DEPARTMENT OF THE INTERIOR

UNITED STATES GEOLOGICAL SURVEY

CHARLES D. WALCOTT, DIRECTOR

GEOLOGIC ATLAS

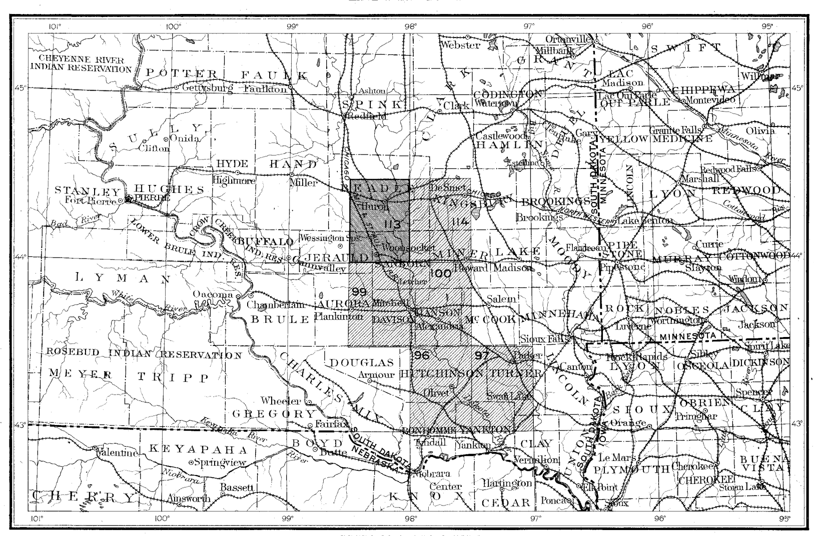
OF THE

UNITED STATES

HURON FOLIO

SOUTH DAKOTA

INDEX MAP



SCALE: 40 MILES = 1 INCH

HURON FOLIO

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HURON FOLIO
NO. 113

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GEORGE W. STOSE, EDITOR OF GEOLOGIC MAPS   S. J. KUBEL, CHIEF ENGRAVER

1904

GEOLOGIC AND TOPOGRAPHIC ATLAS OF UNITED STATES.

The Geological Survey is making a geologic map of the United States, which is being issued in parts, called folios. Each folio includes a topographic map and geologic maps of a small area of country, together with explanatory and descriptive texts.

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 which are most important 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 altitudinal interval represented by the space between lines being the same throughout each map. These lines are called *contours*, and the uniform altitudinal space between each two contours is called the *contour interval*. Contours and elevations are printed in brown.

The manner in which contours express elevation, form, and grade is shown in the following sketch and corresponding contour map (fig. 1).

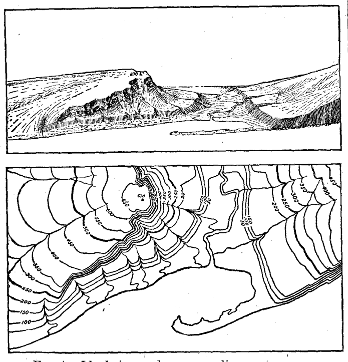

FIG. 1.—Ideal view and corresponding contour map.

The sketch represents a river valley between two hills. In the foreground is the sea, with a bay which is partly closed by a hooked sand bar. On each side of the valley is a terrace. From the terrace on the right a hill rises gradually, while from that on the left the ground ascends steeply, forming a precipice. Contrasted with this precipice is the gentle slope from its top toward the left. In the map each of these features is indicated, directly beneath its position in the sketch, by contours. The following explanation may make clearer the manner in which contours delineate elevation, form, and grade:

1. A contour indicates a certain height above sea level. In this illustration the contour interval is 50 feet; therefore the contours 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 sea; along the contour at 200 feet, all points that are 200 feet above sea; and so on. In the space between any two contours are found elevations above the lower and below the higher contour. Thus the contour at 150 feet falls just below the edge of the terrace, while 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 sea. The summit of the higher hill is stated to be 670 feet above sea; accordingly the contour at 650 feet surrounds it. In this illustration all the contours are numbered, and those for 250 and 500 feet are accentuated by being made heavier. Usually it is not desirable to number all the contours, and then the accentuating and numbering of certain of them—say every fifth one—suffice, for the heights of others may be ascertained by counting up or down from a numbered contour.

2. Contours define the forms of slopes. Since contours are continuous horizontal lines, they wind smoothly about smooth surfaces, recede into all reentrant angles of ravines, and project in passing about prominences. These relations of contour curves and angles to forms of the landscape can be traced in the map and sketch.

3. Contours show the approximate grade of any slope. The altitudinal space between two contours is the same, whether they lie along a cliff or on a gentle slope; but to rise 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.

For a flat or gently undulating country a small contour interval is used; for a steep or mountainous country a large interval is necessary. The smallest interval used on the atlas sheets of the Geological Survey is 5 feet. This is serviceable for regions like the Mississippi delta and the Dismal Swamp. In mapping great mountain masses, like those in Colorado, the interval may be 250 feet. For intermediate relief contour intervals of 10, 20, 25, 50, and 100 feet are used.

Drainage.—Watercourses are indicated by blue lines. If a stream flows the entire year the line is drawn unbroken, but if the channel is dry a part of the year the line is broken or dotted. Where a stream sinks and reappears at the surface, the supposed underground course is shown by a broken blue line. Lakes, marshes, and other bodies of water are also shown in blue, by appropriate conventional signs.

Culture.—The works of man, such as roads, railroads, and towns, together with boundaries of townships, counties, and States, are printed in black.

Scales.—The area of the United States (excluding Alaska and island possessions) is about 3,025,000 square miles. A map representing this area, drawn to the scale of 1 mile to the inch, would cover 3,025,000 square inches of paper, and to accommodate the map the paper would need to measure about 240 by 180 feet. Each square mile of ground surface would be represented by a square inch of map surface, and one linear mile on the ground would be represented by a linear inch on the map. This relation between distance in nature and corresponding distance on the map is called the *scale* of the map. In this case it is "1 mile to an inch." 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 an inch" is expressed by $\frac{1}{63,360}$.

Three scales are used on the atlas sheets of the Geological Survey; the smallest is $\frac{1}{250,000}$, the intermediate $\frac{1}{125,000}$, and the largest $\frac{1}{62,500}$. These correspond approximately to 4 miles, 2 miles, and 1 mile on the ground to an inch on the map. On the scale $\frac{1}{62,500}$ a square inch of map surface represents about 1 square mile of earth surface; on the scale $\frac{1}{125,000}$, about 4 square miles; and on the scale $\frac{1}{250,000}$, 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 in English inches, by a similar line indicating distance in the metric system, and by a fraction.

Atlas sheets and quadrangles.—The map 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 $\frac{1}{250,000}$ contains one square degree—i. e., a degree of latitude by a degree of longitude; each sheet on the scale of $\frac{1}{125,000}$ contains one-fourth of a square degree; each sheet on the scale of $\frac{1}{62,500}$ contains one-sixteenth of a square degree. The areas of the corresponding quadrangles are about 4000, 1000, and 250 square miles.

The atlas sheets, being only parts of one map of the United States, disregard political boundary lines, such as those of States, counties, and townships. 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 the names of adjacent sheets, if published, are printed.

Uses of the topographic map.—On the topographic map are delineated the relief, drainage, and culture of the quadrangle represented. It should portray to the observer every characteristic feature of the landscape. It should guide the traveler; serve the investor or owner who desires to ascertain the position and surroundings of property; save the engineer preliminary surveys in locating roads, railways, and irrigation reservoirs and ditches; provide educational material for schools and homes; and be useful as a map for local reference.

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 the structure sections show their underground relations, as 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.—These are rocks which have cooled and consolidated from a state of fusion. Through rocks of all ages molten material has from time to time been forced upward in fissures or channels of various shapes and sizes, to or nearly to the surface. Rocks formed by the consolidation of the molten mass within these channels—that is, below the surface—are called *intrusive*. When the rock occupies a fissure with approximately parallel walls the mass is called a *dike*; when it fills a large and irregular conduit the mass is termed a *stock*. When the conduits for molten magmas traverse stratified rocks they often send off branches parallel to the bedding planes; the rock masses filling such fissures are called *sills* or *sheets* when comparatively thin, and *laccoliths* when occupying larger chambers produced by the force propelling the magmas upward. Within rock inclosures molten material cools slowly, with the result that intrusive rocks are generally of crystalline texture. When the channels reach the surface the molten material poured out through them is called *lava*, and lavas often build up volcanic mountains. Igneous rocks thus formed upon the surface are called *extrusive*. Lavas cool rapidly in the air, and acquire a glassy or, more often, a partially crystalline condition in their outer parts, but are more fully crystalline in their inner portions. The outer parts of lava flows are usually more or less porous. Explosive action often accompanies volcanic eruptions, causing ejections of dust, ash, and larger fragments. These materials, when consolidated, constitute breccias, agglomerates, and tuffs. Volcanic ejecta may fall in bodies of water or may be carried into lakes or seas and form sedimentary rocks.

Sedimentary rocks.—These rocks are composed of the materials of older rocks which have been broken up and the fragments of which have been carried to a different place and deposited.

The chief agent of 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. In smaller portion the materials are carried in solution, and the deposits are then 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 deposits 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*. Rocks deposited in layers are said to be stratified.

The surface of the earth is not fixed, as it seems to be; it very slowly rises or sinks, with reference to the sea, over wide expanses; and as it rises or subsides the shore lines of the ocean are changed. As a result of the rising of the surface, marine sedimentary rocks may become part of the land, and extensive land areas are in fact occupied by such rocks.

Rocks exposed at the surface of the land are acted upon by air, water, ice, animals, and plants. They are gradually broken into fragments, and the more soluble parts are leached out, leaving the less soluble as a *residual* layer. Water washes residual material down the slopes, and it is eventually carried by rivers to the ocean or other bodies of standing water. Usually its journey is not continuous, but it is temporarily built into river bars and flood plains, where it is called *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 a variety of processes, rocks may become greatly changed in composition and in texture. When the newly acquired characteristics are more pronounced than the old ones such rocks are called *metamorphic*. In the process of metamorphism the substances of which a rock is composed may enter into new combinations, certain substances may be lost, or new substances may be added. There is often a complete gradation from the primary to the metamorphic form within a single rock mass. Such changes transform sandstone into quartzite, limestone into marble, and modify other rocks in various ways.

From time to time in geologic history igneous and sedimentary rocks have been deeply buried and later have been raised to the surface. In this process, through the agencies of pressure, movement, and chemical action, their original structure may be entirely lost and new structures appear. Often there is developed a system of division planes along which the rocks split easily, and these planes may cross the strata at any angle. This structure is called *cleavage*. Sometimes crystals of mica or other foliaceous minerals are developed with their laminæ approximately parallel; in such cases the structure is said to be schistose, or characterized by *schistosity*.

As a rule, the oldest rocks are most altered and the younger formations have escaped metamorphism, but to this rule there are important exceptions.

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, a rapid alternation of shale and limestone. When the passage from one kind of rocks to another is gradual it is sometimes 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 is constituted of one or more bodies either containing the same kind of igneous rock or having the same mode of occurrence. A metamorphic formation may consist of rock of uniform character or of several rocks having common characteristics.

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

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*.

(Continued on third page of cover.)

As sedimentary deposits or strata accumulate the younger rest on those that are older, and the relative ages of the deposits may be determined by observing their positions. This relationship holds except in regions of intense disturbance; in such regions sometimes the beds have been reversed, and it is often difficult to determine their relative ages from their positions; then *fossils*, or the remains and imprints of plants and animals, indicate which of two or more formations is the oldest.

Stratified rocks often contain the remains or imprints of plants and animals which, at the time the strata were deposited, lived in the sea or were washed from the land into lakes or seas, 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. When 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 found 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 often difficult or impossible to determine the age of an igneous formation, but the relative age of such a formation can sometimes 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 is sometimes 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 of their metamorphism.

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.

Symbols and colors assigned to the rock systems.

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

Patterns composed of parallel straight lines are used to represent sedimentary formations deposited in the sea or in lakes. 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 by which formations are labeled 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 recognized series, in proper order (from new to old), with the color and symbol assigned to each system, are given in the preceding table.

SURFACE FORMS.

Hills and 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; sea cliffs are made by the eroding action of waves, and sand spits are built up by waves. Topographic forms thus constitute part of the record of the history of the earth.

Some forms are produced in the making of deposits and are inseparably connected with them. The hooked spit, shown in fig. 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, and these are, in origin, independent of the associated material. 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 afterwards 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. When a large tract is for a long time undisturbed by uplift or subsidence it is degraded nearly to base-level, and the even surface thus produced is called a *peneplain*. If the tract is afterwards uplifted the peneplain at the top is a record of the former relation of the tract to sea level.

THE VARIOUS GEOLOGIC SHEETS.

Areal geology map.—This map shows the areas occupied by the various formations. On the margin is a *legend*, which is the key to the map. To ascertain the meaning of any colored 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 given formation, its name should be sought in the legend and its color and pattern noted, when 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 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.—This map represents the distribution of useful minerals and rocks, showing their relations to the topographic features and to the geologic formations. The formations which appear on the areal geology map are usually shown on this map by fainter color patterns. The areal geology, thus printed, affords a subdued background upon which the areas of productive formations may be emphasized by strong colors. A mine symbol is printed at each mine or quarry, accompanied by the name of the principal mineral mined or stone quarried. For regions where there are important mining industries or where artesian basins exist special maps are prepared, to show these additional economic features.

