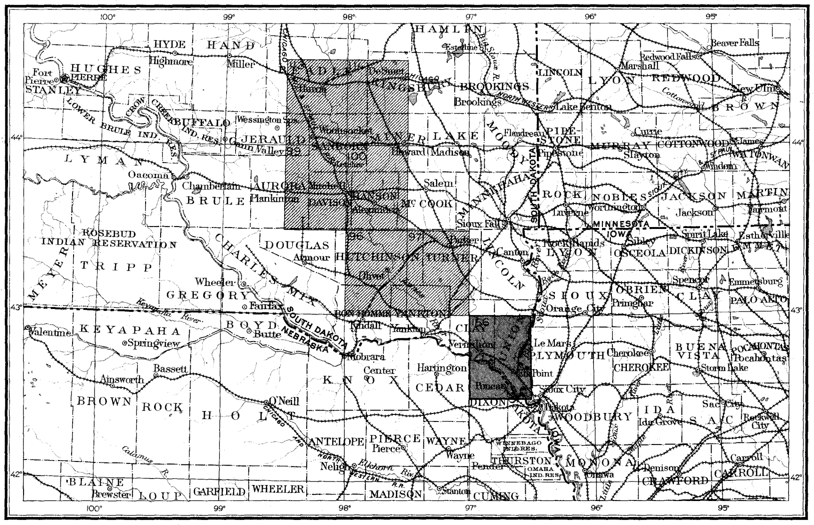
DEPARTMENT OF THE INTERIOR
UNITED STATES GEOLOGICAL SURVEY
CHARLES D. WALCOTT, DIRECTOR

GEOLOGIC ATLAS
OF THE
UNITED STATES

ELK POINT FOLIO
SOUTH DAKOTA - NEBRASKA - IOWA

INDEX MAP



SCALE: 40 MILES-1 INCH

■ ELK POINT FOLIO

▨ OTHER PUBLISHED FOLIOS

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

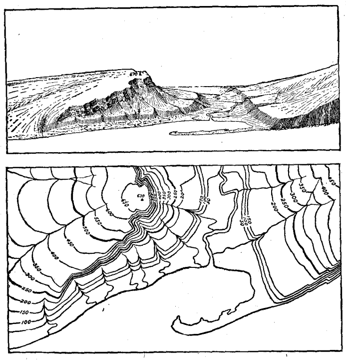


FIG. 1.—Ideal view and corresponding contour map.

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.
	Tertiary	Pliocene Miocene Oligocene Eocene	T	Yellow ocher.
Mesozoic	Cretaceous		K	Olive-green.
	Jurassic		J	Blue-green.
	Triassic		TR	Peacock-blue.
Paleozoic	Carboniferous.	Permian Pennsylvanian Mississippian	C	Blue.
	Devonian		D	Blue-gray.
	Silurian		S	Blue-purple.
	Ordovician		O	Red-purple.
	Cambrian	Saratogan Acadian Georgian	€	Brick-red.
	Algonkian		A	Brownish-red.
	Archean		AR	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:

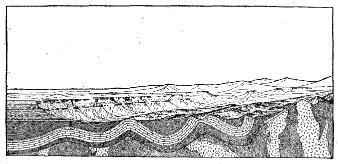
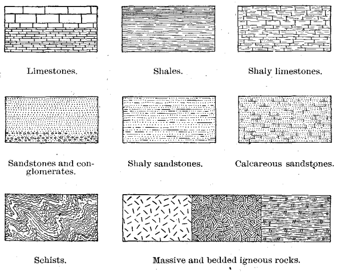


Fig. 2.—Sketch showing a vertical section at the front and a landscape beyond.

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:



Limestones. Shales. Shaly limestones.

Sandstones and conglomerates. Shaly sandstones. Calcareous sandstones.

Schists. Massive and bedded igneous rocks.

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

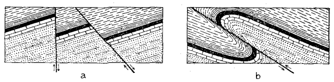


Fig. 4.—Ideal sections of strata, showing (a) *normal* faults and (b) a *thrust* fault.

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 ELK POINT QUADRANGLE.

By J. E. Todd.

INTRODUCTION.

LOCATION AND AREA OF THE QUADRANGLE.

The Elk Point quadrangle includes the quarter of a square degree which lies between meridians 96° 30′ and 97° west longitude and parallels 42° 30′ and 43° north latitude. It measures approximately 34½ miles from north to south and 25½ miles from east to west, and its area is about 878 square miles. It lies in the Missouri Valley, on the western slope of the Mississippi basin, mainly in Union and Clay counties, S. Dak., but including also portions of Dixon and Dakota counties, Nebr., and Plymouth and Sioux counties, Iowa.

OUTLINE OF THE GEOGRAPHY AND GEOLOGY OF THE PROVINCE.

Eastern South Dakota forms part of the Great Plains, lying in the broad, indefinite zone in which these plains merge into the prairies of the Mississippi Valley. It lies within the area of glaciation, and most of its surface features show the characteristics of a drift-covered region. The country is not 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, due to preglacial erosion, many of which are 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, for the most part 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.

The surface of eastern South Dakota is in large part covered with a mantle of glacial deposits of varying thickness, consisting of gravel, sand, silt, and clay, which are described in detail on page 3, under the heading "Quaternary system."

The formations underlying this region are exposed in few places 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. Extensive sheets of Cretaceous clay and sandstone here lie upon an irregular floor of granite and quartzite of Archean and Algonkian age. Under most of the region this floor of "bed rock" is more than a thousand feet below the surface, but toward the northeast it rises gradually to the surface. There is also an underground quartzite ridge of considerable prominence that extends westward from outcrops in southwestern Minnesota to the vicinity of Mitchell, S. Dak.

The lowest sedimentary formation above the quartzite is a succession of sandstone and shale of wide extent, termed the Dakota formation, which furnishes a large amount of water for thousands of wells. It reaches a thickness of 300 feet or more in some parts of the region, but thins out and does not continue over the underground ridge just referred to. It is overlain by several hundred feet of Benton shale, with thin sandstone and limestone layers, and a widely extended sheet of the Niobrara formation, consisting largely of chalkstone at the south and merging into calcareous clay toward the north. Where these formations approach the underground ridge of quartzite they rise in an anticlinal arch of considerable prominence, 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 outcropping in the vicinity of Sioux City, Iowa, and thence 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 uplifts already mentioned. This formation 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 formerly extended east of Missouri River, but they also have undergone widespread erosion and only small areas 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 areas still remaining in the Bijou Hills and other higher ridges.

TOPOGRAPHY.

GENERAL STATEMENT.

The surface within this quadrangle presents three principal kinds of topography. The flat valley lands lying along Missouri, Big Sioux, and Vermilion rivers comprise about 200 square miles. In this area there are a few shallow depressions which mark the location of former channels of the Missouri and other streams. These depressions hold water a part of the year and they are in places bordered by ridges 10 to 15 feet high.

The northwestern part of the quadrangle includes about 200 square miles of undulating country characteristic of glaciated regions. It lies mainly in the old Vermilion Valley, being bounded on the east by Brule Creek and on the south and west by the Missouri Valley. Throughout this area the surface rises gradually northward, except in the steep banks along Vermilion River and its principal tributaries, where there are many steep ascents of 50 to 80 feet from the valley to the adjoining highland. On its south side this area is separated from the Missouri Valley by bluffs 80 to 100 feet high.

The remaining 400 square miles, lying in the northeastern and southwestern portions of the quadrangle, present a deeply eroded surface characteristic of heavily loess-covered regions, such as are common in southwestern Iowa and eastern Nebraska. The only level lands in these districts are the narrow alluvial flats bordering the larger streams. Few of these flats exceed one-half mile in width, and above them the intervening divides rise from 150 to 200 feet. There are many long slopes of 10° to 15°, and others having a gradient of 20° to 30° are not uncommon, especially along the high divides near the largest streams. The summits of the highest areas are in general rounded, with gentle slopes.

RELIEF.

The range of altitude within the quadrangle is moderate. The lowest point, in Missouri River near the southeast corner of the quadrangle, is about 1090 feet above sea level, and the highest point, near the western boundary, in sec. 8, Daily Township, reaches an elevation of 1640 feet. Much of sec. 8 of Clark Township, just south of Daily, is more than 1600 feet above the sea. From these higher points there is a more or less regular decline in the altitude of the summits toward Missouri River, where the bluffs on the Nebraska side average 1400 feet above sea level. On the Iowa side of the Big Sioux, north of Joy Creek, there are summits that rise to an altitude of 1520 feet, but the average is about 1400 feet and the elevations decline toward the north. In the South Dakota portion of the upland the general altitude is about 1400 feet, but near the northern boundary, in Big Springs Township, it rises to 1480 feet, and a height of 1500 feet is reached about a mile east of Brule Creek on the south line of sec. 28, Emmet Township.

DRAINAGE.

The largest watercourse in the Elk Point quadrangle is Missouri River, which passes diagonally across it. The stream exhibits many of its characteristic features in this region. Under normal conditions it is from 600 to 1500 feet wide and from 6 to 20 feet deep. It has a fall of about 6 inches to the mile and pursues a meandering course through a flood plain which ranges from 5 to 10 miles in width. The bottom lands are mainly underlain by fine sand, which is readily undermined by rapid currents, a condition which greatly facilitates shifting of the stream bed. The tendency of the stream to cut into the right bank is well illustrated in this district. Many changes take place in the course of the stream. Oxbows form and often lengthen rapidly. As they work downstream that portion of the bend which meets the resistance of the firmer Cretaceous rocks is retarded, resulting in the peculiar forms occurring between Vermilion and Elk Point.

As this oxbow form develops and the upper side becomes elongated, its broad, shallow channel becomes more or less choked by sedimentation, while the lower, retarded part of the bend, being narrow, is deeply scoured. Under these conditions the river exhibits a tendency in times of flood to break across the narrow neck of land, thus cutting off the upper part of the loop. A change of this kind took place at Vermilion in 1881, and another at some earlier time near Elk Point. In 1901 the large bend now forming Lake Goodenough was cut off.

