPHY OF THE UPPER MISSISSIPPI BASIN SUBPROVINCE.

Extent and general relations.—The Upper Mississippi basin subprovince lies west of Lake Michigan, east of the Coteau des Prairies, north of the Carboniferous basin or coal fields of Illinois and Iowa, and south of The Ranges, a southward extension of the Laurentian highlands into Minnesota and Wisconsin. The southern part of the region includes about 10,000 square miles which was not covered by the northern glacier and which is called the "Driftless Area." In other respects, however, the history of the Driftless Area is similar to that of the surrounding region. The Ranges are covered with drift and in this respect are similar to the Glaciated Plains, though different in many other respects. The Ranges comprise a region of old crystalline rocks and of worn-down or leveled mountain ranges, whereas the Glaciated Plains are underlain by a series of nearly horizontal beds of sedimentary rocks. The rocks in the Dakota subprovince are Cretaceous sedimentary formations. Most of those in the Central Mississippi basin and the Michigan syncline are Carboniferous and other late Paleozoic sedimentary rocks. The Upper Mississippi basin subprovince is underlain chiefly by Ordovician and Cambrian rocks.

Relief.—The Upper Mississippi basin is in general a broad rolling plain which shows in its different parts no great diversity in the form of its surface. It stands from 600 to 1,500 feet above sea level, but the greater part of it is at elevations between 900 and 1,200 feet. The valley of the Mississippi from Minneapolis southward is fairly regular. It is from 300 to 600 feet deep, is generally 2 to 5 miles wide, and its flat bottom lies between steep slopes. The tributary valleys are also deep and have steep sides. The general slope of the surface of the subprovince is toward the Mississippi Valley.

Drainage.—Practically all this subprovince is drained to the Mississippi. Its central-southern part, which includes the Driftless Area and areas covered by old glacial drift, is well drained through deep, mature valleys. The districts on its eastern, northern, and western borders are poorly drained, because they have been more lately glaciated and are covered by comparatively recent glacial drift, which blocks many of the valleys. Many of the streams have irregular courses and there are numerous lakes and swamps, some with outlets and others without them. The drainage systems in those districts are slowly approaching the condition found in the older drift-covered and driftless districts.

Stratigraphy.—The hard rock formations immediately under the drift in the Upper Mississippi basin subprovince are sedimentary. They are thickest on the south and thin out toward the north. The sedimentary rocks lie everywhere upon older crystalline igneous and metamorphic rocks of pre-Cambrian age. These older rocks come to the surface chiefly in the northern part of the subprovince, where the sedimentary rocks are absent. The structure of the crystalline rocks is complex and their surface was deeply eroded and planed down before the sedimentary deposits were laid down upon them. The general distribution of the rock formations at the surface in this region is shown in figure 3.

The Cambrian system comprises sandstones and some dolomitic formations and has a maximum thickness of about 1,000 feet. The beds lie nearly horizontal and thin out toward the north, abutting against the older crystalline rocks, which formed most of the land at the time they were deposited. At some places a thick series of red sandstones and shales of supposed Algonkian age lie beneath the Cambrian strata.

The Ordovician system consists of thin formations of limestone, dolomite, shale, and some sandstone. The deposits that formed these rocks were laid down upon the Cambrian rocks over all this subprovince but at the north have been removed by erosion, so that the Ordovician rocks do not extend so far northward as the Cambrian. Each formation of the Ordovician system is less widespread than the next underlying one, and the complete succession is found only in the neighborhood of overlying Silurian or Devonian limestones.

Representative formations of the Silurian system were laid down over only the outer border of this subprovince, in eastern and southern Wisconsin, in Illinois, and in Iowa, but not in Minnesota. They are chiefly dolomitic limestones, which include many coral reefs. They were laid down in clear, shallow seas while this region was a low coastal plain between the Laurentian highlands on the north and the sea on the south.

The Devonian system covers the Silurian and overlaps it on the north so that it rests on the Ordovician in southern Minnesota (see fig. 3), but elsewhere it has been more strongly eroded away and is less extensive than the Silurian system. It consists of limestones and clay shales, which were laid down under nearly the same conditions as the Silurian deposits.

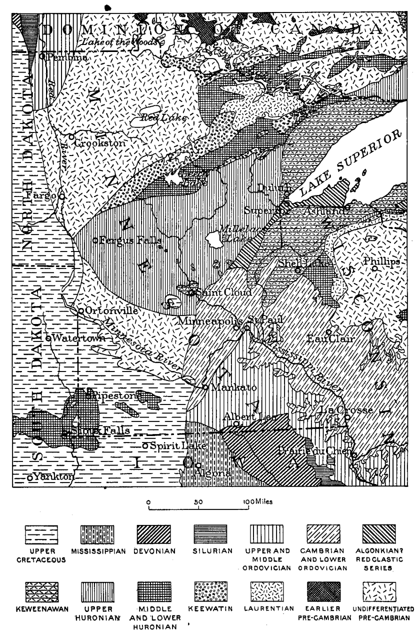


FIGURE 3.—Geologic map of Minnesota and adjacent region showing distribution of the rock formations at the surface.
In much of the area the bedrock is deeply covered with glacial drift. (From the geologic map of North America in U. S. Geol. Survey Prof. Paper 71, 1912.)

During the Carboniferous period, when the Pennsylvanian and Mississippian series were formed in the neighboring subprovinces on the south and east, this region was a lowland area subject to slight erosion. Essentially the same conditions prevailed later, during the Triassic and Jurassic periods, although the seas were then farther distant from this region.

Cretaceous fluviatile and estuarine beds, consisting of generally unconsolidated sands and clays, are found at some places in southern Minnesota. The more extensive marine formations of the same age in the Dakota subprovince, on the west, do not reach the Mississippi basin. During the Tertiary period the present Mississippi drainage system was established and the valleys were eroded deeper than they are now. No Tertiary deposits are known in the subprovince.

The Quaternary system is widespread. Glacial drift, including unconsolidated deposits from melting ice, from rivers, and from lakes, covers the greater part of the surface and has in places a thickness of several hundred feet. Even within the Driftless Area nearly all the surface is covered with Quaternary wind-deposited loess.

Structure.—The structure of the consolidated sedimentary formations in the Upper Mississippi basin subprovince is simple. A broad, low arch, pitching southward, whose crest runs nearly northward, extends through Wisconsin and northern Illinois, separating the Upper Mississippi basin subprovince from the Michigan syncline subprovince. The dips on the west side of this arch are nearly flat but are in general southwestward. In the western part of the Upper Mississippi basin there is a broad synclinal trough toward which the rocks dip away from the broad arch just described. The strata having this general southwestward dip include minor undulations that show variant dips. The Minneapolis and St. Paul area is in one of these minor folds that produces the farthest northward extension of the Ordovician strata.

Outline of geologic history.—The pre-Cambrian history of the region is long, complex, and obscure. There were several periods of deposition, some of them accompanied by local volcanic eruptions, and these periods were separated by periods of uplift and deformation. The deformed rocks were once or twice intruded by masses of plutonic igneous rocks and the whole complex was several times subjected to erosion so prolonged as to lay bare even intrusive rocks that had solidified at great depths. Near the close of the Algonkian period a large part of the region had been reduced to a nearly featureless plain lying but little above sea level.

Early in Paleozoic or late in Algonkian time most of the region was submerged by a sea that at times occupied much of the interior of North America. The height and slope of the bordering land and the outline and depth of the sea, and hence the position of its shores, were always slowly changing, and parts of the region were at times areas of deposition and at other times of erosion. By the close of the Ordovician period the sea had withdrawn from the immediate neighborhood of the Minneapolis and St. Paul district, but areas on the southeast and south were submerged until well into Carboniferous time, when the whole region was uplifted and slightly deformed.

Throughout Triassic, Jurassic, and Lower Cretaceous time Minnesota lay far inland and its surface was being reduced by erosion, but no record of that time is preserved in the State. In Upper Cretaceous time the land on the west subsided and the interior Cretaceous sea spread eastward nearly if not quite to St. Paul. It soon withdrew, however, its brief period of deposition being terminated by renewed uplift, which was followed by erosion that continued through Tertiary time.

In the Pleistocene epoch great ice sheets formed about centers of accumulation in Canada and spread outward in all directions, grinding down the surface over which they passed, picking up and carrying along quantities of rock débris, and, when they melted, leaving the surface greatly changed and nearly everywhere covered with a blanket of transported materials. The Keewatin center was on the west side and the Labradorean center on the east side of Hudson Bay and there may have been another—the Patrician—southwest of the bay. According to the generally accepted view, ice sheets from one or more of the centers invaded the northern United States at least five times. At their greatest extent they reached central Missouri and southern Illinois and Indiana. The several invasions were separated by intervals when the ice melted away, perhaps altogether, and when the climate was as mild as at present, or even milder, and the land was inhabited by plants and animals.

Minnesota was invaded but probably never wholly covered by each ice sheet in turn. (See fig. 11, p. 10.) Each came from a different direction, as shown by the striæ on bedrock, covered a somewhat different area, and left a characteristic deposit of drift. In the latest or Wisconsin glacial stage the State was twice invaded by the ice, one ice tongue coming from the northeast and another from the northwest, and each leaving a drift of a distinctive color. When the margin of the last ice sheet had melted back past the divide between the streams now flowing to the Mississippi and those now flowing to Lake Winnipeg, a lake called Lake Agassiz was formed between the ice front and the higher land on the south. It eventually reached an enormous size and for a long time discharged southward into the Mississippi basin through a large river called River Warren, which flowed in the valley of the present Minnesota River. (See fig. 11.) A similar glacial lake, called Lake Duluth, filled the Lake Superior basin about this time. After these lakes had disappeared the conditions in the State became essentially those now prevailing.

TOPOGRAPHY.

RELIEF.

General features.—The surface of the Minneapolis and St. Paul district is of moderate relief but of diverse character. The western, southern, and eastern parts are in general hilly, having the undulating and knolly surface peculiar to drift-covered, recently glaciated regions, but the northern part is a plain broken by low sand dunes, and Mississippi and Minnesota rivers are bordered by terraced alluvial plains whose surfaces are nearly level. Only a minor part of the relief is due to erosion by the present streams. Fairly steep slopes of rather small vertical extent are abundant in the hilly districts and along the Minnesota-Mississippi valley, but the surface elsewhere is in most places level or gently sloping.

The general altitude is not high in view of the position of the area in the heart of the continent and its distance from the sea. In the hilly districts many summits reach 1,000 feet or more above sea level, and near the southern margin of the area a few exceed 1,100 feet. The highest point is Lebanon, in the southwest corner of the St. Paul quadrangle, which has an altitude of 1,180 feet. The general level of the plains is about 900 feet in the northern part of the area and from 800 to 860 feet along the rivers. The Minnesota-Mississippi valley bottom lies 100 feet or so lower, and the lowest point, which is a little less than 680 feet above sea level, is in the flood plain of the Mississippi in the southeast corner of the St. Paul quadrangle.

The district may be divided into five topographic areas—the belt of greater hills, the belt of lesser hills, the intramorainic plain, the river terraces, and the Minnesota and Mississippi river bottoms. (See fig. 4.)

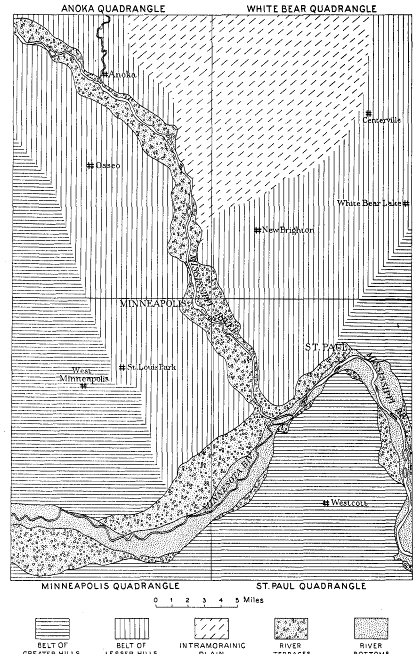


FIGURE 4.—Sketch map of the main surface features of the Minneapolis and St. Paul district.

The belt of greater hills.—A belt of knoll-like hills curves across the southern part of the district, occupying most of the St. Paul and Minneapolis quadrangles, though not the site of the city of Minneapolis. It crosses the corner of the White Bear quadrangle east and south of Gervais and McCarron lakes, and the corner of the Anoka quadrangle west and northwest of Medicine Lake. This belt is divided into three parts by the belts of terraces and flood plains that extend along Mississippi and Minnesota rivers. It is characterized in general by an extremely undulating surface, comprising large, prominent knolls and intervening deep kettle holes. In this belt there are many ponds and lakes, most of which have no outlets. The surface is strewn with bowlders and the subsoil is mostly clay. The belt includes some gravel plains, which are less broken than the hills, but which nevertheless contain many small kettle holes and are in part knolly.

The altitude of the hilly part of the belt ranges from 700 to more than 1,100 feet above sea level. The gravel plains have a mean altitude of nearly 900 feet.

The belt of lesser hills.—Within the curve of the belt of greater hills there is another belt, which extends from Bald Eagle and White Bear lakes to Minneapolis and thence northwestward past Eagle and Hayden lakes. It occupies most of the southeast half of the White Bear quadrangle and the southwest half of the Anoka quadrangle, besides corners of the St. Paul and Minneapolis quadrangles. Its surface is characterized by complex topography but is somewhat lower and less rough than that of the belt of greater hills and contains fewer but larger lakes. The belt of lesser hills is broken across by a series of gravelly or sandy plains, lying as high as or a little higher than those in the belt of greater hills.

The intramorainic plain.—The northwestern part of the White Bear quadrangle and the northeastern part of the Anoka quadrangle are occupied by a plain, which is diversified by low sand dunes, wire-grass marsh, and lakes. It lies about 900 feet above sea level and is relatively flat. Its surface is all sand and bog, without bowlders, pebbles, or clay beds.

The river terraces.—Mississippi and Minnesota rivers are bordered by plains that are the terraces of glacial rivers. These plains are in places 1 or 2 miles wide, are bounded by distinct escarpments, and lie 740 to 860 feet above sea level. They are generally covered with gravel but are in some places strewn with bowlders and in others are floored with sand, clay, or limestone.

Minnesota and Mississippi river bottoms.—The most conspicuous topographic feature in the district is the river bottom of the Mississippi below its confluence with the Minnesota at Mendota and the river bottom of the Minnesota, which together form a continuous, broad, flat-bottomed valley inclosed between high, abrupt walls. (See Pls. I to IV.) The rivers meander across the valley bottom and are bordered by natural levees, behind which are lakes or swamps or lower levels of the flood plain. The valley and gorge of the Mississippi between the Falls of St. Anthony and Fort Snelling are treated in more detail on pages 11–13.

DRAINAGE.

General features.—The district as a whole is not well drained. As the surface is not only extremely irregular but owes its character largely to glacial deposition, lakes and swamps abound in nearly all parts of the area, a considerable fraction of which is under water. Many of the basins have no outlets, though some have outlets into adjoining basins, so that, in spite of the large amount of surface water, streams are scarce and in considerable portions of the area there are none. In all that part of the St. Paul quadrangle that lies south of Minnesota and Mississippi rivers the only streams are those that drain the margin of the hilly area, of which Black Dog Creek, the largest, is less than 3 miles long. Large parts of the Anoka and Minneapolis quadrangles are without streams.

All the surface drainage that finds an outlet within the district is discharged into Mississippi River, which crosses the area from the northwest to the southeast corner. The Mississippi and the Minnesota, a large stream rising many miles away and the chief tributary of the Mississippi in the district, flow in valleys from 40 to 120 feet deep and are independent of the minor relief of the surface. The local streams, however—those rising within or not far outside the district—wander in devious courses through the hills and across the plains, here flowing through swamps, there expanding into lakes, and as a rule occupying well-marked valleys only in comparatively short stretches between basins. Near their mouths most of the creeks descend to the main valleys in narrow gorges, from 40 to 100 feet deep, and have steep slopes and swift currents for the last mile or so of their courses.

Streams.—The Mississippi in its course across the district is from an eighth to a quarter of a mile wide. It has a rapid current and falls about 160 feet in crossing the area, from an altitude of nearly 840 feet to one of less than 680 feet above sea level. The slope of the stream is not gradual nor uniform in the district. Fully half the fall, 85 feet, is at the falls and rapids of St. Anthony. (See Pl. II.) From the northwest corner of the Anoka quadrangle to the falls the descent is 40 feet. At Coon Rapids the river is shallow and wide and its bottom is strewn with bowlders and at times of low water the slope of the stream is at places notably greater than at other times. From below St. Anthony Falls and rapids to Gray Cloud Island, in the southeast corner of the St. Paul quadrangle, the descent is 40 feet, but the gradient decreases so much that the current, which for the first mile is swift, diminishes in rate to St. Paul. Even at high stages the river flows mainly between high banks without flood plains as far down as the mouth of Minnesota River, at Fort Snelling, but from that place to Gray Cloud Island the banks are mainly low and the flood plain ranges in width from half a mile to nearly 2 miles. The islands in the stream, except Nicollet and Hennepin islands and a part of Gray Cloud Island, are parts of the flood plain.

Minnesota River, which enters the area a few miles north of the southwest corner of the Minneapolis quadrangle and joins the Mississippi near Mendota, is normally 300 to 400 feet wide, but at times of flood it spreads like a lake over the marshes of the adjoining flood plain. It is deep but sluggish, and as its gradient is low its course is somewhat crooked, and its current is influenced by the variations in the stage of the Mississippi.

Rum River enters the Anoka quadrangle near the middle of its north side and joins the Mississippi at Anoka. Its length in this stretch is less than 6 miles. It is closely confined, even at flood stages, between banks 20 to 40 feet high. It is ponded by a dam at Anoka.

Coon Creek, which drains the northwestern part of the White Bear quadrangle and the northeastern part of the Anoka quadrangle, rises in Wiregrass Marsh near the middle of the north side of the White Bear quadrangle. It flows west nearly to Round Lake, and there turns abruptly a little east of south and follows that course to the Mississippi. It has low banks and meanders in part across broad bogs or swamps, in part along a well-defined narrow valley between low hills. It receives the drainage of the marsh through several ditches. From Coon Creek station it descends to the river through a terraced gorge.

Rice Creek, which drains the northeastern, eastern, central, and western parts of the White Bear quadrangle, rises just outside the northeast corner of the quadrangle and flows southwestward to the Mississippi at Fridley. In the upper half of its course it flows through a chain of swamps and lakes; in the lower half through a well-defined meandering valley with flat bottom and between banks 20 to 40 feet high. Its chief branch, Clearwater Creek, receives the overflow of White Bear Lake through Bald Eagle Lake. Another branch rises just north of Johanna Lake and flows through Long Lake. The flow of Rice Creek has been greatly depleted by conduits leading from Centerville Lake and from Baldwin Lake to the St. Paul water system.

The southeastern part of the White Bear quadrangle and the northeastern part of the St. Paul quadrangle, including a large part of the area now occupied by the city, were formerly drained by two branches of Phalen Creek, flowing respectively from Phalen Lake and from McCarron Lake. The flow of the streams has been greatly depleted by the use of the water of the lakes for a part of the city supply, and the streams have been largely obliterated by the erection of buildings, but a small stream still reaches the river at the south side of the city.

Elm Creek, which drains the western part of the Anoka quadrangle, rises west of it and flows northeastward, with a fall of about 50 feet, through Rice and Hayden lakes to the Mississippi opposite Anoka. Its chief branches are Rush Creek and the creek draining Diamond Lake, streams that in parts of their courses flow through narrow irregular valleys and in other parts through swamps and lakes.

Shingle Creek drains the central portion of the Anoka quadrangle, flowing from Eagle Lake to the Mississippi at Camden. It flows at first northward along the border of the plains, then eastward through a shallow valley to Palmer Lake, thence southward and southeastward to the Mississippi. In the lower part of its course it now runs through an artificial channel. Its total fall is about 80 feet, of which about 40 feet is in the last mile.

Bassett Creek drains the southern part of the Anoka quadrangle and the northern part of the Minneapolis quadrangle. It flows from the south end of Medicine Lake through Minneapolis to the Mississippi opposite Nicollet Island. It is very crooked, and it flows through a succession of swamps, between which it falls rapidly.

Minnehaha Creek flows in general eastward across the Minneapolis quadrangle from Lake Minnetonka to the Mississippi not far above Fort Snelling. In the greater part of its course it flows through swamps and small ponds that are separated by short stretches of narrow valley. About half a mile from its mouth it plunges into a gorge nearly 100 feet deep, forming the famous Minnehaha Falls. (See Pl. VIII.) From Lake Minnetonka to the Mississippi the stream falls about 230 feet, 125 feet of its descent lying between the lake and the brink of the falls, which are 65 feet high. The stream has one small tributary, which flows from Harriet and Calhoun lakes. It is ponded at Edina by a milldam.

Ninemile Creek, which drains the central part of the Minneapolis quadrangle, has two main branches, one rising near Hopkins and the other in Island Lake, and flows southeastward to the Minnesota. As far as Bloomington these streams flow between low banks and across swampy basins, its descent between the basins being rapid. Near Bloomington the creek enters a valley and descends nearly 100 feet in 2 miles before it emerges upon the flood plain of the Minnesota, where it turns westward about a mile to join that river.

Purgatory Creek rises in several small branches from springs, lakes, and swamps south of Lake Minnetonka and drains the western part of the Minneapolis quadrangle. It flows southeastward to the Minnesota, its course being mainly across flat swampy lands, but in the last 3 miles it descends a hundred feet through a gorge in the gravel plain of Eden Prairie.

Credit River flows northward into the Minnesota at Savage (formerly Glendale). It enters the Minneapolis quadrangle in a deep, narrow valley, from which it emerges upon the flood plain of the Minnesota. Many small spring creeks flow from the slopes bounding the large valleys into the Minnesota and into the Mississippi below Minneapolis.

Lakes.—More than 600 lakes, about 130 of which have been named, are shown on the maps of the four quadrangles. Lake Minnetonka, which is more than 10 miles long, and White Bear Lake, also a large lake, are only partly within the area. Bald Eagle and Medicine lakes are each more than 2½ miles long and a mile wide, and thirty of the other lakes are a mile or more in greatest diameter. Besides the many small lakes mapped, there are others too small to be shown.

Most of the larger lakes have surface outlets, either through streams or through swamps. Most of the small lakes have no outlet. Twelve of the lakes, of which Terrell Lake is the largest, occupy depressions in the flood plain of the Minnesota-Mississippi valley and are called river lakes. A few others, such as Deans Lake and Sandy Lake, occupy basins made or walled in by dune sand. All the rest are in basins of glacial origin. Some of the lakes are said to be 100 feet deep, but many are very shallow, there being all stages between clear lakes and mere swamps.

CLIMATE AND VEGETATION.

The climate in this area is that of the northern midcontinental region. The summers are warm, the winters are cold, the winds vary greatly in direction and force, and the daily temperatures show considerable changes. The annual rainfall ranges from 10 to 45 inches, but in most years is between 20 and 35 inches. The average annual rainfall for 75 years is about 27 inches. There is more or less snow in winter and early in spring. The rainfall is generally greatest at the time of the growth of early vegetation, in May and June. Nearly all the trees and shrubs are deciduous.

In its wild state this area was in large part covered with forests but included some small prairies. Those parts that are marked on the geologic maps as dune sands and gravel outwash plains were overgrown with prairie vegetation, chiefly grass and shrubs, but bore also a few trees, such as burr oak (*Quercus macrocarpa*), black oak (*Quercus velutina*), and aspen (*Populus tremuloides*). The hilly tracts were generally wooded, except the steep southern slopes, which were covered with prairie vegetation and a few trees. The northern slopes were the more heavily wooded. The tracts of red till shown on the geologic maps were less heavily forested than the tracts of gray till, which bore the "big woods" of white oak (*Quercus alba*), maple (*Acer saccharum*), linden or basswood (*Tilia americana*), and elm (*Ulmus americana*). Coniferous trees—the white pine and tree juniper or red cedar—grew on a few cliffs in this area. The white birch grew on cliffs and also on steep north slopes. The alluvial lands bore willow, elm, linden, cottonwood, and here and there oak and maple. In the swamps there were forests of the tamarack or larch (*Larix laricina*), a deciduous conifer.

At present only a small part of the original forest and prairie remains, though small tracts of each surrounded by pastures and fields of exotic plants are seen in nearly all parts of the area. Some swamps still remain, though by cutting and burning most of them have been changed to marsh or meadowland.

CULTURE.

The population of the area is about 500,000 and is chiefly urban. Minneapolis, the metropolis of the State, stands near the center of the area and embraces the adjacent corners of the four quadrangles. St. Paul, the capital of the State, is east of Minneapolis, in the northern part of the St. Paul quadrangle. Besides the "twin cities" and several suburban towns and villages, White Bear, Centerville, Anoka, Champlin, Osseo, Savage (formerly called Glendale), and Mendota are within the area. The suburban and rural population have taken up and utilized nearly all the land outside the cities and towns.

The relation of the cities, towns, and villages to the rivers and lakes is obvious. The three important rivers—Mississippi, Minnesota, and Rum rivers—were the routes along which the early explorers and traders passed through the region. At the mouth of the Minnesota are the oldest posts in this region—Fort Snelling (established in 1823 and still a military post) and Mendota. St. Paul is the first convenient harbor below the junction of Minnesota and Mississippi rivers. St. Anthony, now East Minneapolis, is at the falls on the Mississippi. Anoka is at the mouth of Rum River.

In their earlier growth the cities were built along the river banks, but later they were extended farther away from their original sites. St. Paul and Minneapolis are growing more in the direction of the gravelly plains of glacial outwash than in the direction of the clay hills of the glacial moraines, as may be seen by referring to the accompanying geologic maps. Anoka lies upon a flat gravel plain, as do also White Bear, Osseo, and the suburban towns, Camden, St. Louis Park, West Minneapolis, South St. Paul, and New Brighton. Many lakes lie within the area and their scenic attractions and the advantages which they afford notably influence the distribution of the population.

Manufacturing and trade are the chief industries. Furs, lumber, and flour, which were once the chief manufactures, are still important products and many others have been added. In the "twin cities" there is a very efficient railway transfer system for receiving and discharging freight. All the great railway systems of the State center in the "twin cities." Most of the railways run along the natural routes afforded by the valleys of the great rivers. During half the year steamboat navigation, which was very important before the advent of railways, about 1875, is still a notable industry, and as a result of the construction of dams in the river as far up as Minneapolis, it is now increasing. Meanwhile lumbering by floating logs and rafts on the river has ceased.

All parts of the two large cities are united by one electric street-railway system. Electric railway lines have been extended also from the "twin cities" to neighboring towns—Anoka, White Bear, St. Louis Park, Hopkins, and West Minneapolis, several points on Lake Minnetonka, Savage (Glendale), and South St. Paul. Besides the paved streets of the cities, macadamized highways, "boulevards," extend between the "twin cities" and out to White Bear and Minnetonka lakes.

GEOLOGY.

STRATIGRAPHY.

GENERAL CHARACTER OF THE ROCKS.

The rocks of the Minneapolis and St. Paul area are of sedimentary origin, but they fall into two distinct groups—hard stratified rocks of Ordovician age, consisting of limestone, shale, and sandstone, which everywhere form the bedrock beneath the surface deposits, and unconsolidated surficial deposits of Quaternary age, comprising glacial drift and alluvial gravel, sand, and silt, which occupy nearly the whole surface of the area. The surface of the bedrock upon which the Quaternary deposits lie is irregular and in some places the deposits are as much as 400 feet thick, though their average thickness is probably between 100 and 150 feet.

The hard rocks are exposed at only a few places, along Mississippi and Minnesota rivers, where the surficial cover has been swept away, but they have been encountered in many excavations and borings throughout the area. Their areal distribution, as nearly as it can be determined from the data available, is shown in figure 7. The thickness of the exposed hard rocks is about 400 feet, but beneath them, as is shown by several deep borings, there lies a further thickness of 1,600 to 1,700 feet of strata of Cambrian and Algonkian (?) age. The whole series of stratified rocks is believed to rest on a floor of pre-Cambrian granite, which was reached in one boring that penetrated the entire series. The sequence, thickness, and general character of the rocks of the area are shown in the generalized columnar sections and well sections, figures 5, 6, and 8. The several formations will be described in the order of their age, beginning with the oldest.