Structure-section sheet.—This sheet exhibits the relations of the formations beneath the surface. In cliffs, canyons, shafts, and other natural and artificial cuttings, the relations of different beds to one another may be seen. Any cutting which 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 the 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 of the earth to a considerable depth. Such a section exhibits what would be seen in the side of a cutting many miles long and several thousand feet deep. This is illustrated in the following figure:

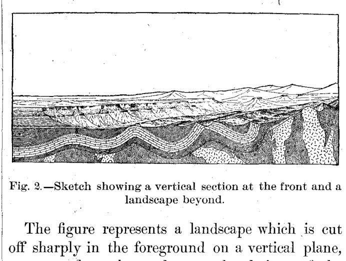

Fig. 2.—Sketch showing a vertical section at the front and a landscape beyond.

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 symbols of lines, dots, and dashes. These symbols admit of much variation, but the following are generally used in sections to represent the commoner kinds of rock:

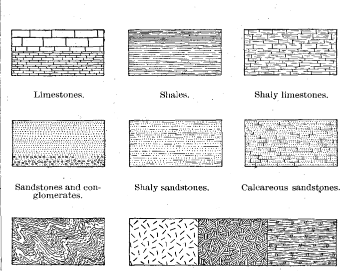

Fig. 3.—Symbols used in sections to represent different kinds of rocks.

The plateau in fig. 2 presents toward the lower land an escarpment, or front, which is made up of sandstones, forming the cliffs, and shales, constituting the slopes, as shown at the extreme left of the section. 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 that the intersection of a bed with a horizontal plane will take is called the *strike*. The inclination of the bed to the horizontal plane, measured at right angles to the strike, is called the *dip*.

Strata are frequently curved in troughs and arches, such as are seen in fig. 2. The arches are called *anticlines* and the troughs *synclines*. But the sandstones, shales, and limestones were deposited beneath the sea in nearly flat sheets; 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 fig. 4.

On the right of the sketch, fig. 2, the section is composed of schists which are traversed by masses of igneous rock. The schists are much contorted and their arrangement underground can not be

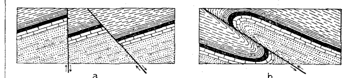

Fig. 4.—Ideal sections of strata, showing (a) *normal* faults and (b) a *thrust* fault.

inferred. Hence that portion of the section delineates what is probably true but is not known by observation or well-founded inference.

The section in fig. 2 shows three sets of formations, distinguished by their underground relations. The uppermost of these, seen at the left of the section, is a set of sandstones and shales, which lie in a horizontal position. These sedimentary strata 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 raised from a lower to a higher level. The strata of this set are parallel, a relation which is called *conformable*.

The second set of formations consists of strata which form arches and troughs. These strata were once continuous, but the crests of the arches have been removed by degradation. 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 at the left of the section. The overlying deposits are, from their positions, evidently younger than the underlying formations, and the bending and degradation of the older strata must have occurred between the deposition of the older beds and the accumulation of the younger. When younger rocks thus rest upon an eroded surface of older rocks the relation between the two is an *unconformable* one, and their 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 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 suffered metamorphism; they were the scene of 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 fig. 2 are ideal, but they illustrate relations which actually occur. 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 which appears in the section may be measured by using the scale of the map.

Columnar section sheet.—This sheet contains a concise description of the sedimentary formations which 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 which state the least and greatest measurements, and the average thickness of each is shown in the column, which is drawn to a scale—usually 1000 feet to 1 inch. The order of accumulation of the sediments is shown in the columnar arrangement—the oldest formation at the bottom, the youngest at the top.

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

CHARLES D. WALCOTT,
Director.

Revised January, 1904.

DESCRIPTION OF THE HURON QUADRANGLE.

By J. E. Todd.

GEOGRAPHY.

GENERAL RELATIONS.

Eastern South Dakota lies on the Great Plains, in the broad, indefinite zone in which these plains merge into the prairies of the Mississippi Valley. It is comprised within the area of glaciation and most of its surface features show the characteristics of a drift-covered region. The country is largely level, but presents long, rolling slopes rising 300 to 800 feet above the broad valleys. The principal elements of relief are massive ridges, or mesas, which are due to pre-Glacial erosion and which are often crowned or skirted by long ranges of low hills due to morainal accumulations left by the ice along lines marking pauses of glacial advance and retreat. Further diversity of topography has been produced by the excavation of the valleys, especially that of the Missouri, which has cut a trench several hundred feet deep, mostly with steeply sloping sides. Between the moraines there are rolling plains of till and very level plains due to the filling of glacial lakes. The upper James River Valley presents a notable example of this lake-bed topography.

LOCATION.

The Huron quadrangle is located between longitudes 98° and 98° 30′ west and latitudes 44° and 44° 30′ north, embracing portions of Beadle, Sanborn, and Jerauld counties, and has an area of about 857 square miles. It lies in the valley of James River, which has a general southward course across the eastern half of the quadrangle.

TOPOGRAPHY.

The region is in general flat, and its features are, with few exceptions, those of very subdued glacial topography, the basins being shallow and widely separated, and the swells very low. Rougher areas occur in the morainic regions, which are shown on the areal geology map. At some points the swells rise into hills from 15 to 25 feet high, which are more fully described under the heading "Moraines."

The upland surface varies in altitude from 1280 to 1485 feet above sea level, the average being about 1300 feet. The highest points are near the western boundary, in Dale Township. The lowest altitude, about 1220 feet, is in Union Township where James River leaves the quadrangle.

Fully 120 square miles of the quadrangle have an altitude of less than 1300 feet above the sea, and as large an area is below 1320 feet. Along the eastern margin of the quadrangle the elevation increases from 1290 feet near the southeast corner to 1330 feet near Cavour, while on the western boundary, which crosses the range of knobby hills, it varies from 1330 to 1470 feet, the higher altitudes being toward the north. There are no important elevations within the quadrangle, the low range of morainic hills in the southern half near the western boundary being the most conspicuous. These stand above the 1400-foot level and at many places rise to 1480 feet.

DRAINAGE.

In general the drainage is simple. The streams belong entirely to the James River system. They are not simple consequent streams, but show the disturbing effects of the Pleistocene ice sheet.

James River is the most important though not the oldest stream in the quadrangle. It follows a fairly direct course from north to south. It is a sluggish stream, at ordinary stages 50 to 100 feet wide and 3 to 10 feet deep, and has a fall of only 20 feet in crossing the quadrangle. Because of steep muddy banks and soft bottom it is rarely fordable. It is subject to high floods, particularly in the spring. The sides of its trough vary much in height at different points; sometimes they are 80 feet high, as in Jackson Township (108 N., R. 61 W.), but very often they are less than 50. The alluvial bottom land is usually half a mile wide and the stream lies 8 to 10 feet below it.

Besides James River, Firesteel, Sand, Marsh, and Pearl creeks are important streams. Firesteel Creek is evidently the oldest stream in this quadrangle. It crosses the western boundary 11 miles from its southern extremity, and runs almost directly south to a point 1½ miles east of the southwest corner of the quadrangle. In this distance it has a fall of about 10 feet. Its flood plain averages about half a mile in width. On its eastern side is an abrupt bank 30 to 40 feet in height, and on the west is a gentle slope verging into an ill-defined plain. It contains no running water during most of the year.

Sand Creek is a remarkable stream in several respects. It is unusually crooked, and the size of its valley varies greatly. It enters the quadrangle about 2 miles north of the southern boundary of Beadle County and flows southeastward. For 5 or 6 miles it flows southeastward in a valley 25 to 45 feet deep and about one-quarter of a mile wide, although at some points it has a width of one-half mile. Then the stream flows eastward for 12 miles in a poorly defined valley to the middle of Warren Township. At the eastern side of this township it turns southeastward and begins to cut a narrow trench, which gradually deepens in the last 12 miles of its course, above the point where it enters James River at Forestburg. A little south of Alpena is an important tributary which has a length of about 12 miles in a southeast direction. Another peculiarity is the number of deep, well-marked, flat-bottom channels which come to it from Cain Creek. Between the west boundary and the middle of Warren Township there are four of these. They were formerly outlets through the third moraine. Still another peculiarity is the amount of sand found along its lower course, and from this phenomenon the stream derives its name. "Long Lake" west of Forestburg is an extensive, well-defined flat, which was formerly a continuation of Sand Creek.

Marsh Creek flows into James River from the east near the boundary between Beadle and Sanborn counties. It runs in a deep, winding trench. Pearl Creek flows southwestward in a shallow valley to James River. Its lower course is remarkable for several fine springs. Cain Creek enters the quadrangle from the west near the northwest corner. It keeps a nearly straight south-southeast course for more than 13 miles, with a flat bottom valley 20 to 30 feet deep and in some places one-half mile wide. It then turns a little north of east, and with a narrower and deeper valley follows a straight course for 8 or 9 miles to James River. Shue Creek occupies a narrow, deep ravine in the northeast corner of the quadrangle. It enters the James from the east after a southwest course of 5 or 6 miles. Besides these quite well-marked watercourses, there are several very shallow, ill-defined channels draining the northern half of the quadrangle. One of these channels passes Broadland and after a meandering course enters the James at Huron. A network of channels drains about 50 square miles east of Huron northward to the mouth of Shue Creek. Another system southwest of Huron drains southeastward to the mouth of Cain Creek.

None of these streams have permanent water in them, except Pearl Creek, which has several fine springs in the lower 4 or 5 miles of its course, and Sand Creek, which receives much seepage from the sand through which it flows in the lower part of its course. All the stream beds contain vigorous streams in the spring or in a rainy season, and some occasionally become impassable torrents.

GENERAL GEOLOGY.

The surface of eastern South Dakota is in large part covered with a mantle of glacial deposits, consisting of gravel, sand, silt, and clay, of varying thickness, which are described in detail later, under the heading "Pleistocene deposits."

The formations underlying eastern South Dakota are seldom exposed east of Missouri River, though they outcrop in some of the hills where the drift is thin and in the banks of a few of the streams. The numerous deep wells throughout the region have, however, furnished much information as to the underground structure. There are extensive sheets of clays and sandstones of Cretaceous age lying on an irregular floor of granite and quartzite of Archean and Algonkian age. Under most of the region this floor of "bed rock" is over a thousand feet below the surface, but it rises gradually to the surface to the east. There is also an underground quartzite ridge of considerable prominence that extends southwestward from outcrops in southwestern Minnesota to the vicinity of Mitchell, S. Dak.

The lowest sedimentary formation above the quartzite is a succession of sandstones and shales of wide extent, termed the Dakota formation, which furnishes large volumes of water for thousands of wells. It reaches a thickness of 300 feet or more in portions of the region, but thins out and does not continue over the underground ridge above referred to. It is overlain by several hundred feet of Benton shales, with thin sandstone and limestone layers, and a widely extended sheet of Niobrara formation, consisting largely of chalkstone to the south and merging into calcareous clays to the north. Where these formations appear at the surface they rise in an anticlinal arch of considerable prominence along the underground ridge of quartzite, but they dip away to the north and west and lie several hundred feet deep in the north-central portion of the State. In the Missouri Valley they rise gradually to the southeast and reach the surface in succession, the Dakota sandstone finally outcropping in the vicinity of Sioux City, Iowa, and southward. The Pierre shale extends in a thick mantle into eastern South Dakota, lying under the drift in the greater portion of the region, except in the vicinity of the higher portions of the anticlinal uplift above referred to. It was no doubt once continuous over the entire area, but was extensively removed by erosion prior to the Glacial epoch. Doubtless the Fox Hills and Laramie formations once extended east of Missouri River, but they also have undergone widespread erosion and few traces of them now remain in the extreme northern portion of the State. Tertiary deposits appear to have been laid down over part of the region, as is shown by small patches still remaining in the Bijou Hills and other higher ridges.

The Huron quadrangle is covered with glacial drift, with the exception of the alluvial flats along the streams. The underlying stratified rocks are not exposed, but data concerning them have been obtained from numerous borings made in sinking artesian wells. These rocks have a nearly horizontal attitude and include representatives of the Cretaceous system and probably the Algonkian. Because of the relation of these underlying rocks to the water supply of the area and the bearing they have on its geologic history they will be briefly considered here.

ARCHEAN AND ALGONKIAN ROCKS.

The basement rocks within this quadrangle, reached only in borings, probably consist mainly of light-colored granite of Archean age, with possibly a few dikes of diabase, overlain by patches of red quartzite. The quartzite, the oldest sedimentary rock known in this region, is called the Sioux quartzite, from its type locality along Big Sioux River, South Dakota. It is of Algonkian age and consists for the most part of intensely compact and durable red or purplish quartzite. It is extensively exposed a few miles south of the quadrangle, both on Wolf Creek and on James River, and probably extends under the Cretaceous deposits into this quadrangle, but has not positively been identified in the deep borings. The basement rocks have been struck in wells at Wolsey and Huron, and while they are known in only a few borings, they doubtless underlie the whole quadrangle. Observations in adjacent territory indicate that these rocks probably occur at an altitude of 400 to 475 feet above sea level along the southern margin of the quadrangle, or at a depth of 800 to 1000 feet below the surface. From this point their upper surface dips very gently to the north into a shallow east-west basin passing near the center of the quadrangle. From Huron northward this old surface rises gently. The configuration of this surface is shown on the artesian water map.