Very little of the surface of the Elk Point quadrangle is drained directly into Missouri River. On the Nebraska side a small area lying north and west of Newcastle is so drained, and there is a similar area 2 to 5 miles wide on the South Dakota side. This combined drainage area includes about 180 square miles. The remainder of the quadrangle is drained by the Missouri's three largest tributaries in the district, Big Sioux and Vermilion rivers and Aowa Creek.

Big Sioux River, with its main tributary, Brule Creek, drains about 375 square miles in the northeastern portion of the quadrangle. It enters at the northeast corner, flows southwestward to the flood plain of Missouri River and, following the outer margin of that plain, with a southeasterly course, finally leaves the quadrangle near its southeast corner. Its flood plain is about 2 miles wide and the stream flows through this plain in a meandering course, for the most part in a channel about 20 feet below its surface. The Big Sioux is a sluggish stream, having a fall of about 2 feet to the mile, and is about 50 feet wide and 6 to 8 feet deep. Many of its meanders are wide, but few of them reach the sides of the valley. The only points at which the river cuts the bluffs on the west are near the northeast corner of the quadrangle and at two places opposite Chatsworth. It flows near the base of its eastern bluffs a short distance north of Chatsworth, near Akron, at the mouth of Rock Creek, and above and below the mouth of Broken Kettle Creek.

Brule Creek, the main tributary of the Big Sioux, enters the quadrangle in the highlands, near the northeast corner of Emmet Township. It flows southwestward for about 7 miles and then turns southeastward, meandering in and out of the hilly country in a remarkable way, but for much of the distance following the eastern edge of the flat glaciated area. It joins the Big Sioux near Richland. The principal smaller tributaries of the Big Sioux are Union Creek from the west, and Westfield, Joy, Rock, and Broken Kettle creeks from the east.

Aowa Creek drains most of the southwestern portion of the quadrangle. It rises in two branches in southern Hooker and northern Daily townships and flows northeastward to Newcastle and then southeastward, entering Missouri River below Ponca, Nebr. Its principal tributary is South Creek, which enters the quadrangle near Martinsburg and flows northeastward to Ponca, where it joins the main stream. Daily Branch, a tributary of South Creek, drains the southwest corner of the quadrangle. Silver Creek, an affluent of Aowa Creek, rises near Silver Ridge and flows northeastward, draining a small area between South and Aowa creeks.

Vermilion River enters the quadrangle at the northwest corner, flows east for about 3 miles and then south in a meandering course, and joins Missouri River 3 miles south of Vermilion. Its bottom lands range in width from 1 to 2 miles, becoming slightly wider toward the north. In places they are more or less marshy. About 2 miles north of Vermilion the stream reaches the flood plain of Missouri River and it follows the eastern margin of this plain closely to Vermilion, where it enters an old channel of the Missouri, through which it flows to the main stream. Clay Creek is the principal tributary of the Vermilion from the west, and a small stream, locally known as Baptist Creek, enters from the northeast. Vermilion River drains about 140 square miles of the quadrangle. It is very sluggish, having a fall of less than 1 foot to the mile, and the amount of water which it carries varies considerably at different seasons of the year.

DESCRIPTIVE GEOLOGY.

STRATIGRAPHY.

GENERAL STATEMENT.

This quadrangle is almost completely covered with deposits of Quaternary age, in greater part consisting of distinct formations whose distribution corresponds to that of the principal topographic districts described in the preceding section. These deposits comprise the till covering the Vermilion Valley, the loess deeply burying the hilly region, and the alluvium spreading over the Missouri Valley. They are underlain by Cretaceous rocks, which lie in nearly horizontal sheets with little or no folding or faulting, and which are exposed in few places except in abrupt bluffs where the surface formations have been cut away by streams. The geologic map and the cross sections (figs. 5 and 6) show the outcrops and structural relations of the different formations, and the following table gives the sequence, character, and thickness of the sedimentary rocks:

Generalized section of the Cretaceous rocks in the Elk Point quadrangle.

	Feet.	
NIOBRARA FORMATION:		
White chalkstone and calcareous shale. Only lower 100 feet exposed in quadrangle		200+
CARLILE SHALE:		
Dark shale with concretions at two horizons near the center, containing *Scaphites, Prionotropis, Inoceramus, Ostrea, Serpula,* and vertebræ and teeth of fishes	100	
Hard clay containing large *Inoceramus* shells and near the middle a layer of white bentonite clay	15	
Dark calcareous shales, with scattered concretions containing *Prionotropis, Inoceramus, Ostrea, Serpula,* etc	100	
		215
GREENHORN LIMESTONE:		
Blue chalky shale	8	
Hard thin-bedded limestone and hard chalky shale with many *Inoceramus labiatus*	12	
Blue thin-bedded chalky limestone containing numerous fish remains	12	
		32
GRANEROS SHALE:		
Dark-bluish shale	50–75	
Dark carbonaceous shale	5	
Dark sandy shale, in places containing thin seams of lignite coal	25	
		80–105
DAKOTA SANDSTONE:		
Soft massive fine-grained white sandstone with shale beds and lignite streaks in upper part. Only upper 25 or 30 feet exposed in quadrangle		350–400

PRE-CRETACEOUS ROCKS.

No pre-Cretaceous rocks are exposed in this quadrangle, nor are they known to come within several hundred feet of the surface. The only deep boring which penetrated strata older than the Dakota sandstone was made at Ponca, Nebr., in 1898, with a diamond drill. It is believed that this boring passed through the Dakota and Carboniferous and into older rocks. The accompanying section (fig. 1) shows the materials penetrated:

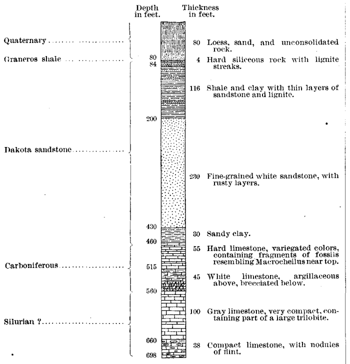


FIG. 1.—Section of diamond-drill boring at Ponca, Nebr.

The deep boring at Elk Point appears also to have reached Carboniferous limestone at a depth of 545 feet, as shown in fig. 2. It is reported that the boring at the university in Vermilion reached quartzite, presumably the Sioux quartzite, at a depth of 630 feet.

CRETACEOUS SYSTEM.

DAKOTA SANDSTONE.

Distribution.—The Dakota sandstone, the most important of the Cretaceous rocks in being the source of artesian water, is known to underlie not only all of the Elk Point quadrangle, but nearly all of South Dakota and most of Nebraska, and to extend as far east as Des Moines River in Iowa. Only 25 or 30 feet of the upper portion of this formation is exposed in the Elk Point quadrangle. It outcrops more extensively near Sioux City and farther south in Nebraska, and it is prominently exposed southwest of the city of Dakota, Nebr., the locality from which it received its name. Around the Black Hills and along the flanks of the Rocky Mountains it is well exposed.

The extent and location of the exposures of the Dakota formation in this quadrangle are indicated on the geologic map, and the structural relations of the rocks are represented in the cross sections (figs. 5 and 6). The Dakota beds appear in Iowa at the base of the bluffs along the Big Sioux from sec. 32, T. 91 N., R. 48 W., southward. On the Nebraska side of the Missouri it is exposed much more continuously, rising about 30 feet above the river near the southern boundary of the quadrangle. It disappears below the river near Limekiln Ravine, about a mile above Ponca Ferry, near the northeast corner of sec. 10, T. 30 N., R. 6 E.

Character and thickness.—The lower beds of the formation were penetrated in the boring at Ponca, where they consist mainly of sandstone, as shown in fig. 1. The clay and sand at the base may represent either the old weathered surface of the Carboniferous, the base of the Dakota, or possible parts of some earlier Cretaceous beds. The upper limit of the Dakota sandstone is somewhat indefinite because the shales which are prominent in its upper portion closely resemble those of the Benton group above and pass into them gradually. In these transitional beds there is considerable variation from place to place, the shales changing laterally into soft sandstone. The most plausible division appears to be at the top of the soft massive sandstone just below the highest lignite bed at Ponca. Where this sandstone is overlain by lignite it abounds in vertical root marks for a depth of 2 or 3 feet. About 25 or 30 feet below this sandstone there is a very hard, concretionary, siliceous layer, which contains fragments of wood and leaves. Above this layer shales of varying character are more prevalent and this break is regarded as the base of the formation. Within these limits the thickness of the Dakota is estimated to be 350 to 400 feet, varying somewhat according to locality. The section presented in fig. 2 shows the succession of beds in the Dakota sandstone underlying Elk Point, S. Dak.

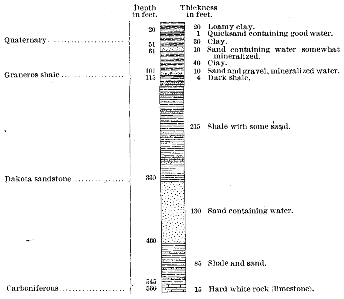


Fig. 2.—Section of deep boring at Elk Point, S. Dak.

As already stated, the Dakota sandstone is made up of sandstone and shale, some of the features of which are given in the detailed sections. No limestones occur in it, except in the form of small concretions, but ferruginous layers abound. The sandstones are commonly fine grained and are in general more consolidated in the upper beds; in many places the lower portions are coarser grained, and as they are less compact they are referred to by the well drillers as gravel. The formation contains numerous traces of plant life in the form of carbonaceous strata, bits of charcoal, root marks, and fragments of leaves; the last mentioned, however, are nowhere abundant. In not a few places vegetable material has accumulated near the top of the Dakota in sufficient purity to form lignite of fair quality but as a rule not more than a few inches in thickness. More commonly so much earth is intermixed with the vegetal material that it forms a black shale which is barely combustible. In adjoining areas the Dakota has yielded a large and characteristic flora, consisting mostly of dicotyledonous plants, as well as a small molluscan fauna of fresh-water types. The strata lie nearly horizontal, dipping slightly toward the north and west. This dip perhaps is no more than can be accounted for by the original slope of the sea bottom or the uneven deposition of sediments. A section of the upper part of the Dakota sandstone is as follows:

Section of the upper part of the Dakota sandstone below the mouth of Aowa Creek, Nebraska.