ROCKS NOT EXPOSED.

PRE-CAMBRIAN GRANITE.

The lowest formation known beneath the area is the granite that was reached in a boring in Minneapolis known as the Lakewood Cemetery well. (See fig. 5.) At the bottom of the boring, which was 2,150 feet deep and reached 1,250 feet below sea level, the drill penetrated granite for about 15 feet. A sample of the granite from the boring was examined by Prof. C. W. Hall, who reported that it contained quartz, feldspar (both orthoclase and plagioclase), hornblende, and a chloritic mineral. Nothing is known regarding the areal extent of the granite beneath the area, but undoubtedly it or other crystalline rocks of pre-Cambrian age underlie the whole area and form a floor upon which the stratified rocks were laid down, as crystalline rocks of the same general age outcrop not many miles away in several directions from the area.

ALGONKIAN (?) SYSTEM.

Red clastic series.—Upon the granite in the Lakewood Cemetery well there lies a formation to which has been applied the descriptive name "red clastic series" because of incomplete

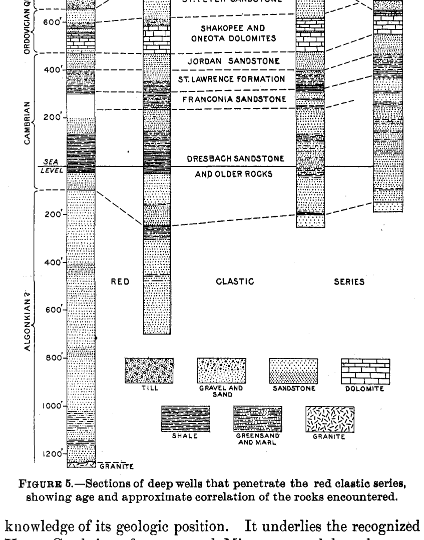


FIGURE 5.—Sections of deep wells that penetrate the red clastic series, showing age and approximate correlation of the rocks encountered.

knowledge of its geologic position. It underlies the recognized Upper Cambrian of east-central Minnesota and has the same general character as the red sandstones that are interbedded with the Keweenawan diabase in the Lake Superior region.

It comprises an alternating succession, more than 1,100 feet thick, of coarse and fine red sandstones and red shale without regular or as yet recognizable divisions into formations.

A number of deep wells in the area have penetrated the red sandstones and shales. (See fig. 5.) The Lakewood Cemetery well is reported by Prof. C. W. Hall to have entered them at a depth of 1,010 feet and to have passed through them to a depth of 2,150 feet. The rocks are recognized by their red or pink color, although the series includes some white sandstone and green shale. The color and stratigraphic position of the series and its known wide extent in the region indicate that it is the same formation as the red sandstones of the Lake Superior region, the sandstone at Hinckley, Minn., and the conglomerate at New Ulm, Minn.

CAMBRIAN SYSTEM.

UPPER CAMBRIAN SERIES.

General features. — The strata of Cambrian age consist chiefly of coarse white sandstone, fine greensand, and green shale, with some dolomitic limestone and pink shale. In well borings they are distinguished from the underlying red clastic series by their green color, where they are colored, and from the overlying Ordovician strata by the absence of massive dolomite or limestone as well as by the presence of greensand. Greensand does not occur in the Ordovician sandstones, although the glauconite grains that give the greensand its color are found sparingly in the Ordovician dolomites. The line of demarcation between the Cambrian and Ordovician strata is readily noted in well borings, as the lowest Ordovician formation is a massive dolomite and the uppermost Cambrian bed is a coarse white sandstone.

Below the top of the Cambrian there are alternating zones of white sandstone and greensand that are not easily distinguished from one another in well borings. In a boring that encounters the lowermost Ordovician strata each zone may be identified more or less definitely by its distance below those beds, but in a boring that passes directly from the glacial drift into the Cambrian strata such identification is not easy.

In neighboring districts, where Upper Cambrian strata are exposed, they have been divided by Walcott and Ulrich into the Mount Simon grit, Eau Claire sandstone, Dresbach sandstone, Franconia sandstone, St. Lawrence formation, and Jordan sandstone, named in order of deposition. Such division is facilitated by the existence of characteristic fossiliferous zones in the Franconia sandstone and in the top of the St. Lawrence formation, and by the presence of three dolomites or calcareous beds here, one in the Franconia sandstone, one near the base of the St. Lawrence formation, and one near the top of that formation. (See fig. 6.) The beds of glauconitic sand or greensand are not regularly distributed through the Upper Cambrian series owing to the cross lamination and lenticular bedding that prevails in that series.

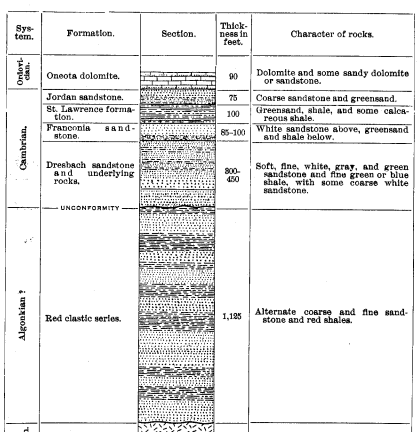


FIGURE 6.—Generalized columnar section of rocks not exposed at the surface, encountered in deep wells in the Minneapolis and St. Paul district.
Scale: 1 inch=500 feet.

Dresbach sandstone and older Cambrian rocks.—The red clastic series is overlain by 350 feet or more of soft fine white, gray, or green sandstone, at least one coarse white water-bearing sandstone, and much fine green or blue shale. (See fig. 6.) These rocks are thicker in the East Minneapolis well than in the Lakewood Cemetery well. Probably they lie unconformably on the red clastic series, and the lowermost beds fill depressions in the surface of the rocks of that series.

The upper and larger part of these beds is assigned to the Dresbach sandstone, which is named from Dresbach, Minn., where about 200 feet of friable white and light greenish-gray sandstone belonging to the formation is exposed beneath the Franconia sandstone. There is still difference of opinion as to the lower limit of the Dresbach, but the formation undoubtedly includes the lowermost of the coarse white cross-bedded water-bearing sandstones that are penetrated in deep borings in these quadrangles.

Franconia sandstone.—The Dresbach sandstone, as is shown by the deep borings, is overlain by beds of greensand and calcareous shale, which are succeeded above by another coarse white water-bearing sandstone. These beds, which are in all borings a similar bed is found near its base. In the texture and hardness of the rocks the formation as a whole is much like the greensand beds of the Franconia.

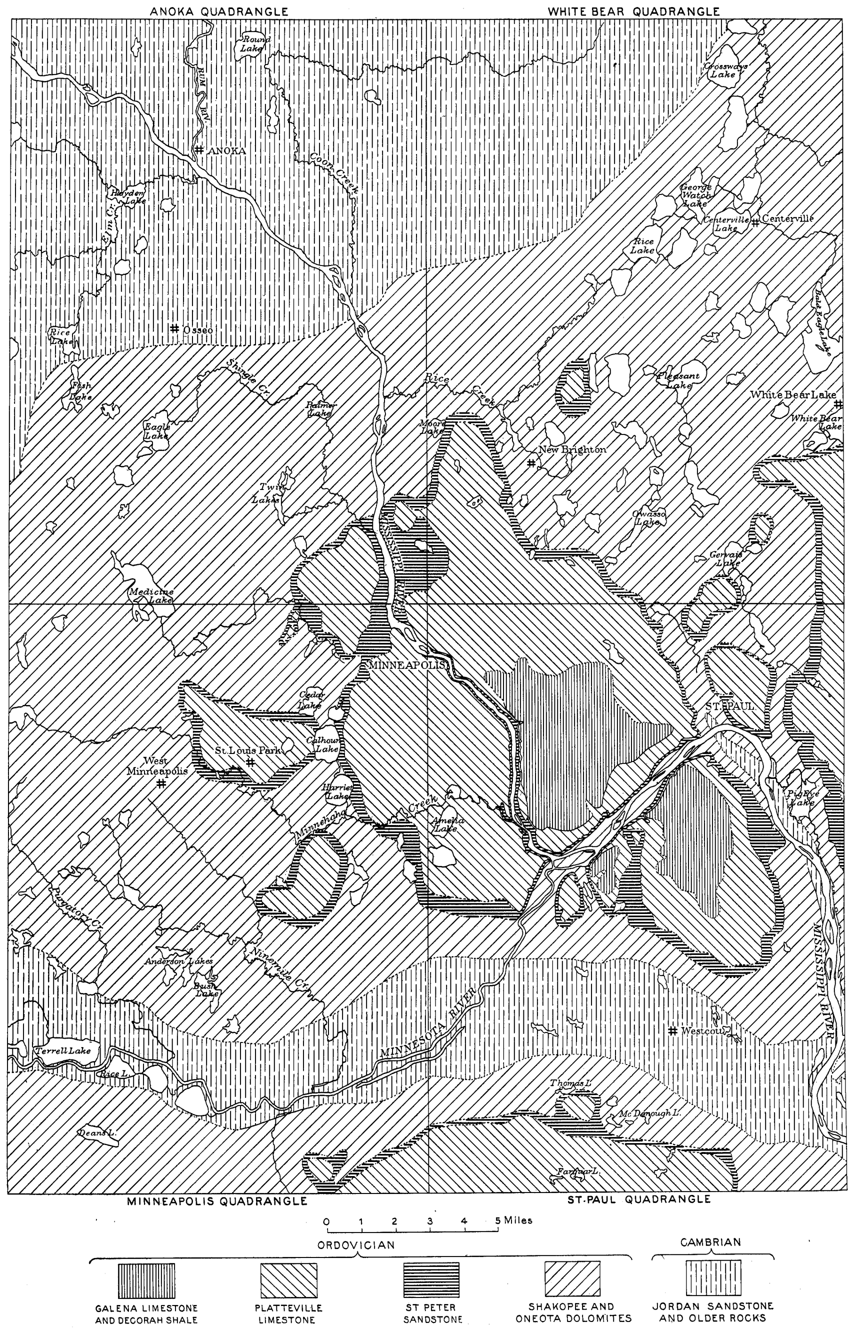


FIGURE 7.—Geologic map of the Minneapolis and St. Paul district showing distribution of the bedrock at the surface and beneath the drift.

about 85 feet thick, are assigned to the Franconia sandstone, so named from Franconia, Minn., in the St. Croix Valley, where the formation is typically exposed. The Franconia formation is characterized by the fossil *Conokephalina misa* (Hall), which is found in the white sandstone.

St. Lawrence formation.—The Franconia sandstone is overlain by about 100 feet of greensand and shale that is correlated with the St. Lawrence formation. In its upper part it contains a bed of dolomitic or, in places, calcareous shale, and in some

The formation is named from St. Lawrence, Minn., where 8 feet of buff crystalline dolomite with interbedded thin shaly and sandy layers is well exposed. The dolomite contains a few scattered grains of glauconite and a few fossils, among them *Dikellocephalus minnesotense* Owen and *Billingsella coloradoensis* Shumard. The dolomitic strata, as well as a great thickness of variously interbedded green shale, fine greensand, white sandy laminæ, and a little red shale, are exposed at several other places in the region.

Jordan sandstone. — The uppermost Cambrian formation penetrated in the deep borings consists of 75 feet of water-bearing sandstone. Its lower part, which grades downward into the St. Lawrence formation, is fine friable cross-bedded sandstone including greensand in alternate beds. The sandstone becomes progressively coarser and whiter toward its top, its most characteristic part, which is very coarse, white, and friable and is made up of clear well-rounded quartz grains. This coarse-grained porous upper part has been leached by circulating meteoric waters and has thus been altered by the removal of cementing material and impurities.

This formation is readily recognized as the Jordan sandstone, which is exposed in typical form along Sand Creek at Jordan, Minn., a few miles beyond the southwest corner of the area here described.

ROCKS EXPOSED.

ORDOVICIAN SYSTEM.

GENERAL FEATURES.

All the hard stratified rocks exposed at the surface in the Minneapolis and St. Paul area are of Ordovician age. The exposures are found only along the valleys of Mississippi and Minnesota rivers and at Sweeney Twin Lake. The distribution of the bedrock exposed at the surface and beneath the drift in the area is shown in figure 7 (p. 4). At some places in the area these rocks may be as much as 500 feet thick.

The Ordovician strata overlie Upper Cambrian strata in apparently conformable succession. They comprise beds of Lower and Middle Ordovician age and have been divided into the following formations, named in ascending order: Oneota dolomite, Shakopee dolomite, St. Peter sandstone, Platteville limestone, Decorah shale, and Galena limestone. (See fig. 8.)

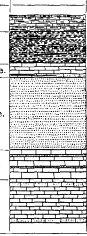
System.	Formation.	Section.	Thickness in feet.	Character of rocks.
Ordovician.	Galena limestone.		35	Shaly limestone.
	Decorah shale.		65	Green clay shale with lenticular layers of crystalline limestone.
	Platteville limestone.		30	Blue and brown limestone, impure at base.
	St. Peter sandstone.		150	White friable sandstone.
	Shakopee dolomite.		60	Chiefly massive dolomite with some interbedded sandstone.
	Oneota dolomite.		90	Dolomite with some sandstone or sandy dolomite at base and near top.

FIGURE 8.—Generalized columnar section of rocks exposed at the surface in the Minneapolis and St. Paul district.
Scale: 1 inch=200 feet.

ONEOTA DOLOMITE.

Name and distribution.—The Oneota dolomite is named from its typical exposures along Oneota River in northeastern Iowa. Only the uppermost beds of the formation are exposed in the Minneapolis and St. Paul area, occurring in small outcrops just above the level of the Mississippi bottom close to the point where the river leaves the St. Paul quadrangle. The formation is well exposed east of the quadrangle and also at Merriam, just outside the southwest corner of the Minneapolis quadrangle.

Thickness.—In the area herein described the formation is 90 feet thick. Its thickness ranges from 60 feet at its northern limit to 150 feet in southern Minnesota. Many of the strata are of irregular thickness and in some places the thin parts of a number of strata coincide, so that here and there the formation is much thinner than elsewhere. Its upper surface is therefore billowy and uneven.

Character.—The character of the formation in the Minneapolis and St. Paul area, as shown by borings, is the same as in neighboring localities where it is better exposed. It consists chiefly of dolomite, but at its base and also near its top it contains, in most sections, some interbedded sandstone or sandy dolomite, which is associated with oolitic dolomite. The dolomite composing the bulk of the formation is thick bedded, massive, and jointed both horizontally and vertically. Its color is gray, pink, or buff, and its texture either compact, granular, or porous.

The formation has undergone considerable alteration, as is shown by the dolomitized shells of gastropods and tests of trilobites that it contains. The fossils in the fine-grained compact beds are generally compressed or fractured and those in the porous beds are nearly destroyed. Some of the porous beds contain concretions of chert and geodes of quartz and dolomite. In some places the rock has a porous brecciated structure; in others it contains irregular small caverns; and in still other places some of its joints have been enlarged by watercourses, here and there containing loose white sand.

Fossils.—Fossils have been found in the formation only near its top. They are preserved as chert casts from refilled molds, as hollow molds, or as dolomitized shells. The fauna consists of a few species each of trilobites, brachiopods, gastropods, and cephalopods. Among the more common species are *Piloceras corniculum* Sardeson, *Raphistoma minnesotense* Owen, *Pleurotomaria* (*Plethospira*) *obesa* Whitfield, and *Murchisonia putilla* Sardeson.

Origin.—That the formation is marine is shown by the fossils and that it was deposited in shallow water is shown by the oolite and the interbedded coarse sandstones. Near the top and bottom of the formation are zones, 1 to 10 feet thick, of large Cryptozoa resembling concretions. They have the same rock texture as the surrounding matrix but have a hemispheric concentric structure. Fragments of them are found as pebbles in the associated intraformational conglomerate; hence they are contemporaneous in origin with the formation. They are either algal or coral reefs and probably the same origin can be ascribed to the formation as a whole except the sandstones and some shaly layers. The interstratified sandstone and dolomite in the basal part of the formation includes some irregular conglomeratic structure of reefs broken up in shallow water. In other places the reefs are faulted or brecciated in a way most readily explained as due to the removal by solution of original beds or lenses of salt or other soluble rock.

SHAKOPEE DOLOMITE.

Name and distribution.—The Shakopee dolomite is named from Shakopee, Minn., just beyond the western border of the Minneapolis quadrangle, where the rock is typically exposed. Between that place and Deans Lake it lies so near the surface in places that it is struck in plowing. It outcrops at Savage (called Glendale on the maps), on Gray Cloud Island, and at places farther north along the river, where it forms cliffs on both sides of the flood plain. The full thickness of the formation is exposed in the Mississippi River valley in the southeast corner of the St. Paul quadrangle.

Thickness.—The formation is about 60 feet thick. At Shakopee, at Savage (Glendale), and at Inver Grove its upper surface is irregular and is marked by low domes or swells, with corresponding arching of the strata. The tops of the domes have been eroded away, but the arching strata indicate that the surface, if restored, would have local differences of 10 to 30 feet in altitude. At Newport the upper surface is much more uniform.

The doming of the surface, where seen, is variously repeated at intervals of a few or of many rods. Some of the domes have a surficial aspect; they do not extend to the base of the formation. Others correspond to inequalities in the surface of the Oneota dolomite. Most of the domes are due to several superimposed strata of unequal thickness, and in places a thickening in one set of strata is equalized by a thinning in the overlying ones, so that no dome shows at the surface of the formation. Still other domes are in part original reef-like structures. Aside from the Cryptozoon reefs the formation was probably deposited in fairly regular strata, most of the present irregularities being apparently due to alteration.

Character.—The formation consists chiefly of dolomite but includes some sandstone and sandy layers. The strata are generally massive, but many are irregular in thickness and in jointing. That the beds were laid down in a shallow sea is shown by the coarse sandy layers, oolite, conglomeratic beds, reefs, and marine fossils.

In the quarries at Shakopee the formation includes at least three interstratified sandstone beds, which are distinctly arched, bent, and crushed. The sandstone is composed of coarse rounded quartz grains, and either the interstices between the grains are completely filled with granular dolomite, or the grains are cemented at their points of contact only, or they are uncemented and loose. The different phases grade horizontally from one to another in the same stratum.

The dolomite also differs in different places, part of it being shaly, but firm fine-grained limestone is more typical. Some of the firm fine-grained rock is fractured and brecciated, and in places the fractures are lined with dolomite crystals, the rock bordering the fractures being megascopically more or less crystalline. This kind grades into a rock that is coarsely granular and crystalline throughout and that again into crystalline cavernous dolomite. (See Pl. VI.) Some caverns are several feet in diameter and contain loose rusty angular fragments of dolomite and some clay. As a rule the firmer rock is found in the domes or hummocks and the leached cavernous parts in the intervening basins. More or less alteration is evident, however, in all parts of the formation.

Fossils.—Fossils may occur in any part of the formation, although they are not found in most exposures. Good fossils have been found only at Shakopee and near Newport. Organic remains were probably buried in only a few of the strata and have been more or less completely destroyed by subsequent alteration of the rock. Defaced casts of molluscan shells are the most abundant, but where good fossils occur they are fairly plentiful. Both casts and dolomitized shells are found. The most common species are the following;

Eccyliomphalus sp.
Raphistoma ruidum.
Hormotoma argylensis (Murchisonia argylensis).
Trochonema pecatonica (Helicotoma pecatonica).
Fusispira exacta (Subulites exactus).
Endoceras consuetum.
Eurystomites kellogi.

Of these the first one characterizes the higher strata of the formation and the fifth and seventh the lower strata.

Large hemispheric concretion-like bodies called *Cryptozoon minnesotense* (see Pl. VII) occur in the Shakopee formation and are similar to those in the Oneota dolomite. They have a concentric structure but are nearly everywhere confluent with the normal bedding and have the same texture as the surrounding matrix. They occur in zones or reefs and apparently are algal structures.

ST. PETER SANDSTONE.

Name and distribution.—The St. Peter sandstone is named from St. Peter River, as Minnesota River was formerly called, near the mouth of which, at Fort Snelling, the white saccharoidal sandstone of the formation is typically exposed. The exposures there, however, are only a part of outcrops that extend along the escarpment on each side of the gorge of the Mississippi beneath a capping of limestone, from Minneapolis to St. Paul. (See Pls. III and IV.) The formation is exposed in like manner for 2 miles on both sides of Minnesota Valley. North of Minneapolis, at Camden and Columbia Heights, there are outlying escarpments of the formation, capped as usual by limestone, and at South St. Paul, Oakland, and Highwood (Highland on the map) there are isolated exposures of the sandstone. A small island in the swamp of Minnesota Valley, 2 miles above Fort Snelling, is formed of St. Peter sandstone.

A characteristic of the formation is the small surface area of its outcrop, as it is found mainly in steep escarpments. It is easily eroded and crumbles rapidly to loose sand on exposure to weathering but is in places protected by the overlying limestone, so that wherever the limestone has been removed the sandstone also has generally been removed, either down to the bottom of the valleys or down to the underlying limestone.

Thickness.—The formation is about 150 feet thick. At Highwood its top is exposed and the sandstone crops out for 140 feet below the top, the base being concealed. A maximum thickness of more than 160 feet is given in published records of well borings. In some such records the top of the Shakopee may have been included as St. Peter sandstone, yet the thickness of the St. Peter is certainly more than 140 feet. At Fort Snelling the sandstone is exposed for 75 feet above the level of the river and, as is shown by borings, extends about 70 feet below that level, so that its total thickness there is 145 feet. The thickness probably differs 20 feet or more within short distances, the differences according with the unevenness of the surface of the Shakopee upon which the formation rests. It is not certainly known, however, that the surface of the Shakopee is as uneven beneath the undisturbed St. Peter as it is where the Shakopee is uncovered.

Character.—The formation is typically a very white sandstone, made up of grains of limpid quartz that are polished to a dead or dull surface and well rounded. It contains little cementing material or impurities of any sort and is therefore porous, friable, and easily fractured. (See Pl. V.) Analyses show that it contains more than 99 per cent silica. Its dazzling whiteness gives the rock a deceptive appearance of uniform grain and structure, but in fact its grains range in size from fine dust to particles a millimeter or more in diameter. The sandstone is thick bedded and jointed, but the bedding and the joints, as well as the cross-lamination, fractures, and faults, appear clearly only where the rock is cemented by calcium carbonate or is stained by iron oxide. The cross-lamination is that of a water-laid deposit. The lower part of the formation is marked by more impurities and discoloration than the upper part and contains some fine siltlike or shaly beds.

The typical white color of the sandstone is due to leaching. The formation is water-bearing and probably has lain in a slightly tilted position, with one edge exposed where water could penetrate it, so that it has been in a position to be leached by descending water, which accounts for its remarkable purity. Even where the sandstone contains numerous fossils in the form of casts not only have the thick calcareous shells been removed but the matrix consists of 99.78 per cent silica, with only a trace of iron and magnesium and no calcium. The entire absence of the original calcareous material of the shell, even from the matrix, indicates very thorough leaching. The original thickness of the shells is shown by the deep muscle scars and marked lines of growth, but the spaces where the shells once were have been closed up and the form of the interior is impressed into the cast of the exterior, showing that the sandstone has been compacted as well as leached. The compacting appears to have kept pace with the leaching.

At Highwood molds of fossils were found partly filled with loose sand only and presenting casts of the interiors of the shells instead of the exteriors. The process by which such fossils were produced must have been gradual. After a shell was buried and the matrix had set, the shell was dissolved away, leaving a solid cast of the interior within a mold of the exterior. The matrix was then further compacted, probably because of the leaching out of its cement, and a new mold was formed about the cast, the obverse of the original interior surface of the shell. The cementing material of the internal cast having been removed by leaching, loose sand was left within the mold. The same matrix contains also distorted compressed reverse casts formed in a similar manner.

Fossils.—Fossils are found at Dayton Bluff in white, slightly cemented sandstone from 60 to 80 feet below the top of the formation. At South St. Paul many fossils are found in white cemented cross-laminated sandstone at a little lower horizon than that at Dayton Bluff. Near Highwood they have been found at a still lower horizon in distorted strata that are stained yellow or brown. All the fossils are casts of the shells of marine mollusks. The principal species are:

Modiolopsis gregalis.	Ctenodonta novicia.
Modiolopsis litoralis.	Pleurotomaria (Plethospira) aiens.
Modiolopsis contigua.	Ophileta fausta.
Vanuxemia fragosum.	Orthoceras minnesotense.
Cypricardites descriptus.	

All the species are different from those of the Shakopee dolomite. The fauna is, in fact, more closely related to that of the Platteville limestone than to that of the Shakopee, as it includes a large proportion of Pelecypoda, species of which are not found in the region in formations older than the St. Peter sandstone but are of common occurrence in younger formations. The species are, however, also different from those of the Platteville, and aside from its general relations the fauna as a whole or in part is not correlated with any other known fauna.

Relations.—The basal contact of the formation is sharp and without transition beds. The Shakopee dolomite includes several intercalated beds of sandstone, but the sandstone that abruptly succeeds the highest bed of dolomite is the basal bed of the St. Peter. No unconformity is evident at the contact, and the basal beds conform to the irregularities of the surface of the Shakopee, already described. At the top the formation grades into the overlying Platteville limestone through a thin transition zone, the change from white sandstone to green shale and limestone including an intervening mixed stratum. The tilting or dip of the strata in this region, which increases from the base to the top of the Oneota dolomite and culminates at the upper surface of the Shakopee dolomite, is compensated by warping and faulting in the lower part of the St. Peter sandstone, so that the upper part of that formation and the overlying limestones and shales are not so greatly tilted. The upper and lower surfaces of the St. Peter are therefore not parallel, but the deformation appears to be wholly secondary and not due to deposition on an eroded surface. In the opinion of the author, the St. Peter sandstone was laid down horizontally and conformably on a level surface of the Shakopee dolomite and was covered conformably by the beds of the Platteville limestone. At a later time the leaching of the sandstone and the solution of constituents from the underlying formations produced a gradual settling and distortion in the base of the St. Peter and in the underlying dolomite.

PLATTEVILLE LIMESTONE.

Name, thickness, and distribution.—In earlier geologic reports the name Trenton limestone was applied to the formation that is now called Platteville limestone, but the younger Galena limestone is now regarded as representing the Trenton epoch. The Platteville limestone is 30 feet thick, this thickness including the shaly transition strata at its base. Its occurrence in this area at the crest of escarpments and upon the St. Peter sandstone has already been noted. In such places it lies mainly at the surface in water-swept rock benches—the terraces of glacial rivers—along the present valley of the Mississippi. (See Pls. III and IV.) It is exposed in vertical section along the crest of the Mississippi escarpments and is quarried at many such places. It is the hard stratum over which the river tumbles at St. Anthony Falls. (See Pls. XXI and XXII.) It is also exposed at a single isolated locality at Sweeney Twin Lake, at the crest of a drift-filled valley.

Character.—The following section at the Government dam near Minnehaha shows the character of the rock and the relative thickness of the several parts:

Section in west bluff of Mississippi River valley near Minnehaha.

	Ft.	in.
Decorah shale:		
Limestone, blue and gray, crystalline		8
Shale, green, with shell fragments	2	6
Limestone, gray, compact, crystalline, in three layers	2	4
Clay or shale, green		4
Limestone, dark brown and blue, carbonaceous and crystalline	1	6
Platteville limestone:		
Corrosion surface.		
Limestone, blue or buff, somewhat magnesian, porous	8	0
Limestone, blue, dense, partly shaly	5	0
Corrosion surface.		
Limestone, with alternate irregular compact laminæ and darker, carbonaceous magnesian layers	13	0
Corrosion surface and pebbles.		
Limestone, gray, porous, with black pebbles	1	0
Shale, green, with cuboidal fracture	1	8
Clay with numerous sandy fucoids		2
Clay, green		3
Sand, impure and cemented		7
Clay parting.		
Sand and clay, equal parts, irregularly mixed		9
St. Peter sandstone down to river	75+	

In the above section the first 4½ feet of beds above the top of the St. Peter sandstone form a lithologic transition from that formation to the Platteville (see Pls. IX and X), but the fossils found in these beds are of the same species as those in the overlying limestone bed and the beds therefore appear to be a part of the younger formation. A similar though not exactly the same series of transition strata occurs in other places.