The only places where crystalline rocks are reported to have been struck in boring are Wolsey and Huron. At Huron crystalline rock was reported at 1090 feet in city well No. 3 and at 1080 feet in a well in the northeast part of the city. The samples preserved are coarse white crystalline quartz grains with minute nodules of siderite (carbonate of iron). In well No. 4 clear evidence of granite was found at a depth of 1138 feet. At Wolsey a "very hard rock" was struck at a depth of 928 feet, apparently on the summit of a ridge of granite which has been traced farther northeast. If this interpretation is correct this rock marks the limit below which it is useless to drill in search of water, but without examining specimens of the material it is impossible to say that the "hard rock" is not merely a hard cap rock to a lower stratum of water-bearing sand.

The granite found in the Budlong and Motley wells northeast of Hitchcock and only a short distance outside this quadrangle, as well as in some wells 5 or 6 miles north of Farmer, in Hanson County, is a fine-grained, light-gray rock abounding in transparent feldspar.

Granite is usually easily recognized when encountered in drilling, but it is sometimes difficult to distinguish quartzite from hard cap rock or siliceous concretions.

The quartzite generally is intensely hard, but sometimes it is a loose or lightly cemented sandstone, as in borings at Mitchell and at Elmspring. It frequently has a delicate pink or purplish tint, although it is sometimes a light gray blotched with darker gray. It may be distinguished from pyrite, which is of about the same hardness, by the fact that layers of the pyrite are rarely more than a few inches in thickness. Its great thickness also serves to distinguish it from some of the hard layers of the Dakota formation, which are rarely over 4 or 5 feet thick. The Dakota sandstones, moreover, are cemented usually by carbonate of lime, which effervesces with acids, or by iron oxide or carbonate, which is of a darker or rusty color, while the quartzite is uniformly of a light shade. However, in some cases a compound microscope is necessary to detect the difference. When so examined the quartzite is recognized by the presence of clusters of sand grains cemented so firmly together by silica that the fractures usually divide the original grain as easily as the cement between them.

The quartzite sometimes occurs in thin beds, and sometimes contains layers of pipestone or red slate a few feet in thickness. At such times the water from the drill is blood red.

PALEOZOIC ROCKS.

This quadrangle and the surrounding area are remarkable for the entire absence of rocks of Paleozoic age. This absence is indicated not only by the borings within the quadrangle but by observations made in the adjoining regions, for the Paleozoic formations that are exposed on the eastern flank of the Rocky Mountains do not appear at any point around the outcropping Algonkian and Archean areas in eastern South Dakota and central Minnesota. The nearest Paleozoic rocks known have been found in deep drill holes at Ponca, Nebr., and Sioux City, Iowa. Doubtless, therefore, this quadrangle and the surrounding region were dry land throughout the long ages during which the coal fields of eastern United States and the great limestone beds in the central States were forming. This is further attested by the uneven surface of the quartzite, which, so far as revealed, is deeply trenched, indicating long exposure above sea level.

CRETACEOUS SYSTEM.

Of the subaqueous rocks above the Sioux quartzite, apparently only the upper Cretaceous is represented in the Huron quadrangle, but it is possible that there are also present the equivalents of the Lakota sandstone and underlying shales of the Black Hills region, which are of lower Cretaceous age. The Jurassic is almost certainly absent, for its area of deposition was far to the west. The

Dakota, Benton, Niobrara, and Pierre have all been recognized in drilling.

DAKOTA FORMATION.

Tho Dakota formation is the principal water-yielding horizon of the region and supplies the more important artesian wells of North Dakota and South Dakota. In this quadrangle it nowhere comes to the surface, though it has been encountered in a number of the deeper wells.

The formation as exhibited in the rim of the Black Hills is usually a brown sandstone, hard and massive below, but thinner bedded above, having an average thickness of 100 feet. It varies from fine- to coarse-grained and usually is only moderately compact. In eastern South Dakota the formation lies on the quartzite, but in the vicinity of Mitchell it abuts against the higher portions of the quartzite ridge, on which the Benton shales and sandstones overlap. The Dakota terminates at this overlap in an old shore line, which has considerable irregularity in outline and altitude, the latter due to local variations in amount of uplift. From this old shore line along the quartzite ridge the Dakota sandstone slopes in all directions. It is believed that this shore line is nearly intact, for probably there was but little erosion before the deposition of the Benton. The dip of the sandstone is more rapid near the quartzite ridge, and gradually diminishes away from this ridge until the rock lies nearly horizontal. In this quadrangle the Dakota formation is a sheet of sandstone mantling the "bed-rock" surface already discussed.

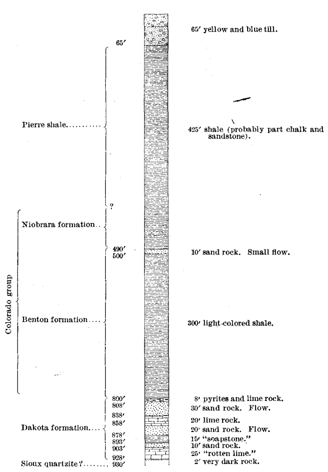

FIG. 2.—Section of Wolsey well. Sec. 24, T. 111, R. 64.

Associated with the sandstone are shale beds which resemble those of the overlying formations, and, like them, contain calcareous concretions which may be mistaken for limestone strata. Sometimes, also, there occur concretions of pyrites large enough to hinder the drilling. The different layers of sandstone are often harder near the top, and this has given rise to the expression "cap rock." Frequently the drill has to penetrate several feet of hard rock before it reaches the water-bearing strata.

The Dakota sandstone is variable in thickness, but, as few borings have gone to its bottom, precise figures are available only for some limited areas. If the second principal sandstone below the chalk be taken as the top of the Dakota, a thickness of about 350 feet is indicated by the deepest boring. It is possible that 50 or even 100 feet of additional strata may be encountered before crystalline rock is struck in the central portion of the quadrangle. The Dakota is of uniform thickness over the whole quadrangle except in the northwest corner, where it seems to be thinner.

The structure section (fig. 1) and well sections (figs. 2 to 6) exhibit the character and thickness of the formation in detail, and in the discussion of the sources of artesian water further light will be given on the number, thickness, and subdivisions of the sand strata in this formation.

In studying the sections it should be remembered that the data given by well borers, upon which the section is based, are indefinite in many respects. The drill commonly used is a hydraulic machine, in which a jet of water is used to bring up the borings; hence the exact character of any particular portion can not be very definitely learned, as the rock brought to the surface is usually pulverized and is mixed with mud from several different strata. Moreover, unfortunately, the driller is usually not disposed to examine the deposit with much care, nor to measure carefully the exact position and thickness of many strata which would be of special interest to a geologist. The driller is interested chiefly in the water-bearing strata, and in only such of them as produce a flow sufficient for his purpose. When asked for a record of a particular well, he is apt to remember only the depths at which water was struck and at which the greatest resistance was encountered. It may, therefore, safely be concluded that the deeper sandstones are often thicker than is represented in the sections.

The Dakota formation is considered by some geologists to be a fresh-water deposit, as the molluscan fossils which are occasionally found in it are of a few distinctly fresh-water species. These have been observed mainly near Sioux City, Iowa, and at outcrops in Nebraska and Kansas. Fossil leaves have also been found in the sandstone of this formation at a number of points. These indicate either that the beds were formed near shore or that strong currents carried the leaves far from land before they were decomposed.

COLORADO GROUP.

The Colorado group includes two distinct formations. The first or lower is called the Benton shale, so named because of its prominent development near Fort Benton, on the upper Missouri. In the southeast corner of South Dakota it consists of lead-colored or dark-gray shale containing calcareous and ferruginous concretions. Where it is exposed along Missouri River it is estimated to have a thickness of about 200 feet, but it thins eastward.

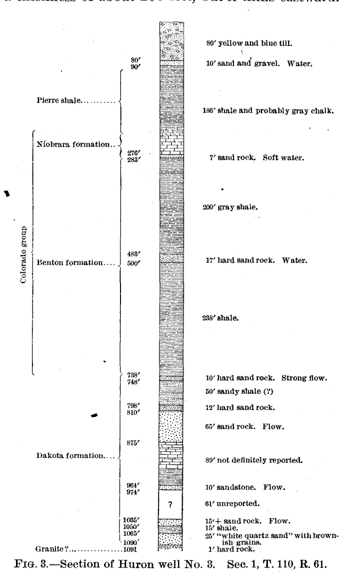

FIG. 3.—Section of Huron well No. 3. Sec. 1, T. 110, R. 61.

In the vicinity of the Black Hills the Benton is much thicker, and is divided into several formations. There it consists largely of dark shale, but exhibits also layers of sandstone, sometimes of considerable thickness, and also a persistent layer of shaly limestone abounding in *Inoceramus labiatus*. These features are also traceable in southeastern South Dakota.

The second or upper member of the Colorado group is the Niobrara chalkstone, named from its prominence near the mouth of Niobrara River. It is usually of a drab color except where it has been weathered. It may be snow-white, but is more commonly of a light-straw color. It varies considerably in composition, often carrying a large proportion of clay. Owing to its variable composition it is not always clearly distinguishable from the Benton shale below. The purer chalk seems to be limited to lenses of large extent, merging into clay. In some exposures chalk may be found at one point and a few rods away its place may be taken by gray clay.

Benton formation.—In this quadrangle the Benton includes a relatively larger amount of sandstone than is common to it elsewhere. It is not exposed at any point in this quadrangle, but the data derived from wells indicate that it is composed of the following strata: Beginning at the top there is immediately below the chalkstone a stratum of plastic clay or shale. This seems to be extremely variable in thickness, ranging from 1 to 50 feet. Beneath this clay is a layer of rusty sandstone which is exposed farther south and which varies from 10 to 100 feet in thickness. Below the sandstone is a thick layer of shale in which, near the middle, there seems to be a thin stratum of sand sufficiently continuous to carry water, which flows when tapped by wells. The whole formation has a thickness of 450 to 500 feet, as nearly as can be judged from well records.

The sandstone contains sharks' teeth and traces of vegetation where it outcrops, and a stratum of fossiliferous limestone 580 feet below the surface in the vicinity of Woonsocket. The most definite knowledge comes from a well 2 miles north of that town, from which fragments of a fossiliferous limestone were frequently thrown out from time to time. Some of these were submitted for examination to Dr. T. W. Stanton, who reports that at least three different species were represented, one of which is a small *Nucula* with striated surface that may be the young of *N. cancellata* M. and H.;

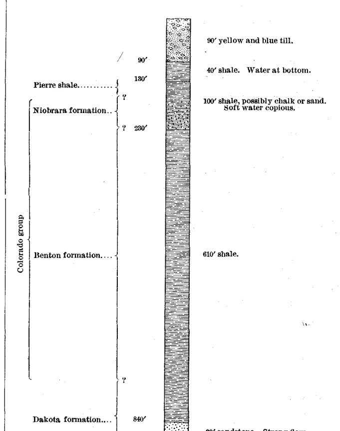

FIG. 4.—Section of well at Poor farm. Sec. 15, T. 110, R. 61.

another is possibly a young *Mactra;* and the third, the most common form, is probably a *Lucina*. The specimens were too imperfect to permit more definite determination. They were found 250 feet below the chalkstone and about 100 feet above the main water flow. These fossils are distinctly marine in character and indicate that this stratum is a part of the Benton. This fossiliferous horizon seems to have a considerable extent around Woonsocket. Other Benton fossils were found in the Ashmore and Farwell wells, in the Alexandria quadrangle.

From a black clay above the sandstone, north of Mount Vernon, in the Mitchell quadrangle, a saurian vertebra about 4 inches long was obtained. A large characteristic fragment of *Prionotropis* is said to have been taken from a depth of several feet on the east side of James River $1\frac{1}{2}$ miles north of Elmspring.

Niobrara formation.—The most characteristic feature of this formation is the chalkstone, but no doubt considerable deposits of clay should be considered as included in it. As the formations both below and above are clay, the areal distribution of the Niobrara can not be very sharply defined in this drift-covered region. It is especially difficult to recognize the different beds in wells, for there the chalk has not been exposed to atmospheric action, and has a leaden color, closely resembling the gray clays of the Benton. Well drillers do not always recognize chalkstone, so that there is considerable uncertainty in the records of borings, a fact which should be borne in mind in considering the well sections (figs. 2 to 6). The best means of distinction between the chalkstone and the shale is that when pulverized the chalkstone does not become plastic and sticky like the shale. The chalkstone behaves more like a sandstone, from which, however, it is readily distinguished by its softness and lack of grit. Features observed farther south in the James River Valley indicate that the chalkstone may have been formed in part contemporaneously with clay. Clay with a very little calcareous matter has been found within a few feet horizontally of typical chalkstone.

The chalk is much more commonly recognized in the southern half of the quadrangle than in the northern half, where most drillers fail to identify it.

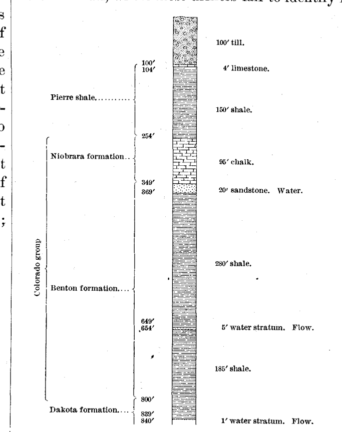

FIG. 5.—Section of E. Schmidt well. Sec. 14, T. 108, R. 64.

There it may be so clayeythat it is in distinguishable from the overlying Montana. The chalkstone is nearly horizontal and seems to be conformable with the Benton beneath. In the southern part of the quadrangle it is about 75 feet in thickness. In some cases it seems to have been removed in part by erosion.