	Feet.
Sandstone, soft, porous, rust colored	10
Clay, dark, with thin sandstone layers	2½
Sandstone, nodular, rust colored	1
Shale, dark, sandy at base	1
Sandstone, with layers of iron concretions	4½
Sandstone, dark, rust colored, with shaly layers	6
Sandstone, porous, rust colored.	
	25

BENTON GROUP.

GENERAL STATEMENT.

In the early descriptions of the geology of this region no subdivisions were made of the Benton group. It was described as consisting mainly of gray shale and clay, with several horizons of calcareo-ferruginous concretions and a few thin layers of sand and sandstone in the lower portion. The investigation by Darton, however, guided by a knowledge of the formations in other regions, has shown that it exhibits here, as elsewhere, three distinct members—the Graneros shale, the Greenhorn limestone, and the Carlile shale, the whole having a thickness of about 350 feet. As the greater part of the surface of the quadrangle is covered by glacial deposits, none of these formations is exposed over extensive areas.

GRANEROS SHALE.

Distribution.—Overlying the Dakota sandstone in this region is the Graneros shale, the lowest formation of the Benton group. The exposures of this formation within the quadrangle are confined mainly to the bluffs near the larger streams. It outcrops at short intervals along the base of the Missouri River bluffs on the Nebraska side, from the southern margin of the quadrangle as far north as the east side of sec. 29, T. 31 N., R. 6 E. There are small exposures also at Ponca and 1 mile east of the mouth of Aowa Creek. Along Big Sioux River on the Iowa side the Graneros outcrops at intervals of 1 to 4 miles from a point below Broken Kettle Creek to the bend above Akron, and on the west side of the river there is a small area exposed in the bend opposite Chatsworth.

Character and thickness.—The deposits of the Graneros formation consist mainly of fine-grained, dark-colored shale, which is more or less sandy at the base and in many places passes into typical sandstone. Concretions of iron carbonate occur at different horizons, and iron pyrite is more or less abundant throughout the shale. In the vicinity of Ponca, where the basal member of the formation consists of sandstone, there is a thin seam of lignite. The Graneros shale varies considerably within short distances in both character and thickness. It is from 65 to 105 feet thick in this quadrangle. At the old mill site above Rock Creek, on Big Sioux River, it has a thickness of 105 feet, of which the lower 25 feet is a sandstone or sandy shale of considerable firmness, weathering into vertical cliffs. At this place the bluffs expose the following section of the Graneros and associated formations:

Section at old mill site on the east side of Big Sioux River, Iowa.

	Feet.	
Greenhorn limestone:		
Shaly limestone		10
Graneros shale:		
Dark-colored shale	80	
Sandstone and shale	20	
Sandy shale	5	
		105
Dakota sandstone:		
Massive sandstone	1	
Gray shaly clay	1	
Gray laminated clay	6	
Soft, massive, yellow sandstone	15	
		23

Below the mouth of Broken Kettle Creek the Graneros is about 100 feet thick, but here the proportion of sand is small. Near the north line of Dakota County, Nebr., the formation is about 90 feet thick and sandy at its base, but farther north it becomes less sandy and considerably thinner. In the vicinity of Ponca Ferry it is represented by about 65 feet of beds.

Few fossils are found in this formation. Some bones of large reptiles, among them those of a plesiosaur, were obtained years ago from the Missouri River bank near Limekiln Ravine, about a mile above Ponca Ferry.

GREENHORN LIMESTONE.

Distribution.—Near the middle of the Benton group is the Greenhorn limestone, lying between the Graneros and Carlile shales. The outcrop is confined mainly to the bluffs along the larger streams, but it appears here and there in the drift-covered area. Along the Missouri River bluffs, in Nebraska, it is exposed at numerous points, giving rise to many prominent cliffs that cap the softer shale of the Graneros formation. It seems to have been largely removed by preglacial erosion between Rock and Broken Kettle creeks in Iowa and about the mouth of Aowa Creek in Nebraska.

Character and thickness.—The formation comprises a thin but very distinctive series of beds of hard, impure limestone with a thickness of about 30 feet. It consists of a basal member, 8 to 10 feet thick, of bluish, chalky limestone; a medial member of hard, thin-bedded limestone about 12 feet thick, containing *Inoceramus* in great abundance and interstratified with a chalky shale; and a top member of bluish limestone, 4 to 6 feet thick. The limits of the formation are generally well marked, although in some places the limestone grades into the adjoining Graneros and Carlile shales. The limestone commonly occurs in large blocks divided by distinct but irregular joints. Besides *Inoceramus labiatus*, which occurs in great abundance, the formation contains fish teeth and scales, the latter of unusually large size; also shark teeth, both of the usual form and of *Ptychodus*.

CARLILE SHALE.

Distribution.—The Carlile shale, the uppermost member of the Benton group, outcrops mainly along the bluffs of Missouri and Big Sioux rivers and Brule Creek, where it is generally overlain by either loess or stratified drift. It rests upon the Greenhorn limestone. Along the Missouri River bluffs it is exposed with many intervals from a point near Ponca to the western margin of the quadrangle, and smaller outcrops appear along many of the tributary streams from the south. It is exposed in the SW. ¼ sec. 26, T. 31 N., R. 5 E., on a small tributary of Aowa Creek southeast of Newcastle, also in sec. 6, T. 29 N., R. 5 E., on the south side of Daily Branch. It appears extensively in the bluffs and larger tributary valleys of Big Sioux River from the mouth of Joy Creek nearly to Westfield, showing in places a thickness of 60 or 70 feet. Along the Missouri River bluffs southeast of Ponca there are no outcrops of the formation that are large enough to be shown on the map.

Character and thickness.—The Carlile formation consists mainly of dark-gray and bluish-gray shale and clay. Calcareous concretions are more or less abundant throughout the deposit, occurring mainly at two horizons, 50 and 60 feet below the top of the formation. Near the middle of the formation there is a thin but widespread deposit of white bentonite clay. Considerable iron pyrite is present in the shale, occurring as crystals arranged in thin bands and concretions. Gypsum is abundant, being as a rule disseminated in the form of crystals of various size, but locally in white powdery veins. A section of the Missouri River bluffs at Vermilion Ferry shows the following beds:

Section at west end of Vermilion Ferry, Nebraska.

	Ft.	in.
Quaternary:		
Loess	30	
Rust-colored sand and granite bowlders	3	
Carlile shale (upper half):		
Drab shale	12	
Irregular, coarse-grained, dark-colored limestone, much of it conglomeratic	1	
Drab shale with small concretions at base	5	
Dark shale with large concretions at base	4	
Darker shale with large concretions at base	15	
Shale with an occasional small concretion	55	
White bentonite clay		2
Dark shale	6	

The abundance of pyrite in the shale, associated with a local excess of carbonaceous matter, often gives rise to spontaneous combustion, producing so-called "volcanoes." A deposit of this character near the Ionia Ferry smoked for many months and burned wood that was thrust into it. One effect of the combustion is the formation of copperas and of acid waters. These combine with the lime in the formation, either that in solution or that in the form of fossils in concretions, and produce the gypsum above described. Owing to this fact, the fossils in many localities have been destroyed.

Fossils are very abundant in the formation, especially in the upper part. They comprise *Scaphites*, *Prionotropis woolgari*, *Inoceramus*, *Placenticeras stantoni*, and small *Ostrea*. Fish remains are more or less common throughout the shale, some thin layers being composed entirely of fish teeth and bones. There are also horizons where the shale for 8 or 10 feet contains shells in such abundance as to harden the beds so that they resist erosion and stand out in cliffs similar to those of the underlying Greenhorn limestone. A large species of *Inoceramus* abounds in these beds.

The formation ranges in thickness from 200 to 215 feet. It is overlain by Niobrara chalk rock, the contact being well defined by an abrupt change in the character of the sediments.

NIOBRARA FORMATION.

Distribution.—Although the Niobrara formation doubtless underlies a considerable portion of the quadrangle, it is generally covered by a thick mantle of drift and is exposed in only a few areas. In the vicinity of Lime Grove there is an outcrop of Niobrara rock and on Lime Creek, less than a mile to the east, it forms a cliff nearly 20 feet high. It is exposed along the east branch of Lime Creek in the northern part of sec. 15, and at the head of Walnut Creek in the NW. ¼ sec. 11, both in Hooker Township; also in the NW. ¼ sec. 5 and the northwest corner of sec. 8, Ionia Township. On Daily Branch west of Martinsburg, at an altitude of 1300 feet, there are a number of springs whose waters contain fragments of Niobrara chalk rock. Chalk rock also outcrops for a short distance in the bottom of a small creek in the NE. ¼ sec. 8, Otter Creek Township, about 4 miles east of Martinsburg. North of Missouri River it is exposed on the north slope of Spirit Mound, and several feet of the formation appear in a ravine near the center of sec. 9, Spirit Mound Township. A small exposure of it was also observed lying on the Carlile shale in the NE. ¼ sec. 32, Emmet Township. The above-described exposures are shown on the geologic map. The Niobrara is not known to appear at the surface elsewhere in the quadrangle, but it has been encountered in wells at several points in sec. 26, Emmet Township, also at Nora post-office, in the SE. ¼ sec. 23.

Character and thickness.—The most characteristic feature of this formation within the Elk Point quadrangle is the chalkstone, but no doubt a considerable thickness of shale should be considered as included in the formation. It has a total thickness of more than 200 feet, but only about 100 feet of the lower portion is present in this area. The chalk rock of the Niobrara when weathered is white or pale yellow, and therefore is in strong contrast with the dark-colored shale of the underlying Carlile, but in many places where the Niobrara is unweathered it is of moderately dark bluish-gray color.

The prevalent fossils of the Niobrara formation are small, deep, cup-shaped oysters (*Ostrea congesta* Conrad), usually found in colonies and often attached to a fragment of a large *Inoceramus*. Teeth of sharks and bones of teleost fishes and large swimming reptiles are also found. A minute lingula was observed in the vicinity of Spirit Mound.