The lower 13-foot limestone bed, which is very persistent and quite distinct (see Pl. IX), is called by quarrymen the building-stone layer. It is the "Lower Buff limestone," formerly recognized in Wisconsin and Iowa. It is typically massive, but where the overlying limestone and shale have been removed and the limestone has been leached by surface waters it separates into thin uneven layers of blue or buff limestone 1 or 2 inches thick, with buff clay partings. On long exposure the rock separates similarly into layers. The whole bed has intersecting vertical joints at intervals of 10 to 20 feet. The fresh unweathered rock has no horizontal joints but can be split along the seams. It appears everywhere to consist of thin, alternate, irregular-surfaced layers that in transverse section appear more like irregular banding than like lamination. Layers of nearly pure blue magnesian limestone, partly fine grained and compact and partly crystalline, alternate with darker, more or less carbonaceous shaly layers that contain little calcium carbonate and very much magnesium carbonate and silica. Laminæ or lenticular layers, rich in fossils and more crystalline than the rest of the rock, are common. Tests of brachiopods and trilobites are preserved in both the limestone and the shale, but molluscan shells have been dissolved away. The molluscan shells left molds in the limestone that have been refilled by crystalline carbonates, but the molds in the shaly layers have been closed by compression.

The limestone of the 5-foot and 8-foot beds differs as a whole from that of the 13-foot bed in being neither banded nor laminated. The lower bed has the same color as the bed beneath, but the upper one is more nearly buff. Where it has been leached and weathered under cover of soil only, or of soil and subsoil, it is separated into thin yellow or buff layers that include thin clay or shale partings. Where the fresh rock is exposed in vertical section it is divided into three or four massive beds, the exposed edges of which break with conchoidal fracture. The lower or 5-foot bed breaks from frost or from saturation and drying and crumbles to clay in a few seasons. It is in fact almost a shale. The upper or 8-foot bed breaks from frost if it is wet. It is limestone of finely granular, partly crystalline texture and contains fossils, the shells and tests of which are entirely or nearly absorbed, leaving molds lined with glistening crystals of calcite or dolomite and in places pyrite. Shelly layers—a sort of fossil coquina—form crystalline lenticular beds 1 or 2 inches thick and several feet across at intervals of 1 or 2 feet vertically. The 5-foot and 8-foot beds are jointed as a whole vertically, the joints intersecting at intervals of 10 to 20 feet, as in the bed beneath them, though in position and direction the jointing does not as a rule coincide with that in the bed beneath. The presence of several corrosion zones is shown in figure 9.

Fossils.—Fossils are abundant throughout the formation. The faunas of the limestones are much alike, a few of the less common species being different in the two. The different preservation of the fossils and the numerical representation of certain species, such as *Rhynchotrema minnesotensis* in the lower bed and *Vanuxemia rotundata* in the upper bed, are the notable distinctions between them.

The faunas of the Platteville limestone and of the St. Peter sandstone consist of different species, but those of the Platteville limestone and of the Decorah shale are much the same. Some species of the Platteville fauna range upward through the Decorah shale into the Galena limestone, as is shown in the following list:

Asaphus gigas.	Orthis tricenaria.
Bumastus trentonensis.	Hebertella bellarugosa.
Dalmanites callicephalus.	Zygospira recurvirostris.
Ceraurus pleurexanthemus.	Escharopora subrecta.
Conchicolites minor.	Rhinidictya mutabilis.
Conradella compressa.	Hallopora (Callopora) multitabulata.
Lophospira conradana.	Streptelasma profundum.
Lingula iowensis.	Hindia parva.
Crania setigera.	
Strophomena filitexta.	

Alteration.—The formation is not much altered. Its original granular texture is modified by a few scattered crystals of calcite and dolomite and by spots in which recrystallization is nearly complete. The small cracks and cavities are lined or filled with calcite and here and there with pyrite. Solution preceding the crystallization formed cavities by dissolving away fossils and small particles of the granular matrix. The several strata are not equally changed, but in general the lower bed of limestone is less leached and more infiltrated than the upper ones. Vertical compression accompanied the leaching. From one-tenth to one-half the original thickness of the layers has been lost, as is shown by the compression of the fossils. The now impure limestone and shaly layers have suffered most compression.

DECORAH SHALE.

Name and distribution.—The Decorah shale, formerly called the Trenton shale, is found in this area only in the northern part of the St. Paul quadrangle. The locality is the northernmost known occurrence of the formation and is separated by the entire width of Dakota County from the main area occupied by it.

The formation is exposed on both sides of the valley of the Mississippi at St. Paul. The largest exposure is in West St. Paul (see Pl. XI), at the quarry of the Twin City Brick Co. near Pickerel Lake. Others are found in the roadway east of Mendota, and there is a practically continuous line of small outcrops on the northeast side of the river from near the center of St. Paul to the western boundary of the city. The most westerly exposure is at the east end of the Northern Pacific Railway bridge near the State University. East of St. Paul, as indicated by the mixture of shales and fossiliferous limestone in the red drift, there may be a small drift-covered area of the formation at Dayton, and evidently others lie outside the quadrangle near Highwood (Highland) and Dayton.

Thickness and character.—The thickness of the formation is rather more than 60 feet, including about 50 feet of green clay shale and a total of 10 feet of crystalline limestones. The limestones alternate with the shale throughout. There are some persistent beds of limestone at the bottom and top of the formation, but most of the limestone occurs in discontinuous lenticular layers. The formation as a whole is shale (see Pl. XI) comprising three beds, which differ in composition so greatly that they are worked separately in the manufacture of brick and tile and which are further distinguished by faunal differences. The lowest shale bed includes the upper 7 feet 4 inches of the section near Minnehaha given above. The details of the formation are shown in figure 9.

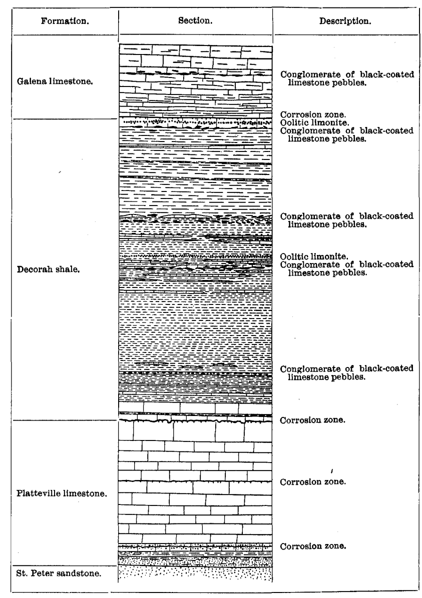


FIGURE 9.—Detailed section of Platteville limestone, Decorah shale, and Galena limestone at St. Paul, Minn., showing corrosion zones and limestone conglomerates.
Scale: 1 inch=20 feet.

The basal bed of the formation is dark brownish-blue pyritiferous crystalline, carbonaceous limestone, with cavities or irregular geodes lined with calcite and pyrite. It is 18 inches thick and forms one or two layers. In some places it is separated by a layer of clay or shale from the Platteville limestone, but in other places the two are united by limestone. In every place the contact is marked by the blackened and corroded surface of the subjacent bed and by abrupt change of color. The basal bed is overlain by about 2 feet of bluish-gray crystalline limestone in three layers, with shaly partings. A third limestone, 6 inches thick, is dark blue and crystalline. These three limestones and some thin fossiliferous layers—about 4 feet thick in all—are included with 6 feet of green shale to make up the lower division of the formation. The middle division, which weathers to a lighter color than the lower one, is about 35 feet thick and is nearly all shale but includes thin lenticular fossiliferous limestone layers. The upper division is again darker and includes thin, more or less regular dark-bluish crystalline limestone. Its topmost bed, 18 inches thick, is dark bluish brown, like the basal bed of the lower division.

There are two thin zones of oolitic limonite as well as four layers of conglomerate consisting of black-coated limestone pebbles, as shown in figure 9. The pebbles are of the same composition as the other limestones of the formation but have black corroded surfaces. They are generally flat, sharp-edged, and from 1 inch to 6 inches wide.

Fossils.—Fossils are abundant in the formation, especially in the limestones. Nearly all except the mollusks are well preserved. Fragments of trilobites and brachiopods and great numbers of bryozoans occur in fine preservation. The three divisions of the formation correspond to distinct faunal zones. Many species occur in one or two zones or beds only; others range either into the Platteville below or the Galena above; and none of the common species characterize the formation as a whole. The Decorah is, in fact, not faunally a unit in this area. It is easily recognized, however, by its association of index fossils, especially brachiopods. A bed near the top of the formation, consisting almost wholly of fucoids (*Camarocladia rugosa*) and shown in Plate XII, may be readily recognized.

Vertical distribution of the common brachiopod index fossils of the Decorah shale and associated formations.

	1	2	3	4	5	6
Orthis tricenaria Conrad	x	x	x	x	x	x
Dalmanella rogata Sardeson	---	---	---	---	x	x
Dalmanella subæquata Conrad (varieties)	x	x	x	x	x	---
Platystrophia lynx Eichwald	---	---	---	---	x	x
Dinorthis pectinella Emmons	---	---	---	---	x	x
Plectambonites minnesotensis Sardeson	---	---	---	---	---	x
Plectambonites sericeus Sowerby	---	---	x	---	x	---
Rhynchotrema increbescens Hall	---	---	---	---	x	x
Rhynchotrema minnesotensis Sardeson	x	x	x	x	---	---
Rhynchotrema ainsliei N. H. Winchell	---	---	x	x	---	---

Nos. 1 and 2 are the lower and upper limestone zones of the Platteville, Nos. 3, 4, and 5 are the lower, middle, and upper divisions of the Decorah, and No. 6 is the Galena.

Alteration.—The formation has been compacted vertically and its content of calcium carbonate has been changed. Most of the limestone contains much crystalline calcite and some pyrite. The shale, on the contrary, is leached. The shells of mollusks are dissolved out and only their casts, filled with fine-grained limestone, remain, with the shale compressed about them. The absence of cavities where the shells were and the general lack of fissility are attributed to vertical recompacting of the rock. The shale is everywhere color-banded but is not laminated or fissile except along some calcareous layers. When fresh it is green, but it weathers buff or brown. On exposure it breaks with cuboidal fracture and weathers to clay in a single season.

GALENA LIMESTONE.

Distribution and thickness.—About 15 feet of limestone and shale that belong to the Galena formation is exposed above the Decorah shale on both sides of the valley at St. Paul. The strata are well exposed in the quarry of the Twin City Brick Co. near Pickerel Lake (see Pl. XI) and also in outcrops from Pickerel Lake more than a mile eastward to High Bridge. On the opposite side of the valley the formation was exposed at intervals for a mile in street grading, especially on Grand Avenue.

The full thickness of the formation, which elsewhere is 100 feet, is not preserved anywhere in the area. A well bored at the old reform school, $1\frac{1}{2}$ miles east of Merriam Park,[1] is said to have penetrated 134 feet of shale and limestone between the glacial drift and the St. Peter sandstone, so that the thickness of the Galena remaining at that place must be 35 feet.

Character.—The exposed strata of the formation are partly limestone and partly shale, both having generally a characteristic lumpy appearance. Some parts consist of clay shale; in other parts irregular rounded lumps of fine-grained limestone are distributed in layers; in still others the lumps are closely aggregated; and some limestone beds appear to consist of such lumps massed and compacted together. Both shale and limestone contain thin layers of fine crystalline limestone and of fossil shells and corals. The formation includes, however, no thick bed of crystalline limestone such as that which forms the top of the Decorah shale.

The fresh rock has a somewhat carbonaceous appearance and is, when fresh, of mixed gray, brown, and dark-bluish color but weathers light green and finally becomes yellowish. The lowermost 7 feet is shaly and very fossiliferous. Intraformational conglomerate occurs in one zone. (See fig. 9.) The pebbles are nearly like those of the Decorah shale but contain fossils and rocks characteristic of the Galena. The shale of the Galena closely resembles the Decorah shale. The preservation of its fossils and the change of its limy constituents resemble that of the other shales in the area, although it is upon the whole more calcareous.

Fossils.—Fossils are preserved in the shaly beds of the formation in great numbers, but they are of somewhat fewer species than those of the Decorah shale. Several kinds, such as *Zygospira recurvirostris* Hall, *Rhynchotrema increbescens* Hall, *Plectambonites minnesotensis* Sardeson, *Pachydictya acuta* Hall, and *Hallopora multitabulata* Ulrich, occur abundantly. *Receptaculites oweni* Hall, which is found in the limestone strata, is a characteristic fossil of the formation.

[1] Winchell, N. H., Minnesota Geol. and Nat. Hist. Survey, vol. 2, p. 259, 1888.

QUATERNARY SYSTEM.

PLEISTOCENE SERIES.

GENERAL RELATIONS.

Character. — A mantle of unconsolidated heterogeneous material, consisting chiefly of glacial drift and reaching in places a thickness of 400 feet, covers the surface of the hard rocks in the area described in this folio except along the Mississippi and Minnesota river bottoms, where it has been partly swept away. It is made up of bowlders, gravel, sand, rock flour, and clay, and much of the stony material consists of fragments of rocks of other sorts than those occurring within the area described. The bowlders in particular are of many varieties of rock, and practically all the formations of northern Minnesota and the neighboring parts of Canada are represented among them. Some rock material of local origin is mingled with débris that has evidently been brought from a distance, and in a few places the drift contains large masses plucked from the underlying bedrock.

The surface of the drift in most of the area is very uneven, its unevenness being due chiefly to inequalities in distribution and deposition but in part to erosion and in part to irregularities in the bedrock surface, which has a known relief of 400 feet within the area. The mantle of drift is not thick enough to obliterate all the irregularities of the bedrock surface, but only in a large way is its surface form consequent upon those irregularities. The drift ranges in thickness from less than 50 to more than 400 feet and, owing to this great difference, its thickness at any place can be estimated only within rather wide limits and can be closely determined only by borings or excavations. Its average thickness in the district is probably between 100 and 150 feet. The chief feature of the drift surface is the great terminal moraine that crosses the southern part of the district in a great loop convex southward.

The surface of the bedrock beneath the mantle of drift is fresh and unweathered and has been glacially eroded and polished. The gouged and pitted surface of the Platteville limestone beneath the drift is shown in Plate XIV. The major features of the preglacial relief still remain, however, and have been worked out from data obtained in outcrops and borings. Chief among them are two valleys, which converge at Gray Cloud Island, one extending from Lake Minnetonka and the other from Vadnais and Phalen lakes. Where the great moraine crosses these valleys their position is indicated by large or deep lakes, such as Lake Minnetonka, Anderson Lakes, and Marcott Lakes. The valleys of the Mississippi and the Minnesota break across the great moraine between the two buried valleys and thus cut deeply through the drift into the bedrock.

At least three drift sheets are readily distinguished in this part of Minnesota. Each consists mainly of till but includes outwash deposits of gravel and sand and some laminated clay. The sheets are distinguished by the color and composition of the till and outwash, and are known respectively as the old gray drift, the red drift, and the young gray drift. The first is regarded as of Kansan age but possibly includes some pre-Kansan, and the other two are regarded as of Wisconsin age. Between the Kansan and the Wisconsin drift are local deposits of silt which appear to be interglacial.

The trend of the striæ on the bedrock in different parts of the State and the direction of ice movement deduced therefrom are shown on the sketch map forming figure 11. In the area of this folio three directions of ice movement are indicated by three sets of striæ. Two sets of striæ may be seen in a street in St. Paul that ascends the south bluff of the Mississippi east of High Bridge, the older trending S. 53°–62° E. and the younger trending S. 10°–14° E. Kansan and Wisconsin red drift are found in that neighborhood and the two sets of striæ were doubtless made by the ice lobes that deposited those two bodies of drift, respectively. At Buchanan and Fifteenth streets NE., Minneapolis, near the southwest corner of the White Bear quadrangle, three sets of glacial striations are found on rock freshly cleared of drift. The oldest, which are polished furrows and fine striæ, trending S. 47°–52° E., were made by the Kansan ice. Those of intermediate age, which are sharp scratches and chatter marks one-fourth inch or less deep and trend S. 2°–4° E., were made by the ice lobe that left the Wisconsin red drift. They cut across the oldest set and both are cut across by the third set, which consists of sharp scratches and chatter marks trending N. 78° E. and were made by the ice that brought the young gray drift.

PRE-KANSAN DRIFT.

Pre-Kansan drift has been recognized at places in Minnesota and Wisconsin on all sides of the Minneapolis and St. Paul district and may at one time have covered the district. Even at those places it has been largely eroded away, only remnants of it being preserved. It has not been certainly identified in the district, though possibly some of the drift regarded as Kansan may be older. The Kansan and the pre-Kansan drift are much alike, both being "old gray drift," and in places where they are not separated by a zone of soil or a weathered and oxidized surface they are not readily distinguished. A small mass of till like the pre-Kansan of neighboring areas, darker and more clayey than that of the recognized Kansan in this area, and containing many fragments of wood, overlies the limestone in the quarry at the foot of Church Street, Minneapolis. It may possibly be of pre-Kansan age.

KANSAN DRIFT.

Distribution and thickness.—All the old gray drift in the district is referred to the Kansan stage, although, as stated above, a little of it may be pre-Kansan. It occurs in many places in the district, over which it doubtless once formed a thick continuous sheet. It has since been greatly eroded and now lies in more or less isolated patches, both in the buried valleys and in the hills. In places it reaches a thickness of more than 200 feet.

Character and relations.—In its deepest part, where it is unleached, the Kansan till is blue-black, but where it has been leached by surface waters it is brownish buff. In both situations it contains numerous pebbles of limestone that have been transported from other areas and some of hard, light-blue shale that splits up on exposure. In the subsoil zone, where it is oxidized, the Kansan till is reddish brown and contains no limestone pebbles. When freshly exposed it is somewhat consolidated, hard, jointed, and stained or leached along the joints. The gravel and sand of Kansan age, when fresh, contain pebbles of several kinds of rock, including many of limestone and a few of shale, but where oxidized, in the subsoil zone, pebbles of limestone and shale are lacking in them as well as in the till. The Kansan drift as a whole contains a relatively large proportion of clay, but it ranges from dense till to nearly clear gravel or sand. As a rule its bowlders are few and large, but in places they are numerous and in other places they are absent.

Where the Kansan drift rests on limestone the surface of the rock is not only fresh and thoroughly eroded but is in places deeply furrowed (see Pl. XIV), and its surface shows everywhere a characteristic polish—rather a clay-polished than a sand-polished surface. Some of the granite bowlders and many of the pebbles have the same polish.

Local details.—Kansan till rises 60 to 80 feet above river level in the north escarpment of the Minnesota River bottom from Terrell Creek to Auto Club, except at Terrell Creek and for half a mile west of Purgatory Creek, where its top is below the valley bottom. Its presence is shown by large protruding bowlders and by small exposures of till along the escarpment. East of Auto Club its top again slopes downward. In these exposures the Kansan is covered by laminated silt and by outwash of the Wisconsin red drift.

Kansan till is exposed also in numerous cuts and outcrops too small to be shown on the maps. It is artificially exposed in cuts along the Minneapolis & St. Louis Railroad near Island Lake and at the highway crossing near the southwest corner of Golden Valley Township in the Minneapolis quadrangle, where 5 feet of fresh buff till with limestone pebbles grades upward into oxidized reddish-brown till without limestone, 3 to 4 feet thick, which is evidently the old weathered surface of the Kansan. It is overlain by 4 feet of blue clay and 5 feet of Wisconsin gray gravel.

Kansan drift, involved in morainic knolls or folds with Wisconsin red and gray drifts, is exposed on the electric railway near Sweeney Lake and north of Glenwood Lake, and at several other places. South of Pickerel Lake and thence eastward to High Bridge, in St. Paul, it lies at a high altitude and consists of a thick basal gravel bed overlain by old gray till. The gravel bed rests on shales belonging to the Galena and Decorah formations and the old gray till is covered by red till of Wisconsin age.

Along the Rock Island Railway between Valley Lake and the wagon road north of Pine Bend hard buff Kansan till appears in two places for a height of 20 feet, with 10 feet of Wisconsin red drift above it. The Kansan was evidently disturbed or plowed up in masses by the Wisconsin glacier. In the quarries near Riverside Park, Minneapolis, Kansan blue-black till, 10 feet thick, is exposed on both sides of the river beneath sheets of Wisconsin red drift and gray drift. On Lexington Avenue, St. Paul, a quarter of a mile southwest of Como Lake, where an underpass beneath the Northern Pacific Railway has been cut through glacial drift, the cut shows about 10 feet of Wisconsin red till over 8 feet of undisturbed laminated silt, beneath which lies 6 feet of Kansan till. Kansan till, beneath 20 feet of Wisconsin red outwash gravel and 10 feet of the young gray outwash, forms the core of a ridge half a mile northeast of Black Lake, in the White Bear quadrangle. At Camden, in the Anoka quadrangle, hard blue-black Kansan till with limestone pebbles underlies laminated brick clay.

The existence of Kansan drift in many places is shown by borings. It evidently fills the buried valleys to a depth of 100 to 250 feet and on some of the higher parts of the bedrock surface the altitude of the surface is due in large part to a thick sheet of Kansan drift.

INTERGLACIAL DEPOSITS.

Certain beds of laminated silt that lie between the Kansan drift and the Wisconsin red drift appear to be interglacial deposits. They are found in areas too small to be mapped and at various altitudes and were deposited upon the Kansan drift by small lakes and streams. Several of these deposits were mentioned in the description of the Kansan drift. On Lexington Avenue, St. Paul, 8 feet of laminated buff or bright reddish-brown silt lies between Kansan till and Wisconsin red till. The laminæ are about an eighth of an inch thick and consist mainly of very fine sand, except within a thickness of more than a foot at the top, which is clay. These beds lie 880 feet above sea level. At Jackson Street and East University Avenue, St. Paul, from 820 to 840 feet above sea level, a similar deposit, made up of alternating layers of buff silt and black clay, is overlain by till and outwash of the red drift. Similar interlaminated buff silt and black or brown clay overlies the Kansan till along the north escarpment of the Minnesota valley from Terrell Creek to Auto Club. The laminated deposit grades upward into fine red sand and that in turn into gravel of the red drift outwash. The red sand appears to be derived from the red drift and is probably a stream deposit formed during the oncoming of the glacier that brought the red drift. Possibly the silt is merely an earlier stream deposit derived from the same source instead of an interglacial deposit derived from the weathering of the Kansan drift.

North of Camden, near the northern boundary of Minneapolis, an interlaminated deposit of silt and clay is exposed in pits, where it is dug for use in making brick and tile. In the southern pit, which is shown on the topographic map, the deposit rests on hard blue-black till containing many white limestone pebbles and may thus be recognized as Kansan. Above the laminated deposit are bowlders, probably of the red drift, and several feet of recent river gravel, with shells. The same deposit occurs at Northtown, across the river from Camden. In both places the laminated silts are tilted or folded by subsequent glacial thrust and their surface has been in part eroded by the river and covered with river gravel. (See Pl. XVII.)

WISCONSIN DRIFT.

General character.

All the drift that lies above the old gray or Kansan drift in the district is referred to the Wisconsin stage. Two sheets—the red drift and the young gray drift—are recognized. They are as different from each other as either is from the old gray or Kansan drift and they are therefore described separately. The red drift is distinguished by its red or pink color when fresh and by the absence from it of limestone pebbles and bowlders (see Pl. XVIII) or by their scarcity and local origin. The young gray drift is blue-black or buff and when fresh contains fragments of light-colored limestone of other than local origin. The oxidized red drift in the subsoil zone is rusty red, whereas the oxidized young gray drift is yellowish brown and contains no limestone pebbles. Although red drift of Illinoian age occurs in the region just southeast of this district (see fig. 11, p. 10) and a thin layer of it may have been deposited over part or all of the district, it has not been distinguished, all the red drift having been referred to the Wisconsin.

Red drift.

Distribution and relations. — The red drift extends from north to south across the entire district and its border lies several miles farther south. In the western and northern parts of the district it is covered by the young gray drift, but in the greater part of the St. Paul quadrangle and in small adjacent parts of the Minneapolis and White Bear quadrangles it is not so covered. It is exposed at many places, and even where it is covered by the young gray drift it is exposed in cuts that are 15 to 25 feet deep. In thickness it ranges from less than 10 feet to more than 200 feet.

Red till.—The till of the red drift in this region contains more stony material and sand and less clay than that of either the old or the young gray drift. It ranges in composition, however, from red clay with few pebbles or bowlders to stony impure sand. Its bowlders are rather small and numerous, but it contains no fragments of limestone except those picked up from the Kansan drift or derived from local formations. These, however, are in places abundant.

Most of the till of the red drift mantles a complex terminal moraine and its surface is very knolly or hilly. It is generally less than 30 feet thick except where red gravel and sand or drift from the Kansan till sheet is involved in it. In many places it merely forms a veneer over the knolls, their interiors being made up of crumpled or mixed older deposits. This relation of the red till to the hills and knolls is general throughout the morainic tract of the red drift and also in most of that of the gray drift. Along both sides of the Mississippi from Coon Creek station to Anoka the red till outcrops beneath later drift in areas too small to be mapped and in that locality it is probably ground moraine rather than part of a terminal moraine.

Red outwash gravel.—The outwash of the red drift is in places very thick. South of Pine Bend, along a deep ravine that is cut into sandy gravel, it is 200 feet thick. At South St. Paul it is 80 to 100 feet thick and includes a thin zone of bowlders and contains much cobble. The Eden Prairie, between Purgatory and Terrell creeks, is underlain by about 100 feet of red outwash beneath gray outwash. West of Terrell Creek the same red outwash is covered by young gray till. A hilly tract extending from Rogers Lake westward to the Minnesota valley south of Mendota consists of red gravel veneered with young gray till. The red outwash is finely displayed in St. Paul in many artificial exposures. From the center of the city, where it fills an old buried valley, it rises toward the west, at first with uneven surface but farther on becoming more even and ending in a nearly flat high plain. The Wiregrass Marsh and dune-sand tract between Coon and Rice creeks may be a red outwash plain covered with young gray till, like the plains at Centerville and near New Brighton.

Along the electric railway south of Savage (Glendale) laminated silt and fine sand that overlies gravel of the red outwash is crumpled and folded into knolls and is overlain by young gray till. In a deep street cut at the Washburn Home, in the southern part of Minneapolis, the morainic hills similarly consist of laminated silt overlain by young gray till. (See Pls. XV and XVI.) On the west side of Smith Lake, north of Medicine Lake, the same kind of silt appears in the hillside, the young gray drift being absent. On Coon Creek, west of Crooked Lake, in the Anoka quadrangle, stratified red sand underlies 15 feet of young gray till. These laminated deposits were formed either in glacial streams and ponds at some distance outside the margin of the melting ice sheet or in water bodies of a later date but earlier than the deposition of the young gray drift. They resemble the laminated silt of interglacial age except in containing less carbonaceous material, and they are like silt that is interbedded in the red drift except that they underlie young gray till instead of red till.

Young gray drift.

Distribution.—The Wisconsin gray or young gray drift extends from west to east over the greater part of the district. Its extreme eastern margin lies 4 miles east of the northeast corner of the White Bear quadrangle. The edge of the sheet runs thence southwestward through White Bear Lake and crosses the district in a meandering course from a point a mile south of White Bear Lake to the south side of the Minneapolis quadrangle near Savage (Glendale).