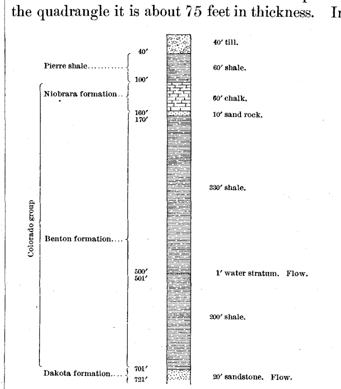

FIG. 6.—Section of L. Feistner well. Sec. 2, T. 106, R. 63.

The chalkstone frequently contains fish teeth and scales, mostly of bony fishes, although sharks'

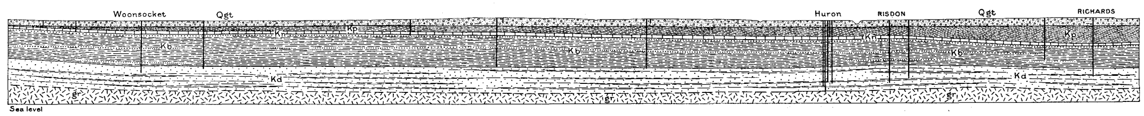

FIG. 1.—Sketch section across the Huron quadrangle along a line through Woonsocket and Huron, showing the artesian wells in the vicinity extending to the Dakota water-bearing sandstone.

Qgt, Glacial till; Kp, Pierre shale; Kn, Niobrara formation; Kb, Benton formation; Kd, Dakota formation; gr, granite, including probably overlying Sioux quartzite in places.

Horizontal scale: 1 inch=3 miles. Vertical scale: 1 inch=1500 feet.

teeth are also found. Occasionally nearly perfect specimens of bony fishes have been found in the outcrops farther south. The most common fossil is the small oyster, about an inch in length, called *Ostrea congesta*. These shells are frequently clustered on fragments of larger bivalve shells, either of *Pinna* or *Inoceramus*, which are rarely found except in fragments, even where there are good exposures.

MONTANA GROUP.

The Montana group is elsewhere made up of two formations, the lower being the Pierre, so named because it constitutes the main part of the Missouri bluffs at Fort Pierre, and the upper the Fox Hills, so named from its occurrence in the hills of that name north of Big Cheyenne River. Only the lower portion of the Pierre is present in this quadrangle.

Pierre shale.—As developed here the Pierre shale consists almost entirely of dark plastic clays, sometimes hardened into shale, with occasional calcareous concretions, and perhaps some thin layers of sand or sandstone. This formation probably underlies the whole quadrangle immediately above the chalkstone. It is comparatively thin, however, particularly along the southern boundary, where it is not over 16 to 20 feet thick. As the lower formations dip toward the north, the Pierre becomes thicker in that direction and has a maximum thickness of 150 to 200 feet along the northern boundary. Well drillers do not report sandstone in it, but as it contains a well-defined water horizon it seems probable that there is a thin sandy stratum, or possibly a bed of porous chalk, a little above its base. No fossils have been obtained from this formation in this quadrangle, unless those from the wells near Woonsocket shall prove to be such.

Well sections showing the character and relations of the Cretaceous formations in different portions of the quadrangle are given in figs. 2 to 6.

QUATERNARY SYSTEM.

PLEISTOCENE DEPOSITS.

The formations thus far described are sedimentary, and with the possible exception of the Dakota are of marine origin. To these the Pleistocene deposits present a marked contrast, not only in their origin but in their mode of occurrence. They are the products of glacial action, and overlie all earlier formations without respect to altitude, forming a blanket over the whole quadrangle with the exception of a few square miles that are covered by alluvium or occupied by outcrops of the older rocks. The deposits include till or bowlder clay, morainic material, and stratified or partially stratified clays, sands, and gravels formed along abandoned river channels and terraces. The bowlder clay forms a great sheet, spreading over nearly the whole quadrangle. The morainic material occurs in a series of rough, knobby hills and ridges that cross the quadrangle from northwest to southeast and occupy its northeastern half. The channel and terrace deposits are found in valleys and over flat areas, mainly near the morainic ridges.

It is not certain that there are in this quadrangle any post-Cretaceous beds of pre-Glacial age. Near the southwest corner there are certain water-bearing beds below the till which may be distinctly older. From wells in that area have been obtained pieces of peat and numerous fresh-water shells which may come from a pre-Glacial marsh deposit that may have been connected with the flood plain of the pre-Glacial James River.

Till or bowlder clay.—The till presents here the features common to the deposit found elsewhere, as in central Minnesota, Iowa, and Illinois. It is an unstratified mixture of clay, sand, and worn pebbles and bowlders, the latter sometimes attaining a diameter of several feet. In it are local developments of stratified sand, sometimes mere pockets, sometimes portions of channels of considerable length, and sometimes sheets that locally separate the bowlder clay into two or more members. The till of this quadrangle is much more clayey than that found farther east, perhaps 90 per cent being clay. This is because of the long distance the ice moved over and deeply eroded the dark-colored clays of the Cretaceous. For the same reason the erratics are perhaps less frequently striated and planed.

The till here, as elsewhere, exhibits an upper, yellowish division, known as yellow clay, and a lower blue portion. The upper clay is simply the oxidized or weathered form of the lower, and the separation between the two is not very clearly defined. They are sometimes distinguished in sections, but not always. The blue clay is apt to be confused by well drillers with the underlying Cretaceous clay of similar color, so that in their reports part of the Cretaceous clay may be included in the Pleistocene formation.

No distinct traces have been found of a general subdivision of the till into different members, as in some other localities, and the whole is believed to have been formed by the Wisconsin ice sheet. It should be noted, however, that even if there be a division there is little likelihood that it would be reported by well borers, for the Pleistocene is not often the source of water supply, and hence the drillers are less critical in their observations of it than of the underlying rocks. Occasional fragments of wood have been reported from it, but in every case they proved to be isolated pieces and not parts of a "forest bed."

The surface of the till shows the characteristic irregularity common to it elsewhere. There are many small, irregularly placed hills or knolls and minor basins without outlet. These features are fainter than usual, and the general surface is almost level. This is because the quadrangle lies entirely within the principal moraines. The pre-Glacial surface had been acted upon by the ice for a long period, and, as the underlying rocks were soft and somewhat uniform in character, it was planed down more evenly than usual. There has also been a considerable amount of filling of the minor basins with silt, laid down by waters escaping from the ice soon after the deposition of the till, and also, in more recent times, with wash, resulting from rain and the melting of snow. In some localities considerable silt has been deposited by the wind, but this influence has not modified the till of this region much, so that its surface is now nearly as it was left by the ice sheet. Around Huron there seems to have been, during the recession of the ice, a shallow lake which covered perhaps 100 square miles. A lake of almost equal extent which was formed a little earlier occupied the area around Woonsocket. In both regions there are now great flat plains marking the sites of these lakes.

The thickness of the till in this quadrangle is estimated to average about 70 feet. In a few cases, as at the extreme southwest corner and in the bottoms of the principal channels, it is less, sometimes falling below 20 feet. In the vicinity of moraines, which are discussed later, it may reach more than 100 feet. In the low land around and east of Woonsocket it is from 80 to 90 feet. In the similar flat land around Huron it is about 50 feet.

The till of the entire quadrangle lies within what is known as the second or Gary moraine, which is described below. Both the moraine and the drift were formed by the Wisconsin ice sheet.

Moraines.—The moraines of this quadrangle are shown upon the areal geology map. With a few exceptions they are not a conspicuous feature. Generally they consist of a low, broad swell showing the usual surface of the till except that occasional scattered peaks rise abruptly 15 to 25 feet above the adjoining surface. The swell may have an altitude of 20 to 30 feet above the till within and without, into which it insensibly merges.

The moraines are composed of material similar to that of the till, but the ridges are more stony. They contain numerous bowlders and considerable masses of gravel.

The moraines of this quadrangle include different members of two principal moraines, which are commonly known as the Gary and Antelope moraines.

The Gary or second moraine is named from Gary, S. Dak., where it is a prominent feature. It is conveniently divided in this quadrangle into three or four members. The first or oldest enters the quadrangle from the west near the north line of Jerauld County, where it rises more than 100 feet above the valley of Firesteel Creek, which closely follows its outer margin. It is finely developed in Dale Township (108 N., R. 64 W.). Farther south it gradually declines in altitude until near the southern boundary of the quadrangle it is a low ridge $1\frac{1}{2}$ or 2 miles in width, with its crest not more than 40 feet above Firesteel Creek. The second member diverges from the first in the southeast corner of Dale Township, widens still more than the first, and becomes a little rougher than the region within or eastward.

A third member, not very closely connected with those already described, enters from the west, on the divide between the two branches of Sand Creek, though it is not well developed. Rough patches and scattered knolls indicate its continuance southeast across Sand Creek to a conspicuous ridge known locally as Pony Hills. These hills begin with scattered peaks in the eastern part of Franklin Township, become a single ridge in sec. 13 of that township, and extend southeastward into sec. 9 of Twin Lake Township (T. 106 N., R. 62 W.). In its highest portions, 3 miles west of Woonsocket, this moraine rises 50 or 60 feet, and in some places over 80 feet, above the level ground east of it. Farther southeast and east it is broken into knolls and knoll ridges. It seems to have formed the barrier on the south which held the waters of the temporary lake between Woonsocket and Artesian.

The Antelope or third moraine is represented mainly by an outer member consisting of a low swell surmounted by occasional peaks or low ridges and by a faintly developed series of irregular knobs lying a few miles to the north, within the second moraine.

The outer member appears about a mile west of Wolsey in the shape of a conspicuous north-south ridge 30 to 40 feet in height. It lies mostly beyond the western boundary of the quadrangle, but enters it in the northern part of Vernon Township (T. 110 N., R. 64 W.). From this point it trends more toward the east, lying close along the north side of the north branch of Sand Creek, where it is about 2 miles in width. It passes north of Alpena, taking a direction nearly due east, so that the southern line of Beadle County coincides with its axis nearly to James River. Cain Creek follows its northern margin, while the north branch of Sand Creek marks its outer margin above Alpena.

East of James River the principal part of the moraine lies south of Marsh Creek, although the inner portion may be traced indistinctly as far north as Pearl Creek.

The inner or second member consists mostly of scattered areas lying north of Cain and Pearl creeks and approximately parallel with the first member. In the western part of Broadland Township (T. 112 N., R. 63 W.) and in Richland Township (T. 110 N., R. 60 W.) south of Cavour these peaks become elevated into ridges.

Ancient channels and terraces.—Throughout the quadrangle are numerous abandoned channels and terraces, the locations of which are shown on the areal geology map. Usually, though not always, these are clearly separable from the present drainage lines, and are evidently much older. In some of the shallower channels the oldest deposits can not be clearly distinguished from those of recent origin, and in these cases the latter have been included under this head. The ancient channels correspond generally with the present waterways, which are the puny successors of the old streams, although in some cases the direction of drainage has been so changed that the course of the water has been reversed. This is particularly the case in the western portion of the quadrangle, between Virgil and Woonsocket, where in a number of places the same channel was occupied more than once, and not always by streams flowing in the same direction.

These channels vary from shallow, flat-bottomed depressions, through which streams passed for a comparatively short time, to a trough 20 to 40 feet deep that contains an abundance of coarse material, showing that it was long occupied by a vigorous stream. The coarser deposits are usually largely covered with finer material. Where the channel deposit has been cut through by the deeper trenching of a later stream, similar differences in the character of the material also occur. In some cases the old channel deposit is at a height of 50 to 60 feet above the present stream. In many cases, however, the old deposits have been slightly trenched, as the later drainage has passed off in another direction.

The older channels connect with the terraces of the present streams, particularly along James River, where sometimes two are present. East of Huron the terraces are about 40 to 60 feet above the stream. They are not always distinctly marked, but may merge into one another. The usual sign of such a terrace is the sharp, stony edge capping the river bluff and the generally flat surface extending for many rods back from the stream. This stony edge is sometimes transformed by subsequent erosion into a conspicuous stony ridge, higher than the portion lying farther back. A notable case of this sort may be seen east of Forestburg.

These ancient channels served to carry off the water from the ice sheet at its different stages. The arrangement of the channels is the strongest evidence of the former presence of glaciers in the region. The size and course of some of the channels and the amount of coarse material found in them can be explained in no other way.

Ancient lakes.—In this quadrangle are areas which may conveniently be called ancient lakes. This does not mean necessarily that they were ever wholly occupied at any one time by sheets of water. It is possible that as the ice receded toward the north the southern portion of these lakes in each case was first occupied by water and filled by the accumulating sediment from the streams draining the adjacent ice sheets, and that successive areas were filled in a similar way, until the region became a flat plain covered with sand or clay, with points of the underlying till rising above it like islands and with shallow channels winding about irregularly upon it. In some cases these plains seem to have been covered for a period by shallow bodies of water.

One of these lakes has been discussed in the Mitchell and Alexandria folios. It extends into the Huron quadrangle and includes nearly the whole of Forestburg and Woonsocket townships, portions of Logan and Union townships, and the northeastern part of Twin Lake and the southwestern portion of Oneida townships. It includes also the southern half of Warren Township and a few square miles in Jackson. Over this area the surface is poorly drained and covered largely by sand, marking the position of deltas or low alluvial fans. In places this sand now forms dunes. In other portions the surface is covered by gumbo, i. e., nearly pure, dark-colored clay. The gumbo seems to overlie the sand where they come together, and underneath the sand is found the till, which in this area extends to a depth of 60 or 80 and sometimes 100 feet. An attempt has been made on the map to outline the sandy areas. As before stated, the higher points of the till frequently rise above the surface of the sand and gumbo. Northeast of this area and outside of the third moraine, in the northeastern part of Oneida Township, the surface is rougher and is occupied by numerous small lake basins. This roughness is probably caused by the burying of numerous small ice blocks at the time of the recession of the ice sheet.