TERTIARY SYSTEM.

ARIKAREE (?) FORMATION.

A deposit composed mainly of light-colored sand extends across the southwestern part of the quadrangle. This sand is believed to represent the eastern extension of the Arikaree formation of the Miocene epoch. It covers an area 1 to 2 miles wide and its distribution is shown on the geologic map. There is considerable difficulty in differentiating the sands of the Tertiary from those of the adjoining Quaternary deposits, the only decisive criterion being the fact that northern erratics, such as quartzite, white limestone, and certain varieties of granite and greenstone peculiar to northern regions occur only in the Quaternary. The granite and greenstone, however, are not easily distinguished from similar rocks of western origin, which are more or less abundant in the gravels of the Tertiary.

Although the Tertiary deposits of this region consist mainly of sand, beds of gray and bluish-gray clay of considerable thickness are also present. These clays do not outcrop in the quadrangle, but, from exposures outside of the quadrangle and from well records, they are known to constitute a part of the formation. The sand is medium to fine grained, and is generally clean and white in unexposed portions, but rusty colored near the surface. It is composed largely of beautifully rounded clear grains. The clays closely resemble loess, except that they are in the main gray instead of buff and contain layers of very pure clay. Wherever the Tertiary sands are not protected by a firm soil, they are blown about by the winds, forming typical dunes and blow-outs.

The records of many of the deep wells in the eastern part of Dixon County, Nebr., report extensive deposits of sand underlying many feet of loess. How much of these deeper deposits of sand is of Tertiary age is unknown, but it is possible that much of Dixon County and portions of the highland district in South Dakota and Iowa are underlain by Tertiary sands, which are now entirely concealed by a mantle of Quaternary material.

QUATERNARY SYSTEM.

GENERAL STATEMENT.

Deposits of the Quaternary system cover the older formations throughout the greater part of the Elk Point quadrangle. They consist of loose unconsolidated material which covers the surface to a depth of 50 to 150 feet. They include till, or bowlder clay, left by the glaciers, stratified drift deposited by flowing waters, and loess or loam, laid down in quiet waters or possibly in part deposited by winds. This classification is based purely on the lithologic character of the material, without reference to its relative age. Probably each class includes material deposited during two or more different stages of the glacial invasion. The deposits may be subdivided according to age and the different members are here described in chronologic order.

There were at least two invasions of the quadrangle by lobes of the great northern ice sheet of the Pleistocene epoch. The principal line of advance in both invasions was down the Vermilion Valley, though in the earlier stage at least ice doubtless crossed the eastern border of the quadrangle from the Minnesota-Iowa glacier, and probably the James River lobe contributed material for deposits, even if it did not quite reach this area. These relations are shown in fig. 3.

The earlier occupation was the more complete, the ice extending 50 or 60 miles farther south than during the second advance and doubtless at one time covering the whole quadrangle. This earlier glacier contributed the lowest sand and gravels, which were deposited along lines of drainage before the advancing ice sheet; the older till formed underneath the ice; and much of the stratified drift was laid down by the waters that were set free by the retreating glacier. Most of the loess was probably formed during or immediately after the deposition of this stratified drift. The glacier of the second advance, which took place after a considerable interval of time, contributed more to the stratified drift, and perhaps somewhat to the loess, deposited the later till, and in its recession formed the old stream deposits along most of the existing channels. A sketch of these events and their cause is given under the heading "Historical geology."

PRE-WISCONSIN DEPOSITS.

EARLIER GLACIAL TILL.

The earlier or pre-Wisconsin till is found under the loess in Iowa and South Dakota, and also in Nebraska farther southwest, though it has not been observed within the Nebraska portion of this quadrangle. Its outcrops are indicated on the areal geology map. It lies upon the uneven surface of the Cretaceous clay, especially on the higher points, but in places sand intervenes. The grayish deposit at the base noticed at a few points may be rearranged Cretaceous material, the result of preglacial weathering. The absence of the till in the southern part of the quadrangle is probably the result of erosion and scanty remnants of it may yet be found.

The till of this quadrangle presents many of the features common to similar deposits elsewhere. It is an unstratified mixture of clay, sand, gravel, and bowlders, in which the clay greatly predominates, comprising at least four-fifths of the deposit. It is hard, tough, and traversed by numerous joints, which extend in all directions and split the material into irregular pieces of different sizes. Where the clay has been exposed and its iron salts oxidized, it is commonly of a yellowish or brownish color; in unoxidized portions it is blue and in places very dark, mainly because of the presence of iron protoxide. These prevalent colors are in some localities replaced by dark red, light gray, light yellow, and here and there even by dark brown. This variety of color is probably due to differences in material, or possibly to the chemical effects of percolating water. The clay is derived mainly from the Cretaceous beds already described and from later deposits of that period farther north.

Most of the bowlders and pebbles embedded in the clay are derived from ledges of rock lying farther north, in the path of the glacier, although some may originally have come from the west, being brought into the glaciated area by streams from the Black Hills. The bowlders from the north consist of red and gray granite, red quartzite, greenstone, and white and yellow limestone, named in the order of their abundance; in those from the west white quartzite, dark granites, and gneisses are most prevalent. The western bowlders of granite and gneiss closely resemble rock of this character in the Black Hills, and for this reason they are believed to have come from that area. In places the till contains masses of sand and gravel in the form of sheets, lenses, and narrow channels or streaks, the last named probably being caused by subglacial streams. These deposits are more likely to be present where a later till sheet was laid down upon the earlier one by a readvance of the ice. Very few fossils occur in the till. Marine shells and saurian bones derived from the Cretaceous rocks are occasionally found and fossil wood is not uncommon. Some limestone bowlders from the Paleozoic contain fossils, mainly corals and crinoids.

Although this earlier till has generally been regarded as of Kansan age, its close resemblance in most exposures to the Wisconsin till and the fact that its upper portion generally effervesces with acids suggest that it may be of Iowan age. It resembles the later till in its general composition, character of embedded bowlders, and color, except that its upper part is locally of a darker-red color, and the lower part, in places at least, is grayer and more loamy and contains fewer bowlders. Features of this character are well shown in an exposure on the west slope of the hill in sec. 19, T. 91 N., R. 48 W. Most of the granite bowlders are firm and fresh looking, although a few are badly decayed.

The thickness of the earlier till varies greatly. As already stated, it has not been found in the Nebraska part of the quadrangle. It has been eroded from the broad valleys of the Missouri, Big Sioux, and Vermilion, and at a few places near the Big Sioux and Brule Creek apparently undisturbed loess rests upon Cretaceous clay with only a few scattered pebbles and bowlders intervening. But in the eastern part of Big Springs Township the till appears, from the evidence of wells, to attain in places a thickness of 75 to 100 feet, and at several points in the bluffs of the Big Sioux it is 30 to 60 feet thick, including many feet of gravelly slope which may be partly stratified drift. Its upper surface was evidently somewhat uneven before the deposition of the loess, and the unevenness has since been intensified by local erosion and creep.

EARLIER STRATIFIED DRIFT.

Deposits of stratified drift are more or less abundant throughout the quadrangle. They consist mainly of sand, coarse gravel, and clay, which were laid down in the form of sheets and in channels, by streams flowing from the glaciers. They occur both below and above the earlier and later till. The exposures of the stratified drift laid down during the earlier glaciation are shown on the areal geology map under the title "earlier stratified drift." The deposits which underlie the earlier till are not exposed in this quadrangle, but they have been penetrated by several well borings. Similar material associated with the later ice is mapped and described as "old stream deposits."

The sands and gravels lying upon the pre-Wisconsin till are exposed only in small areas, owing to the loess covering. Probably they lie along definite lines of drainage which must be inferred from a consideration of the general glacial relations. The streams depositing these sediments naturally followed the valleys of the preglacial surface, and such valleys correspond in a measure to the courses of present streams.

The process of deglaciation from the pre-Wisconsin ice probably reached this quadrangle first near the southeast corner, in the valley of the Big Sioux, and gradually extended up that valley, following the thinner and comparatively sluggish ice between the more active Minnesota-Iowa and Dakota glaciers. Meanwhile the withdrawal of the ice from the southwest may have been nearly as rapid. Daily Branch and South Creek were the next streams to appear. They drained the ice front of the Vermilion lobe, and tapped a higher stream flowing southward from the James River lobe. The relations of the James River and Vermilion ice lobes during the pre-Wisconsin stages are shown in fig. 3. The relations of the Dakota and Minnesota-Iowa glaciers are less positively determined, but the basis for the outlines shown in the figure may be briefly stated as follows:

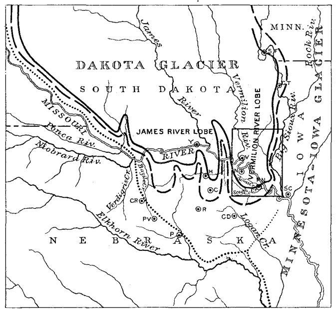


FIG. 3.—Sketch map showing pre-Wisconsin stages of the Dakota Glacier. Dotted line, ice front at maximum advance; dashed line, first stage of recession; solid line, second stage of recession. Rectangle shows location of the Elk Point quadrangle.

CT, Canton; C, Coleridge; CD, Concord; CR, Creighton; H, Hartington; N, Newcastle; P, Pierce; PV, Plainville; PN, Ponca; R, Randolph; SC, Sioux City; SF, Sioux Falls; V, Vermilion; Y, Yankton.

1. The margin of the drift, particularly the till, makes, so far as known, a deep reentrant in northeastern Nebraska.

2. The pre-Wisconsin ice moved, as nearly as can be determined from present knowledge, along the same lines as that of the Wisconsin stage. That this was true at least of the Dakota ice sheet with its sublobes, Vermilion, James River, etc., is indicated by the course of the Missouri above Yankton, the distribution of bowlders, and the thickening of the older till in eastern Union County, S. Dak.

3. The streams in the region have courses which would naturally have been largely determined by the postulated successive positions of the retreating ice margin. This is further discussed under "Historical geology."