Young gray till.—The young gray till is blue-black in its unleached part and buff or gray in its leached part, which extends downward 15 to 20 feet from the surface. The oxidized and leached or lime-free subsoil zone—5 feet or less deep—is yellowish brown. The unleached till contains relatively much clay and much calcareous matter. It is like that of the old gray drift in its general character but has somewhat lighter ferruginous colors and is not consolidated, hard, or jointed where freshly exposed. Its bowlders are few and of much smaller average size than those of the old gray or Kansan till.

The gray till of Wisconsin age is everywhere thin and unequally distributed. At its extreme border it is represented either by light-gray clay, kneaded into the top of the red till, or by scattered surface patches 1 to 5 feet thick, but as a rule the farther it lies from its border the thicker it is and the more persistently present. At only few places in the district is it more than 15 feet thick, but in the first cut on the Minneapolis & St. Louis Railroad east of Purgatory Creek it is fully 20 feet thick. From 3 to 5 feet of its lowermost part at that place is blue-black and unleached and contrasts strongly with the red till which is exposed beneath it, but it grades upward into the leached buff or gray till. In the clay pit of the brick plant at Coon Creek all the young gray till is blue-black. The section there from the surface downward includes 5 feet of dune sand, 6 feet of gray gravel, 10 feet of blue-black till, and 20 feet of red clay to the bottom of the pit.

Where young gray till overlies red outwash deposits its knolly surface is due in part to unequal thickness of the till, but rather more to a displacement or deformation of the underlying gravel and sand, such as is found south of Savage (Glendale). Here an older outwash plain has been converted into a knolly plain. In places where the gray till overlies the red till moraine it is also knolly, but its knolls are small and are superimposed, as it were, on the morainic swells of the red drift. The young gray till at such places does not efface the topographic forms of the red drift, which are much the stronger. Nearly all the surface of the area covered by the young gray till in this district is rolling, of morainic form, and in the greater part of this area the gray till thinly masks red drift terminal moraine.

Gray outwash gravel.—The outwash of the young gray drift is of wide extent but is not so thick as that of the red drift. It forms pitted plains and covers the red outwash on Eden Prairie and at some other places. The pits of the red and young gray outwash plains in many places coincide and are otherwise alike. Some of this outwash is very coarse gravel, but most of it is almost clear sand.

West of Lemay Lake, south of Mendota, there is a brown loesslike clay, 5 feet thick, which contains calcareous concretions. The same kind of clay occurs at many other places, especially along the border of the gray Wisconsin till. It either lies on or takes the place of that till and it looks like young gray till without pebbles. It occurs also in the glacial river valleys.

EARLIER TERRACE GRAVEL.

The higher terraces along the valleys of Mississippi and Minnesota rivers are broad and extensive and most of them are covered with gravel. Notable exceptions are the Platteville limestone benches on both sides of the valley below Fort Snelling, which were swept bare by the glacial rivers. The surface of the Shakopee dolomite at Inver Grove and between Shakopee (just west of the district) and Savage (Glendale) was denuded of everything but heavy bowlders. Bowlder-strewn till surfaces which bear evidence of erosion are found on the highest terrace of the Mississippi, especially near Coon Rapids, and sparingly in other places on the higher terraces, but in most places the terraces are strewn with gravel or sand, even where the surface is rather knolly. The highest terrace along either valley is developed chiefly in glacial outwash, and the terrace gravel is so closely associated with the outwash as to be in part not distinguishable from it. At Northtown the terrace sand contains much detritus of the St. Peter sandstone, doubtless derived from erosion of the adjacent cliff, and in places gravel from the red drift is mixed with gray outwash, or gray gravel with the red.

LATER TERRACE GRAVEL.

The lower terraces lie in the deep part of the valleys and are narrow. They consist of gravel derived mainly from the drift sheets but in places contain some limestone from near-by sources. On the terrace at Newport there are many fossiliferous limestone slabs from the Decorah shale. The terrace at an elevation of 740 feet on the south side of the river at St. Paul consists of sand with much limestone gravel and few erratic bowlders. Mendota stands on a similar terrace. The narrow terrace at an elevation of 730 feet just north of Nicols, in the Minnesota Valley, is coarse gravel and cobble. The isolated gravel terrace between Deans Lake and Shakopee and the narrow terraces along Mississippi River are covered with fine gray gravel.

DUNE SAND.

The entire north-central part of the district, between Rice and Coon creeks is occupied by dune sand, which extends both beneath and between the Wiregrass Marsh and meadows and overlies young gray till. Eastward toward White Bear and southward toward Cardigan Junction and Bulwer Junction, however, it rests partly on young gray sandy outwash. A few low dunes stand on the outwash plain between Rum River and Coon Creek, and others are near Camden. From Fridley southward through eastern Minneapolis dunes occur both on the highest river terrace and on the adjacent morainic hills. They occur likewise on the highest terrace and on the adjacent outwash plain near Fort Snelling and westward to Bloomington. South of Minnesota River dunes occupy the higher terrace east of Nicols. Dune sand is 12 to 15 feet thick on the low limestone terrace by Deans Lake, west of Savage. Apparently none lies on Shakopee Prairie, which is the adjacent high terrace on the south.

Nearly all the dune sand lies on young gray drift or on still later terraces. East and north of McCarron Lake some small dunes lie on Wisconsin red drift, and small dune-sand tracts occur north of Merriam Park, St. Paul, but all these are near the border of the Wisconsin gray drift border.

Sandy soil that is probably of the same origin as the dunes occurs in association with them, but only where the sand is deeper than the soil and is of considerable extent can it be recognized with assurance. The dune sand is from 5 to 25 feet or more thick. It is without bedding or cross-bedding except certain characteristic wavy soil bands. (See Pl. XIX.) It ranges in color from light yellow to brown.

RECENT SERIES.

The deposits of Recent age include alluvial sand, silt, and clay, and beds of muck and peat. Along Mississippi River above St. Anthony Falls fluviatile deposits of sand form interrupted narrow, low terraces and islands. From the falls to a point 3 or 4 miles above Fort Snelling the terraces and river bed are stony, but from that point down the river channel is in sand and gravel, which is 70 feet deep at the fort. The Minnesota-Mississippi valley bottom from Shakopee to Gray Cloud Island is also filled with sand and gravel to a depth of 50 to 75 feet.

Numerous small alluvial fans of sand and gravel line the Mississippi and Minnesota valley bottoms, and a few are large and high enough to be shown on both the topographic and geologic maps. Two conspicuous fans on the limestone terrace are crossed by the road from Fort Snelling to St. Paul; others are at Oakland, Spring Park, Nicols, and Savage; and many small fans line the shores of lakes and streams. Those which lie low in the valleys, like that at the mouth of Big Foot Creek, are merged and confused with the alluvial plain of the river. Most of the small fans are not shown on the maps.

Many lakes and many swamps that formerly were lakes have well-developed beaches and ice ramparts. Innumerable small and large lake basins contain Recent silt, muck, or even peat. Deposits of peat from 1 foot to 10 feet thick are common. The most notable are those of the Wiregrass Marsh region and that along the south side of Minnesota River from Savage to Mendota. The peat deposits overlie dune sand as well as the older deposits, but in some places in eastern Minneapolis dune sand overlies the peat and is very recent.

STRUCTURE.

The stratified rocks of the Minneapolis and St. Paul area must have been laid down nearly level and have undergone very little deformation. At present, however, they are not quite level but dip gently from all sides toward a point about midway between St. Paul and Minneapolis, thus forming a very shallow basin. The accompanying sections (fig. 10) show the attitude of the rocks as deduced from data obtained in rock exposures and well borings. The basin-like structure is well shown in the sections and also by the altitude of the base of the Platteville limestone at different localities shown on the maps. It lies about 775 feet above sea level along the bluffs between St. Paul and Fort Snelling and up the gorge of the Mississippi as far as St. Anthony Falls but rises to more than 800 feet above sea level in Nicollet Island and 850 feet at Columbia Heights. It is 860 feet at Highwood (Highland), and it is 920 feet at a point southeast of Savage, just outside the Minneapolis quadrangle.

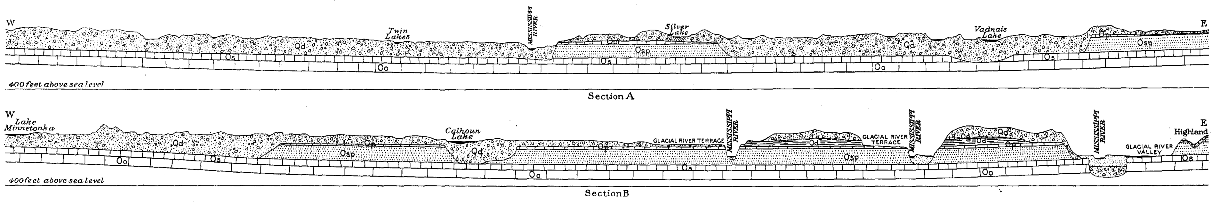


FIGURE 10.—Sections across the Minneapolis and St. Paul district.

A, Section across the southern part of the Anoka and White Bear quadrangles, through Twin Lakes and Vadnais Lake.
B, Section across the northern part of the Minneapolis and St. Paul quadrangles, from Lake Minnetonka to Highland.
Shows the general synclinal attitude of the bedrock and the preglacial and interglacial valleys filled with glacial drift. Oo, Oneota dolomite; Os, Shakopee dolomite; Osp, St. Peter sandstone; Op, Platteville limestone; Od, Decorah shale; Og, Galena limestone; Qd, Glacial drift.
Horizontal scale: approximately 1 inch=2 miles. Vertical scale: 1 inch=1,000 feet.

GEOLOGIC HISTORY.

PRE-CAMBRIAN TIME.

The earliest event recorded in the rocks of the Minneapolis and St. Paul area was the irruption of the bodies of granite or other igneous rocks that are believed to underlie the whole region. Nothing is known, however, of the conditions under which they were formed or of their relation to the land surface of that time. Presumably they solidified at some depth below the surface and were afterward laid bare through the erosion of the overlying rocks, whatever those may have been. At any rate, so far as can be learned from the meager evidence remaining, the surface of the general region toward the close of pre-Cambrian time was formed of such crystalline rocks.

In the region on the northeast, south of the area in which Lake Superior now lies, great sheets of lava were poured out upon the old land surface. Deposition was also going on in that area, and the lava sheets, now the Keweenawan diabase, were interbedded in a thick series of tuff, sandstone, and shale. The lava did not extend as far west as the Minneapolis and St. Paul area, but either during the time of its eruption or a little later considerable sand and mud, now forming the sandstone and shale of the red clastic series, were deposited in the area. The material was probably derived in part by erosion from the lava sheets and is therefore strongly ferruginous, and it was evidently deposited in water, but its red color, which presents a strong contrast to the white and green of the overlying sandstones of marine origin, and the absence of indications of the presence of the sea, lead to the conclusion that it was probably laid down in a land-locked basin.

PALEOZOIC ERA.

CAMBRIAN PERIOD.

During early and middle Cambrian time the region was probably land from which material was being removed by erosion. In later Cambrian time the region was invaded from the south by a shallow sea in which were deposited the sediments that now make up the several Upper Cambrian formations. The sea reached a little to the north of the Minneapolis and St. Paul area, its extent in that direction being indicated by shore deposits now exposed at Taylors Falls, near Rush City, near Monticello, and at Cambria. Toward the south there was open sea for a long distance, as shown by the wide extent of the formations in that direction.

Throughout the Cambrian period the land on the north gradually sank and the sea spread farther northward, and each successive formation was deposited over a wider area, so that at its margin it overlapped the formation next beneath and the last formation overlapped upon the pre-Cambrian floor. Each formation is therefore thinnest at its northern landward margin and much thicker toward the south. The sea was always shallow, however, and currents played an active part in deposition, carrying material far from the shore and depositing it with the oblique bedding characteristic of the formations. The total thickness of the Upper Cambrian beds in these quadrangles—600 feet—is so small compared with the length of the Cambrian period that they were probably laid down during epochs of rapid deposition that were separated by epochs of nondeposition.

During most of Upper Cambrian time life was fairly abundant in the sea. It consisted chiefly of trilobites and brachiopods but included a few mollusks. The area was occupied by three faunas in succession—one in Dresbach time, one in Franconia time, and one in St. Lawrence time. The faunas of these separate times consisted mainly of different species, though a few species survived from one to the next. Early in Upper Cambrian time and again toward its close, when coarse sands were being deposited and constantly shifted by strong currents, the conditions seem to have been unfavorable to the existence of life. At any rate no fossils are preserved in beds of those ages.

ORDOVICIAN PERIOD.

Oneota deposition.—The subsidence of the sea floor continued into the early part of the Ordovician period, but the conditions of deposition changed. The time was one of comparative quiescence in the relations of land and sea in the region and the neighboring land appears to have been low and flat. The sediment deposited in the sea contained comparatively little material derived from the land and the bulk of it was calcareous mud of marine origin. At first the sea was very shallow, and some beds of sand and of oolite were intercalated with the other material. At times the sediment was deposited so rapidly that its surface rose above the water in places or else slight upwarpings of the sea bottom produced the same effect. At any rate mud flats here and there were laid bare to the sky and the mud dried and cracked open. When more sediment was spread over the sun-dried mud the cracks were filled with sand. Later the sea became so deep that sand was no longer deposited away from the shore; hence the main body of the formation is clear dolomite. Before the close of the epoch, however, subsidence gave way to uplift, the sea again became shallow, and more beds of sand were washed in. Deposition at length ceased and was probably followed by a time of emergence and erosion.

Whether the rock, now dolomite, which constitutes the bulk of the Oneota and similar formations, originally contained so much magnesium carbonate as at present is a matter of doubt. It seems probable, however, that part of the magnesium carbonate was an original constituent of the sediment and that part was introduced in subsequent alteration of the rock, perhaps replacing original calcium carbonate. Imprints of seaweeds, as well as reefs of Cryptozoa, regarded as calcareous algæ, are abundant in the Oneota dolomite and contributed much rock-forming material. The suggestion has been made that the plants were magnesium-bearing and that the rock owes much of its dolomitic character to them. It has also been pointed out that during much of the epoch the sea was shallow and sediment was deposited close beneath or at the surface of the water, and the alternative suggestion has been made that the rock owes its large amount of magnesium carbonate to more rapid deposition of that salt from sea water concentrated under such conditions.

During Oneota time a new fauna appeared and life was abundant in the sea. The fauna included, besides a few species that survived from the Cambrian period, a few species of trilobites and brachiopods and many of gastropods and cephalopods. Mollusks of the class last mentioned first appeared in the waters of the region during this epoch.

Shakopee deposition.—After a considerable interval, presumably a time of uplift and denudation, deposition was resumed under much the same conditions as in Oneota time. Cryptozoan reefs (see Pl. VII) were again abundant, and again the bulk of the sediment formed was calcareous mud. At times, too, the water was shallow and layers of oolite were formed or beds of sand were washed in. Occasionally parts of the sea floor rose above the water and were broken up by the waves and limestone conglomerates were formed of the débris. At length deposition was again terminated by uplift and an interval of subaerial erosion ensued.

The marine life of Shakopee time was much like that of Oneota time, but no species survived the interval between. Gastropods and cephalopods were again abundant and trilobites much less so, but brachiopods were absent, at least in this region. Essentially the same fauna existed throughout the epoch, regardless of minor changes in the character of deposition.

St. Peter deposition.—In St. Peter time deposition was again resumed under conditions not greatly different from those of late Cambrian time. A period of nondeposition preceded it and in parts of Wisconsin the surface of the Shakopee had been more or less eroded, but in the Minneapolis and St. Paul area there had been little or no erosion. When the sea again invaded the region it advanced over a smooth, nearly level surface, upon which were deposited sheets of sand of remarkably uniform thickness, the sand being carried long distances by strong currents and thus widely and evenly spread. In places the currents left their records in the oblique lamination of the beds. Deposition under such conditions probably continued for a long time, as so great a thickness of sand so evenly deposited could not well have been laid down rapidly.

The entire Shakopee fauna was exterminated during the hiatus preceding the deposition of the St. Peter, and the fauna of St. Peter time, though still molluscan, was wholly of new species. The epoch was characterized by the first appearance of pelecypods in the region. The fauna probably changed somewhat during the progress of deposition, but evidence on this point is meager, except that the fossils of the topmost beds in parts of Minnesota show that the life at the close of the epoch was somewhat transitional in character.

Platteville deposition.—Apparently the deposition of the St. Peter was followed directly by that of the clay and calcareous mud of the Platteville, which was laid down upon the wide, flat, sandy sea floor formed in St. Peter time. The sea bottom became thickly occupied by living forms, and the calcareous deposit formed by the disintegration of their hard parts eventually made limestone. The abundance of life interfered somewhat with the deposition of sediment and appears to have prevented regular lamination, and the rock therefore has an irregularly mottled structure, or pseudo-brecciation. The deposition of sediment as a whole was, however, uniform. The sea was rather shallow and of wide extent to the south. Its extent northward, northeastward, and northwestward was probably not nearly so great but is not known, as erosion has destroyed all traces of shore deposits. The material forming the clay beds was, however, probably derived from land on that side.

Marine life was abundant in Platteville time and included, besides fucoids (Pl. XII) and other algæ, a Chara-like plant—Chætocladus—which is supposed to have inhabited only rather shallow water. Animal life was also abundant in the sea, and the fauna was, on the whole, one adapted to life on a hard seafloor thinly covered with fresh sediment. It comprised many crawling and free-swimming animals, as well as others that were anchored to the sea bottom. Burrowing animals, including worms and wormlike forms, seem also to have been numerous. In places some animals, such as the brachiopod *Leptæna minnesotensis*, lived in small colonies and their remains have been preserved in lenticular shell beds. The life of the epoch came in gradually and at first was sparse both in numbers and in kinds. Fucoids appeared first and were followed later by animals of the sorts whose remains are abundant in the limestone.

Decorah deposition.—The deposition of the Decorah was essentially continuous with that of the Platteville, and the extent and depth of the sea in this region remained essentially the same. A change somewhere in the relations of land and sea, perhaps to the north of this area, produced a change in the character of the sediment, which in Decorah time was chiefly clay and included relatively little calcareous material. Sedimentation was irregular, however, and three times during the epoch, as well as at its beginning and again at its close, deposition ceased for a time and the surface of the beds just deposited was corroded by solution in the sea water and somewhat broken up. On the other hand rapid deposition of calcareous material in some places and for short times, especially near the beginning and end of the epoch, resulted in the formation of lenses and beds of limestone.

The life of Decorah time was much like that of Platteville time and included many of the same species, but seaweeds were abundant only near the beginning and toward the close of the epoch. During the middle part the distinguishing feature of the life was the existence of reef-like colonies of animals, characterized by an abundance of various species of monticuliporoids and so diverse in that respect that different faunules may be said to have lived in different parts of the area at the same time. The earlier ones also differed from the later ones so greatly that the formation is divisible into three faunal zones on that basis.

Galena deposition.—Subsidence continued into the Galena epoch and kept pace with sedimentation, so that Galena deposition succeeded Decorah deposition without sharp break and with no marked change in the extent of the sea. The character of the deposition as a whole was much like that of Platteville time, though it continued much longer, and the thickness of sediment formed was greater. At first, however, the conditions were more nearly similar to those of Decorah time and there was at least one brief period of nondeposition, with resulting corrosion of the surface of the newly formed beds. Only a small part of the formation—one faunal zone out of four known elsewhere—is now represented in this area, but it is probable that deposition continued here during the whole epoch and that most of the formation was removed by erosion. During the early part of the epoch the life was much like that of Decorah time and included many of the same species but was also marked by others that were new. Reef-like beds or colonies of animals still existed, as in the previous two epochs.

Later Ordovician time.—In the Minneapolis and St. Paul area no record now remains of the deposition of Ordovician strata younger than those of Galena age, but in southeastern Minnesota such strata are still preserved, and it seems probable that the sea of that time covered central Minnesota till the end of the period. It is possible, however, that, owing to the uplift which had already set in, the area had already emerged from the sea and formed part of a coastal plain about its northern border.

SILURIAN TO CARBONIFEROUS PERIODS.

So far as the area considered in this folio is concerned the record of the rest of the Paleozoic era is a blank. The sea lay in regions south and southeast of the area nearly all the time till well toward the close of the Carboniferous period, and strata of Silurian, Devonian, and Carboniferous age were deposited and still remain in those regions. The land surface was continually affected by alternate slow uplifts and subsidences, and the outline and depth of the sea and the position of the shore were undergoing constant changes. There is no reason to believe, however, that the sea again invaded the Minneapolis and St. Paul area or that younger Paleozoic strata were deposited there. Throughout the rest of the era the area was undoubtedly part of a coastal plain, undergoing some degree of reduction and furnishing some material for the beds that were being laid down farther south.

In the Silurian period the shore was far to the south, across northern Iowa and Illinois, but subsidence in Devonian time allowed it to encroach on southeastern Minnesota, though it probably did not reach so far north as St. Paul. In Carboniferous time it had again withdrawn southward, reaching only to the southern boundary of Minnesota, and eventually it withdrew altogether from the upper Mississippi basin.

The final withdrawal of the sea from the region was followed, near the close of the era, by some deformation of the strata, which were slightly warped from their original nearly horizontal position into low folds or wrinkles. At the same time the surface of the land was uplifted, presumably several hundred feet at least, and a long-continued era of subaerial denudation set in.

MESOZOIC ERA.

The uplift that brought Carboniferous deposition to a close, affected a great part of North America and left the Minneapolis and St. Paul area in the interior of a great land mass and probably at an altitude of 1,000 or 2,000 feet or more above sea level. The surface, however, must have been smooth or gently rolling and the topographic conditions must have been much like those of parts of the present Great Plains. Throughout the Triassic and Jurassic periods and the early part of the Cretaceous period the surface of the area was being reduced by subaerial denudation. It was thus lowered some hundreds of feet at least, and, in common with that of a great surrounding region, it was probably at least once reduced nearly to base level and thus again formed a low-lying, nearly featureless plain.

In Lower Cretaceous time the region on the west was depressed and a new interior sea occupied the area that is now the Great Plains. The streams of the Minnesota region then probably flowed westward into that sea and the waste of the land was carried out and spread over the sea floor. Subsidence continued into Upper Cretaceous time and the sea advanced nearer if not quite to the Minneapolis and St. Paul area, spreading a thick sheet of sand and clay—now forming the Dakota sandstone and Benton shale—over the truncated edges of the Paleozoic and older formations. Some fresh-water sediments were also deposited at that time along the courses of the streams or in small lakes. Subsidence soon gave place, however, to renewed uplift, and the sea withdrew westward until, by the close of Cretaceous time, this area was again far inland and subaerial erosion was once more actively reducing its surface.

CENOZOIC ERA.

TERTIARY PERIOD.

In early Tertiary time several brackish or fresh water lakes still occupied parts of the interior Mesozoic sea, but they lay hundreds of miles west and southwest of the Minneapolis and St. Paul district, and whether any streams of the Minnesota region flowed into them is not known. A progressive uplift of most of the interior of the continent was going on and affected the district in common with the surrounding regions. The uplift was much greater on the west, and the land surface was thus tilted to the east, standing at altitudes ranging from 5,000 or 6,000 feet along the eastern base of the Rocky Mountains to less than 1,000 feet in the Mississippi basin. A new system of drainage was developed everywhere in the region, and in the Minneapolis and St. Paul area the new streams flowed southward and southeastward and ultimately reached either the Mississippi or the St. Lawrence.

The surface of the district was considerably dissected, most of the Cretaceous deposits were removed, and the main valleys were cut into the Paleozoic strata to a depth of about 500 feet below the upland surface. The principal stream, the predecessor of the present upper Mississippi, flowed across the district in a large valley which followed the course of the present Purgatory Creek valley, crossed the present Minnesota Valley below Savage (Glendale), and extended past Westcott to the southeast corner of the St. Paul quadrangle. Another valley, which extended southward through St. Paul and thence along the present course of the Mississippi, was cut deeper than the present valley. A third extended through Northtown, past Bassett Creek, toward Cedar Lake, and through Calhoun Lake to join the valley first mentioned. Cross sections of these valleys, filled with drift of later age, are shown in figure 10 (p. 9). The valley sides were characterized by an alternation of benches and steep slopes, due respectively to the more resistant limestones and the less resistant sandstones and shales. The limestone terrace on which Savage (Glendale) is now situated was then a bench 200 feet above the old valley on the east. By the cutting back of tributary valleys the interstream areas were dissected into flat-topped hills like mesas, such as that now forming the rock foundation of Columbia Heights.

QUATERNARY PERIOD.

PLEISTOCENE EPOCH.

In early Pleistocene time the climate in the northern hemisphere was moist and cold, so that snow and ice accumulated in this region in large quantities, as they now accumulate in Greenland, forming immense sheets that spread southward from the centers of ice accumulation. This ice sheet, spreading from the north, entered Minnesota and crossed the Minneapolis and St. Paul area. Climatic changes caused the ice alternately to advance into and to melt away from the area. The positions occupied by the ice sheets during their several advances are shown in figure 11.

PRE-KANSAN TIME.

The pre-Kansan ice sheet invaded the region from the northwest and reached points in Minnesota south of the Minneapolis and St. Paul area and others in Wisconsin east of it. No deposits that can be certainly identified as pre-Kansan have been found within the area, although it seems not to have been covered by ice at that time. So far as is known the conditions in the area after the disappearance of the ice in later pre-Kansan time were not greatly different from those of the Tertiary period.

KANSAN GLACIATION.

In Kansan time an ice sheet from the Keewatin center west of Hudson Bay invaded the area, crossed it from northwest to southeast, and extended some distance beyond. Striations on bedrock show that the direction of ice movement in the quadrangles was S. 60° E. The ice removed all soil and other surficial deposits and grooved and polished the underlying bedrock. In some places grooves 1 or 2 feet deep were gouged into limestone (see Pl. XIV), and the surface of the grooves was polished like the rest of the surface of the rock. The ice sheet brought with it a quantity of heterogeneous rock débris picked up from the surface over which it passed, among which were many pebbles and bowlders of fossiliferous limestone from Silurian and Devonian formations of Manitoba. The Kansan glaciation lasted a long time. When the ice finally melted away it left the surface of the area covered with a blanket of drift of predominantly gray color, part of which was assorted and redeposited as sand and gravel by streams flowing from the melting ice or laid down in small lakes and ponds formed in low places. On such a surface a new system of drainage began afresh the work of dissection and reduction.

INTERGLACIAL TIME.

The Kansan glaciation was followed by a long interval during which the area was free from ice and was again undergoing erosion. The streams of that time followed mainly the same lines as the preglacial streams, but, as the Tertiary valleys were partly filled, they began flowing at nearly the same levels with relation to the bedrock as do the present streams. In many places the entire thickness of Kansan drift was removed and the bedrock was laid bare, and in some places new channels were cut in the bedrock, as east of Mendota, where the gorge of Big Foot Creek now crosses a deep interglacial gorge filled with red Wisconsin drift. The interval appears to have been so long that the streams of the area became more nearly mature than those of the present time, and the entire surface, including all ponds, swamps, and kettle holes, was well drained.

ILLINOIAN GLACIATION.

In late Illinoian time a tongue of ice approaching from the northeast crossed St. Croix and Mississippi rivers near their junction and extended a little way into Minnesota. On melting it left a thin sheet of red drift, which can not be clearly distinguished in the Minneapolis and St. Paul area, although the ice probably covered the eastern part of the area.

WISCONSIN GLACIATION.