An extensive area around Huron presents similar features. It has, however, a much more varied surface than that near Woonsocket, but on the whole is very level and evidently had very sluggish drainage when first vacated by the ice.

In Clyde Township (T. 110 N., R. 62 W.) and portions of adjacent townships is a level area with an irregular network of very shallow channels, not more than 5 or 6 feet in depth, which drain as a whole eastward. In this region, especially in the southwestern half of Clyde Township, the till is 60 feet thick, but about 30 feet below the surface is a sheet of sand a few feet in thickness, which is water-bearing. This seems to be the bottom of a lacustrine basin, which subsequently, probably while the ice was near at hand, was filled with pebbly clay.

Scarcely separated from this basin on the northwest is a level area which covers most of Theresa Township (T. 111 N., R. 67 W.), Valley Township (T. 111 N., R. 61 W.), and Custer Township (T. 110 N., R. 61 W.), and portions of the adjacent townships. In this region the till has a thickness of 50 to 60 feet. Here, at a depth of about 30 feet, is a similar sheet of sand, which is especially well developed in Custer Township. Farther north it does not seem to exist, though there is very frequently a deposit of sand lying at the surface, especially in the channel-shaped depressions which are there present.

In Valley Township and the northern part of Custer Township is a peculiar network of channels leading northward. These are connected with shallow basins in a way that suggests that they were the lines of drainage from ice blocks that were detached from the ice sheet as it receded. Moreover, certain peculiar knolls and hillocks which at first appear to be of morainic origin are more satisfactorily explained by supposing that they were accumulations of débris, somewhat like alluvial cones, around the margins of these ice blocks. They have a very irregular arrangement and can not be correlated with any of the moraines that have been recognized.

It should be remembered that James River followed its present course from the time when the ice withdrew from this region, and that at first it flowed near the level of the general surface, into which it has cut its present trough. It was in this earlier stage that the terraces were formed along its banks and the lakes outlined above were filled. For some time after the ice had left the borders of this area the James and some of its longer tributaries were flooded and heavily laden with sediment. The erosion of its present trough began at the time when the melting of the ice sheet contributed largely to the vigor of the streams.

RECENT DEPOSITS.

Since the retreat of the glaciers there has been very little deposition in this quadrangle. The present streams and the winds are, however, making some changes in the surface deposits. The gravels of the ancient channels and lake basins are thickly covered with fine silt, which is in part dust deposited from the air.

Alluvium.—All of the streams that traverse the region are subject to sudden floods, caused not only by occasional excessive rainfall but by the rapid melting of abundant snows. The streams at such times take up a heavy load of material, which is deposited as the water recedes, forming alluvial plains. The alluvial plain of James River is about half a mile wide. Some portions of it are dry and are well adapted to cultivation; other parts are marshy, and all are more or less subject to occasional floods. The alluvial deposits are from 10 to 20 feet thick, the upper 3 to 5 feet being usually fine black loam, and the lower portion sand.

GEOLOGIC HISTORY.

The earliest phases of the history of the region of which this quadrangle is a part may be stated very briefly. At some stage preceding the formation of the Sioux quartzite a land surface composed of granite and slate occupied central Minnesota, and to this land mass probably belonged the granite encountered in the deeper wells of this quadrangle. From that land area material was derived, both by the action of streams and by wave erosion along the shore, which was laid down over the region now occupied by the Sioux quartzite. The deposits consisted mainly of stratified sands, but occasionally comprised thin beds of clay. They were thicker toward the center of the broad area that now extends southwestward from the vicinity of Pipestone, Minn., and Sioux Falls, S. Dak. After this period of deposition there seems to have been an epoch of volcanic and igneous outflow, as is shown by the occurrence of a dike of basic eruptive rock in the quarries at Sioux Falls and of olivine-diabase in borings at Yankton and Dover, S. Dak., and of quartz-porphyry near Hull, Iowa.

Through silicification the sandstone was changed to an intensely hard and vitreous quartzite, while some local clay beds were transformed to pipestone and more siliceous red slate, as at Palisade. Microscopic examination shows that this silicification was effected by the crystallization of quartz around the separate grains of sand until the intervening spaces have been entirely filled. The material of the quartzite was laid down in the sea, and at first may have included scores, or even hundreds, of feet of material above that which is now found. In time the region was lifted above the sea, and during some part or all of the long Paleozoic age it was a peninsula. It may at times have been submerged and have received other deposits, but they have been eroded. That it was not far from the ocean, at least during a portion of the time, is attested by the occurrence of Carboniferous rocks under Ponca, Nebr.; and since Paleozoic, Jurassic, and Triassic rocks are found in the Black Hills, it is evident that the shore line during those ages repeatedly crossed the State some distance to the west.

With the beginning of the Cretaceous period the sea began to advance over the land; in other words, this quartzite area began to subside relatively. As the waters gradually advanced, waves and currents carried away finer material and left well-washed sands spread as more or less regular sheets extending from the eastern shore line across the shallow sea to the Rocky Mountains. From time to time the activity of the erosion diminished and finer material, or mud, was deposited, or both the sands and the mud may have been laid down contemporaneously in different areas. It is not unlikely also that strong tidal currents, sweeping up and down the shallow sea, may have been important in distributing so uniformly the sands and clays. Where the currents were vigorous, sands mainly would be laid down; where they were absent or very gentle, clay would accumulate; and not improbably these tidal currents would shift from time to time by the variable warping of the sea bottom and the shore. At any rate, several continuous sheets of sand lie over this region and are more or less perfectly separated by intervening sheets of clay. The process resulted in the Dakota formation.

The fossils found in the Dakota formation are some fresh-water shells and leaves of deciduous trees, like the sassafras, the willow, the tulip tree, and the eucalyptus.

During Colorado and still later Cretaceous times marine conditions prevailed and the region was further submerged until the shore line was probably as far east as central Minnesota and Iowa. During most of this time only clay was deposited in this quadrangle, but calcareous deposits accumulated in the form of chalk during the Niobrara epoch, when the ocean currents brought less mud into the region.

During these epochs the sea abounded in swimming reptiles, some of gigantic size, whose remains have been found at several points; also sharks and a great variety of other fish, although the remains of these are not abundant at most points.

After the Cretaceous period the sea seems to have receded rapidly toward the northwest, and all eastern Dakota again became dry land.

During the early Tertiary, according to the prevalent view, large rivers deposited widespread sediments in the region to the west and southwest, but this area received little material and probably abounded in vegetation and animal life which exhibited features not markedly different from those of the present age. Probably the climate was then much warmer and moister. During the later part of the Tertiary there was doubtless a large stream somewhere near the present position of James River, flowing southward. Into this White River probably came through the basin of White Lake and the valley of Firesteel Creek. These rivers doubtless had many small tributaries, which rapidly cut into the soft material composing the surface. The elevated region in the southwestern part of Davidson County may be considered as a remnant of the old divide south of White River. This older James River seems to have made for itself a large valley, which was much wider than the valley of Missouri River. Apparently it did not cut down to the depth of the present James River.

During the Pleistocene epoch the great ice sheet moved down James River Valley, entering it probably from the north and northeast. It advanced slowly, preceded by waters from the melting ice, which gradually spread a mantle of sand and gravel over nearly the whole pre-Glacial surface. This ice sheet flowed according to the slope of the pre-Glacial surface, moving more rapidly on the lower and more open portions of the valley, and becoming almost stranded on the higher elevations. It certainly extended as far as the outer, or Altamont, moraine. Some geologists are confident that it extended down the Missouri Valley and became confluent with the similar sheet flowing down the Minnesota and Des Moines valleys, both sheets extending into Kansas and central Missouri. However that may be, during the formation of the Altamont moraine the ice filled the whole James River Valley and extended westward at different points to the present channel of Missouri River, near Andes Lake, Bonhomme, and Gayville, so that the Altamont moraine forms an almost continuous ridge or system of stony hills around the edge of the ice sheet of that epoch, except where it was removed or rearranged by escaping waters. Morainal deposits of this stage are not found in this quadrangle.

In course of time the strength of the ice current was checked and the front gradually melted back, until perhaps a portion of this quadrangle was uncovered. It is barely possible that the marsh deposits near the southwest corner of the quadrangle, before referred to as possibly of pre-Glacial age, are to be referred to that time, but as no till is known to occur under them, and so far as known they rest on Cretaceous clays, they seem to antedate the coming of the ice.

After this period of retreat the ice sheet readvanced and formed the first member of the Gary moraine. At that time the southwest corner of this area was uncovered, and the drainage from the west side of the ice passed through the valley of Firesteel Creek. A little later the second member of this moraine was formed a short distance within the first. When the ice receded to form the third member the west branch of Sand Creek drained down the channel west of the Pony Hills.

While the Antelope moraine was being formed the north fork of Sand Creek, fed by several streams from the ice sheet, washed much débris into the basin east of Woonsocket. At the same time Redstone Creek sustained a similar relation on the east side of the James. Eventually the ice seems to have become stagnant and to have melted in place. Apparently it lay in extensive blocks in the basin east of Huron. This was true even after James River was running in its present course, perhaps with icy banks. A portion of the basin north of Huron seems to have been more open and to have received much sand and silt from the melting ice sheet farther north, not only through the James, but by a channel which led past the present location of Broadland.

After the retreat of the ice the streams occupied their present courses, and though at first they were somewhat larger than they now are, they have affected the surface of the country little except to deepen the channels which were occupied by permanent water. It is believed that James River had cut nearly to its present depth before the ice had disappeared. The main change since the disappearance of the ice has been the formation of soil by the accumulation of alluvium along the principal streams, by the deepening of fine material over the general surface through the burrowing of animals, by the wash from the hillsides, and by the settling of dust from the atmosphere.

ECONOMIC GEOLOGY.

This quadrangle contains no deposits of valuable mineral or of coal. The few samples which are sometimes submitted as "mineral" are invariably iron pyrites, which has no value unless found in very large quantities. Fragments of coal are sometimes found in the drift, in either gravel or till, but they have been brought by the ice or by streams from the northern part of the James River Valley, in which are found beds of lignite—the so-called coal of North Dakota.

BUILDING STONE.

The most abundant stone in the quadrangle is that brought by the glaciers of the Pleistocene. It is in the form of bowlders, which are scattered over most of the country, but are much more abundant in the morainic areas. These bowlders consist mainly of granite, other crystalline rocks, and limestone. They are not easily prepared for ordinary building purposes, because of their hardness and toughness, and thus far they have been used principally for foundations. Red quartzite, which is so common farther south, is not found in this quadrangle.

CLAY.

Although the till is composed largely of clay, it is so mixed with gravel, and especially with calcareous matter, that it has nowhere been successfully used for economic purposes, not even in the manufacture of brick. Deposits of clay of economic value are not certainly known to exist in this area. Diligent search might disclose beds of silt near James River, or of gumbo in the lake basins, in sufficient quantity to be of some local value in making brick, but there is apt to be so much lime and coarse material mingled with them that probably bricks will not be manufactured extensively.

SAND AND GRAVEL.

Plastering sand and gravel suitable for ordinary purposes are found at many points, especially along the ancient channels and terraces, and in some of the knolls in the morainic areas.

WATER RESOURCES.

Under this head is included an account of the most important natural resources of this quadrangle, water, which may be divided into surface and underground water. Under surface water are included lakes, springs, and streams, and under underground water the sources which furnish shallow wells, artesian wells, and tubular wells.

Surface Waters.

Lakes.—Lakes receive their waters directly from the rainfall, and endure according to the extent of the drainage basins, their depth, and the amount of rainfall. The rainfall of this region varies greatly in different seasons, but averages about 20 inches a year. After a succession of wet years the lake beds over the whole district are full of water, and are usually filled in spring, if there has been much snow during the winter. In the latter part of summer most of the ponds become dry. Within the last twenty-five years some of these lakes have remained throughout a summer with 10 to 15 feet of water, while a few years later they would be dry enough for tillage. One of the largest and most notable is Lake Cavour, about 3 miles northwest of the station of that name. It is channel-like, with abrupt sides 15 to 20 feet in height, and usually has a considerable surface of open water.

Streams.—James River is the only stream that can be depended on to contain water throughout the year, although 7 or 8 miles of the lower portion of Sand Creek and 3 or 4 miles of the lower portion of Pearl Creek are rarely entirely dry. Since the opening of large artesian wells a few other watercourses contain running water.

Along Firesteel Creek, the middle portion of Sand Creek, and parts of Cain Creek are ponds which are connected by running water in spring, but in the latter part of summer become separated. There is, however, sufficient movement through the sand in the bed of the channel to prevent their stagnation in many cases. If they are kept free from contamination they are likely to afford good water.

Springs.—Permanent springs are rare, though a few occur. They have their source either in the sands and gravel of the older terraces or in sand beds buried in the till. Springs fed from deeper sources are unknown in this quadrangle. Springs deriving their supply from the first-named source are usually transient and unreliable. There are only two areas in which they are important. In the sandy area west of Forestburg water sometimes comes to the surface in large amounts. Along the edge of the James River Valley copious springs are found at the head of ravines leading to the river. Two or three are found south of Forestburg, in secs. 6 and 7, Union Township. North of Forestburg, both east and west of the river, springs arise from a similar deposit, which may be called the old delta of Redstone Creek.