4. A driftless area several miles in extent occurs north of Garretson, S. Dak., indicating a glacial island or patch of stagnant ice between the Minnesota-Iowa and the Dakota ice sheets.

These points may not amount to a demonstration, but are thought sufficient to justify the representations of fig. 3. Further investigations may require important modification of details.

At a later stage Aowa Creek held relations to the James River and Vermilion lobes similar to those which Daily Branch and South Creek had sustained, but it flowed at a somewhat lower level. Still later a stream flowed a little north of the line of the present Missouri from a point beyond the limits of this quadrangle. The Missouri has been shifting southward most of the time since. Union and upper Brule creeks were probably opened by this time. All these streams date from the earlier or pre-Wisconsin ice invasion, and they formerly flowed at higher levels than at present, as is indicated by the position of the earlier stratified drift.

The general level or slope of the sand deposits on the older till is indicated by the following exposures: Northwest of Spirit Mound, near the western margin of the quadrangle, they occur at an altitude of 1300 feet; in Big Springs Township, at 1280 feet; along Missouri River toward the southern line of the quadrangle, at about 1200 feet; along the Missouri bluffs on the Nebraska side, opposite the mouth of Vermilion River, at 1220 to 1300 feet; near the head of Daily Branch, at 1500 feet; and near Martinsburg, at 1350 to 1400 feet. The deposits in the two last-mentioned localities were probably laid down by streams from a body of water farther west which was held by the ice at a higher altitude.

According to these figures the stratified deposits overlying the older till have about the same level as the later stream deposits, which lie approximately on the surface of the later till. The only exceptions are the higher bodies of drift near and southwest of Daily Branch. If these higher deposits belonged to the same system of drainage, there was a slope of 12 to 15 feet to the mile between the western border of the quadrangle and Martinsburg. This is difficult to understand until the coarseness of the material and the probably shallow and divided nature of the stream which struggled with such a load are considered. Similar steep grades also existed about the head of Aowa Creek. Further discussion of these facts will be found under "Historical geology."

Near Martinsburg sand and gravel pits have been opened 80 to 130 feet above the creek. The coarser materials at the top contain not only numerous bowlders of crystalline rock from the north, but also fragments of the gray sandy clay which is found in the Tertiary or Pleistocene, and is locally known as "putty clay," from its color and consistency. There are also similar balls of pebbly clay or till in this deposit—a fact which strongly suggests the presence of beds of till not far away.

LOESS.

Distribution.—The loess is the most widely distributed formation within the Elk Point quadrangle. It occupies the surface in the greater part of the upland areas lying east of Big Sioux River in Iowa, between Big Sioux River and Brule Creek in South Dakota, and south of Missouri River in Nebraska. Its distribution is shown on the areal geology map, but attention may here be called to certain features not thus represented. As the larger streams of the district have deepened their valleys by erosion, exposing the underlying rocks in the faces of the bluffs, the overlying loess has slipped down the sides and covered the older formations. As a result of these conditions loess 15 to 50 feet thick may extend from the streams up to the highest points, giving the deposit a vertical range of more than 500 feet.

Character and thickness.—The loess in this quadrangle is composed of very fine clayey sand cemented with lime and iron oxide so that it weathers like a soft, massive rock. It is in general not stratified, but is traversed by numerous vertical joints. Microscopic examination shows that it is composed largely of fine quartz grains ranging in size from 0.01 to 0.2 millimeter; the larger being few in number. The clay particles intermixed with the sand are usually much finer. The iron oxide in the loess gives it a light-buff color like that of the underlying till, and if the percentage of clay is large it shows deeper tints. In localities where the iron has been leached out, the loess has a light-gray color. At certain horizons, generally at the base but in places near the surface of the ground water, the loess has a reddish tinge and seems to contain an increased amount of clay. Toward the base it may also show a few bowlders and pebbles, locally arranged in thin layers. South of this quadrangle lenses of gray bowlder clay 3 to 4 inches thick have been found in the loess considerably above the base. These clay masses were probably dropped from floating icebergs.

The thickness of the loess varies considerably in different parts of the quadrangle. It is probably greatest on the high hills along Missouri River. The maximum thickness measured, in a well near the center of sec. 33, T. 32 N., R. 4 E., is 138 feet. In some of the highest hills between Aowa Creek and Missouri River and in the high area southeast of Westfield its total thickness, including the redder and more clayey deposit near its base, may possibly exceed 200 feet. The rearranged loess may be 40 to 50 feet thick in the bottoms of valleys. On steep slopes the loess is generally thin, particularly where the cores of the hills are composed of some older formation that is firmer than sand.

Along the east side of Big Sioux River, south of Westfield, there is a ridge or series of peaks capped by loess, which reach elevations 60 to 100 feet higher than the general upland level to the northeast. This occurrence may be explained by supposing that the increased thickness of the loess is the result of northwesterly winds blowing very fine sand from the sand bars of the Missouri River valley and depositing it on the uplands. This agency was probably more efficient in earlier times, when the adjacent bottom land was largely without vegetation.

Erosional features.—The loess forms numerous vertical cliffs 10 to 50 feet in height. These will endure for many years if dry at the base, but when moistened the loess is rendered more or less plastic by the solution of its carbonate of lime, particularly if the moisture is charged with carbonic acid, as is usually the case. When the base is in this plastic condition the mass above is often fractured by gravity into a series of step faults. If the moisture is very abundant, landslides of considerable extent may occur. Where loess rests upon an impervious stratum, as it does in many places, this accumulation of moisture at the base frequently occurs, causing the loess to creep slowly down the slopes. Of course the amount and rate of such motion depend on the steepness of the slopes. In recent railway cuts faults with a displacement of 4 to 6 inches have been known to form in less than a year. This characteristic of the loess largely explains its wide vertical range and also the step-like surface which appears on most of the steeper slopes.

The dissolution of the cement material of the loess by moisture also greatly promotes surface erosion. Although much of the loess in stream beds resists erosion like massive rock, and a similar resistance is shown in roads and other bare places after a heavy rain, yet when the material is thoroughly water-soaked it is easily eroded. In a similar way, the bottom of a watercourse may be cut out more rapidly than the sides, owing to the fact that the water thoroughly softens the cement. As a result of these conditions the great mass of loess near the surface has been either wholly rearranged or more or less moved from its original position.

Fossils.—The loess in this area is regarded as mostly older than the Wisconsin and younger than the older till. Supplementing additions of eolian origin probably continue to the present time. The loess in most exposures shows no trace of fossil life, but at a few localities it contains the land shells which are common in the region farther south. In the NW. ¼ sec. 19, T. 91 N., R. 48 W., there is an exposure of dark-colored loess high on the western slope of a hill that appears to have existed during its deposition. The deposit lies 40 to 50 feet above the base of the hill, is 3 feet thick, and can be traced for some distance. In this dark loess and for a few feet above it there are numerous specimens of *Helcina occulta*, *Succinea avara*, and a few other species. While the opportunities for the introduction of land shells into the loess are generally good, no refilled crevices were discovered and there is no disturbance of the original stratification where the fossils were found. There was probably a temporary, isolated island at this place, which continued long enough for the growth of vegetation and land shells. Similar species occur also at Ponca in typical loess, apparently undisturbed, 15 to 20 feet below the surface. Mention should be made here also of a fossiliferous fresh-water deposit, apparently at the base of the loess, in Limekiln Ravine, which is described under "Later terrace deposits."

OTHER LOAMS AND LOAMY CLAYS.

Thin beds of gray or bluish clay lie below the loess in certain localities, especially near the older streams. This clay resembles those of the Tertiary previously described. The beds are exposed at few places in this quadrangle. Deposits of this character occur along the Missouri River bluffs in the northeastern part of Dakota County, near Ponca Ferry, and toward the north on Brule Creek 2 miles northwest of Richland. The clay on Brule Creek is fine grained and of a greenish tinge. Loam on the surface of the later till is more or less common. It occurs as a rule on the southeast or leeward side of slight elevations or in shallow channels. These deposits may possibly be the result of floods attending the recession of the ice sheet, but a few of them have probably been formed by accumulation of dust from the atmosphere. Capping the west edge of the till east of Clay Creek is a shallow deposit of fine sand, which appears to have been collected from the bottom lands farther west by the action of prevailing northwesterly winds.

WISCONSIN DEPOSITS.

LATER TILL, OR GROUND MORAINE.

The later till, or Wisconsin ground moraine, occupies the old Vermilion Valley as far east as Brule Creek, except a wedge-shaped area west of upper Brule Creek and portions of loess-covered hills farther south. It is not generally covered by loess, but in a few places deposits of loess several feet thick have been observed lying upon it. It exhibits the usual gently undulating topography of fresh till, and its top is generally lower than that of the older till, especially in that portion of the material which is not raised into moraines. It rises to a little over 1300 feet above sea level at the north line of the quadrangle, on the east side of Vermilion Valley, and declines to a little less than 1200 feet northwest of Richland. It has a thickness of 60 to 120 feet, which is greater than that of the earlier till, but it does not differ markedly from the older deposit in any other respect. Its color is yellowish brown or buff above and bluish gray below where it is thick enough to have an unweathered portion. The yellowish portion varies much in thickness according to circumstances. It is generally thicker on higher elevations, or where it contains less clay or is more jointed, for these conditions favor weathering and leaching.

TERMINAL MORAINES.

The terminal moraines occurring in this area are all members of the Altamont or first moraine, of Wisconsin age, and are associated with the till in the Vermilion Valley. Some of them here, as elsewhere, rest upon preglacial ridges, in places at a considerable height, for some parts of the ice sheet were several hundred feet thick. Others lie at low levels with comparatively even surfaces, the result of formation in water. In still other places the material brought by the ice may have been washed away by streams from the ice front as rapidly as it was set free. A moraine of the first sort lies on the ridge west of Spirit Mound; of the second, at the edge of the till near Vermilion and farther east; the third condition is illustrated along the west side of Brule Creek. It is also probable that much of the moraine which was originally formed near Missouri River has since been removed by the encroachment of that stream upon its northern bank. The thick development of pre-Wisconsin till under the loess in eastern Big Springs Township may possibly be part of an early moraine formed upon a preglacial ridge that extended north and south when the ice was more widespread than at the later stage. These moraines are made up of clay, sand, gravel, and bowlders, similar to the morainal deposits farther north. They differ from the common ground moraine only by having as a rule a larger proportion of pebbles and bowlders.