Earlier invasion.—In middle Wisconsin time a tongue-shaped ice lobe, which entered the State from the northeast (see fig. 11), crossed the Minneapolis and St. Paul area in a general southward direction, as is shown by striæ now found

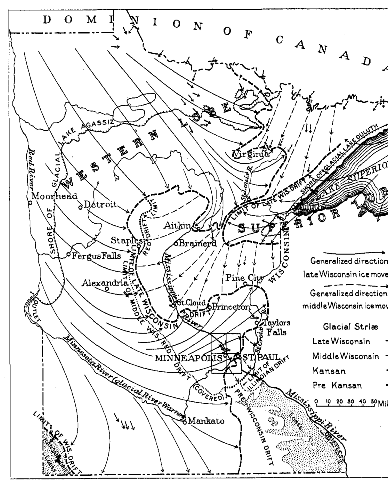


FIGURE 11.—Map of Minnesota showing the extent of the glacial ice sheets, directions of ice movements, and shores of glacial lakes. By Frank Leverett.

on the bedrock, and advanced a few miles farther south. It soon began to melt away, however, and it left only a thin deposit of red drift in the extreme southeast corner of the St. Paul quadrangle. Several times the ice resumed its forward motion, but each time it soon came to rest and began to melt away again, and it thus formed a belt of terminal moraines across the area from a point south of White Bear Lake, on the east side, to a point south of Lake Minnetonka, on the west side. Finally the ice melted away altogether from the area, leaving a thick irregular sheet of red till that covered the surface of the Kansan drift nearly everywhere and filled most of the interglacial valleys.

The water from the melting ice flowed away southward or collected in drift-dammed valleys and in depressions in the surface of the till. The main drainage line of the quadrangles then followed the course of the present Minnesota Valley to Savage and there turned southward through a valley, traces of which still remain, leading to Vermilion River. Material from the red drift was carried by the glacial streams and redeposited along their courses or in the beds of lakes.

Later invasion.—In late Wisconsin time two tongues of ice entered Minnesota, one, called the western lobe, from the northwest, and the other, called the Superior lobe, from the northeast. This lobe entered the State only a short distance. The western lobe moved southward and southeastward across the northern and western parts of the State. In some places its eastern margin spread out in lobate fashion so that part of the ice moved eastward and even northeastward, as shown in figure 11. The Minneapolis and St. Paul area lay nearly in the path of such a lobe, which pushed eastward across St. Croix River to Grantsburg, Wis., and the ice of the southern part of the lobe entered the area from the west and advanced eastward and northeastward nearly across it before stopping, while the main ice tongue pushed on southward to Des Moines, Iowa. The area thus lay virtually in an interlobate space, where the movement of the ice was not so vigorous and the deposition of drift not so marked as elsewhere—a space in which no pronounced terminal moraine was formed. When the ice melted it left a thin sheet of characteristic gray drift, so thin that the relief of the red drift moraine is only partly masked.

The lobe at its greatest extent occupied nearly the whole area, but it left approximately the southeast half of the St. Paul quadrangle uncovered. The principal stream flowing from the melting ice in this area followed the old interglacial valley past Westcott to Vermilion River and carried a considerable quantity of outwash, which was deposited along its course for miles. The present valley of the Mississippi between Mendota and St. Paul was not then in existence.

Development of drainage.—As the ice melted away and its margin retreated northwestward it uncovered a surface whose former relief had been modified by the deposition of the younger gray drift and upon which a new set of streams began to flow, finding such courses as they could between the many knolls and ridges. At first they were swollen with water from the melting ice and flowed with swift and strong currents and were able to cut broader and deeper valleys and to do much more work, both in erosion and transportation, than at present. They were laden with débris, partly outwash from the melting ice, partly drift from places where they were actively eroding, which was carried a long way and spread out for miles along their courses and which now forms the gravel floors of the high terraces along the valley of the Mississippi. Probably all the depressions were occupied by lakes and ponds, each of which discharged through the lowest point of its rim to some neighboring lower tract, and thus the courses of many streams became fixed. In time many of the lakes were drained and streams meandered across their former beds, and so by degrees the present system of drainage was developed.

The present valley of Minnesota River must have been even then a relatively low area, along which one of the main lines of drainage was early established. As the ice melted from the site of St. Paul it uncovered a low place in the divide between the interglacial valley leading southeastward past Westcott and the old preglacial valley, partly filled with Kansan and Wisconsin red drift, running southward from St. Paul. The main stream turned across the divide into the preglacial valley, which became established as the master valley of the region, and the interglacial valley that runs past Westcott was abandoned.

By the time the Wisconsin ice had finally disappeared from the area two principal streams were established in it—the glacial Mississippi and the glacial Minnesota. Both were fed by melting ice in areas on the northwest and both carried considerable débris and were actively eroding their channels. These streams joined a mile northeast of Fort Snelling, forming a stream that flowed northeastward in a new course to St. Paul and thence southward, as described in the previous paragraph. This stream was swift and vigorous, a mile wide, and in places 40 feet deep, and it soon cut a gorge through the Decorah shale to the Platteville limestone. Where it flowed off the limestone bed into the old valley a low fall was soon developed. At Dayton Bluff, where the stream turned southward, it undercut the east bank and formed a scarp and terrace that still remain above the high bluff.

The glacial Mississippi had much the same drainage basin above Minneapolis as the present river, but it carried a larger volume of water and in places was a mile across, though shallow. In two places in the quadrangles it spread out in lakes. Its bed was uneven and was being cut down in some places and filled up in others. The high-level terraces already described were cut by the stream at this time and floored with outwash deposits that it was then transporting. As soon as the ice had melted out of its drainage basin the river shrank to its present normal volume and began cutting the lower series of terraces and depositing alluvium on them.

The glacial Minnesota was a larger stream than the glacial Mississippi, being 2 miles wide in places, where it was perhaps more like a sheet flood than a stream. Like the Mississippi it flowed over an uneven bed, some of the depressions in which have not yet been filled with sediment, and it cut high-level terraces and floored them with outwash. Unlike the Mississippi, however, it did not shrink to its present volume when the ice disappeared from its drainage basin, for it was long the outlet of Lake Agassiz and carried an even greater volume of water than before.

River Warren, the glacial stream through which Lake Agassiz first discharged southward to the Mississippi basin, as described below, followed the course of the present Minnesota River, as shown in figure 11. It was the main stream of the region, to which the Mississippi above Fort Snelling was only a tributary, and it carried a large volume of water and greatly changed the topography of the area. It cleared most of the drift out of the old valley south of St. Paul, cut terraces on the side slopes, and deposited sand and gravel on them. It cut the deep gorge of the Mississippi from Mendota to St. Paul, through the recession of the fall that had formed at the lower end of the gorge. When the head of the gorge passed the point where the Mississippi entered, at Fort Snelling, a fall was formed on that stream also, and cut its way back to its present position at St. Anthony Falls. When the main fall had receded to the eastern wall of the buried preglacial valley that crosses the Minnesota Valley 2 miles above Mendota, and all the limestone layers in the river bed that formed the fall had been cut away the fall disappeared. The history of the falls, gorges, and rapids is given in greater detail in a subsequent section.

After the disappearance of the fall River Warren deepened and broadened the Minnesota River valley. At Shakopee and in the western part of the Minneapolis quadrangle, where glacial Minnesota River flowed at first in a broad sheet across what is now Shakopee Prairie and later in several channels, River Warren finally occupied the northernmost channel. As the stream lowered its bed, after the limestone in the gorge at St. Paul had been cut away, this channel was divided at Shakopee, and the stream took the northern of the two channels, abandoning the southern one, which extended from Shakopee through the site of Deans Lake. The stream abandoned each of these channels in turn as it became rock-bound and finally followed the one that was most easily eroded. Thus the valley shifted northward, even beyond the former north bank of the glacial Minnesota. Purgatory Creek, which had previously entered the glacial river below or north of the present site of Bloomington Ferry, was captured above that place by River Warren. At St. Paul the channel of River Warren was cut more than 50 feet deeper than the present gorge, but it is thought not to have been so deep at Shakopee.

Eventually the ice front melted so far back that Lake Agassiz began discharging eastward through a new outlet into the Lake Superior basin, the southward discharge ceased, and River Warren subsided. Since then Minnesota River has had virtually the same volume as at present.

Formation of sand dunes.—One of the episodes of the closing stage of the Pleistocene epoch was the accumulation of the dune sand that occupies much of the area. The sand was derived chiefly from the glacial outwash plains and river flats and was driven eastward by the wind. So much sand was blown away from the surface of some of the outwash plains, such as the one near Anoka, that the surface is now covered largely with polished pebbles, though the material just beneath the pebbles is chiefly sand. Most of the sand lodged finally on low till-covered tracts, probably because such tracts contained many ponds that wet the sand and held it down. Dunes were also formed, however, on the glacial river terraces, and to some extent on the shores of the larger lakes, and a few still remain on the outwash plains and glacial river flats.

RECENT EPOCH.

Since River Warren subsided the Mississippi has not been able to transport all the sediment brought into it by its tributaries. Its bed has been aggraded at least 50 feet in places in the gorge at St. Paul and even in the open valley below the gorge aggradation has been considerable, the current has been slackened, and the valley bottom is largely swampy. The bed of the Minnesota has not been so rapidly aggraded, but the river has been so much slackened by the raising of the bed of the Mississippi that it is almost ponded, and it has formed a flood plain that is occupied chiefly by swamps and lakes.

The smaller streams in the area, except Rice and Coon creeks, at first followed glacial drainage lines, but their valleys have been cut chiefly in Recent time. Those that are tributary to the Minnesota or to the Mississippi below St. Anthony Falls have cut small gorges near their mouths. Above the falls, Rum River and Coon Creek have made terraces that correspond in age and position to the Recent terraces of the Mississippi. Probably the volume of the small streams has changed very little since their beginning.

Some of the smaller lakes along the courses of streams have been partly or wholly drained by the cutting down of their outlets. Other lakes, some without outlets, have been formed in previously empty basins. Within the last few years Rogers Lake, near Mendota, has grown by submerging the swamp that formerly occupied the north end of its basin. The largest lakes, such as Minnetonka, Medicine, Eagle, Pleasant, Bald Eagle, and White Bear lakes, have changed very little except along their shores, where they have cut high banks and built spits and bars. The deep lakes, like Medicine, Eagle, Calhoun, Pleasant, and Bald Eagle lakes, and those which, like the Marcott Lakes, lie in deep basins are in no present danger of being filled or drained, either naturally or artificially. Some former shallow lakes, such as Lambert, Mother, and Palmer lakes, have already been converted to marsh or meadow by draining.

Many swamps, especially those traversed by creeks, are surrounded by cut banks, beaches, or ice ramparts, showing that they are the sites of former lakes. Some appear to be small lakes that have been overgrown by bog. Other swampy areas have been extended by the growth of peat bogs, as along the south side of Minnesota Valley between Savage and Mendota, where small streams flowing down the slope have been choked by the growth of peat. In the dune-sand tracts the growth of peat in the depressions tends not only to fill them with swamps, but also to raise the level of ground water in the dunes, and thus the peat extends itself onto the sides of the dunes.

At present no typical sand dunes are being formed. In places where the sand is exposed by the destruction of the vegetation or the impoverishment of the soil, blow-outs are soon formed, but the growth of new vegetation checks the drift of the sand and prevents regular dune formation. That the same process has occurred in the recent past is shown by the existence of soil bands in the upper layers of some dunes and beneath the bases of others.

DETAILED HISTORY OF THE GORGES, FALLS, AND RAPIDS.

FALL AND GORGE OF RIVER WARREN.

When River Warren superseded glacial Minnesota River the gorge from Mendota to St. Paul had probably been cut through the Decorah shale and the stream was flowing over a bed of Platteville limestone. A fall developed where the river flowed off the limestone into the preglacial valley extending southward through St. Paul, the rock bottom of which was considerably lower than the bottom of the shallow gorge at that time. The crest of the fall crossed the present valley of the Mississippi a little east of the line of Wabasha Street, and remnants of the fall scarp are still preserved on both sides of the river. On the north side it extends from the present river bluff northward, just east of the courthouse, to Jackson Street and East University Avenue. The fall at that time was nearly 1½ miles wide and 40 feet high.

Up to that time the fall remained nearly stationary, as the fall scarp was made by the Platteville limestone, which was worn away very slowly. The fall had grown in height, however, through the excavation of a pool at its base, chiefly in drift and other loose débris. When the fall reached a height of 40 feet, or, rather, when the pool had been excavated to a depth of 40 feet below the crest of the fall, all the loose material had been removed and the bottom of the pool was being scoured in the friable St. Peter sandstone. This sandstone was rapidly worn back by the surging water in the pool, and the limestone, thus undermined, broke off in joint blocks 10 to 30 feet square, exposing the sandstone beneath to further erosion, similar to the recent erosion of the falls shown in Plate XXII. In such manner the fall receded upstream.

The recession appears to have been more rapid on the south side of the broad upper channel, and as the fall worked upstream the new deep gorge formed below it was only about half as wide as the channel above the falls. The river thus became concentrated in a narrower bed, and a large part of the bed of the old channel was abandoned and still remains as the limestone terrace along the north side of the river between Fort Snelling and St. Paul. Blocks of limestone that fell at the side of the fall and were not removed by the current in the lower gorge still lie on the eroded surface of the St. Peter sandstone on the north side of the river above High Bridge. (See Pl. XX.) When the gorge had been cut back to the northeast wall of the buried preglacial valley 2 miles above Mendota and all the limestone in the river bed had been removed, the fall ceased to exist, and the river rapidly cut down into the sandstone. The sandstone island east of Minnesota River about 2 miles above Mendota marks approximately the point where the fall ceased.

ST. ANTHONY FALLS AND GORGE OF MISSISSIPPI RIVER.

Formation of falls, gorge, and rapids.—Below Nicollet Island the Mississippi of Pleistocene time at first flowed over a bottom of drift or of Decorah shale to its confluence with River Warren, which then was at a point a mile northeast of Fort Snelling. Before the fall in River Warren had receded to that point, however, the Mississippi had probably cut its bed down to the Platteville limestone and seems to have shifted to its present course, so as to join River Warren at Fort Snelling, leaving the surface of the abandoned channel as a rock terrace north of the small drift hill on the north bank of the present river. When River Warren had cut its deep gorge back to Mendota it encountered a narrow buried preglacial valley that extended northwestward up the present course of the Mississippi about a mile and southeastward past Mendota and Augusta and Lemay lakes. River Warren quickly cleared the drift from the part of the buried valley that crossed its gorge and the River Warren Fall began again on the west side of the buried valley. The Mississippi likewise rapidly cleared the drift from the old valley up to a point about a mile above Fort Snelling, where it entered that valley over the rock wall on the north side. As the drift was scoured away a fall was formed where the river plunged from its rocky bed into the old valley. This was the beginning of the falls of the Mississippi, which have therefore not receded all the way from Fort Snelling to their present position but began about a mile above the fort. This part of Mississippi River was formerly called St. Anthony River and the falls were therefore called St. Anthony Falls.

The history of St. Anthony Falls is in general similar to that of the River Warren Fall but differs therefrom in several important details, owing to the circumstances that have controlled the development of the falls. These were, briefly: (1) the volume of the Mississippi was much less than that of River Warren; (2) the river was at several places, divided into more than one channel; (3) the rock strata were not quite the same; and (4) during the existence of River Warren the Mississippi was only a tributary, but since the subsidence of that river it has been the main stream. As a result of the combined influence of these factors both the older, higher channel and the newer, deeper gorge of the Mississippi above Fort Snelling are narrower than those of River Warren, the height of the falls and the slope of the stream both below and above the falls have varied considerably from time to time, and the manner of recession has been rather different.

When the falls had reached a point just above the site of Lake Street Bridge, where part of a fall scarp is preserved on the west side of the gorge (see figs. 12 and 13), the upper rapid had a descent of 15 feet in 300 feet to the crest of the falls, which began at the top of the lower limestone bed and were 20 feet high. From their base a lower rapid descended with a gradually decreasing slope about 40 feet in 300 feet. This total descent of 75 feet marks the highest stage of the falls and resulted in the cutting of the deep lower gorge, now partly filled with rock waste, as shown in figure 13.

During the last 4 miles of recession of the falls the river, while excavating the gorge through that distance, has been partly filling up the gorge below, from Lake Street Bridge to Fort Snelling and thence on to St. Paul and beyond, as shown by the valley fill in figure 13. When Father Hennepin first saw the falls, in 1680, they were a little above the site of the Tenth Avenue Bridge (see fig. 14), where a part of the fall scarp remains on the east side of the river. The falls as sketched by Richardt in 1857 are shown in Plate XXI. Since then the falls have entered the lower end of the Nicollet Island rapids.

The bed of the river through the Anoka quadrangle is in glacial drift. At Nicollet Island the stream begins to flow upon the Platteville limestone. The limestone was uncovered by the glacial Mississippi, and when that stream subsided the modern Mississippi at once developed a rapid at the upstream edgé of the limestone. The rapids are therefore older than St. Anthony Falls. The river first encountered the limestone at a level higher than the present surface of the island, and what is now the west end of the island was at first a part of the rapids, but it soon became a rocky island in the stream. Alluvial terraces on the island show that the river then covered all the part that now lies east of the railroad. The rapids were then on either side of the west end of the island, but as the channels were gradually deepened the rapids moved slowly downstream, because the limestone dips in that direction. The whole thickness of the Platteville limestone was thus beveled by the river between the head of the rapids and the site of the Tenth Avenue Bridge. This has had an important effect on the rate of recession of the falls during the last 250 years.

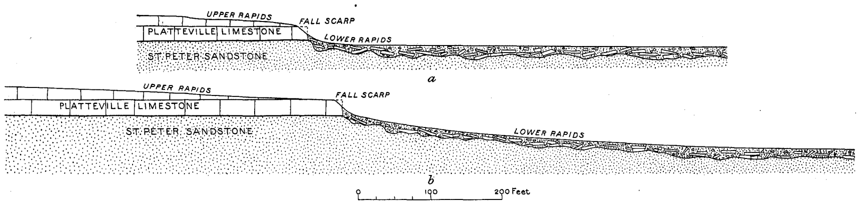


Figure 12.—Detailed profiles of St. Anthony Falls at an early and a later stage.
a, Early stage; east fall scarp at Soldier Ravine, below the mouth of Minnehaha Creek.
b, Highest stage; at Lake Street Bridge, on west side of the Mississippi gorge.

The breadth and slope of the stream and the height and character of the falls at several stages in their history are shown by terraces and remnants of fall scarps at a number of places along the gorge. As shown in figure 12 there was always an upper rapid or slope which descended from the top of the upper bed of the Platteville limestone to the top of the lower limestone bed and a vertical fall from the top of the lower limestone. The height of the vertical fall varied from time to time with the depth to which it had excavated the underlying St. Peter sandstone. At the foot of the fall there was a lower rapid over a talus of large limestone blocks that rested on an irregular sandstone surface, similar to the talus shown in Plate XX. At their beginning, at Soldier Ravine, a mile above Fort Snelling, the falls, including an upper rapid, were 35 to 40 feet high, measured from the top of the Platteville limestone, and the lower rapid descended about 5 feet more in 150 feet. The profiles of the falls at several stages of their recession are shown in figure 13.

Mode of recession.—The recession of the falls has not been altogether due to the wearing away of the sandstone by the surging water at the foot of the falls, although that was the chief cause of recession when the falls were new, but has been influenced largely by the jointing in the limestone, which does not, as a rule, coincide in the upper and lower beds. As long as both beds remained in place the crest of the fall scarp was both rigid and impervious to water, but as fast as erosion cut away the upper bed from the crest of the falls some water worked down through the joints in the exposed lower bed and, by washing away the friable sandstone beneath, undermined the limestone, which fell in large blocks. (See Pl. XXII.) Further erosion of the sandstone beneath the fallen blocks

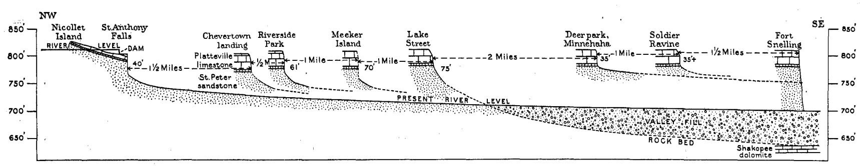


Figure 13.—Generalized profiles showing successive stages of St. Anthony Falls from Soldier Ravine to the present falls below Nicollet Island.
The bluff at Fort Snelling, shown at the right, is not a fall scarp.

During their recession through the half mile above the mouth of Minnehaha Creek the falls were divided by an island, now the point between the gorge of Minnehaha Creek and that of the Mississippi. The west branch of the river was finally abandoned, but its former existence is shown by a shallow channel that leads to the head of the gorge of Minnehaha Creek, at the deer park opposite Minnehaha Falls, where a somewhat defaced fall scarp still remains. The bottom of the gorge has since been eroded and deepened, but a block-covered terrace on the east side shows the position of its former bottom. The height of the fall (see fig. 13) was 30 to 40 feet as measured from the top of the limestone ledge down to the top of the terrace.

gradually lowered them and thus the slope of the lower rapid was formed. The mode of recession was pointed out years ago by Professor N. H. Winchell,[1] who wrote: "It is not so much the excavation at the foot of the falls that causes the recession as the excavation of the sandstone just below the limerock by water that enters natural joints in the rock and comes in contact with the crumbling sandrock, causing dislodgment and final downthrow of large blocks." Since 1871 the falls have been artificially protected by an apron and the recession has practically stopped. Two small breaks that have occurred in later years were caused by the process described by Winchell.

[1] Final Rept. Minnesota Geol. and Nat. Hist. Survey, vol. 2, p. 338, 1888.

Rate of recession.—The rate of recession has depended on the rate at which the upper limestone bed was eroded away and the lower limestone bed exposed. Although the slope of the stream below the falls and the rate at which débris was removed from the foot of the falls have varied, and therefore the height of the fall scarp has also varied, the rate of recession has not been affected by the variation, as the height of the scarp has always been greater than the thickness of the limestone, and the sandstone has always been exposed to erosion at the foot of the falls. The volume of the river at Minneapolis has neither increased nor decreased to any great extent since the ice melted from its drainage basin, as is shown by the channel at Coon Rapids and by the nearly uniform width of the gorge formed by the recession of the falls. The limestone is practically uniform in thickness and hardness from Soldier Ravine, above Fort Snelling where the falls began, to the Tenth Avenue Bridge, and as the volume of the stream was nearly constant the rate of recession of the falls was presumably uniform up to that point.

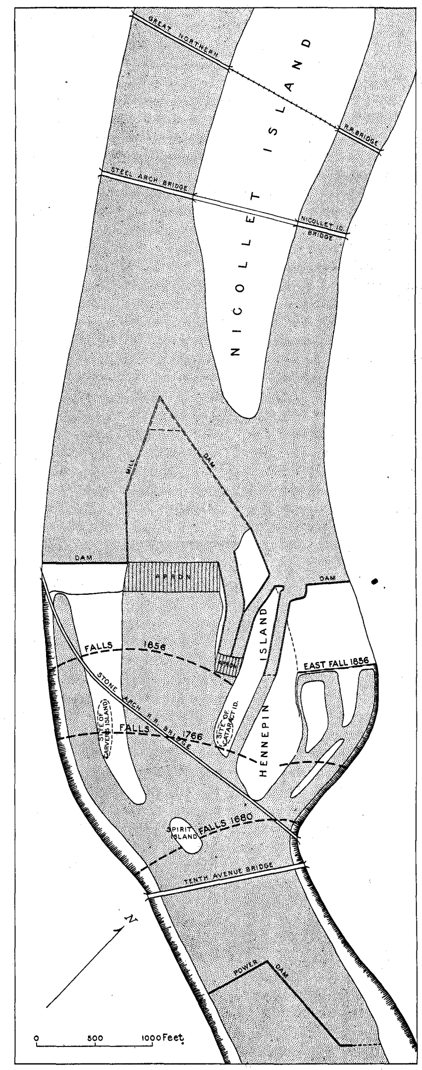


Figure 14.—Detailed map of Mississippi River at St. Anthony Falls, showing the present position of the falls and their positions at earlier stages: As seen in 1856, as seen by Jonathan Carver in 1766, and as seen by Hennepin in 1680.
Redrawn after N. H. Winchell, Geological and Natural History Survey of Minnesota, vol. 2, p. 336, 1888.

Professor N. H. Winchell determined, from all available written accounts and pictures of the falls, their rate of recession in historic times. A detailed map of the Mississippi gorge at St. Anthony Falls showing observed positions of the falls at earlier stages is given in figure 14. From 1680, when Father Hennepin saw the falls, to 1766, when they were visited by Jonathan Carver, they receded 412 feet, or 4.79 feet a year. From 1766 to 1856 they receded 606 feet, or 6.73 feet a year. There was, therefore, according to Winchell's determination, an increase of 40 per cent in the rate of recession during the second period, due to the fact that the falls had entered the

Nicollet Island rapids, where the limestone, rising northwestward, had been beveled by the river, and a steadily decreasing thickness of the upper limestone bed had to be removed. When Father Hennepin saw the falls in 1680 they were at a point where, owing to the beveling, only about half the upper limestone bed formed the crest of the falls, and by 1856 they had receded so far that none of that bed remained. After allowing for the increase in rate of recession due to the cause just stated, it is now estimated that the rate of recession of the falls before they entered the Nicollet Island rapids was 2.44 feet a year, or a mile in 2,163 years. The falls have therefore been in existence more than 12,000 years.

The recession of the falls has been contemporaneous with the deepening and partial refilling of the gorge and with like changes in the River Warren gorge. When the falls were 2 miles above Fort Snelling the descent of the fall and rapids was 40 feet and the gorge at Fort Snelling was probably the same depth as that of River Warren, 60 feet. When the falls were at Lake Street the descent at the falls was 75 feet, the greatest height they attained. This stage was probably contemporaneous with the maximum excavation of the gorge, the bottom of which, as shown by borings, was 175 feet below the top of the limestone at Fort Snelling. The deep channel was developed as far north as the mouth of Minnehaha Creek, but not above Lake Street Bridge. River Warren therefore subsided just after the falls had reached their greatest height and when they were 4 miles below their present position. That was, accordingly, more than 8,000 years ago.

Recession to the lower end of Nicollet Island would bring the falls to the northwestern limit of the Platteville limestone in the river bed and, the limestone being thus entirely removed from the river's course, both the falls and the Nicollet Island rapids would come to an end. In view of the rapidly increasing rate of recession it is believed that the end would have been reached by this time had not recession been artificially checked by an apron and retaining wall.

MINNEHAHA FALLS.

When the falls on the west branch of the Mississippi, which flowed through the present site of the deer park at Minnehaha, receded past the junction of Minnehaha Creek, Minnehaha Falls began as a cascade about 40 feet high. The cascade has receded 600 feet and has increased in height to 60 feet (see Pl. VIII), and the gorge below has been deepened, so that the descent from the foot of the falls to the river is more than 40 feet. Minnehaha Creek carries but little sediment and therefore has little power of corrasion. The recession of the falls is caused by the weathering and crumbling of the bed of shale which lies at the contact of the St. Peter sandstone and Platteville limestone, about in the middle of the height of the escarpment. The limestone layers are thereby undermined and slowly break off, so that an overhanging shelf is formed around the head of the gorge, which is about 200 feet across at the top, and the stream cascades over part of the shelf. The sandstone is worn away slowly and a dry bench remains back of the cascade upon which one can cross under the falls.

ECONOMIC GEOLOGY.

BUILDING MATERIALS.

SAND AND GRAVEL.

The glacial drift affords an abundance of sand and gravel. The cities and towns are built on and near gravel deposits, and abundant materials for both mortar and concrete are therefore close at hand. The practice of making excavations for basements or cellars for all houses commonly supplies all necessary sand and gravel for building. Numerous large and small gravel pits in this area now furnish material both for mortar and for concrete paving stone. (See Pls. XV to XVII.)

If a uniform grade of sand or gravel is needed the drift materials must be screened, as in many beds of sand that are entirely free from pebbles the sand is too fine or is mixed with silt. Beds of gravel contain also more or less good sand. Gravel that is free from sand commonly includes cobble or even bowlders. The drift materials are readily prepared for ordinary uses by dry screening. A plant, however, has been built on the Great Northern Railway a mile west of Cedar Lake to wash and screen gravel and sand. The gravel of the red drift is best for most purposes, because it is free from limestone pebbles and from green Cretaceous shale pebbles, which tend to absorb water and when frozen to flake off the surface of concrete work. Red gravel can be found both in the areas which are mapped as red drift and in many places under a few feet of till in the areas mapped as gray drift. (See Pl. XVIII.)