Springs fed from buried sand beds are more permanent. The bed of sand in the till in the flat area about Huron supplies a number of springs. Three of these are found along Pearl Creek, one in the northern part of sec. 18, T. 109 N., R. 60 W., another in the southern part of sec. 7, and still another in the southern part of sec. 11, T. 109 N., R. 61 W. There is a series of springs where this stratum outcrops along the east bank of James River in sec. 32, T. 111 N., R. 61 W. One is found in the northwest corner of sec. 21, another in the southeast corner of sec. 14, and another in the northwestern part of sec. 12, in T. 111 N., R. 61 W.

These springs furnish clear, hard water, depositing in some cases considerable travertine. The limestone ledge thus formed near Huron, and stained with iron, has been thought by some persons to resemble the surface rock found in the vicinity of gold mines, and hence the presence of gold there has been inferred. It scarcely need be stated that such a conclusion is entirely unwarranted.

Subterranean Waters.

Waters obtained from below the surface by artificial means will be considered under the headings "Shallow wells," "Tubular wells," and "Artesian wells."

SHALLOW WELLS.

Shallow wells are those supplied by water which has recently fallen on the surface and which can be reached without penetrating an impervious layer. The most common source of supply for these wells is the water that lies near the surface and seeps through the upper portion of the till toward a watercourse wherever there are shallow accumulations of sand that form conduits for it. The water flows slowly through the lower portion of these sand accumulations and appears at intervals in water holes along the upper courses of the more prominent streams. In these it rarely comes forth in sufficient strength to attract attention. Where the surface slopes toward an undrained basin, the water of the yellow till accumulates in the lowest portion. It may be drawn upon by shallow wells, and for a number of years may be entirely adequate for the demands of neighboring farms, but in time of drought it is gradually exhausted. Where the surface slopes toward a watercourse the water accumulates in larger quantity, but it also flows away more quickly. Shallow wells, therefore, along the ancient watercourses that were occupied by streams of considerable size while the glaciers were present in the vicinity, afford the most copious water supply. When the region was first settled the shallow wells were the main dependence of the farmers. In 1881 and a few years later, water was abundant in these wells, but after a series of dry years this supply became exhausted and the farmers were forced to go deeper in order to obtain water.

Shallow wells are common in this quadrangle, and usually obtain water at a depth of from 10 to 30 feet. They do not afford a copious or permanent supply except when located near the bottom of a large depression or near a channel draining a considerable area. The reason for this is that the water comes from the rainfall only, and the region is often subject to continued drought. Only those which are so situated as to draw from a large catchment basin can be counted upon as permanent. If water is not obtained before striking the blue bowlder clay, none will be found until the bottom of the latter is reached.

Permanent shallow wells may be obtained in the extensive flat areas about Huron and Woonsocket. In the eastern and southern part of the Woonsocket basin west of Sand Creek a copious supply of water is found in the sand at a depth of from 10 to 20 feet. In the vicinity of the broad meandering channels north and northwest of Huron abundant water is found, except in very dry seasons, at a depth of 10 to 15 feet. In the area southwest of Huron, where the stratum of sand already noted is found about 30 feet below the surface, are permanent wells which may be considered as belonging to this class.

TUBULAR WELLS.

Under this head will be included simply the deeper wells in which a tubular or force pump is usually necessary. The water frequently rises nearly to the surface and occasionally flows. These wells derive water from the sand and gravel at the base of the drift, from a stratum in the Pierre clay above the chalk, and from the sands below the chalk. In many wells the water rises to within 5 to 25 feet of the surface. Some, in fact, are flowing wells, as shown on the artesian water map. The approximate depths to the bottom of the till in different parts of the Huron quadrangle are shown in fig. 7. There are many local variations of small amount which can not be represented on a diagram of this character, and, moreover, the sub-till sand sheet is not everywhere filled with water, especially in the more elevated regions. Therefore, a boring may pass through the sand to the Cretaceous shales below without obtaining water.

Wells in the bowlder clay.—Below the till is commonly a stratum of sand or gravel which is invariably filled with water. At ordinary levels, as soon as the till has been drilled through, the water rises several feet, sometimes nearly to the surface. The water from this source is heavily charged with lime, and sometimes with iron. It is commonly cool and wholesome. In some places, however, either at first or soon after the well is dug, the water becomes so impregnated with the soluble salts which abound in the bowlder clay that it becomes offensive and sometimes injurious. This is especially true of the wells in the plains east and north of Woonsocket. This horizon has produced some valuable flowing wells. Such an area extends from the southeast into the southern part of Floyd Township (T. 108 N., R. 60 W.). This will be more fully discussed under the heading "Artesian wells."

Wells in Pierre clay.—In the Pierre clay is another water horizon, which is commonly present in the northeastern part of the quadrangle and has been most drawn upon in the plain east of Huron. It does not appear to lie at a uniform level, but is struck at depths of from 115 to 175 feet, the depth increasing toward the north. Since sand has not been distinctly recognized at this horizon, the water may possibly come from fissures or local lenses of a porous formation deposited in the clay. The water from this source is commonly spoken of as from the "soapstone," and is soft. Judging from wells farther south, it seems probable that what is called "soapstone" is gray chalk.

Wells in the upper Benton sandstone.—The third and most important pump-well horizon is the upper sandstone of the Benton formation, which throughout the quadrangle seems to lie just below the chalk. It is the source of the most desirable and most permanent wells in the whole southern half of the quadrangle, and is well-known in the northeastern quarter, but in the northwestern portion has not been found. This is probably due, not to its absence, but to its greater depth and the better supply of water from more accessible strata.

Since this horizon is an unfailing source of soft water, which usually rises within a few feet of the surface, it seems worth while to give in considerable detail the depths at which it may be struck. Beginning at the southeast corner of the quadrangle, it lies at a depth of 130 to 140 feet. Near Woonsocket it is reached between 140 and 175 feet. Farther west its depth increases as the surface rises, so that at the southwest corner it lies about 400 feet below the surface. Near the northwest part of Franklin Township (T. 107 N., R. 63 W.) it is reached at a depth of a little over 200 feet. In the Schmidt well it is struck 350 feet below the surface. In sec. 21, Carlyle Township (T. 109 N., R. 63 W.), a well nearly 200 feet deep did not reach it. In the eastern part of Custer Township (T. 110 N., R. 61 W.) it lies at a depth of 230 feet. Near Cavour it is found at a depth of about 200 feet. In the southeastern part of Iowa Township (T. 112 N., R. 61 W.) this horizon is about 300 feet below the surface, and in sec. 29 of the same township it has a depth of 250 feet. About Huron it is found at a depth of 200 to 210 feet.

The water from this stratum is uniformly soft, although containing considerable mineral matter. The ingredients probably are salts of soda. It is commonly said to be "soft as rain water," and in some localities is sold for washing purposes.

In the southern part of the quadrangle the water horizon is frequently spoken of as being in the chalkstone, and where the water is reached at less depth than usual it may have escaped from the sandstone into the overlying chalkstone by way of crevices or more porous strata.

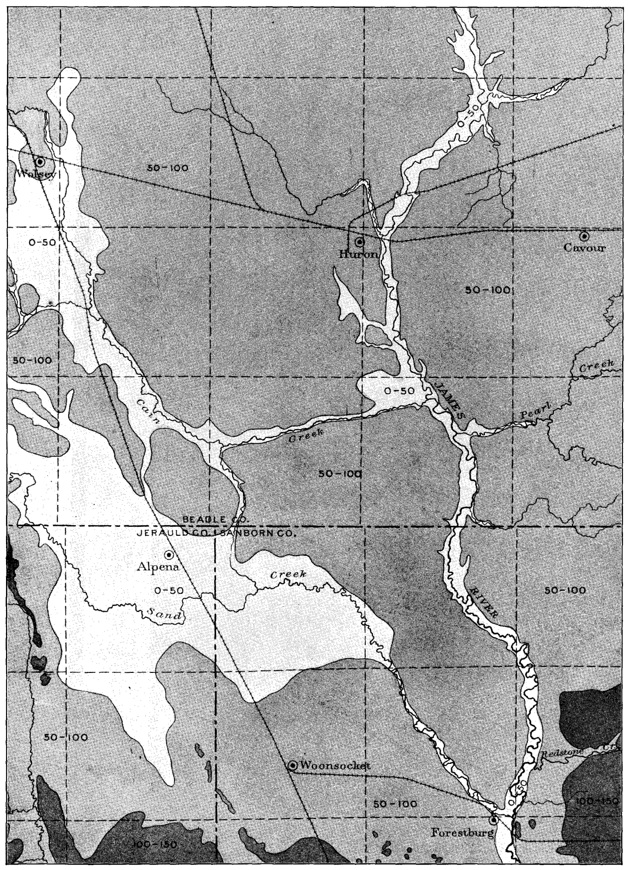

FIG. 7.—Sketch map of Huron quadrangle showing approximate depths to the bottom of the till.
Water can usually be obtained from sands and gravel at the base of the drift, and generally rises many feet in wells.

The water from this source rises uniformly to nearly 1300 feet above the sea. Some of the wells in the lower portion of the plain east of Woonsocket were reported to have flowed when first opened. The wells in the town of Forestburg are among the oldest flowing wells of the region, and are supplied from this source. Without much doubt wells sunk in the valley of James River a little below the top of the bluffs would obtain flowing water from this source anywhere in this quadrangle. This has been indicated on the artesian water map.

ARTESIAN WELLS.

In drilling wells, a water-bearing stratum in which the water is under pressure is generally spoken of as a "flow" and the well is classed as "artesian," although some persons would limit the term artesian to wells in which there is sufficient pressure to raise the water to the surface. The latter is the usage employed in this folio. Artesian wells are common in the Huron quadrangle and derive their supply mainly from the Dakota sandstone. Some wells, however, draw their supply from Pleistocene sands.

PLEISTOCENE ARTESIAN WELLS.

The Pleistocene artesian wells derive their waters from the sand underlying the till. There are few wells of this class in the quadrangle. They occupy 8 or 10 square miles in the southern part of Floyd Township (T. 108 N., R. 60 W.) and the northern part of Oneida Township. This is an extension of the area about Artesian, in the De Smet quadrangle. These wells vary in depth from 75 to 100 feet. Their flow is copious but their pressure is slight. As scores of wells have been sunk to this horizon the head has been gradually declining. It seems to have fallen 8 or 10 feet in a dozen years. Some wells have ceased to flow and others have been made to continue their flow only by lowering their outlets.

MAIN ARTESIAN SUPPLY.

The main supply of artesian water in this region is undoubtedly derived from the sandstone and sand beds of the Dakota formation, which is the source of artesian water not only under much of eastern South Dakota but in a wide area in adjoining States. It owes its efficiency to four factors: (1) Its great extent, since it underlies most of the Great Plains from the Rocky Mountains eastward to about the ninety-fifth meridian; (2) its highly elevated western border, which is located in the moist region of the mountains and crossed by numerous mountain streams; (3) its being extensively sealed in its eastern margin by the overlapping clays of the Benton formation, or, where they are absent, by the till sheet of the Glacial epoch; and (4) the cutting of wide valleys, especially in South Dakota, by pre-Glacial streams, so as to bring the land surface below the pressure height or "head" generated by the elevated western border of the formation. From this formation is derived also a copious pumping supply over wide areas where the pressure is not sufficient to produce flowing wells. Water-bearing Dakota sandstones underlie the whole quadrangle. Below this is the "bed rock" of well drillers, the limit of profitable boring; the depths to its surface are indicated in fig. 8.

The water-bearing strata seem to lie more nearly horizontal and to have a more regular structure in this area than farther south. There are no marked irregularities to indicate local subdivisions of the water-bearing strata, as elsewhere. On the other hand, it is impossible to speak as definitely concerning the depth of the different formations in this area as in some others, because artesian wells are not so numerous.

There are three quite distinct water-bearing strata under this quadrangle, and in the north-central portion there is probably a fourth. These are known as the first, second, third, and fourth flows, and they correspond respectively to the lower Benton, possibly corresponding to the Greenhorn-limestone horizon, and to the first, second, and third sandy strata of the Dakota formation. They seem to be distinct from one another, though observations of the pressure of the water from each horizon are not yet complete enough to make this point certain.

The first flow yields soft water, and the quantity is usually so slight that it is not generally drawn upon for a permanent supply. A few wells which obtain water from this stratum have flowed for several years, and observations made farther south, about Letcher, indicate that the flow is unfailing. The water probably comes from a thin stratum of sand, which may not be as continuous as the thicker ones below. At several localities it either has not been struck or has been overlooked. This flow is not shown on the artesian water map, which shows the depth of the lower or main flows. The following table gives the depths at which this flow has been found.

Depths below average upland level at which the lower Benton flow occurs.

	Feet.
Floyd Township (T. 108 N., R. 60 W.)	530
Pearl Creek Township (T. 109 N., R. 60 W.)	475
Southwest Grant (T. 109 N., R. 62 W.)	500
Near Huron	510
At Wolsey	490
Northeast Dale (T. 109 N., R. 64 W.)	650

The next horizon is that which is most frequently drawn upon. The supply is copious and the water is palatable, although hard. It is struck at a depth below general level of 650 to 750 feet in the southern part of the quadrangle. It occurs at about 800 feet near Alpena and at about 750 feet near Huron, while farther north it is 800 feet and farther west a little more.

The third flow supplies the Melville, Riverside, and Wolsey wells from a depth of 900 to 950 feet.

The Risdon and White wells, the third city well, and the railroad wells at Huron apparently derive the waters from the horizon still 100 feet deeper. Moreover, this lower stratum is thick and may be subdivided in some wells.