OLD STREAM DEPOSITS.

After the deposition of the loess, Big Sioux River and its larger tributaries and Missouri River and Aowa Creek with their tributaries were all reopened along their former lines of drainage. Except that of Brule Creek, the courses of the streams upon the later till are in general easily understood. That the streams were mostly weak is indicated by the fineness of their deposits, coarse sand and gravel being rarely found. The positions of these old streams on the later till are shown on the areal geology map, and their order of development is indicated by numbers.

RECENT DEPOSITS.

LATER TERRACE DEPOSITS.

Terrace deposits occur at only a few localities within this quadrangle. Owing to their small extent they are not shown on the geologic map. Their rarity is probably due mainly to the active meandering of the larger streams, which have removed nearly all the older deposits between the bluffs. Along its southern edge, bordering Missouri River, the later till is capped by a deposit of fine stratified silt several feet thick. This material was probably laid down by the Missouri when it was flowing at that altitude. At both Yankton and Sioux City there are well-formed terraces corresponding in level to the silt deposits.

Remnants of a lower terrace about 80 feet above Missouri River are present in Brule Township. The material on the terrace is mostly till and appears to have been derived, in part at least, from the general mass of the upland deposits. This terrace probably marks a level which the Missouri held for some time, and it is possible that it was once capped with aqueous deposits which have since been removed by erosion. Along Aowa Creek, near the mouth of South Creek, its principal tributary, a series of delta terraces lie 50 to 70 feet above the present water level and probably mark a higher stage of the stream. Imperfectly formed alluvial deltas are present also on Big Sioux River and its tributaries from 40 to 60 feet above the stream, where they have not been removed by recent shifting of the channel. These deposits are evidently not ancient, for fresh unio shells are found in them. They appear to have nowhere the characteristic outlines of a river terrace, but it is possible that evidence will eventually be found upon which to base a correlation between these deltas and the bayou deposits at Otis mill site on Big Sioux River opposite Chatsworth, No. 4 of the following section:

Section at old Otis mill site, SW. ¼ sec. 29, T. 94 N., R. 48 W.

	Feet.
1. Loess slope	55
2. Gravelly slope	45
3. Till slope	22
4. Dark clayey silt with many fresh-water shells and a lower jaw of a fossil horse	6
5. Tough yellow clay, mottled with blue (Cretaceous)	4
6. Thin-bedded bluish limestone, containing *Inoceramus*	14
7. Dark shale	8
	154

The fossiliferous silt, No. 4, has a nearly horizontal upper surface and is overlain by several feet of till toward the south and by sand and loess a few rods farther north. The rational interpretation is that the dark silt was deposited in an obstructed part of the former bed of the Big Sioux opposite a cut bank of till. Later, after much of the cliff of till had caved down upon it, the river again flooded or occupied part of this channel and deposited the sand, and later still the loess crept down over all. Among the fresh-water shells the following forms have been determined: *Planorbis*, 2 sp., *Amnicola*, *Limnæa*, *Valvata*, *Succinea*, *Pisidium*, and *Sphærium*. The fossil jaw and three molars have been identified as either *Equus scotti* or, more probably, *E. complicatus*.

In this connection should be mentioned a recent discovery of a similar fossiliferous deposit in Limekiln Ravine, apparently at the base of the loess and therefore older than the one just mentioned, though it also may prove to be of recent origin. It is about 90 feet above high water of the Missouri and about 15 feet above the Greenhorn limestone, from which it is separated in the same section by stratified drift. Over it lies loess scores of feet thick, with a very steep slope. The fossiliferous stratum consists of black earth more than a foot thick, containing many specimens of *Sphærium sulcatum*, fewer of *Planorbis bicarinatus*, and a larger species of *Planorbis*.

Lower terraces in the alluvium are briefly discussed in the next section.

ALLUVIUM.

Alluvium is widely distributed in the Elk Point quadrangle, covering at least one-third of its area. The broad zone of bottom land 8 to 10 miles wide which adjoins Missouri River is covered with a thick alluvial sheet deposited by the river in relatively recent time. The maximum thickness of the deposit is not definitely known, but it is probably more than 100 feet, to judge from deep borings made near Elk Point. It consists of fine sand, gravel, and clay, mixed with more or less decayed organic matter. The deposit is overlain by black soil 3 to 6 feet thick, composed largely of carbonaceous matter mixed with fine materials much like those of the loess.

Alluvial deposits of similar nature occur along Big Sioux and Vermilion rivers. They are less extensive, however, and probably contain a larger per cent of local material. The valley of Big Sioux River in this quadrangle has an average width of about 2 miles; the Vermilion River valley is somewhat narrower, especially in its lower course, but widens toward the north. Deposits of alluvium of considerable extent are present on Brule Creek in Spink and Emmet townships, and also along Aowa and South creeks and Daily Branch. All the smaller valleys of the quadrangle contain alluvial deposits, or wash, of greater or less extent and thickness, but only the larger of these are represented on the geologic map.

The alluvium attains a depth of more than 100 feet in the valley of the Missouri, and is not uncommonly 50 feet deep in the valleys of small streams. Many of the smaller valleys also show repeated filling and excavation, producing terraces 5 to 50 feet in height. This condition is particularly notable in the valleys connecting directly with the Missouri. It is not due to fluctuations in the level of that stream, but rather to the frequent shifting of its course. A stream may sometimes reach the level of the Missouri as soon as it emerges from the bluffs; at other times it may have to flow several miles to reach the same level. In the latter case the alluvium in the valley between the bluffs might be filled 20 to 30 feet higher than in the former.

HISTORICAL GEOLOGY.

PRE-CRETACEOUS TIME.

The earliest phases of the history of the region of which this quadrangle is a part may be stated very briefly. The granite which is found in the deeper wells and which underlies much of the region was formed at an early period. Later it constituted the land surface in central Minnesota, from which was derived, both by the action of streams and by wave erosion along the shore, the material that now forms the Sioux quartzite. This formation, though widespread in the region, is not known to occur in the Elk Point quadrangle. The deposits consisted mainly of stratified sands and 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 their deposition there seems to have been an epoch of slight volcanic and igneous outflow, as is shown by the occurrence of basic material in a dike at the quarries at Sioux Falls and in borings at Yankton and Alexandria, S. Dak. 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 had been entirely filled.

The sand that formed the quartzite was laid down in the sea, and at first the formation may have been hundreds of feet thicker than at present. 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 was at times, at least in part, submerged and received other deposits, which have been largely eroded. This submergence is proved by the occurrence of Carboniferous rocks under Ponca, Nebr.; and as Paleozoic, Triassic, and Jurassic rocks occur in the Black Hills, it is evident that the shore line during these ages crossed the State some distance to the west.

CRETACEOUS SEAS.

With the beginning of the Cretaceous period the quartzite area began to subside relatively. As the waters of the sea gradually advanced over the land, waves and currents carried away finer material and left well-washed sands spread out as more or less regular sheets from the eastern shore line across the shallow sea to the Rocky Mountains. From time to time erosion became less active and finer material, or mud, was deposited, or both sands and 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, sand 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 sandstone.

The fossils found in the Dakota sandstone are 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 time 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 in general not abundant.

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

TERTIARY TIME.

During the early Tertiary, according to the prevalent view, large rivers from the Rocky Mountains deposited widespread sediments in the region farther west and southwest, but this area received only the sands and silts already described. Vegetation and animal life apparently abounded, exhibiting characteristics not very different from those of the present age. The evidence of fossils indicates that the climate was then warm and moist. Later in Tertiary time there was probably a large stream flowing southward somewhere near the present position of James River. Into this stream White River probably came, through the basins of Red and White lakes and the valley of Firesteel Creek, also the Niobrara through a well-defined valley to a point a few miles north of Yankton. This older James River seems to have made for itself a large valley, which was much wider than the valley of the present Missouri. Apparently it did not cut down to the depth of the present James River. In late Miocene time the Elk Point quadrangle received extensive deposits from this stream, which were evenly spread over the surface, and the hills and valleys which had been eroded in the late Cretaceous and earlier Tertiary were all deeply buried. These Miocene deposits probably reached a thickness of 200 to 300 feet. During Pliocene time there was considerable erosion by the larger streams in the region. This may have been caused by an elevation of the land surface to the west, or by an increase in the amount of rainfall. There is some evidence that during Pliocene time Missouri River may have cut down nearly to its present level, but this may have been done at a later date.

QUATERNARY PERIOD.

Glacial conditions in this region began by the invasion of the ice sheet of the north in two great lobes—the Dakota Glacier and the Minnesota-Iowa Glacier. The Dakota Glacier entered the James River valley from the northeast and advanced slowly down the valley, preceded by streams from the melting ice, which brought sand and gravel from the preglacial surface. The ice sheet flowed according to the slope of this surface, moving more rapidly in the lower and more open portions of the valley and becoming almost stranded on the higher elevations. A branch passed eastward over the low divide, filled the Vermilion Valley, and probably became confluent with a branch of the Minnesota-Iowa Glacier going down the Big Sioux, which at that time emptied its waters into the lower Vermilion Valley. Eventually, at the greatest development of the ice sheet, the James River valley was filled with ice 1000 to 2000 feet deep, and the valleys entering it from the west were probably filled with ice as far west as the present Missouri River. All the higher divides were doubtless covered with ice, and the Dakota Glacier probably became generally confluent with the Minnesota-Iowa Glacier on the east. The latter filled the Des Moines Valley and probably pushed far over into eastern Nebraska. The Dakota ice sheet extended over the higher lands of northern Nebraska, continuing southward as far as Pierce, Nebr., as indicated by an area of till west of Randolph. This till lies at an altitude of over 1700 feet, which indicates either that there has since been a rise of the region to the west, or that the ice was so thick that flow was induced to that altitude from the lower altitude of the preglacial surface farther north. That this deposit was the work of the James River ice lobe is further proved by the presence of red quartzite bowlders derived from ledges between Mitchell and Parker and of white limestone bowlders from ledges in Canada. This development of the Dakota Glacier and its relation to the Minnesota-Iowa ice sheet are shown in fig. 3.