The St. Peter sandstone also yields sand readily. It is a very friable rock and can be removed by pick and shovel as sand. (See Pl. V.) The sand is very pure, but as the grains are round and dull polished it is for most purposes not so desirable as the angular, sharp sands of the drift. On the other hand it is much used for molding sand in foundries and is shipped to distant places for that purpose. It is also used in making sand-lime brick. Because of its purity and its freedom from iron it can be crushed for making pottery and glass.

BUILDING STONE.

Because of their abundance bowlders and cobble from the glacial drift are often employed, either alone or with limestone, in basement walls. They are sometimes worked into ornamental walls, a use for which they are well adapted because of their great variety of color and size.

The Platteville ("Trenton") limestone is the local natural building stone where range rock is desired. The lower bed of the Platteville (see Pl. IX) is locally called "the building stone." It includes 12 to 15 feet of hard rock that consists of interlaminated dense or semicrystalline blue-gray limestone and irregular darker, somewhat shaly bands. Where it has weathered in place this rock divides along the shaly bands into rubble. In the quarries the unweathered rock is jointed at wide intervals and must be broken and split to yield range rock. This stone has been used, both hewn and rough dressed, for walls of buildings. It is durable, but its color fades and on exposed surfaces its shaly bands weather to seams. The walls of the old fort at Fort Snelling, built in 1823, are made of this stone. It is now used chiefly for footings or foundations. The upper limestone or second bed of the Platteville is massive. Its lower strata crumble if exposed to frost, but the rest—about 7 feet of buff fine-grained limestone—is durable. It is much used for walls and foundations that are not exposed to view. The layers of limestone in the Decorah shale are also used. Recently the buff upper part of the Platteville limestone has come into use, in the form of rough-dressed blocks 4 to 12 inches in diameter, for ornamental outside walls of large buildings.

The Platteville limestone has been quarried at many convenient places along the bluffs of the Mississippi from Minneapolis to St. Paul. In that part of St. Paul which lies on the limestone terrace the Platteville limestone is necessarily removed in the excavations made for basements and cellars. Many city squares have also been quarried away in anticipation of their use for building sites. In part of northeast Minneapolis the same condition exists.

Locally indurated St. Peter sandstone has been used for retaining walls near South St. Paul, and the oldest house at Mendota, built in 1836, is made of rock of the same kind, quarried on the little island in the Minnesota Valley. The stone is very durable, but the supply of it is rather small. The Shakopee dolomite is not much quarried for building stone here.

CRUSHED STONE.

Crushed limestone for concrete and for macadamized roads is made both in St. Paul and Minneapolis. The "building stone layer"—the lower zone of the Platteville limestone—when crushed and well screened, makes a very good and durable stone. Sometimes a part of the upper zone of the granular buff limestone of the upper or second zone of the Platteville formation is crushed with that of the "building stone layer." On the contrary several feet of the upper zone that lie next to the lower or "building stone layer" yield crushed stone that breaks or disintegrates too easily from changes of weather, but the rejected stone from those weak strata mixed with more or less quarry rubble has been crushed and used for macadam on some of the city streets. The layers of limestone in the Decorah shale are suitable for use as macadam. The best grade of crushed Platteville limestone is also shipped or hauled for use in neighboring places.

The Shakopee dolomite, a very durable stone, well suited for use as riprap or ballast, is for some reason not quarried for crushed stone. Even the riprap used by the railroads in this area was shipped in from neighboring places that were convenient for loading. The abundance of good gravel in the same places where the Shakopee outcrops also precludes its use locally.

BRICK CLAY AND SHALE.

Several persons or companies have attempted to make brick from the shales of the Decorah and Galena formations, but the only one that has succeeded is the Twin City Brick Co., which operates a large plant near Pickerel Lake in St. Paul, where pressed face brick, ornamental building tile, and drain-tile are made. The brick and tile are hard and smooth surfaced, and of a variety of colors—gray, brown, red, "sunrise," greenish, or yellow—and either plain or mottled with light or with dark spots, according to the kind or mixture of shales used and the manner of the burning. The blue-green shale used is quarried from the face of the river bluff. The lowest 10 feet of the Decorah shale, or the first zone above the Platteville limestone, is not much used. Two other zones comprised in the Decorah shale are worked separately in the quarry. The shale from the overlying Galena limestone is also used, together with the 18 feet at the top of the Decorah shale. (See Pl. XI.) The shale beds that are quarried are altogether about 70 feet thick but include many thin limestones, which are separated by hand in quarrying. The shale is ground and pressed while it is quite dry. The brick shrink remarkably in burning but do not warp.

Interglacial clay and silt are used for making brick and hollow tile, or "fireproofing," on both sides of the Mississippi in the northern part of Minneapolis and several brickyards are in operation there. They make stiff-mud, side-cut or end-cut brick, of cream color, as well as soft-mud, sand-mold brick. The brick range from soft to hard according to the burning. The clay for hollow brick, or "fireproofing" tile, is mixed with sawdust before molding, and the sawdust burns out, leaving the brick light in weight. Some pottery also has been made there. The brick and tile are made of laminated blue-black clay and silt. The deposit used rests on Kansan till which contains many pebbles, some of which are limestone, and is overlain in part by red till but for the greater part by a few feet of river gravel only. The clay beds are generally tilted, folded, or disturbed from their original horizontal position. (See Pl. XVII.) The beds have been observed several miles north of the place where they are now used and are evidently extensive.

Clay or till of the Wisconsin red drift is used for making building and paving brick at Coon Creek station, on the Great Northern and Northern Pacific railways, 6 miles southeast of Anoka. Red to dark-brown paving brick are made there by the stiff-mud process. The kilns and clay pit are near the bank of Coon Creek, by the railway. The pit is worked by steam shovel. It shows 5 feet of dune sand, 6 feet of glacial river gravel, and 10 feet of blue-black till of the young gray drift. Under this lies 20 feet of red till or clay, of which the brick are made. The clay contains a few pebbles and some bowlders. The clay deposit is evidently extensive.

A soft red brick is made from red till in a brickyard near Pickerel Lake, in West St. Paul, Dakota County, near St. Paul.

The glacial river clay found along the Bassett Creek valley in Minneapolis was used for making brick until the growth of the city made the land too valuable for use as brickyards.

Minnesota River silt or alluvium is extensively used at Shakopee for making cream-colored brick by the soft-mud process. The pits now in use are on the flood plain of the river just outside the area here considered, on the alluvial plain which extends within the area. The same kind of brick is said to have been formerly made of alluvium on the west side of the river in St. Paul.

Sand-lime brick.—Sand-lime brick are made successfully in St. Paul from the St. Peter sandstone. The product is a clear-white face brick that is used chiefly for outside walls of houses. A similar product is made in the northeast part of Minneapolis from glacial river sand. The sand there consists in part also of grains from the St. Peter sandstone. Sand for sand-lime brick can be had here in inexhaustible quantity.

PEAT.

Peat beds are not used in this region except as they are converted to soil. The peat is of good quality but has not been used for fuel and has no economic value for that use now. A large part of the marsh and swamp lands shown on the accompanying maps are peat beds. The peat is generally 5 to 10 feet thick. The greatest deposit is the Wiregrass Marsh, in the northern part of the area. The peat beds burn persistently when accidentally set afire, but comparatively little has yet been destroyed in that way.

SOILS.

The soil is black, 1 or 2 feet thick, but is very diverse from place to place, the greatest diversity appearing where fields made from former peat bogs join with the dune-sand surface. The peat swamps or marshes are converted by artificial drainage to meadows and to fields, or to rich market gardens. The soil on the dune sands is light and is easily exhausted. The gravel plains have also a light soil, but in many places it is loamy and rich, the variation in its character being due to the great diversity of the constituents of the gravel. The soil of the glacial till ranges from sand to clay. That of the gray till surface is heavier than that of the red till. The richest soil is perhaps the alluvium of the Minnesota-Mississippi valley, but only part of that surface is secure from inundation by floods. Comparatively small areas have soil that lies upon limestone, and these are chiefly meadows and pastures.

MINERALS.

Profitable mining for ore is not to be expected in this area. The bowlders of iron ore that are occasionally seen have been brought by glaciers from the northern part of the State. Nuggets of native copper occasionally found in the drift are derived from the Keweenawan copper-bearing rocks of the north. Pieces of gold-bearing quartz and bowlders with argentiferous galenite are likewise erratics from places farther north. A small amount of sphalerite occurs in small pockets with calcite and pyrite in the basal beds of the Platteville limestone and of the Decorah shale. Gold in fine flakes is distributed through the upper part of the St. Peter sandstone to the value of 5 cents or less in a ton of sand. The aggregate amount of this gold may be very great, but there is not enough for profitable mining.

WATER RESOURCES.

WELLS.

Water can be obtained from shallow wells in nearly all parts of the area, and such wells constitute the chief source of supply outside the cities and are also used to a great extent within the cities. Most of the shallow wells are sunk in the glacial drift, but some are supplied from dune sands, from the St. Peter sandstone near its outcrops, or from alluvial deposits. Some that merely penetrate the sand and gravel down to a less pervious bed are likely to become polluted by surface drainage. Wells in the glacial drift range in depth from 10 to 400 feet. The deepest of these penetrate one or more impervious clay beds and are less likely to be polluted than the shallow wells. Most of those that go deep into the drift are artesian—that is, the water rises in them from the bed in which it is struck.

There are many deep wells in the area, especially in Minneapolis and St. Paul. They draw their supplies chiefly from the sandstone formations. The sandstones that carry the most water are the St. Peter, the Jordan, the Franconia, and the Dresbach. In St. Paul and Minneapolis the St. Peter sandstone is tapped by wells not more than 300 feet deep, the Jordan sandstone by wells not more than 500 feet deep, and the Dresbach sandstone by wells not more than 1,000 feet deep. As the St. Peter sandstone is the first reached by the drill it is heavily drawn upon. The Jordan is sufficiently coarse and porous to allow the water to percolate through it with great freedom, and hence affords copious supplies. The Dresbach and Franconia carry large supplies of water. The Shakopee dolomite and the Oneota dolomite carry relatively little water. The sandstone beds in them, once called the New Richmond, contain a moderate supply, though much less than the thicker sandstone formations. The St. Lawrence formation contains only small supplies, which, in part at least, are highly mineralized. The red clastic series contains much less water than the sandstones at higher horizons and the water is of poorer quality. A well 2,150 feet deep at Lakewood Cemetery, in Minneapolis, passed through at least 1,140 feet of the "red clastic series" and penetrated the underlying granitic rock. (See fig. 5, p. 3.)

The water rises in the wells, and those that are on low ground close to the rivers are flowing wells. The alternate pervious and impervious bedrock formations dip from all directions toward an area that lies midway between Minneapolis and St. Paul, and their edges lie in higher positions below the glacial drift, so that water entering the sandstones at their edges descends to the places where the formations are tapped by the wells, where it is under pressure or head.

The public water supplies of Fort Snelling and the towns of Anoka, West Minneapolis (Hopkins), and South St. Paul are taken from deep wells that reach rock formations. Part of the supply of North St. Paul comes from a deep well, and part of that of St. Paul is taken from deep wells adjacent to the main source, Phalen, Vadnais, and other lakes.

SPRINGS.

Numerous small springs in the morainic areas around the borders of lakes and swamps carry the natural drainage from one morainic depression to another, or from one lake to another where surface streams have not been formed. Along the valleys of small streams there are also many such springs, all coming from the glacial drift, and some are of large size. Excellent springs flow from the gravel beds between the Kansan till and the red Wisconsin till. An example is Glenwood Spring, on Bassett Creek, in Minneapolis, from which large quantities of drinking water are sold.

In many places springs come out on the sides of the river valleys, mainly from the drift and especially from the red drift that overlies the Kansan till, the Decorah shale, or the Platteville limestone. Some come from beneath the Kansan till, and a few come from the St. Peter sandstone, or even from the Shakopee dolomite. As most of the springs emerge above the bottom of the valleys they afford power by which water may be raised to houses some distance from the springs, and many are utilized in that manner, especially along the north side of Minnesota River. East of Dayton Bluff the water from a series of springs is gathered into a sluice along the side of the hill for use at the State Fish Hatchery.

LAKES.

The public water supply of St. Paul is obtained north of that city, chiefly from lakes. The largest are Phalen and Vadnais lakes, to which several others have been joined, the original creeks between them having been replaced by covered conduits or by open sluiceways. By the aid of a pumping station at Centerville Lake another connected group of lakes is there linked to Vadnais Lake. The surface supply is supplemented by more than 30 wells, most of them deep, at the Vadnais and Centerville pumping stations. The daily consumption of water from these sources is 10,000,000 gallons.

STREAMS.

The public water supply of Minneapolis is taken from Mississippi River at a pumping station near the northern limit of the city, whence water is elevated to a settling basin of 75,000,000 gallons capacity. The water is purified by sedimentation and rapid sand filtration, calcium hypochlorite, lime, and alum being used. The filtered water goes to a covered 45,000,000-gallon clear-water basin, whence it runs into the mains. As the settling basin is about 200 feet higher than the river, sufficient head is available for distribution by gravity.

MINERAL CONTENT OF WATERS.

Data regarding the average chemical composition of ground water from various horizons in Minneapolis and St. Paul are given in the following table:

The figures given in this table represent averages of analyses of composite samples collected daily from each river for a year. After it is filtered, the water of Mississippi River is better adapted to general industrial use than the ground waters, because it contains less mineral matter. It usually carries very little suspended matter, but the unfiltered water is highly colored. The water of Minnesota River contains a notably large proportion of mineral ingredients, especially of sulphates, and it is therefore less desirable for general use. Rum River furnishes water which is rather more highly colored than that of Mississippi River but which is still lower in mineral content.

WATER POWER.

The power afforded by the natural fall at Minneapolis, called St. Anthony Falls, is utilized by two dams. The upper dam is owned jointly by the St. Anthony Falls Water Power Co. and the Minneapolis Mill Co., and both companies supply water to flouring, feed, cereal, and woolen mills and to other factories in the immediate vicinity of the dam. The St. Anthony Falls Water Power Co. also supplies water to the Minneapolis General Electric Co. and to its own large hydroelectric plant, which utilizes surplus water at the upper dam for the Twin City Rapid Transit Co. Besides this plant about 40 turbine units, operated under heads of 35 to 50 feet and affording about 35,000 horsepower, have been installed. The lessees of these powers also operate auxiliary steam plants, not only because the water available is at times insufficient to supply

Average chemical composition of ground water at Minneapolis and St. Paul.[a]

Constituents.	Glacial drift.		St. Peter sandstone.		Sandstones in Shakopee or Oneota dolomites, previously called New Richmond.		Jordan sandstone.		Dresbach and Franconia (?) sandstone.	
	Minneapolis.	St. Paul.	Minneapolis.	St. Paul.	Minneapolis.	St. Paul.	Minneapolis.	St. Paul.	Minneapolis.	St. Paul.
Silica (SiO_2)	21	16	14	12	15	9.7	16	6.3	13	8.1
Iron and aluminum oxides ($Fe_2O_3+Al_2O_3$)	....	1.7	1.7	2.4	....	....	4.4	....	3.4	2.2
Calcium (Ca)	47	55	64	56	68	58	80	58	75	52
Magnesium (Mg)	11	22	28	22	29	23	30	22	29	20
Sodium and potassium (Na+K)	17	9.2	5.6	8.6	11	7.9	9.4	6.8	6.5	10
Bicarbonate radicle (HCO_3)	164	269	297	293	360	328	405	278	378	252
Sulphate radicle (SO_4)	31	11	26	1.8	....	....	12	6	21	4.1
Chlorine (Cl)	12	5.1	4.2	6.4	7.7	....	6.2	5	2.5	5.3
Total solids	214	280	354	254	316	261	350	246	328	236

[a] Hall, C. W., Meinzer, O. E., and Fuller, M. L., Geology and underground waters of southern Minnesota: U. S. Geol. Survey Water-Supply Paper 256, Pls. X and XIV, 1911. Most of the analyses were made at the Dearborn laboratory.

Waters from the same formation differ from one another in mineral content about as much as do those from different formations, though all the supplies are calcium carbonate waters of moderate mineral content, fair for boiler use and acceptable for general industrial use. They form a moderate quantity of soft scale and can be improved for boiler use by treatment with lime and soda ash. The water from the glacial drift has rather a wide range of mineral content, but the available analyses show that it has a slightly lower average hardness than the sandstone waters. The mineral content of the waters from the rock formations increases westward, as is shown by the differences between St. Paul and Minneapolis in the above table.

The following table shows the chemical composition of the water of Mississippi and Minnesota rivers at Shakopee, only a short distance outside the area here considered:

Average chemical composition of water from Minnesota River at Shakopee and Mississippi River at Minneapolis.[a]

Constituents.	Mississippi River.		Minnesota River.	
	Parts per million.	Percentage of anhydrous residue.	Parts per million.	Percentage of anhydrous residue.
Turbidity	10	....	97	....
Suspended matter	7.9	....	142	....
Coefficient of fineness	1.13	....	1.18	....
Silica (SiO_2)	15	7.8	23	5.0
Iron (Fe)	.07	.1	.09	.0
Calcium (Ca)	40	20.8	82	17.9
Magnesium (Mg)	14	7.3	35	7.6
Sodium and potassium (Na+K)	10	5.2	23	5.0
Carbonate radicle (CO_3)	.0	48.0	.0	31.7
Bicarbonate radicle (HCO_3)	188	....	296	....
Sulphate radicle (SO_4)	18	9.3	144	31.4
Nitrate radicle (NO_3)	1.4	.7	2.0	.4
Chlorine (Cl)	1.6	.8	4.7	1.0
Dissolved solids	200	....	480	....

[a] Dole, R. B., The quality of surface waters in the United States; Part I, analyses of waters east of the one hundredth meridian: U. S. Geol. Survey Water-Supply Paper 236, pp. 74–75, 1909. Samples collected in 1906–7 and analyzed by W. M. Barr, W. D. Collins, R. B. Dole, Chase Palmer, H. S. Spaulding, and Walton Van Winkle.

their needs but also because some wheels do not furnish sufficient power.

The lower dam is owned by the St. Anthony Falls Water Power Co. and gives a gross head of 20 feet. The total installed power of the Minneapolis Mill Co. is 35,000 horsepower and that of the St. Anthony Falls Water Power Co. is 12,000 horsepower at the upper dam and power house and 10,000 horsepower at the lower dam and power house. Thus the total installed power is 57,000 horsepower, the average developed power being 48,000 horsepower.

A dam on Mississippi River at Coon Rapids, 11 miles above Minneapolis, forms an 18-foot head. The installed units have a capacity of about 12,000 horsepower. A 30-foot dam with a lock 85 feet wide is being built at Fort Snelling by the Federal Government, chiefly for the purpose of making Mississippi River navigable between Minneapolis and St. Paul. There are also small water powers on the outlet of Hayden Lake at Champlin and on Minnehaha Creek at Edina.

A 12-foot timber dam in Rum River at Anoka creates a head of 13 feet, which is utilized in the Lincoln Mill by wheels with a combined capacity of 350 horsepower.

The following table summarizes the power developments around Minneapolis:

Total horsepower developed or under construction near Minneapolis.

Stream and location.	Head in feet.	Horsepower (80 per cent efficiency).		
		Lowest monthly.	Lowest monthly during average low year.	Highest monthly during average low year.
Mississippi River at Coon Creek Rapids	18	1,640	3,360	7,050
Mississippi River at St. Anthony Falls:				
Upper dam	50	4,550	9,320	19,500
Lower dam	20	1,820	3,730	7,820
Mississippi River at Fort Snelling[a]	30	2,730	5,620	11,900
Rum River at Anoka	13	73	110	183

[a] Dam under construction.

December, 1914.

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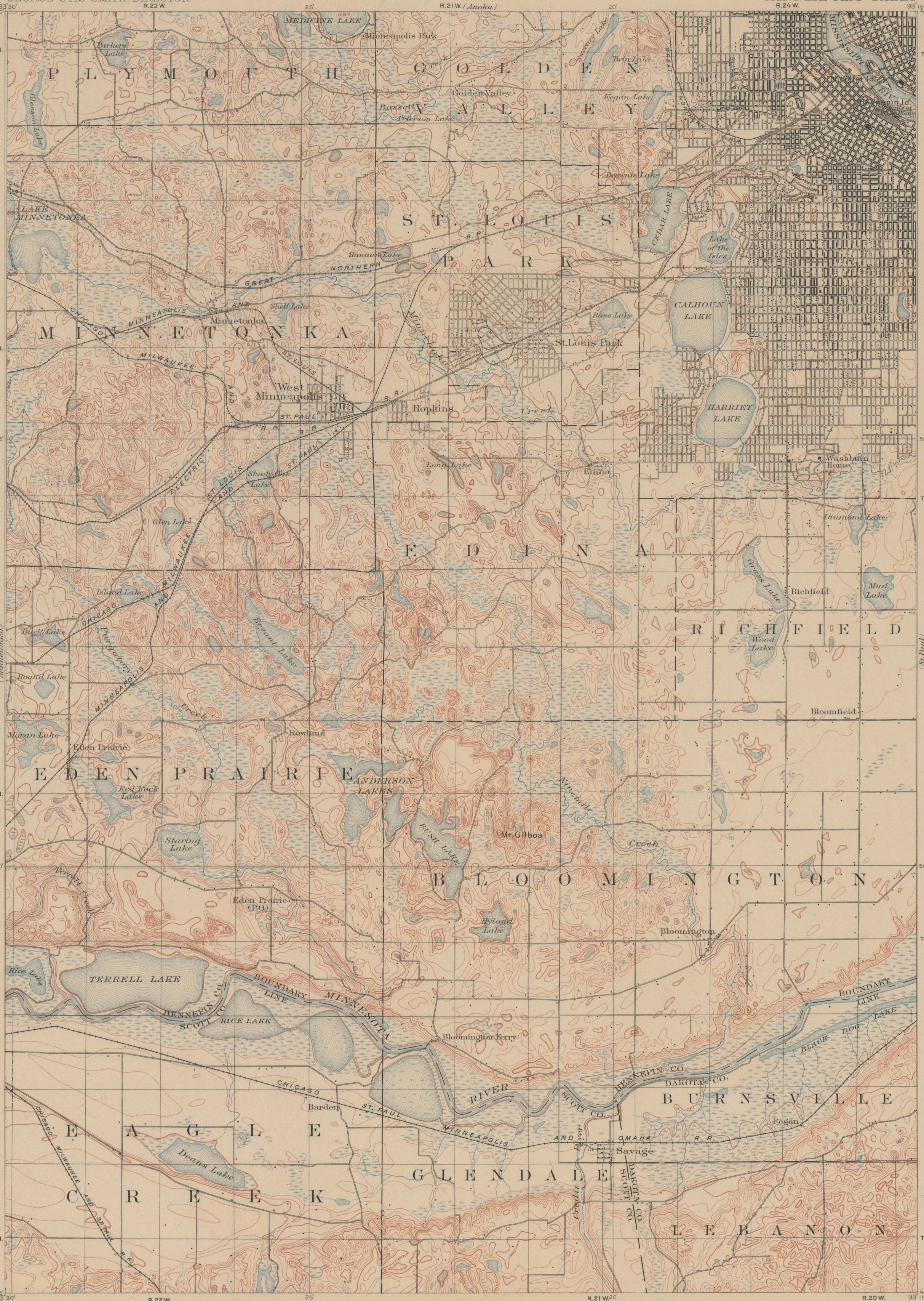
MINNESOTA
MINNEAPOLIS SHEET



Henry Gannett, Chief Topographer.
Jno. H. Renshawe, Topographer in charge.
Triangulation by U.S. Coast and Geodetic Survey.
Topography by H.L. Baldwin Jr.
Surveyed in 1894.

APPROXIMATE MEAN DECLINATION 1915.

Scale $\frac{1}{62500}$

Contour interval 20 feet.
Datum is mean sea level.

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
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Edition of Oct. 1901, reprinted April 1915.

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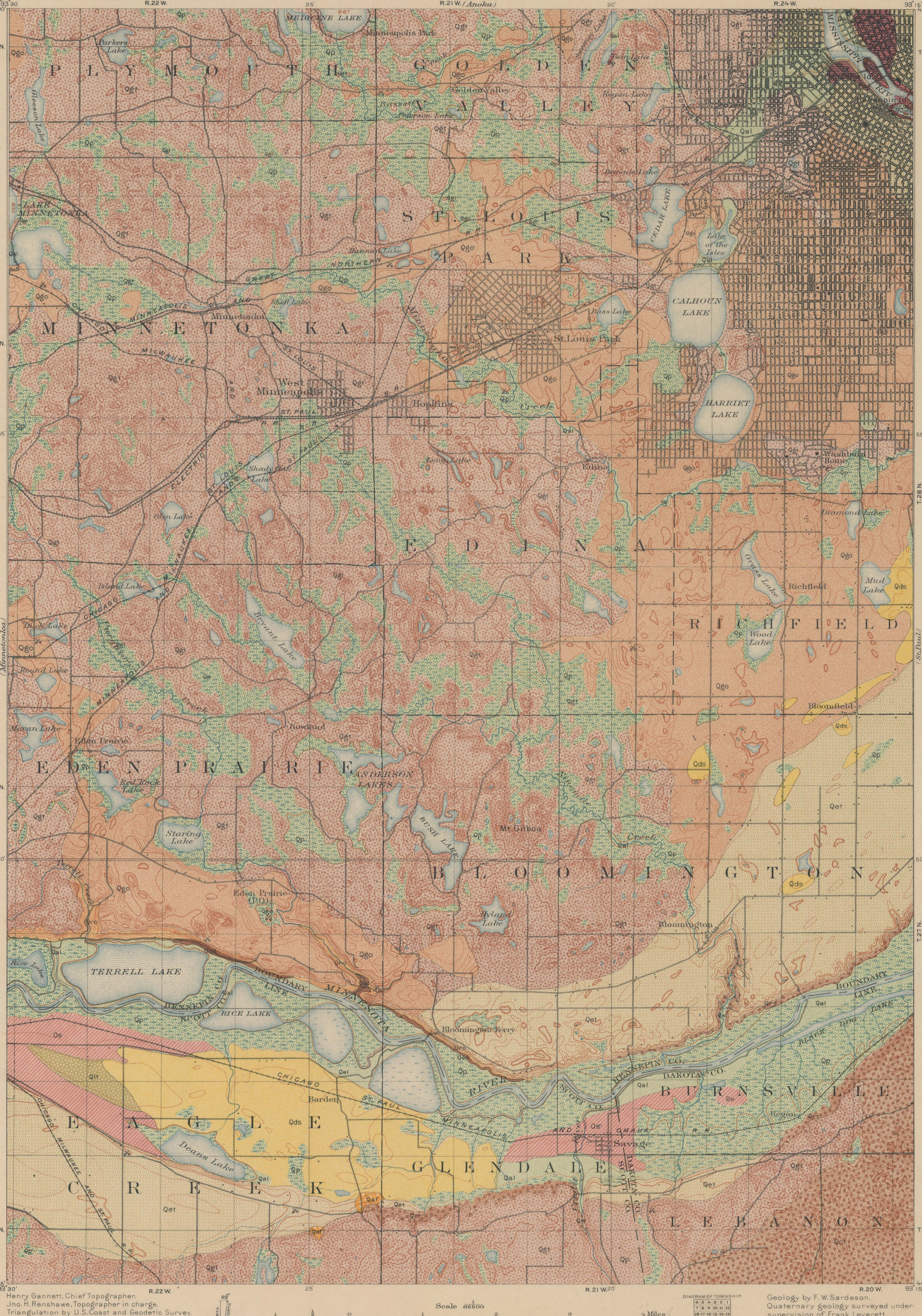
AREAL GEOLOGY

MINNESOTA
MINNEAPOLIS SHEET



LEGEND

SEDIMENTARY ROCKS

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

QUATERNARY

Recent

- Qp — Peat and muck in marsh land
- Qal — Alluvium and lacustrine deposits *(chiefly sand and fine silt)*
- Qaf — Alluvial fans *(chiefly gravel and sand)*

Pleistocene — Wisconsin stage — Late Wisconsin

- Qds — Dune sand *(derived from glacial river gravels and outwash from young gray drift)*
- Qlt — Later terrace gravels of glacial River Warren *(outlet of glacial Lake Agassiz)*
- Glacial Mississippi River channel floor on Platteville limestone *(cut in bedrock during and after deposition of earlier terrace gravels)*
- Qet — Earlier terrace gravels of glacial Minnesota and Mississippi rivers *(issued from young gray drift; includes some nearly bare till surfaces and some later wash on terrace slopes)*
- Qgo — Gray outwash gravel of the young gray drift
- Qgt — Young gray till *(thin sheet, chiefly ground moraine)*

Middle Wisconsin

- Qro — Red outwash gravel of the red drift *(red sand and gravel containing few limestone pebbles)*
- Qrt — Red till *(red bowlder clay containing few limestone pebbles; chiefly terminal moraine)*

Kansan stage

- Qod — Old gray drift *(till and sand)*

ORDOVICIAN

Bedrock deeply covered in most places by glacial deposits

- Op — Platteville limestone *(blue to gray limestone, with clay beds at the base)*
- Osp — St. Peter sandstone *(very white, friable, quartzose sandstone)*
- Os — Shakopee dolomite *(chiefly massive-bedded dolomite with some sandstone)*

⚒ *Quarries*
✂ *Gravel pits*

Economic data: *Building stone and crushed rock can be obtained from Platteville limestone, and rough stone for ballast from Shakopee dolomite; lime from Shakopee dolomite; clay for common brick and tile from lacustrine deposits,* Qal, *and red till,* Qrt; *sand for lime-brick and molding sand from St. Peter sandstone; building sand and gravel for concrete from* Qro, *and gravel for roads from* Qro, Qgo, Qet, *and* Qlt.