All these depths are estimated for the upland level. Allowance may be made for the variations of the surface above or below this.

Artesian pressure.—From a superficial study of artesian wells some persons think that all the artesian water in a basin has the same head or rises to the same plane. Such, however, is far from true, particularly in North and South Dakota. In general the pressure declines toward the margin of the water-bearing strata. This fact is readily explained in shallow basins by supposing that the water is moving as a slow current toward outlets or leaks along the margin of the formation, where the latter laps against the older rocks or where fissures may connect it with the bottoms of streams. Each flow, in general, shows this same decline in pressure toward the southeast.

The lower flows from the Dakota formation have higher pressures because the leakage along the eastern edge is much less free. On the artesian water map are contours representing the altitude or "head," which, in its downward slope southeast may be regarded as a "hydraulic gradient." It would be impossible to represent the pressure for each water-bearing stratum; therefore the data from the more important wells have been taken, or, in other words, the contours showing altitude of head representing the relative pressure in the more available and accessible stratum, viz, the first of the Dakota formation. It is not unlikely that in many cases the sinking of wells to lower flows may show considerably increased pressure.

For several reasons the pressure at the wells in this quadrangle has not been satisfactorily determined. The first pressure, or that of the first wells opened, was usually much higher than any at present. For example, at Huron the pressure first reported, probably of water from the second flow, was 120 pounds, but at present none of the wells of the city can obtain a pressure of more than 80 pounds. The pressure registered by the railroad well, formerly known as the Wilcox or Syndicate well, is 71 pounds.

The Riverside well, opened last year, gave a satisfactory pressure of 105 pounds, but only a little farther east, at the poor farm, a pressure of only 85 pounds was obtained.

It seems certain that where wells are multiplied in close proximity the pressure steadily declines, that presssures as high as those first reported can not be repeated without closing all the wells at the same time, and that even then days and possibly weeks would have to pass before the water had accumulated to replace the local exhaustion.

In the latitude of Huron the water rises toward the west at the rate of about 4 feet to the mile. This conclusion is arrived at by comparing the earliest reported pressures and by making allowance for the local exhaustion. Toward the south the pressure declines.

A study of recent wells on the east now shows a slight rise of pressure in that direction. This seems at first anomalous, but it may be accounted for by the withdrawal of water from wells in the James River Valley and the probable greater leakage toward the edge of the Dakota in the valley, which does not occur so freely farther east because of thicker and more perfect cover.

The contours of pressure height on the artesian water map are drawn for the first strong flow, which comes from the third water stratum below the chalk or the first Dakota flow. Some wells, notably the Risdon well, draw from lower horizons and consequently show greater pressures; others, though drawing from the same, also communicate with the higher horizons, and consequently can give no higher pressures than are found in the latter.

The contour of 1500 feet around Huron may be ascribed to the local withdrawal of the water by numerous large wells, for when wells were first opened there the pressure was considerably above that figure.

Cause of apparent decline in pressure.—It is now generally admitted not only that the amount of water flowing from each well rapidly decreases, but that the closed pressure also declines. This becomes evident without the use of instruments, first by a shortening of the distance to which the water is thrown from a horizontal pipe, and second by the fact that after a time the stream which first filled a given pipe fails to do so. In some cases a test with the gage shows that there is merely a decline in amount of flow, without material decline in pressure. It may be accounted for by the deposition of mineral matter about the bottom of the pipe in such a way as to clog the pores of the sand through which the water comes. More commonly, however, the pressure itself has been found to diminish. Thus some wells at Huron that once showed a pressure of 120 pounds when closed now fail to reach 80 pounds. Similar facts have been reported from Mitchell, Mount Vernon, and Plankinton.

The unwelcome conclusion derived from these facts has led many persons to search for other reasons than the one first suggested, the partial exhaustion of the artesian supply. It is claimed, and apparently correctly, that new wells frequently have a pressure equal to that of early wells supplied from the same source. Since the closed pressures, however, are less frequently taken than formerly, and from the nature of the case liberal allowance must usually be made for leakage, it is difficult to prove the strict truth of this statement.

The first sign of apparent decline is a less copious flow. This is usually due to the clogging of the well. As wells are usually finished by extending a perforated pipe into the water-bearing rock, it will be readily seen that the surface opened for the delivery of water to the well is equal to the perforated portion of the pipe. As the water continues to flow, sand gradually accumulates on the inside of the pipe and so diminishes the surface supplying water to the well. Something of the same sort may less frequently occur even when the pipe terminates in the cap rock. Sand gradually works in from the sides, and portions of the cap rock are undermined and drop down, so that free access of the water is considerably diminished.

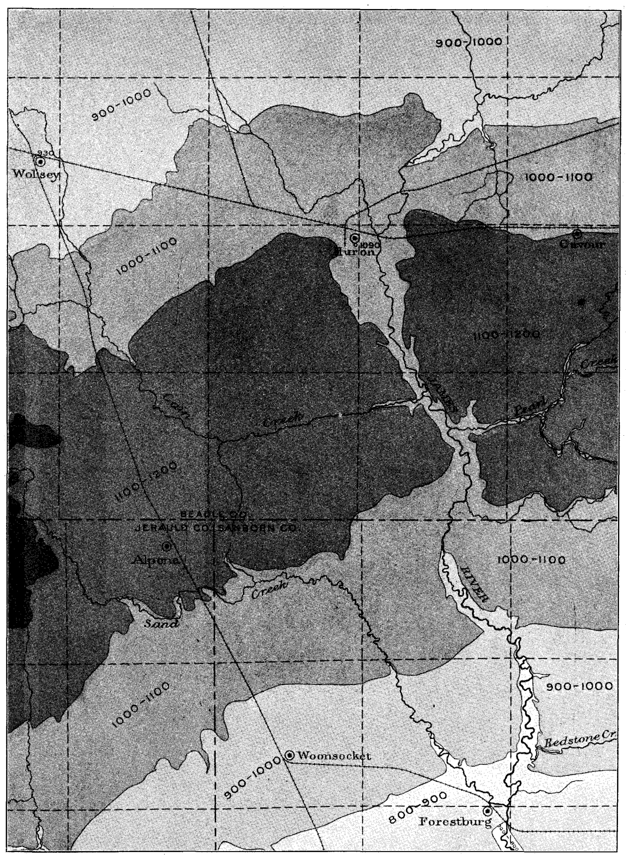

FIG. 8.—Sketch map of Huron quadrangle showing approximate depths to the surface of the Sioux quartzite, "bed rock" of well drillers, which is the lower limit of water-bearing strata.

Theoretically the closed pressure should be the same whether the well is flowing freely or not, so long as the head of the water is the same. If the well becomes clogged, as suggested above, the only difference in pressure would be that when a gage is attached it takes longer to reach the maximum point. As this rise may be very gradual, some errors of reading have doubtless resulted because the observers did not wait long enough.

Another cause of diminished pressure is leakage. As is well known, pipes deteriorate rapidly under the influence of most artesian water, and it becomes almost impossible to close the joints perfectly. Where there is a long pipe, as in the case of the distributing pipes of a city, one can never be sure that all leaks are stopped. This may sometimes explain the apparently diminished pressure in older wells.

The diminished pressure in a particular well may sometimes be due to the opening of another well not far away. The distance to which this influence extends will of course be greater where the water-bearing stratum is of coarse texture, and the movement of the water freer. Where water has been drawn freely from several wells, or even from one large well, there is no doubt a local depression in the head, or lowering of pressure, which may not be restored for sometime. This might occur without permanent decline of supply.

Notwithstanding all the considerations offered thus far, it seems not unlikely that the rapid multiplication of wells in any region may really reduce the pressure over the whole region to the amount of a few pounds. It is therefore important that facts should be collected to ascertain whether this is the case, and if so, to determine the amount of diminution. In view of the possibility of overtaxing the supply, it would seem desirable to limit in some way the number of large wells allowed to flow freely. A single thousand-gallon-a-minute well would be sufficient to supply 450 wells furnishing 100 barrels a day, which would be an adequate supply for an ordinary farm.

SOILS.

The soils of this quadrangle have not been carefully studied and only the more obvious characteristics are noted below. They may be divided into stony soils, sandy soils, clayey soils or "gumbo," and loam.

Stony soils.—Stony soils are found only in limited areas, mainly upon the rougher surface of the moraines and along the edges of the terraces skirting the principal streams. The morainic areas usually carry bowlders on the surface, which must be removed to permit ordinary cultivation.

Bowlders mingled with pebbles are thickly strewn along the terraces, particularly near the edges, and seem to run under the finer material farther back, so that they offer more serious hindrances to cultivation. The slopes of the steeper bluffs along the streams are often covered with bowlders that have either slipped down from the stratum capping the terraces or have been stranded in times of flood. In some cases the bowldery stratum has offered such resistance to the erosion, which took place in part, at least, before the close of the Glacial epoch, that they are detached from the terraces and form ridges. A notable example is found east of Forestburg, where a ridge nearly 2 miles in length appears, simulating an osar.

The predominance of bowlders may mark a sandy soil or a loam, more frequently the latter.

Sandy soils.—Sandy soils are not very extensive in this quadrangle and are confined to the delta-like deposits filling the Woonsocket and Huron basins. They occur along James River near the mouths of Sand and Redstone creeks. These areas are marked upon the map. The larger area is along the right bank of Sand Creek. It begins at the northwest corner of Forestburg Township (T. 107 N., R. 61 W.), widens to a breadth of 3 miles west of Forestburg, and extends beyond the southern boundary of the quadrangle. In some places near the center of Forestburg Township the sand forms dunes entirely bare of soil. A smaller area occupies about 10 square miles in the eastern part of Forestburg Township, including a prominent landmark known as Belcher's Mound, rising abruptly from the west side of James River, opposite the mouth of Redstone Creek. A considerable grove is found on its eastern slope, though the west slope shows only drifting sand.

A series of sand patches extends along the west side of James River from sec. 25, T. 111 N., R. 62 W., through Huron to the southern part of sec. 19, T. 100 N., R. 61 W. In all these areas the sand is mingled with much humus or black loam and forms fertile soils, except where the breaking of the surface allows the wind to drift the sand.

Gumbo.—The typical representative of soils of this class is a dense, fine, drab-colored clay, sometimes light colored. It is soft and very sticky when wet, and intensely hard when dry. In the latter condition it is seamed with cracks. It prevents almost completely the sinking of rain water into the ground and the rising of moisture from the subsoil in time of drought. While it is damp grasses may flourish upon it, but they wither when the dry season comes. Such soils are found in the bottom of lake basins, along some of the alluvial flats near the principal streams, and in the northwestern part of the Woonsocket basin, which lies in the northeastern part of the township of that name, and extends southeast into Logan Township (T. 106 N., R. 61 W.). Some of the accumulations are the result of recent wash, but the most extensive areas were probably formed during the latter part of the Glacial epoch. It is significant in this connection that on the gumbo flats northeast of Woonsocket are scattered areas of cactus similar to those found in the western part of the State.

Loam.—This term may best describe the soils which occur on the upland and rolling surfaces generally and which uniformly cover the till. The action of frost, the leaching influence of surface waters, the mingling of dust from the atmosphere, and the work of burrowing animals have all contributed to produce this kind of soil from the more clayey till. It is fertile, and generally of sufficient depth except upon the highest points of the till. Under this head would fall also most of the alluvial soils, both those upon the flood plains of present streams and those of ancient streams. Some of the best examples are found upon the upper flat portions of the terraces. These soils are characterized by a mixture of clay and sand, with usually a minor content of calcareous material.

Spotted areas.—In the rougher morainic areas and in pitted plains, where small basins are numerous, gumbo is found in the bottoms of the basins, while the surrounding surface is loamy. The differences in soil are not usually great enough to require special treatment. Ordinary tillage so mingles the different soils that they are mutually beneficial. On the Woonsocket plain, and, in a less degree, on the plain around Huron, the clay and loam soils are mixed quite differently. The surface is generally loamy, but small patches of clay, usually only a few feet across, are scattered on it in an irregular way. In many cases the clay seems to mark points where the underlying till sticks up through the water-laid loam or sand. In a few cases the clay seems to be lower than the general surface, and may be the result of the solution of silica by alkali minerals. The supposition has not, however, been verified by chemical analysis.

July, 1903.