The drainage of the whole western edge of the general ice sheet in pre-Wisconsin time must have been during the maximum advance of the ice along the line of the present Missouri and lower Niobrara rivers and Verdigris Creek, past Creighton and Norfolk into Elkhorn River. When melting had reduced the thickness of the ice it flowed over the higher elevations with difficulty and largely withdrew from them, and the Vermilion lobe of the Dakota Glacier became partly separated from the broader James River lobe, as indicated in fig. 3 by the line showing the first stage of recession. The drainage on the west of the ice sheet was much as above described, with the possible exception that part of it flowed along the line of Bazile Creek. Meanwhile the drainage from the area between the James River and Vermilion ice lobes flowed southward by way of East Bow Creek past Concord into Logan Creek, and the drainage from the area east of the Vermilion lobe passed down the lower Big Sioux and the Missouri.

Later, at the second stage of recession, as shown in fig. 3, the further shrinking of the ice permitted the water from the west to make its way around the front of the James River lobe, past Hartington and Coleridge to Logan Creek. About the same time water began to escape from the Bow Valley down Daily Branch and South Creek to the Missouri and later directly down Aowa Creek. All the lines of drainage from the James River ice lobe lay at a much higher altitude than the present Missouri and its tributaries. Where the present valleys cross these old drainage lines, as north and west of Hartington, flat-topped knobs and ridges capped with gravel occur on the sides of the valleys. These glacial streams traversed Tertiary sands and loams, also thin beds of till wherever such beds had been deposited. Because of the easy erosion of the Tertiary material, particularly the sand, much of the overlying till was carried away or rearranged. As already stated no till has yet been observed in this quadrangle south of Missouri River.

The conditions just described were probably succeeded by an increase in temperature which produced more rapid melting of the ice, causing the streams to become flooded and in places to approach lacustrine conditions that were suitable for the deposition of loess. Most of the loess of the Elk Point quadrangle was probably laid down during this period, but, as has been stated, considerable portions of it, especially the deposits found on elevated ridges, are of eolian origin, the material having been slowly gathered from bare flats along adjacent streams similar to those occurring along Missouri River at present. After the flood stage which attended the recession of the ice, there was a decline of waters, with rapid erosion along the main line of drainage. This process was at first greatly assisted by springs, which for a long time discharged the water that had been stored in the sands and loams since their deposition.

Meanwhile the ice had receded far beyond the northern limits of the quadrangle, and the present courses of the Missouri and other large streams were established. The time of warmer climate was of long duration, for to this period must be referred the cutting down of Missouri, James, and Vermilion rivers nearly to their present level, as indicated by the sands underneath the later till.

In the early part of the Wisconsin stage—the next advance, to which has been referred the later till—the ice seems to have been pushed forward less vigorously but to have remained a longer time. It did not attain its former extent, owing mainly to the greater deepening of the troughs of the streams. The ice extended into the Vermilion Valley and produced ponding of the waters, resulting in the erosion of a gorge from near Canton to Rock River, thus establishing the present course of the Big Sioux. In the Elk Point quadrangle the ice was restricted to the deepened trough of the Vermilion River valley more closely than in the previous advance. On the sands in the bottom of this valley was laid down a thick sheet of till, and the ice pushed forward so as to obstruct if not fill entirely the trough of Missouri River and to extend along its course nearly to Sioux City. Otherwise it is difficult to account for the occurrence of considerable masses of fresh till only 30 to 40 feet above the Missouri a little below the mouth of Big Sioux River on the Iowa side.

Moraines, portions of which remain northwest of Spirit Mound, were formed on the western side of the ice lobe. Along the eastern side, a short distance west of Brule Creek, less prominent moraines are to be found. Around the southern margin of the ice little morainic material accumulated, because of the activity of the adjacent streams, Missouri River and Brule Creek. The more recent erosion of the Missouri has probably removed much of the southern margin of the original till sheet. The recession of the Wisconsin ice sheet was more rapid than that of the earlier glaciers and seems also to have been attended by a flooded condition of the streams. These conditions are indicated by the numerous gravel-filled channels on the surface of the Wisconsin till, and by terraces along Big Sioux River above Hudson, S. Dak., along the Missouri near Yankton, and at Sioux City. To these conditions also may be referred the loesslike silt capping of the southern edge of the later till which fills the Vermilion Valley and appears as a terrace facing Missouri River for many miles. The terrace at and south of Sioux City is well formed, is composed mostly of loess, and rests upon a base of sand. It rises from 150 to 200 feet above Missouri River.

The old channels that were occupied during the recession of the Wisconsin ice form an intricate network in this quadrangle; the order of their development is indicated by numbers on the areal geology map. The following sketch may aid in their interpretation.

During the Wisconsin epoch the ice of this quadrangle had the form of a large valley glacier. At its maximum stage it probably extended to the southern limit of the area in the present trough of the Missouri, the Big Sioux draining one side and the Missouri the other. It is possible, however, that the ice ended abruptly a little south of the present bluff line between Vermilion and Richland; at any rate the ice front occupied that position early in the recession. At that time the marginal drainage flowed by way of Brule Creek on the east and Clay Creek on the west. The slender terminal wedge of the ice sheet between these streams furnished little marginal morainic material. The hills west of Brule Creek, northwest of Richland, have the same characteristics as the highland to the east, with little or no morainic deposit. Those northwest of Spink are similar, though morainic features appear on their western flanks. The recession of the ice sheet on the southeast was consequently the more rapid and the occupation of the successive channels numbered 3 and 4 was brief. Moreover the gathering ground of the waters was small, hence such channels were little eroded and show little coarse material.

The channels numbered 5 on the map were occupied longer and mark a stage occurring after the glacier had shrunk from the sides of the valley. The western stream was the more vigorous, and this may have had some influence in diverting the main subglacial drainage toward the west by way of Vermilion River, but for a short time it seems to have gone directly southward by a distinct channel. When the glacier began to shorten as well as to narrow, the marginal drainage on the east found its way across the front by successive channels (numbered 6 to 11) to the Vermilion. The channel past Spirit Mound on the west kept its course for a longer time. The further deepening and widening of the valleys of the Big Sioux, Vermilion, and Missouri took place after the ice had retreated beyond the limits of this quadrangle. Brule Creek is not much excavated, because it early ceased to receive water from the ice sheet.

After the disappearance of ice from this quadrangle there were repeated revivals and slight readvances of the ice sheet before its final extinction. Meanwhile Missouri, Vermilion, and Big Sioux rivers were deepening and widening their valleys and atmospheric agencies were gradually bringing the surface of the quadrangle to its present condition.

ECONOMIC GEOLOGY.

MINERAL RESOURCES.

The Elk Point quadrangle contains no valuable deposits of ores and only a small amount of coal. Nodules of iron ore occur here and there in the upper part of the Dakota sandstone, but they give no promise of yielding a valuable supply. The coal is a lignite and occurs in the Cretaceous formations of the southern part of the quadrangle. Various valuable clays are found in the Cretaceous and Quaternary deposits, and building stone, sand, gravel, volcanic ash, and material for cement are minor resources.

CLAY.

Workable beds of clay belonging to the Cretaceous formations are exposed along Big Sioux and Missouri rivers; but the deposits are undeveloped. Clay of similar character has been tested at Sioux City and found to be well suited for the manufacture of pottery. Fire clay also occurs, associated with lignite, in parts of Dixon and Dakota counties, Nebr. Brick and tile of good quality are made from the loess at Ponca. This material is admirably suited for the manufacture of ordinary building brick, wherever it is free from the small lime concretions that in some places are very abundant. The quality of the brick made from the loess can sometimes be improved by adding a small proportion of Dakota clay.

In many places the alluvial silts of the Missouri Valley contain a sufficient amount of clay to furnish a good brick material, and this clay has been used successfully for several years in the vicinity of Vermilion. Loam overlying the later till is also a promising brick material, and deposits of this kind near Vermilion have given good results when tested for this purpose.

BUILDING STONE.

There is no good building stone in the quadrangle, although several strata are known from which an inferior but useful article can be obtained. The bowlders brought by the glaciers from the north furnish the most abundant stone in the district. These bowlders are distributed over the surface, being most numerous in the morainic areas. They are hard and durable, but vary greatly in color, size, and form, and many of them are difficult to shape. They occur along the bluffs of Vermilion River, Brule Creek, and Big Sioux River, but are rare in most of the loess-covered regions. They are very numerous in Dixon County, Nebr., in the southwestern portion of the quadrangle, where they are used mainly for foundations and rough walls.

The Dakota, which is mostly a sandstone formation, is in the main too soft for building purposes, although a few hard, nodular layers have been found which make a fairly good foundation stone. In some localities the Greenhorn limestone contains layers suitable for use in construction, and small quarries of this rock have been opened along the east side of Big Sioux River.

SAND AND GRAVEL.

Gravel is not widely distributed in the quadrangle, nor is much of it easily accessible. Most of the pits are in the bluffs along the larger streams, and the overlying loess is continually slipping down and covering them. A few exceptions to this general statement occur along Union Creek and near Martinsburg, where the slopes are gentle and the loess thin, also along the bluffs of Vermilion River, where there is but little loam overlying the gravel. The gravels are composed mainly of crystalline rock, but the coarser varieties include bowlders of sedimentary rock and some clay or till. Sand suitable for general masonry work is associated with the Pleistocene gravel, and river sands of medium to fine grain can be obtained in abundance from recent sand bars in Missouri River. Sand suitable for general use occurs in the Tertiary deposits in the southwestern portion of the quadrangle. Near the southern boundary the bluffs of Missouri River afford extensive sand pits in Quaternary deposits. The pits are high in the bluffs and the sand is loaded by chutes into barges and taken down the river.

CEMENT.