Much of the area marked Qgt *and* Qrt *is first-class agricultural land;* Qal *and* Qp *are good lands when properly drained;* Qro, Qgo, Qet, *and* Qlt *are level productive lands with soil of loose texture;* Qds *and* Qaf *are undulating lands with dusty sandy soils.*

Henry Gannett, Chief Topographer.
Jno. H. Renshawe, Topographer in charge.
Triangulation by U.S. Coast and Geodetic Survey.
Topography by H.L. Baldwin Jr.
Surveyed in 1894.

TRUE NORTH — MAGNETIC NORTH — 8½°
APPROXIMATE MEAN DECLINATION 1915.

Scale $\frac{1}{62500}$

1 ½ 0 1 2 3 4 Miles

1 ½ 0 1 2 3 4 5 Kilometers

Contour interval 20 feet.
Datum is mean sea level.
Edition of Sept. 1915.

DIAGRAM OF TOWNSHIP

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Geology by F. W. Sardeson.
Quaternary geology surveyed under supervision of Frank Leverett.
Surveyed in 1911.

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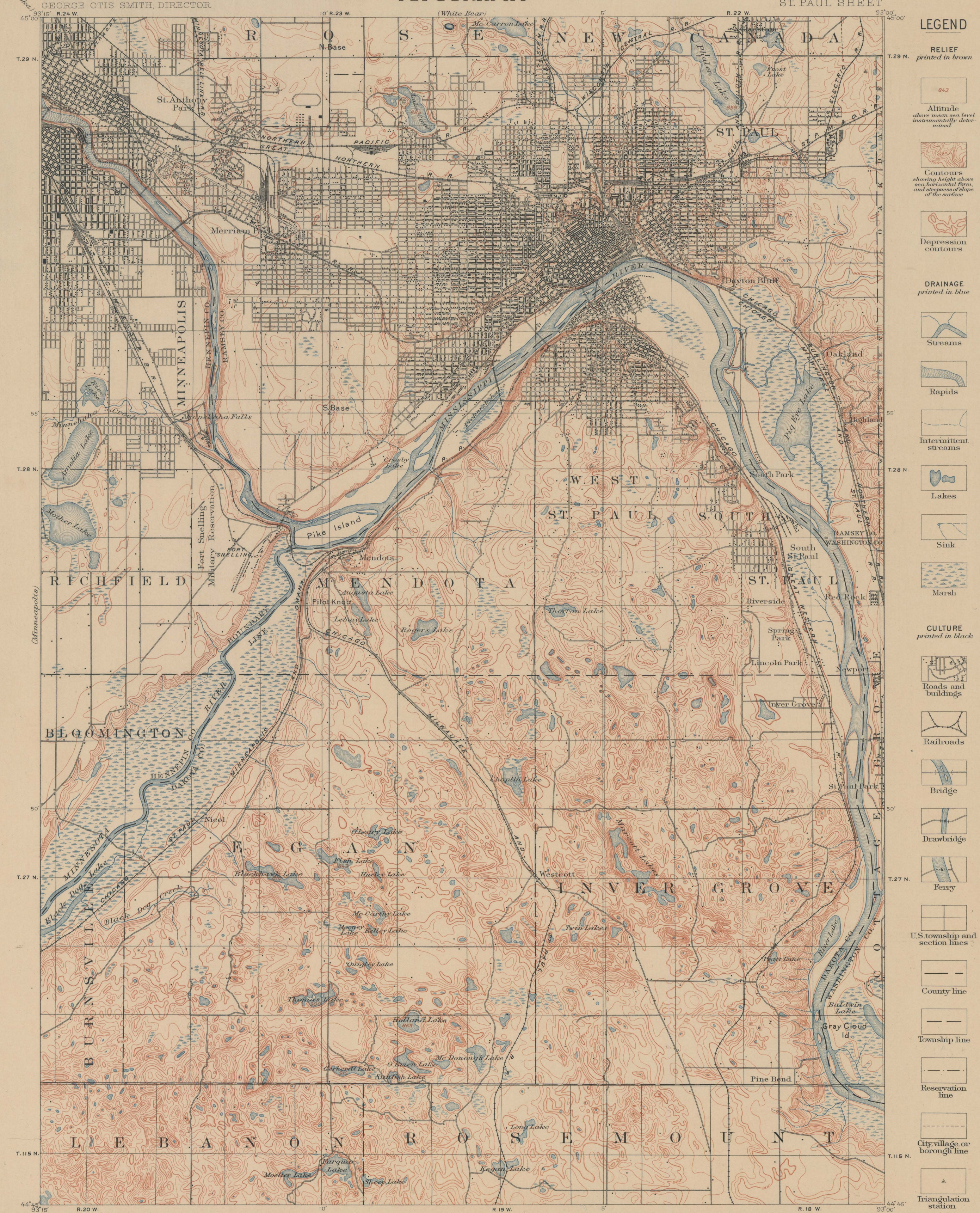
MINNESOTA
ST. PAUL SHEET



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Triangulation by U.S. Coast and Geodetic Survey.
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Edition of Oct. 1896, reprinted Apr. 1915.

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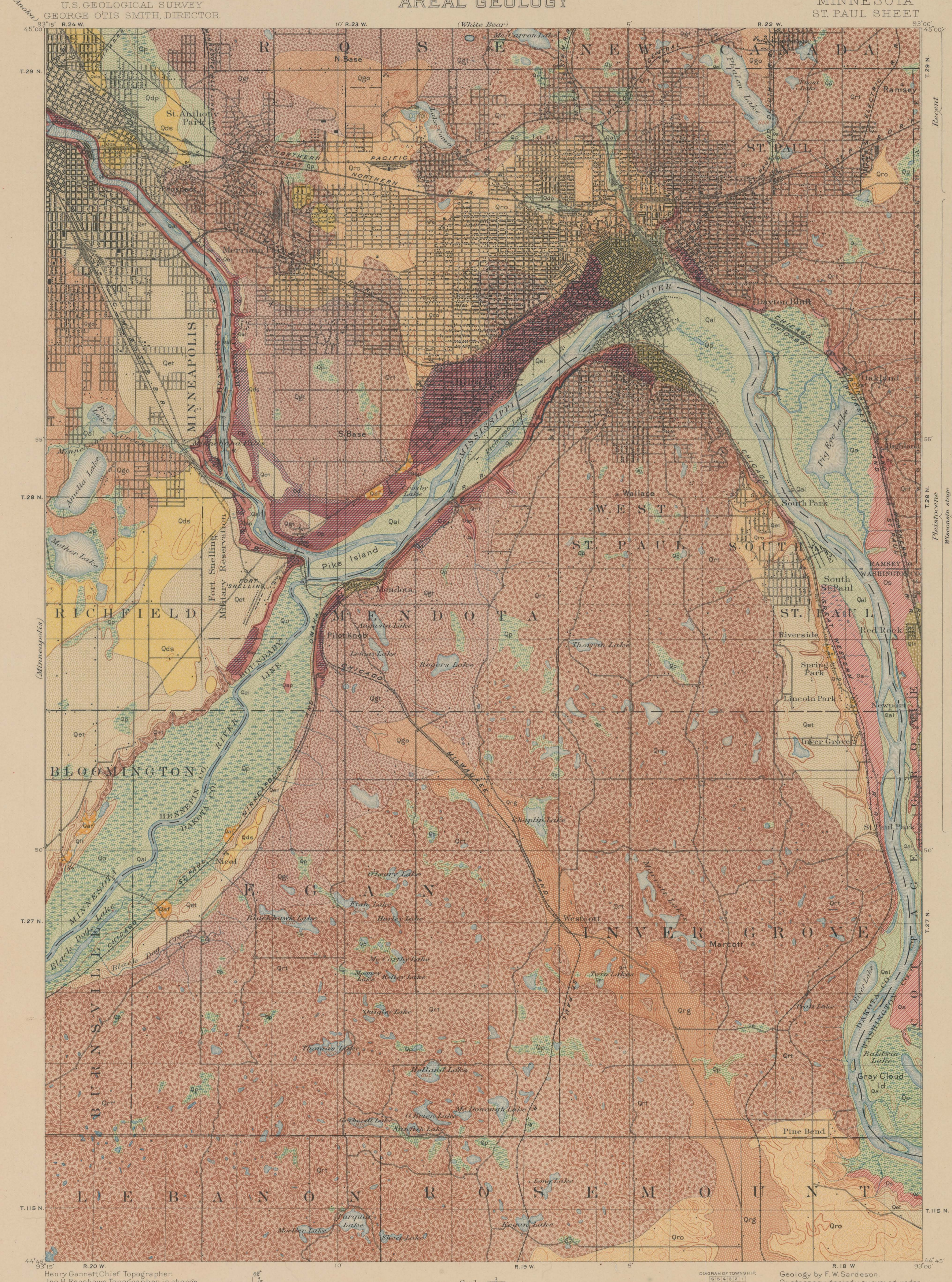
AREAL GEOLOGY

MINNESOTA
ST. PAUL SHEET



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Surveyed in 1911.

LEGEND

SEDIMENTARY ROCKS

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

QUATERNARY

Recent

Qp Qdp — Peat and muck in marsh land *(dry peat in drained marshes indicated by Qdp)*

Qal — Alluvium and lacustrine deposits *(chiefly sand and fine silt)*

Qaf — Alluvial fans *(chiefly gravel and sand)*

Pleistocene — Wisconsin stage — Late Wisconsin

Qds — Dune sand *(derived from glacial river gravels and outwash from young gray drift)*

Qlt — Later terrace gravels of glacial River Warren time *(deposited in River Warren outlet of glacial Lake Agassiz and in the channel of Mississippi River)*

Glacial Minnesota and Mississippi river channel floors on Decorah shale and Platteville limestone *(a higher terrace, generally on Decorah shale, cut in the bedrock during the deposition of the earlier terrace gravel; a lower terrace, generally on Platteville limestone, cut somewhat later; about 100 feet above present flood plains)*

Qet — Earlier terrace gravels of glacial Minnesota and Mississippi rivers *(issued from young gray drift, includes some nearly bare till surfaces and some later wash on terrace slopes)*

Qrg — Glacial river gravel in partly filled pre-Wisconsin channel *(thin and discontinuous gravel partly from younger gray drift, deposited over red till)*

Qgo — Gray outwash gravel of the young gray drift

Qgt — Young gray till *(thin sheet, chiefly ground moraine)*

Middle Wisconsin

Qro — Red outwash gravel of the red drift *(red sand and gravel containing few limestone pebbles)*

Qrt — Red till *(red bowlder clay containing few limestone pebbles; chiefly terminal moraine)*

ORDOVICIAN

Bedrock deeply covered in most places by glacial deposits

Og — Galena limestone *(shaly limestone and shale)*

Od — Decorah shale *(green shale and some interbedded crystalline limestone)*

Op — Platteville limestone *(blue to gray limestone with clay beds at the base)*

Osp — St. Peter sandstone *(very white, friable, quartzose sandstone)*

Os — Shakopee dolomite *(chiefly massive-bedded dolomite with some sandstone)*

Oo — Oneota dolomite *(dolomite with some sandstone near the top)*

⚒ *Quarries*
Gravel pits
Clay pits and brickyards

Economic data: *Building stone and crushed rock can be obtained from Platteville limestone, and rough stone for ballast from Shakopee dolomite; lime from Shakopee dolomite; shale for pressed brick and tile from Decorah and Galena formations, and clay for common brick and tile from lacustrine deposits,* Qal, *and red till,* Qrt; *sand for lime-brick and molding sand from St. Peter sandstone; building sand and gravel for concrete from* Qro, *and gravel for roads from* Qro, Qgo, Qet, *and* Qlt.

Much of the area marked Qgt, Qrt, *and* Qrg *is first-class agricultural land;* Qal *and* Qp *are good lands when properly drained;* Qro, Qgo, Qet, *and* Qlt *are level productive lands with soil of loose texture;* Qds *and* Qaf *are undulating lands with dusty sandy soils.*

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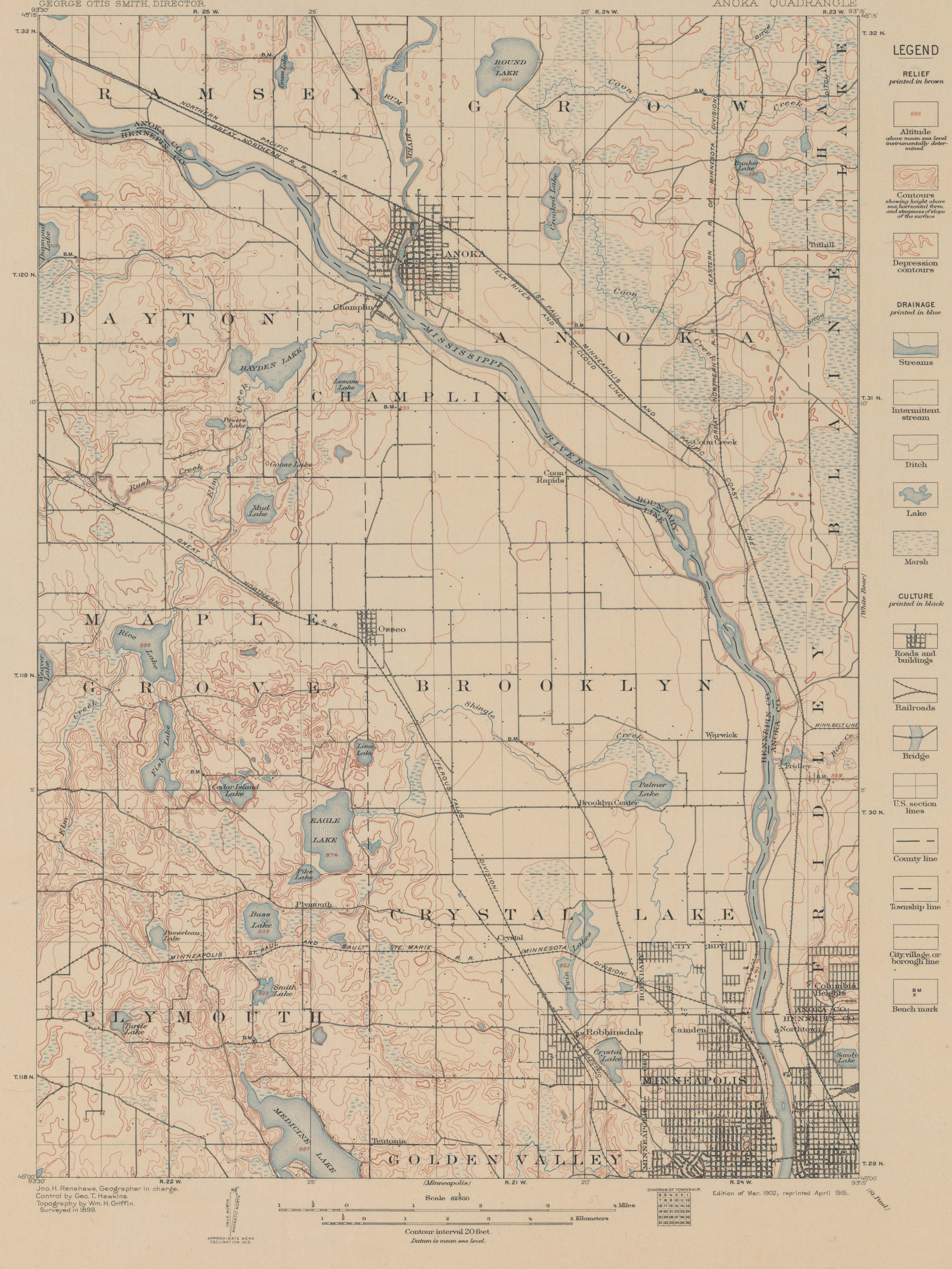
MINNESOTA
ANOKA QUADRANGLE



Jno. H. Renshawe, Geographer in charge.
Control by Geo. T. Hawkins.
Topography by Wm. H. Griffin.
Surveyed in 1899.

Edition of Mar. 1902, reprinted April 1915.

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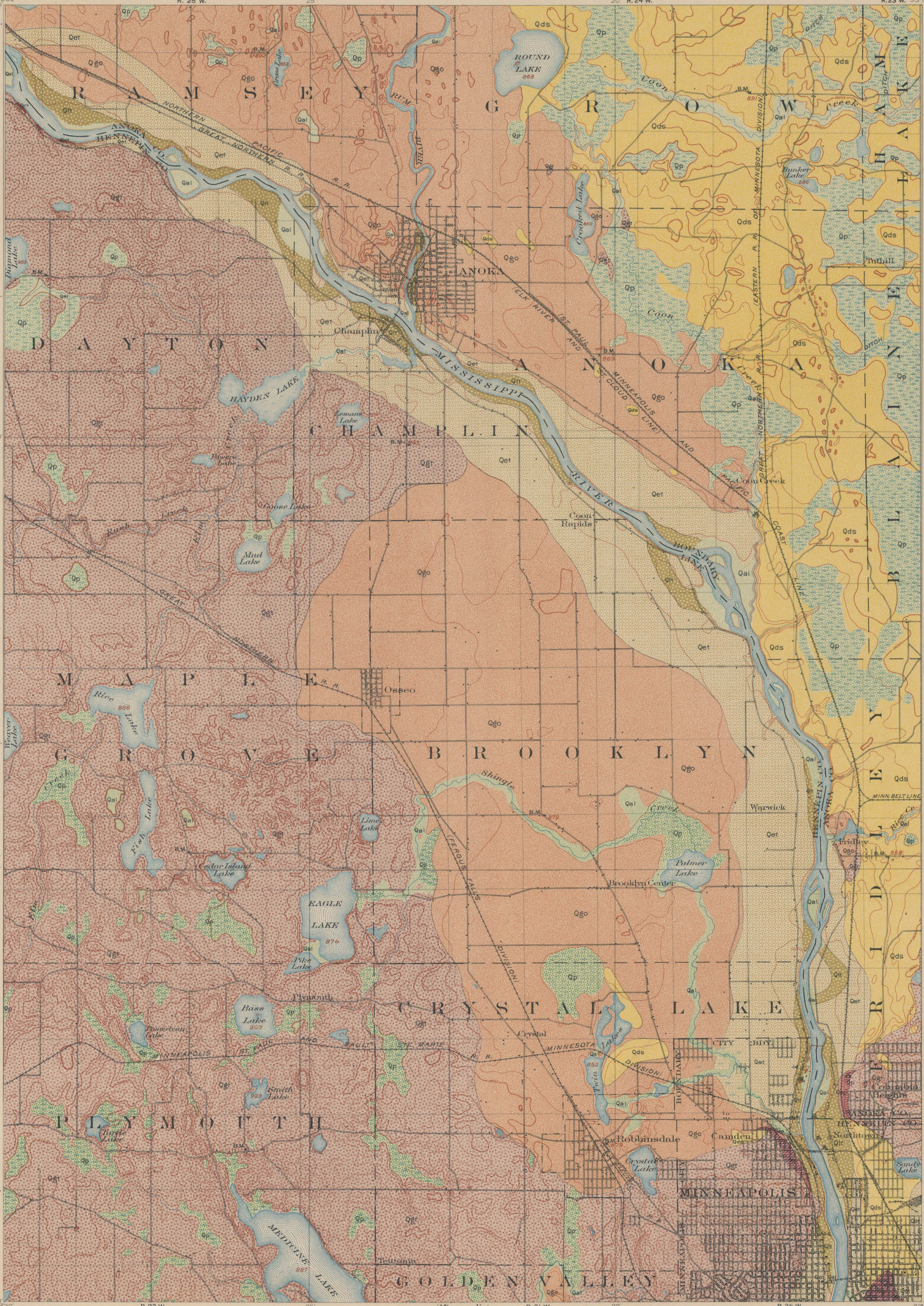
AREAL GEOLOGY

MINNESOTA
ANOKA 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

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- Qal — Alluvium and lacustrine deposits *(chiefly sand and fine silt)*

Pleistocene — *Wisconsin stage* — *Late Wisconsin*

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- Qgt — Young gray till *(thin sheet, chiefly ground moraine)*

(White Bear) *Middle Wisconsin*

- Qrt — Red till *(red bowlder clay containing few limestone pebbles)*

ORDOVICIAN

Bedrock deeply covered in most places by glacial deposits

- Op — Platteville limestone *(blue to gray limestone with clay beds at the base)*
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Quarries
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TRUE NORTH / MAGNETIC NORTH
APPROXIMATE MEAN DECLINATION 1915.

Scale $\frac{1}{62500}$

1 ½ 0 1 2 3 4 Miles

1 ½ 0 1 2 3 4 5 Kilometers

Contour interval 20 feet.
Datum is mean sea level.

Edition of July 1915.

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Geology by F. W. Sardeson.
Quaternary geology surveyed under supervision of Frank Leverett.
Surveyed in 1911.

U.S. GEOLOGICAL SURVEY
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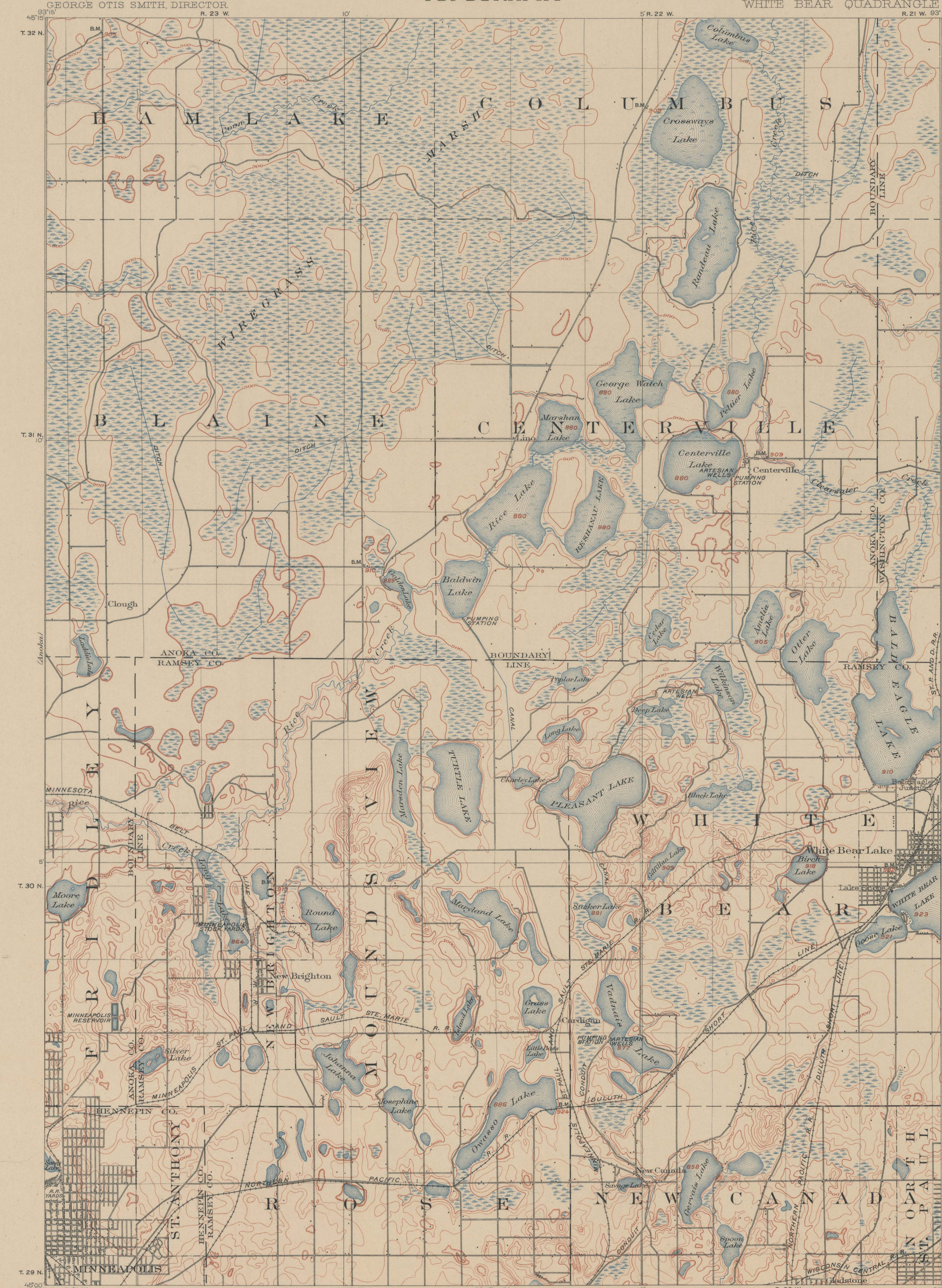
MINNESOTA
WHITE BEAR QUADRANGLE



LEGEND

RELIEF *printed in brown*

Altitude above mean sea level instrumentally determined

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

Depression contour

DRAINAGE *printed in blue*

Stream

Intermittent stream

Canal or ditch

Lake

Reservoir

Marsh

CULTURE *printed in black*

Roads and buildings

Railroads

U.S. section lines

County line

Township line

City, village, or borough line

Bench mark

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Edition of Mar. 1902, reprinted Apr. 1915.