U.S. GEOLOGICAL SURVEY
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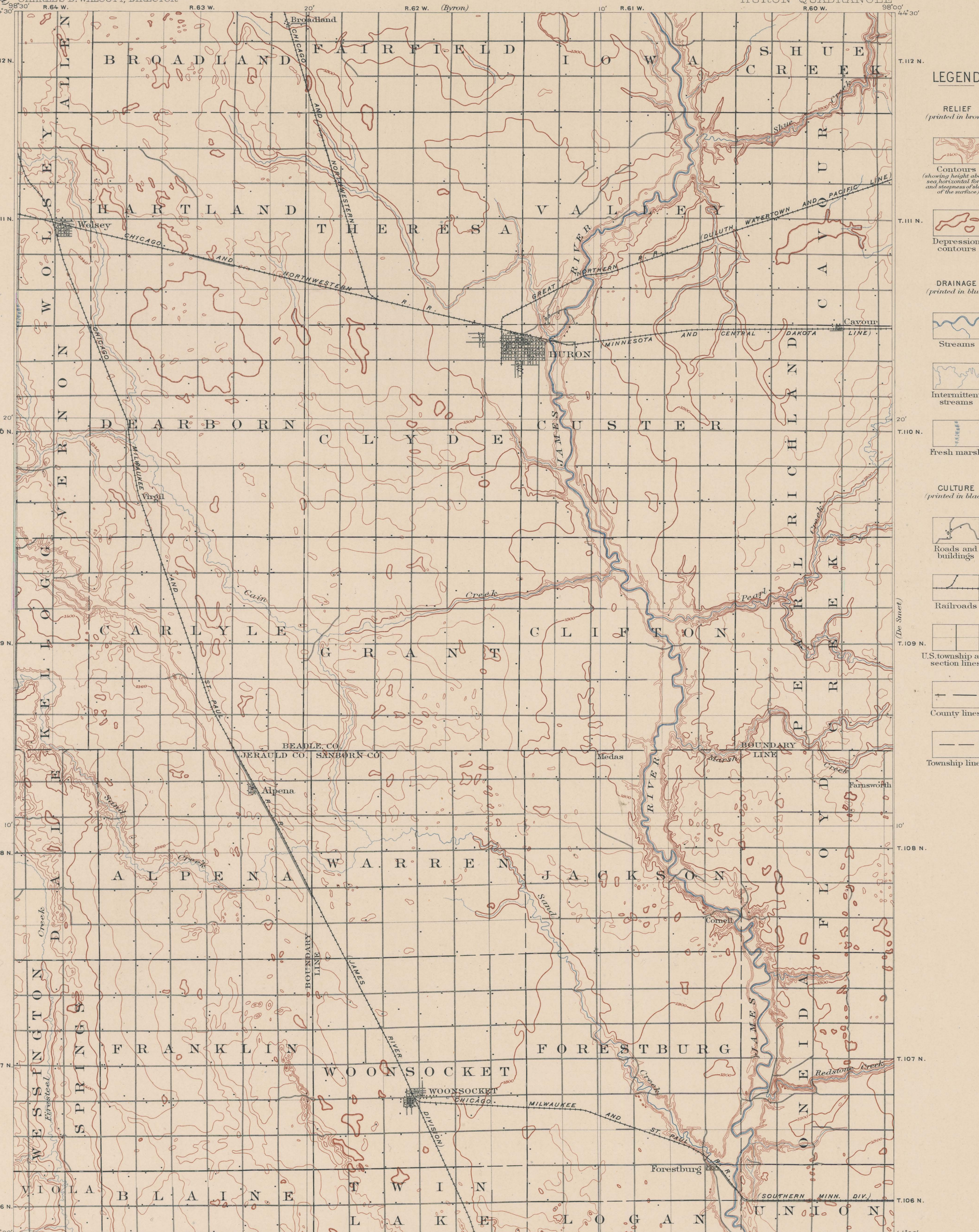
TOPOGRAPHY

SOUTH DAKOTA
HURON QUADRANGLE



Henry Gannett, Chief Topographer.
Jno. H. Renshawe, Topographer in charge.
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Topography by D. C. Harrison.
Surveyed in 1894.

APPROXIMATE MEAN DECLINATION 1902.

Scale $\frac{1}{125000}$

Contour interval 20 feet.
Datum is mean sea level.

DIAGRAM OF TOWNSHIP

Edition of June 1904

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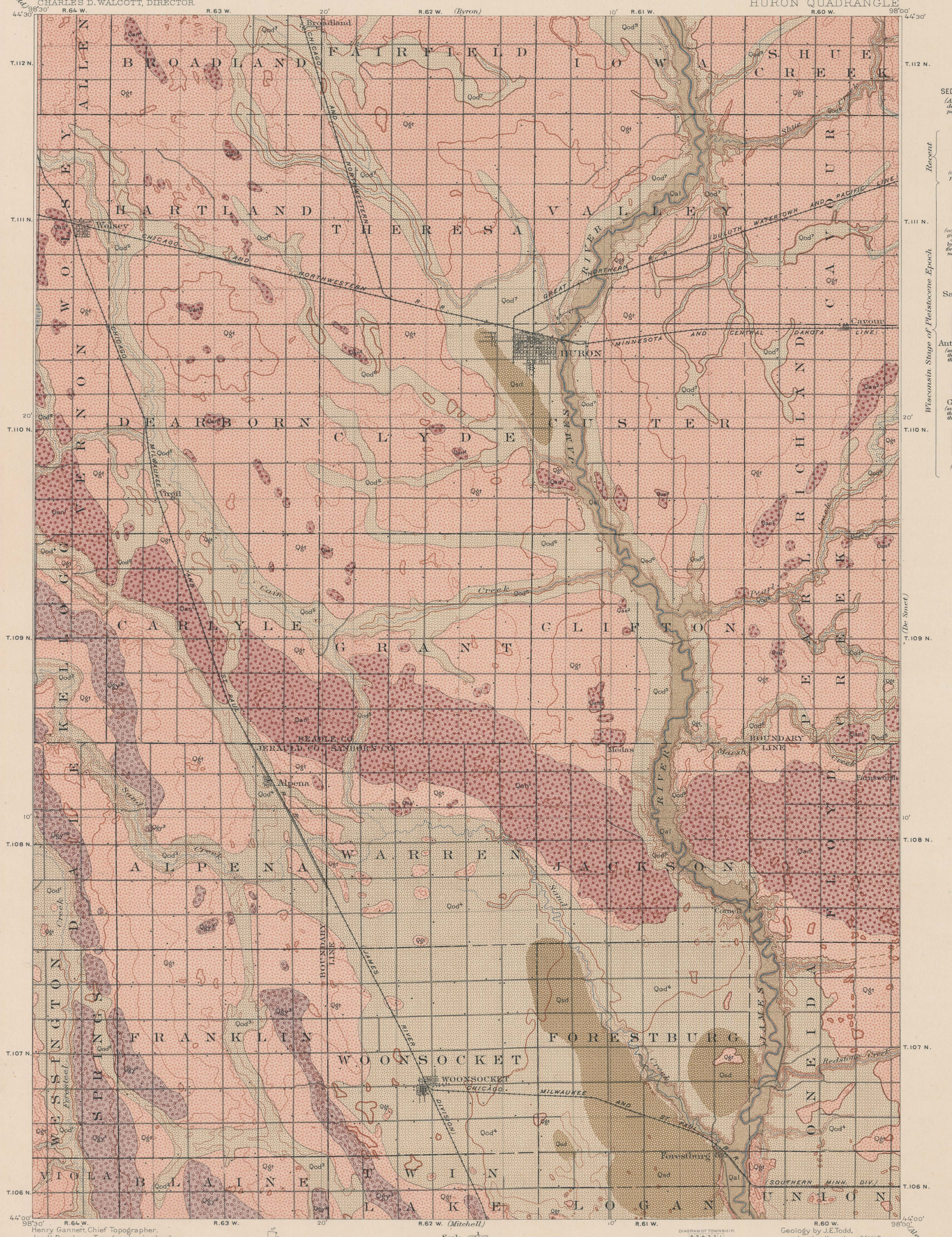
AREAL GEOLOGY

SOUTH DAKOTA
HURON QUADRANGLE



LEGEND

SEDIMENTARY ROCKS
(Areas of subaerial deposits are shown by patterns of dots and circles)

QUATERNARY

Recent

Qal — Alluvium *(only the larger deposits represented)*

Wisconsin Stage of Pleistocene Epoch

Qod — Old stream deposits *(occupying channels of glacial streams; chronologic order indicated by numbers; probable former extension of channels shown by dashed lines)*

Qsd — Sandy deposits *(probably old stream deltas)*

Qan — Antelope moraine *(successive positions of the retreating ice in this quadrangle shown by numbers)*

Qgy — Gary moraine *(successive positions of the retreating ice in this quadrangle shown by numbers)*

Qgt — Glacial till *(unstratified clay, sand, and gravel)*

Henry Gannett, Chief Topographer.
Jno. H. Renshawe, Topographer in charge.
Control by Geo. T. Hawkins.
Topography by D.C. Harrison.
Surveyed in 1894.

APPROXIMATE MEAN DECLINATION 1902.

Scale $\frac{1}{125000}$

Contour interval 20 feet.
Datum is mean sea level.

Edition of June 1904.

DIAGRAM OF TOWNSHIP

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

Geology by J.E. Todd,
under the direction of N.H. Darton.
Surveyed in 1899-1900.

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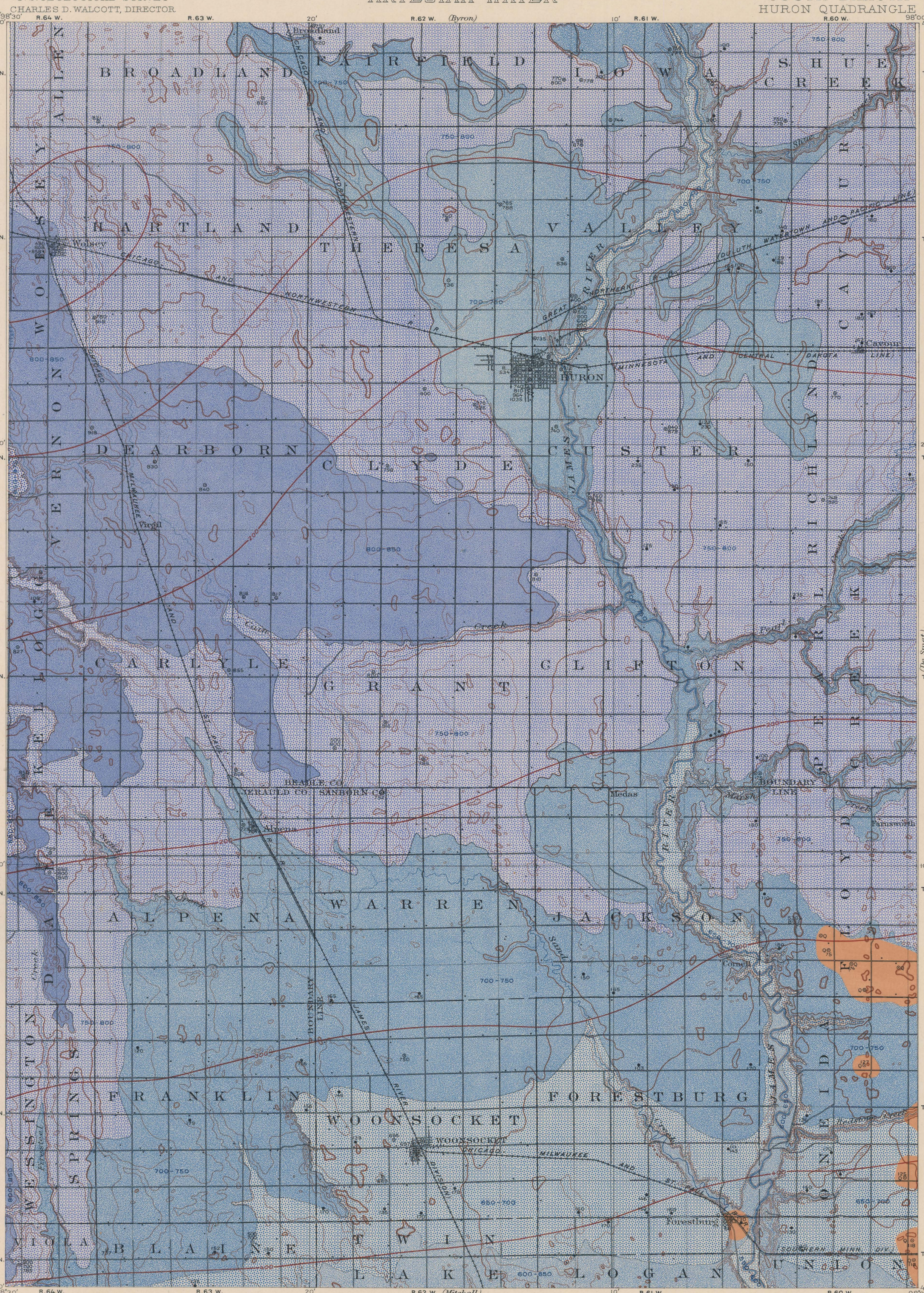
ARTESIAN WATER

SOUTH DAKOTA
HURON QUADRANGLE



LEGEND

550-600
600-650
650-700
700-750
750-800
800-850
850-875

Area in which Dakota sandstone will probably yield flowing wells

(depth to top of Dakota sandstone indicated by pattern. Flowing water may be expected from 10 to 100 feet below the top of Dakota sandstone)

Area in which Quaternary deposits will probably yield flowing wells

300
200

Contours on surface of quartzite or granite

(Sioux quartzite in the south and granite in the north; lines show altitude above sea and configuration of the surface of "bed rock" of well drillers, the limit of profitable boring)

⊙ *Flowing wells in Dakota sandstone*

⊙B *Flowing wells in Benton formation*

⊙Q *Flowing wells in Quaternary deposits*

• *Nonflowing deep wells which do not reach Dakota sandstone*

Depths to principal water horizons shown by figures

Henry Gannett, Chief Topographer.
Jno. H. Renshawe, Topographer in charge.
Control by Geo. T. Hawkins.
Topography by D. C. Harrison.
Surveyed in 1894.

TRUE NORTH
MAGNETIC NORTH
11°
APPROXIMATE MEAN DECLINATION 1902.

Scale $\frac{1}{125000}$

1 ½ 0 1 2 3 4 5 Miles

1 ½ 0 1 2 3 4 5 Kilometers

Contour interval 20 feet.

Datum is mean sea level.

Edition of Oct. 1904

DIAGRAM OF TOWNSHIP

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

Geology by J. E. Todd,
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Surveyed in 1899 and 1900.

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57	Telluride	Colorado	25
58	Elmoro	Colorado	25
59	Bristol	Virginia-Tennessee	25
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