U.S. GEOLOGICAL SURVEY
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AREAL GEOLOGY

MINNESOTA
WHITE BEAR QUADRANGLE

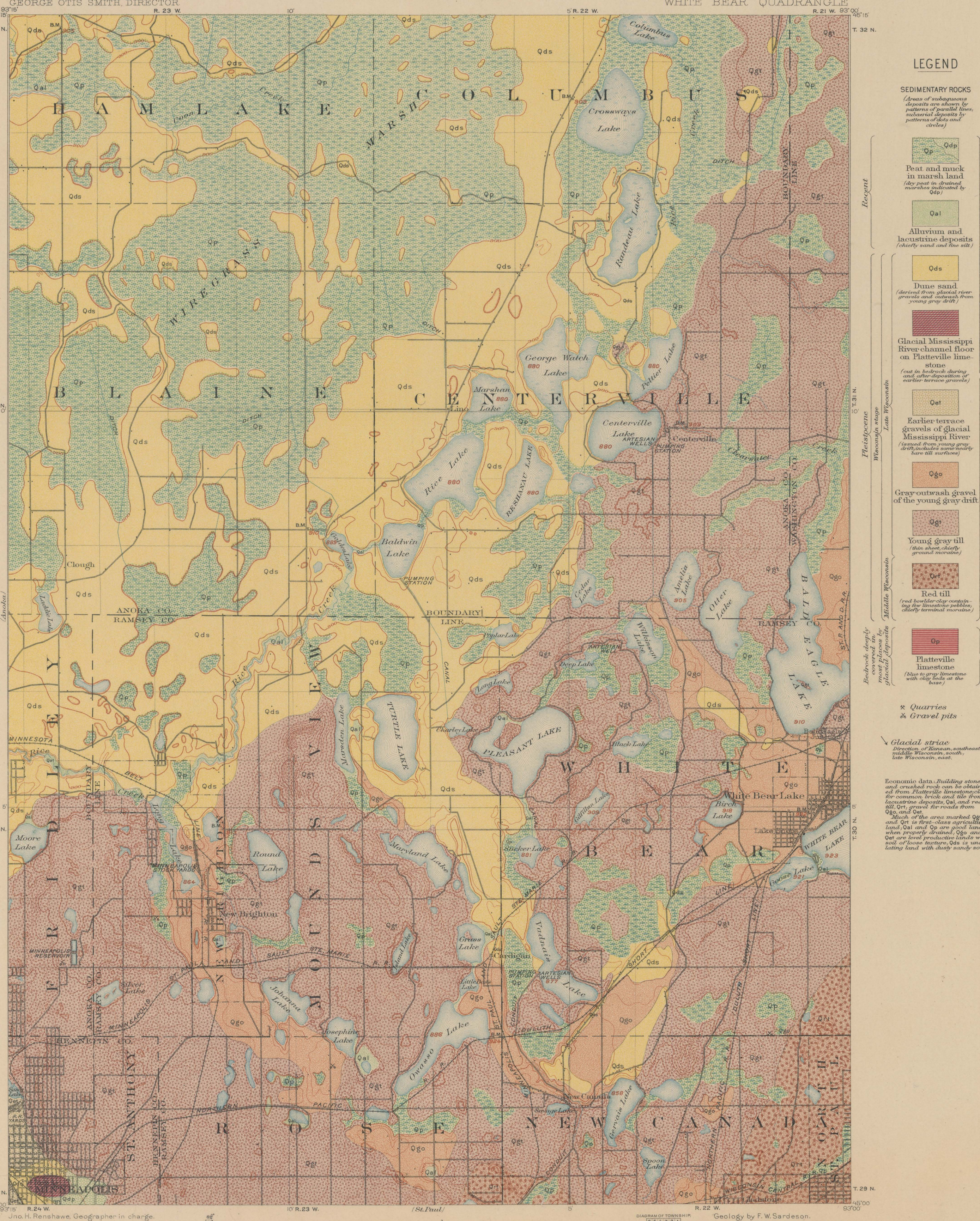

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DIAGRAM OF TOWNSHIP

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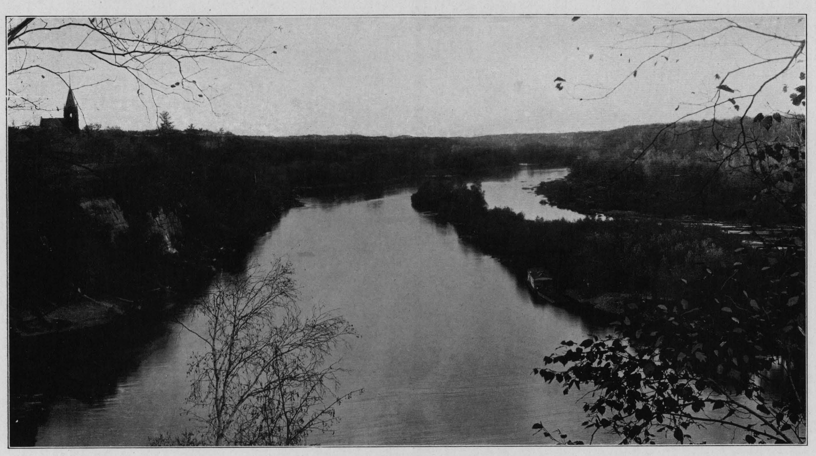

PLATE I.—MISSISSIPPI RIVER AND GORGE AT MINNEHAHA.
View looking upstream from mouth of Minnehaha Creek. St. Peter sandstone capped by Platteville limestone in bluff at left.

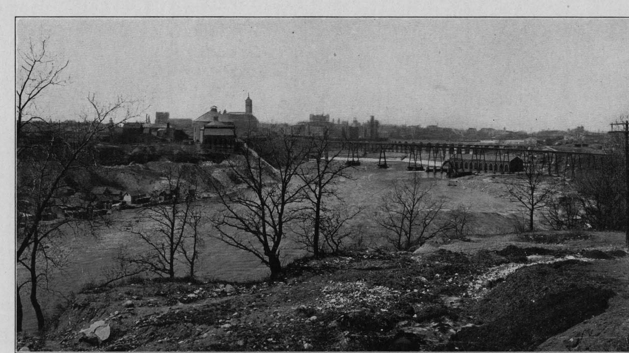

PLATE II.—MISSISSIPPI RIVER AND GORGE AT MINNEAPOLIS.
View from campus of the State University looking upstream toward St. Anthony Falls, concealed by the bridges. The lower dam and power house are seen under the bridges. The river above the falls is seen over the power house.

PLATE III.—EAST WALL OF THE MISSISSIPPI GORGE ABOVE WASHINGTON AVENUE BRIDGE, EAST MINNEAPOLIS.
St. Peter sandstone overlain by Platteville limestone, which is capped by glacial drift.

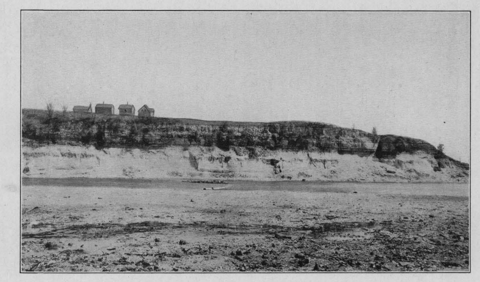

PLATE IV.—EAST WALL OF THE MISSISSIPPI GORGE BELOW WASHINGTON AVENUE BRIDGE, EAST MINNEAPOLIS.
St. Peter sandstone overlain by Platteville limestone which is capped by glacial drift. The escarpment and bench at the right are remnants of an old falls scarp of St. Anthony Falls.

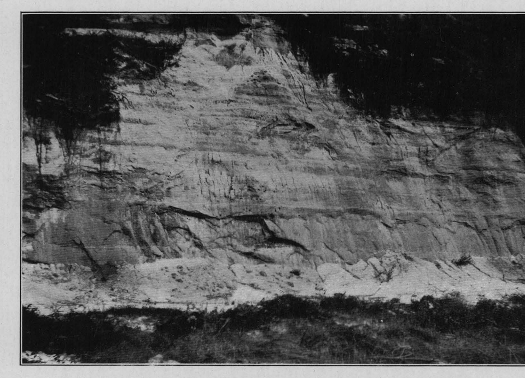

PLATE V.—ST. PETER SANDSTONE IN CLIFF OPPOSITE MINNEHAHA.
The friability of the sandstone is shown by the loose sand at base of the cliff and its purity by its whiteness.

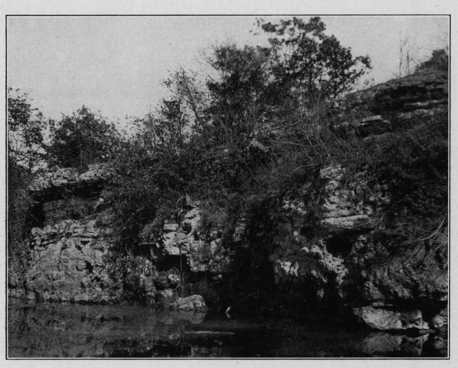

PLATE VI.—SHAKOPEE DOLOMITE IN CLIFF ON EAST SIDE OF MISSISSIPPI RIVER BELOW NEWPORT.
Shows the irregular bedding and the cavernous weathered outcrop of the formation.

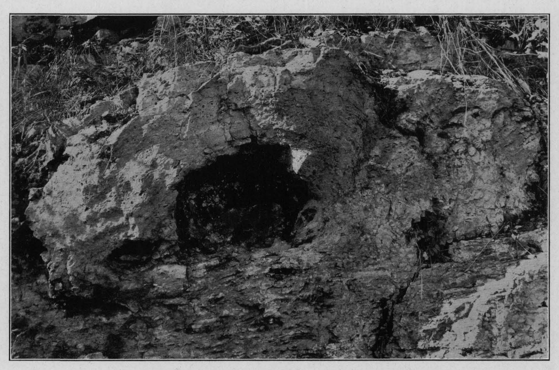

PLATE VII.—CRYPTOZOON MINNESOTENSE, A CALCAREOUS MASS SECRETED BY ALGÆ IN SHAKOPEE DOLOMITE.
South of Inver Grove. Diameter of mass about 6 feet.

PLATE VIII.—MINNEHAHA FALLS.
The stream falls 63 feet over Platteville limestone capping St Peter sandstone.

PLATE IX.—PLATTEVILLE LIMESTONE OVERLYING ST. PETER SANDSTONE, IN CLIFF OF MISSISSIPPI GORGE AT THE STATE UNIVERSITY.
The character of the lower limestones of the Platteville and the shale band at the contact with the St. Peter sandstone are well shown.

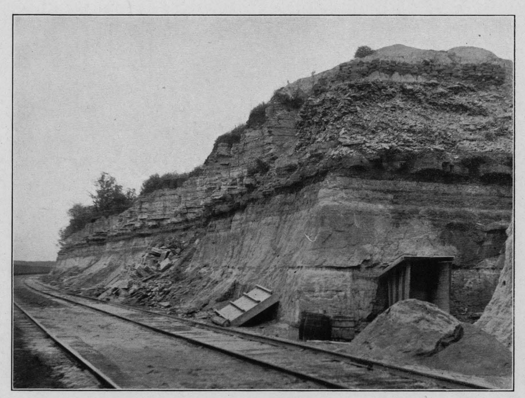

PLATE X.—UPPER PART OF ST. PETER SANDSTONE AND BASAL BEDS OF PLATTEVILLE LIMESTONE IN RAILROAD CUT IN ANOKA COUNTY NEAR NORTHTOWN, NORTHEAST MINNEAPOLIS.
The dark shale makes the contact very sharp.

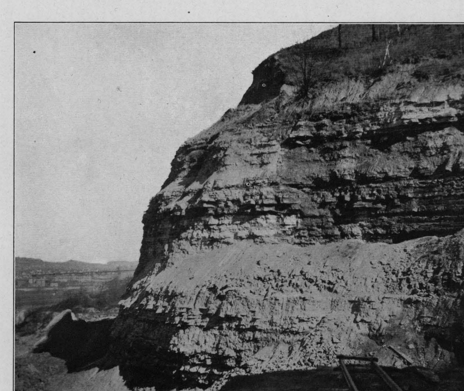

PLATE XI.—DECORAH SHALE AND OVERLYING SHALY LIMESTONE OF THE GALENA IN QUARRY OF THE TWIN CITY BRICK CO. NEAR PICKEREL LAKE, ST. PAUL.
The shaly Galena limestone in the upper part of the cliff is overlain by Kansan drift.

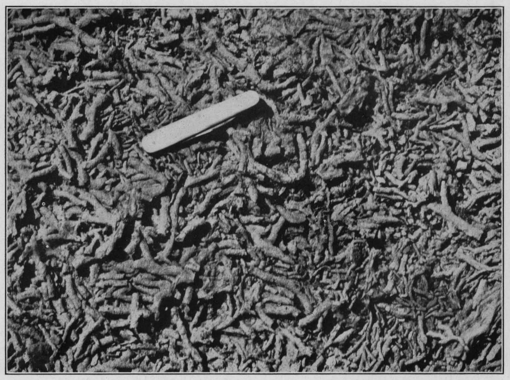

PLATE XII.—FUCOID BED NEAR TOP OF DECORAH SHALE, CHARACTERISTIC OF THE FORMATION IN THE AREA.
The fucoid stems are weathered in relief on the bedding surface.

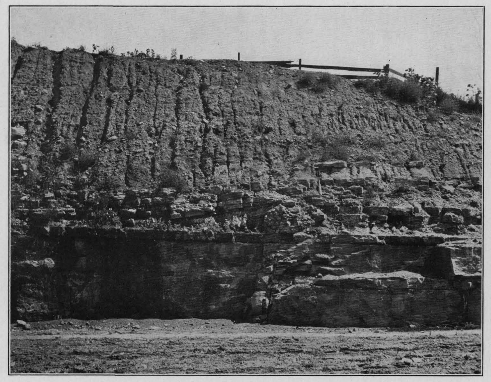

PLATE XIII.—BEDS OF DECORAH SHALE DISLOCATED BY THE ADVANCE OF THE ICE SHEET FROM THE LEFT.
In cut on boulevard at foot of State Street, Minneapolis. Layers of Decorah shale have been dislocated so that at the left they rest on undisturbed Platteville limestone, but at the right they lie on undisturbed Decorah shale. They are overlain by glacial till.

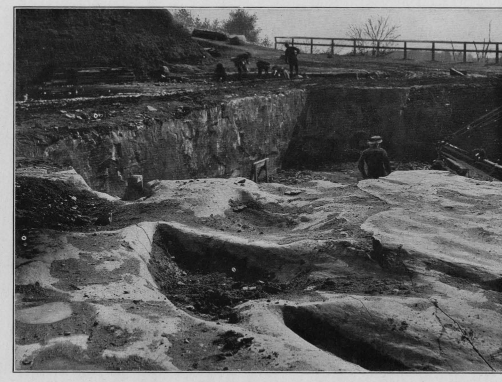

PLATE XIV.—SURFACE OF PLATTEVILLE LIMESTONE SMOOTHED AND GROOVED BY THE KANSAN ICE SHEET.
Quarry south of the State University, Minneapolis. The limestone is overlain by hard Kansan till.

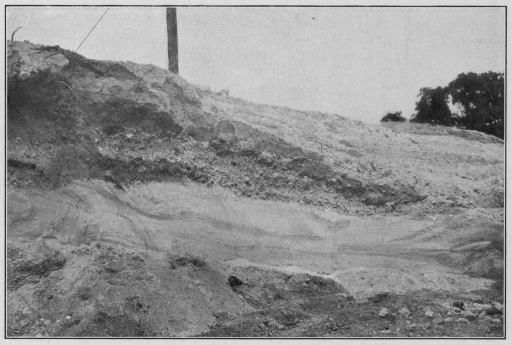

PLATE XV.—RED OUTWASH SAND AND GRAVEL OVERLAIN BY WISCONSIN GRAY TILL, STATE UNIVERSITY CAMPUS MINNEAPOLIS.

PLATE XVI.—NEAR VIEW SHOWING DETAILS OF RED OUTWASH SAND AND GRAVEL SHOWN IN PLATE XV.

PLATE XVII.—INTERGLACIAL LAMINATED CLAY TILTED BY THE THRUST OF THE ADVANCING WISCONSIN ICE SHEET.
Overlain by river gravel. Clay pit at Northtown.

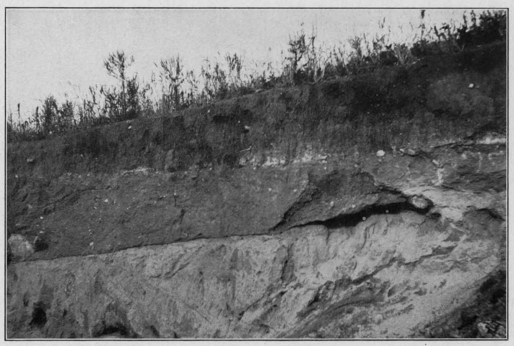

PLATE XVIII.—THIN SHEET OF WISCONSIN GRAY TILL OVERLYING A THIN SHEET OF WISCONSIN RED TILL WHICH RESTS ON RED GLACIAL SAND.
In sand pit on Snelling Avenue southwest of St. Paul. In the gray till there are white limestone pebbles and below it lies the red till, which is free from limestone pebbles and is streaked with lime leached from the gray till above.

PLATE XIX.—SOIL BANDS IN PLEISTOCENE DUNE SANDS ON STE. MARY'S AVENUE, PROSPECT PARK MINNEAPOLIS.

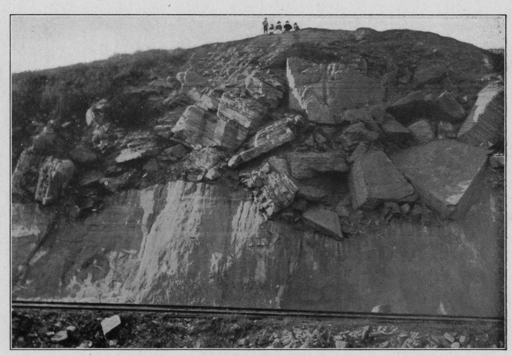

PLATE XX.—BLOCKS OF PLATTEVILLE LIMESTONE ON ERODED SURFACE OF ST. PETER SANDSTONE LEFT IN THIS POSITION AT FOOT OF RECEDING FALLS OF RIVER WARREN.
Exposed in railroad cut west of High Bridge, St. Paul.

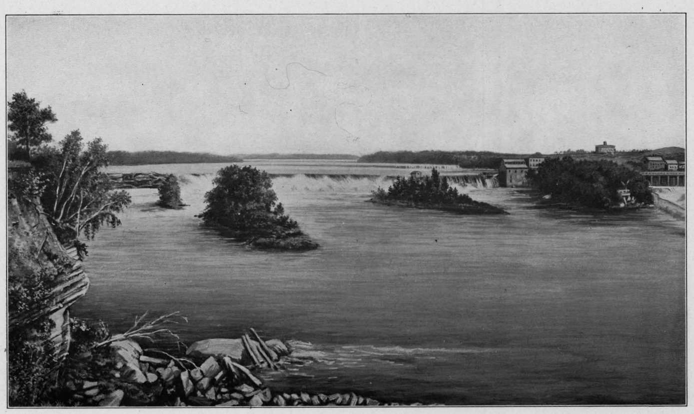

PLATE XXI.—GENERAL VIEW OF ST. ANTHONY FALLS IN 1857, SEEN FROM THE WEST BANK.
Shows Spirit Island, Cataract Island, and Hennepin Island, from left to right, below the falls. The middle part of the falls has receded 700 to 800 feet since this painting was made. From painting by Fred. Richardt. After N. H. Winchell, Minnesota Geol. and Nat. Hist. Survey, vol. 2, 1888.

PLATE XXII.—ST. ANTHONY FALLS VIEWED FROM HENNEPIN ISLAND IN 1851.
The method of recession of the falls is shown by the angular blocks of Platteville limestone (formed by joint cracks) that have fallen from the crest. From daguerreotype by Alex. Hesler, Chicago. After N. H. Winchell, Minnesota Geol. and Nat. Hist. Survey, vol. 2, 1888.

			Cents.
‡1	Livingston	Montana	
‡2	Ringgold	Georgia-Tennessee	
●3	Placerville	California	
‡4	Kingston	Tennessee	
●5	Sacramento	California	
‡6	Chattanooga	Tennessee	
‡7	Pikes Peak	Colorado	
‡8	Sewanee	Tennessee	
‡9	Anthracite-Crested Butte	Colorado	
‡10	Harpers Ferry	Va.-Md.-W.Va	
●11	Jackson	California	
‡12	Estillville	Ky.-Va.-Tenn	
‡13	Fredericksburg	Virginia-Maryland	
‡14	Staunton	Virginia-West Virginia	
‡15	Lassen Peak	California	
‡16	Knoxville	Tennessee-North Carolina	
‡17	Marysville	California	
‡18	Smartsville	California	
‡19	Stevenson	Ala.-Ga.-Tenn	
20	Cleveland	Tennessee	5
‡21	Pikeville	Tennessee	
‡22	McMinnville	Tennessee	
23	Nomini	Maryland-Virginia	5
24	Three Forks	Montana	5
‡25	Loudon	Tennessee	
‡26	Pocahontas	Virginia-West Virginia	
‡27	Morristown	Tennessee	
‡28	Piedmont	West Virginia-Maryland	
‡29	Nevada City Special	California	
‡30	Yellowstone National Park	Wyoming	
‡31	Pyramid Peak	California	
‡32	Franklin	West Virginia-Virginia	
‡33	Briceville	Tennessee	
‡34	Buckhannon	West Virginia	
‡35	Gadsden	Alabama	
36	Pueblo	Colorado	5
‡37	Downieville	California	
‡38	Butte Special	Montana	
‡39	Truckee	California	
‡40	Wartburg	Tennessee	
‡41	Sonora	California	
42	Nueces	Texas	5
‡43	Bidwell Bar	California	
‡44	Tazewell	Virginia-West Virginia	
‡45	Boise	Idaho	
46	Richmond	Kentucky	5
47	London	Kentucky	5
‡48	Tenmile District Special	Colorado	
‡49	Roseburg	Oregon	
‡50	Holyoke	Massachusetts-Connecticut	
‡51	Big Trees	California	
52	Absaroka	Wyoming	5
53	Standingstone	Tennessee	5
‡54	Tacoma	Washington	
‡55	Fort Benton	Montana	
‡56	Little Belt Mountains	Montana	
‡57	Telluride	Colorado	
58	Elmoro	Colorado	5
‡59	Bristol	Virginia-Tennessee	
‡60	La Plata	Colorado	
61	Monterey	Virginia-West Virginia	5
62	Menominee Special	Michigan	5
‡63	Mother Lode District	California	
64	Uvalde	Texas	5
65	Tintic Special	Utah	5
‡66	Colfax	California	
67	Danville	Illinois-Indiana	5
68	Walsenburg	Colorado	5
69	Huntington	West Virginia-Ohio	5
‡70	Washington	D. C.-Va.-Md.	
‡71	Spanish Peaks	Colorado	
‡72	Charleston	West Virginia	
‡73	Coos Bay	Oregon	
74	Coalgate	Oklahoma (Ind. T.)	5
75	Maynardville	Tennessee	5
76	Austin	Texas	5
77	Raleigh	West Virginia	5
78	Rome	Georgia-Alabama	5
79	Atoka	Oklahoma (Ind. T.)	5
80	Norfolk	Virginia-North Carolina	5
‡81	Chicago	Illinois-Indiana	
‡82	Masontown-Uniontown	Pennsylvania	
‡83	New York City	New York-New Jersey	
84	Ditney	Indiana	5
85	Oelrichs	South Dakota-Nebraska	5
86	Ellensburg	Washington	5
87	Camp Clarke	Nebraska	5
88	Scotts Bluff	Nebraska	5
89	Port Orford	Oregon	5
90	Cranberry	North Carolina-Tennessee	5
91	Hartville	Wyoming	5
92	Gaines	Pennsylvania-New York	5
93	Elkland-Tioga	Pennsylvania	5
‡94	Brownsville-Connellsville	Pennsylvania	
95	Columbia	Tennessee	5
96	Olivet	South Dakota	5
97	Parker	South Dakota	5
98	Tishomingo	Oklahoma (Ind. T.)	5
99	Mitchell	South Dakota	5
100	Alexandria	South Dakota	5
101	San Luis	California	5
102	Indiana	Pennsylvania	5
103	Nampa	Idaho-Oregon	5
104	Silver City	Idaho	5
105	Patoka	Indiana-Illinois	5
106	Mount Stuart	Washington	5
107	Newcastle	Wyoming-South Dakota	5
108	Edgemont	South Dakota-Nebraska	5
109	Cottonwood Falls	Kansas	5
110	Latrobe	Pennsylvania	5
‡111	Globe	Arizona	
112	Bisbee (reprint)	Arizona	25
113	Huron	South Dakota	5
114	De Smet	South Dakota	5
115	Kittanning	Pennsylvania	5
116	Asheville	North Carolina-Tennessee	5
117	Casselton-Fargo	North Dakota-Minnesota	5
118	Greeneville	Tennessee-North Carolina	5
119	Fayetteville	Arkansas-Missouri	5
‡120	Silverton	Colorado	
121	Waynesburg	Pennsylvania	5
122	Tahlequah	Oklahoma (Ind. T.)	5
123	Elders Ridge	Pennsylvania	5
124	Mount Mitchell	North Carolina-Tennessee	5
‡125	Rural Valley	Pennsylvania	
126	Bradshaw Mountains	Arizona	5
‡127	Sundance	Wyoming-South Dakota	
128	Aladdin	Wyo.-S. Dak.-Mont	5
‡129	Clifton	Arizona	
‡130	Rico	Colorado	
‡131	Needle Mountains	Colorado	
‡132	Muscogee	Oklahoma (Ind. T.)	
133	Ebensburg	Pennsylvania	5
‡134	Beaver	Pennsylvania	
135	Nepesta	Colorado	5
136	St. Marys	Maryland-Virginia	5
137	Dover	Del.-Md.-N. J	5
‡138	Redding	California	
‡139	Snoqualmie	Washington	
140	Milwaukee Special	Wisconsin	5
‡141	Bald Mountain-Dayton	Wyoming	
‡142	Cloud Peak-Fort McKinney	Wyoming	
143	Nantahala	North Carolina-Tennessee	5
‡144	Amity	Pennsylvania	
‡145	Lancaster-Mineral Point	Wisconsin-Iowa-Illinois	
146	Rogersville	Pennsylvania	5
147	Pisgah	N. Carolina-S. Carolina	5
148	Joplin District (reprint)	Missouri-Kansas	50
149	Penobscot Bay	Maine	5
‡150	Devils Tower	Wyoming	
‡151	Roan Mountain	Tennessee-North Carolina	
152	Patuxent	Md.-D. C	5
‡153	Ouray	Colorado	
‡154	Winslow	Ark.-Okla. (Ind. T.)	
155	Ann Arbor (reprint)	Michigan	25
156	Elk Point	S. Dak.-Nebr.-Iowa	5
‡157	Passaic	New Jersey-New York	
158	Rockland	Maine	5
159	Independence	Kansas	5
160	Accident-Grantsville	Md.-Pa.-W. Va.	5
‡161	Franklin Furnace	New Jersey	
‡162	Philadelphia	Pa.-N. J.-Del	
‡163	Santa Cruz	California	
‖164	Belle Fourche	South Dakota	5
‖165	Aberdeen-Redfield	South Dakota	5
‖166	El Paso	Texas	5
¶167	Trenton	New Jersey-Pennsylvania	5
‖168	Jamestown-Tower	North Dakota	5
‖169	Watkins Glen-Catatonk	New York	5
‖170	Mercersburg-Chambersburg	Pennsylvania	5
‖171	Engineer Mountain	Colorado	5
‖172	Warren	Pennsylvania-New York	5
‖173	Laramie-Sherman	Wyoming	5
‖174	Johnstown	Pennsylvania	5
¶175	Birmingham	Alabama	5
‖176	Sewickley	Pennsylvania	5
¶177	Burgettstown-Carnegie	Pennsylvania	5
‖178	Foxburg-Clarion	Pennsylvania	5
‖179	Pawpaw-Hancock	Md.-W. Va.-Pa	5
‖180	Claysville	Pennsylvania	5
‖181	Bismarck	North Dakota	5
‖182	Choptank	Maryland	5
‖183	Llano-Burnet	Texas	5
‖184	Kenova	Ky.-W. Va.-Ohio	5
§185	Murphysboro-Herrin	Illinois	25
§186	Apishapa	Colorado	5
§187	Ellijay	Ga.-N. C.-Tenn	25
§188	Tallula-Springfield	Illinois	25
189	Barnesboro-Patton	Pennsylvania	25
§190	Niagara	New York	50
§191	Raritan	New Jersey	25
192	Eastport	Maine	25
§193	San Francisco	California	75
194	Van Horn	Texas	25
195	Belleville-Breese	Illinois	25
196	Philipsburg	Montana	25
§197	Columbus	Ohio	25
198	Castle Rock	Colorado	25
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