At Yankton, west of this quadrangle, Portland cement is manufactured from Niobrara chalk rock and Pierre shale mixed in suitable proportions. At several localities in the quadrangle the Niobrara chalk rock occurs in quantity, closely associated with Carlile shale, and tests made in Sioux City have demonstrated that materials from these two formations can be mixed in proportions suitable for the manufacture of Portland cement. The chalk rock and shale are in contact at Lime Grove; in sec. 5, T. 31 N., R. 5 E.; at Spirit Mound; and at a point 2 miles northwest of Spirit Mound.

VOLCANIC ASH.

A deposit of fine, white volcanic ash suitable for polishing occurs in the SW. $\frac{1}{4}$ sec. 18, Richland Township. The bed is 18 inches thick, but its extent has not been definitely determined. Similar deposits are reported from Dixon County, Nebr., but their exact location has not been ascertained.

LIGNITE.

Lignite is present in the southern part of the quadrangle, in the Dakota and overlying Benton formations. The deposits are more or less lenticular and they occur at several horizons. The most productive bed is near Ponca, where coal was taken out for some time from a deposit about 15 inches thick. There is another lignite bed near Ponca Ferry, 30 feet below the one just mentioned, and deposits at still lower elevations have been reported from regions to the south. Considerable prospecting was done in 1902 on the farm of C. H. Goodfellow, 9 miles south of Ponca, Nebr., beyond the limits of this quadrangle. Several deep holes were sunk in this vicinity, and their records indicated the presence of lignite at three horizons. The upper bed, 6 to 10 inches thick, occurred about 35 feet above the level of Missouri River; a second deposit between $1\frac{1}{2}$ and 2 feet thick was found about 50 feet lower down; and a third deposit reported to be 42 inches thick occurred 170 feet lower. The following analyses have been made of the lignite of Dakota County:

Analyses of Dakota County lignite (air-dried basis).

[E. F. Burchard, analyst, Proc. Sioux City Acad. Sci. and Letters, vol. 1, 1904, pp. 172, 174, 175. Lumps from shaft, sec. 22. T. 29 N., R. 7 E. Depth to bed, 82 feet; thickness of bed, 23 inches.]

PROXIMATE.

Moisture	6.85
Volatile matter	31.05
Fixed carbon	45.08
Ash	16.15
Sulphur	.86

ULTIMATE.

Moisture	6.47
Carbon	58.90
Hydrogen	2.70
Nitrogen	1.48
Sulphur	.86
Oxygen	10.41
Ash	19.18

Calorific value of Dakota County lignite.

[Based on ultimate analysis.]

Calories	5296.55
British thermal units	9533.8

WATER RESOURCES.

SURFACE WATERS.

The most important natural resource of this quadrangle is water, which may be divided into surface water and underground water. The surface water includes springs, lakes, and streams; the underground water is the source of supply for shallow and tubular wells.

SPRINGS.

There are numerous springs in the Elk Point quadrangle. They issue at various horizons from all the formations in the area, except those that are predominantly shaly. In the till area most of them are supplied from the weathered porous upper part of the till, or from local beds of sand and silt overlying it. They are generally located at the heads of ravines with steep gradients. Many of them occur along the western and southern edges of the till area and in the bluffs of the Vermilion River valley. Another source of springs is the sand underlying the till, generally at a level below the present stream valleys; the water in this sand rises to the surface by hydrostatic pressure. The wet bottom lands of the Vermilion River valley are probably caused by springs of this character.

The seeping springs in the loess areas are more or less common along streams and in valleys and are supplied from the lower part of the loess, where the ground water, being checked in its downward course by impervious till, gray clay, or underlying Cretaceous clay, is allowed to escape at the surface. Here and there the collection and discharge of the water from the loess is greatly assisted by a stratum of sand just below the formation. In places, where the spring is low in the hill, the sand feeding it may be below the till. Owing to the thin and patchy character of the till, it is often difficult to distinguish which of these sources furnishes the water in a particular spring. The large springs in the SW. $\frac{1}{4}$ sec. 25, T. 94 N., R. 49 W.; the NW. $\frac{1}{4}$ sec. 2, T. 93 N., R. 49 W.; and the E. $\frac{1}{2}$ sec. 9, T. 93 N., R. 49 W.; and probably those north of Chatsworth and southwest of Akron are of this class.

The sands of the Tertiary are probably also an important source of spring water along Daily Branch and its tributaries, especially on Lindsay Branch in the northeastern part of T. 29 N., R. 4 E., and the southeastern part of the next township north. It is also possible that Tertiary sands contribute water to the springs above referred to, occurring south of Akron and east of Westfield.

The Greenhorn limestone and the Niobrara chalk rock are both water-bearing formations. In the vicinity of Chatsworth and southwest of Akron occur large springs which are probably supplied in great part from the Greenhorn limestone. The water is considerably mineralized, containing much iron. There are prominent springs which doubtless receive their water supply mainly from the Niobrara chalk rock in the northwest corner of T. 29 N., R. 5 E., in sec. 25, T. 30 N., R. 4 E., and also at the heads of Lime, Deer, and Walnut creeks. A number of springs of moderate size in secs. 3 and 10, T. 94 N., R. 51 W., and in the NE. $\frac{1}{4}$ sec. 9, T. 93 N., R. 52 W., have their sources in the chalk rock. Springs in the alluvial flats are not uncommon throughout the quadrangle. They are usually found in small depressions which extend below the surface of the ground water.

LAKES AND PONDS.

The only lakes worthy of mention in the quadrangle have been formed by bends cut off from Missouri River. Several lakes and ponds of this character occur within the area. The most important is McCook Lake, in the extreme southeast corner of the quadrangle. It is 5 to 6 miles long, oxbow shaped, and situated so conveniently to the railroad that in recent years it has become a popular summer resort. A big bend formerly existed in Missouri River just west of McCook Lake, but it was cut off from the main stream in 1901, partly by artificial means, and now forms Lake Goodenough.

Norwegian Lake, in the southeastern part of T. 92 N., R. 52 W., is a depression caused by the uneven filling of the Missouri flood plain. Formerly it was a large lake, but recently it has been drained and reduced to a marsh. Other marshes and sloughs on the bottom lands are partially filled old channels of the streams. A large slough of this character lies southwest of Elk Point, and a number of marshy places covering many acres lie along the northern edge of the Missouri bottom lands between Norwegian Lake and Vermilion River. A few pond holes with abrupt sides, occurring on the Missouri bottom, were caused by strong local currents in times of overflow of the stream. Others are the result of ice gorges, as is illustrated in the SW. $\frac{1}{4}$ sec. 23, T. 92 N., R. 52 W. On the till area of the Vermilion Valley there are numerous pond holes which were probably caused by the burying of ice blocks during the recession of the ice sheet. They are shallow, as a rule, but hold water much of the time. Many pond holes of this character exist west and south of Spink. A few of these depressions are deep and steep sided and hold more or less water continuously in ordinary years. Such are those in the SE. $\frac{1}{4}$ sec. 3 and the NE. $\frac{1}{4}$ sec. 10, T. 92 N., R. 51 W., and in the SW. $\frac{1}{4}$ sec. 4 and the NW. $\frac{1}{4}$ sec. 9, T. 93 N., R. 51 W. In loess regions marshes of small extent, which are probably due to imperfectly drained springs, occur along the streams, locally at high levels.

STREAMS.

The principal streams of the quadrangle are described under the heading "Drainage" and only a few general statements need be added here. The waters of all these streams are relatively pure, unless contaminated by artificial means. The Missouri River water, though muddy, is generally pure; it is also soft and affords a better domestic water supply than is commonly found in wells and springs. This is also true of the Big Sioux River water though not in so marked a degree. The smaller streams traversing the loess areas throughout the quadrangle are generally more enduring than those of the till, even the smallest streams in the loess district being commonly perennial.

WATER POWER.

At several places along the larger streams of the quadrangle the conditions are favorable for the utilization of water power. In many of these places mills are now located; others which were formerly occupied have been abandoned. At Akron and Richland, on Big Sioux River, flour mills which use about 100 horsepower are operated; and smaller plants are located at Martinsburg and Ponca, on South and Aowa creeks. The fall of the Big Sioux is about 1 foot to the mile, and the stream carries an abundance of water throughout the season. Aowa and South creeks have less water and a steeper gradient.

UNDERGROUND WATER.

SHALLOW WELLS.

Shallow wells are supplied by water which has recently fallen on the surface and been absorbed, and which can be reached without penetrating an impervious bed. They are in general less than 50 feet deep, and those in the till area range from 10 to 30 feet. During ordinary seasons these shallow wells furnish an abundance of excellent water for domestic use, but the supply is not sufficient for stock unless the wells are located in some large catchment basin or near some channel draining such an area. After a series of dry years the shallow wells usually fail. In the loess areas shallow wells range from 20 to 80 feet in depth, the deeper ones being where the loess has greater thickness or the steepness of the slope has lowered the surface of the ground water. Few of the loess wells furnish a large amount of water, for it escapes slowly through the fine material; but the quality is excellent. There is less danger of surface contamination of the water in the loess than in the till, because the material is exceedingly fine grained and rarely contains crevices that are connected with the surface. On the bottom lands shallow wells are from 5 to 20 feet deep, but the water is usually poor, owing to the presence of organic matter in the alluvial deposits and of mineral salts derived from the Cretaceous shale on the adjacent uplands.

TUBULAR WELLS.

Throughout the quadrangle water is found in a bed of sand below the till, where that is present, and may usually be reached by drilling to a depth of 80 to 120 feet. The depths to this sand are shown in fig. 6. The water obtained is generally under sufficient pressure to rise 50 or 60 feet, but toward the edge of the till area, where more or less leakage occurs, the pressure is greatly diminished. There is an abundance of water at this horizon and, although slightly mineralized, it is commonly regarded as a valuable supply for domestic use. It is found at a sufficient depth below the surface to be entirely free from contamination. The water of the shallower wells is often preferred for ordinary household uses, but where a large supply is required the tubular well is almost indispensable. In some localities this water-bearing sand is absent and the till rests directly upon Cretaceous clay. Areas of this kind occur around and to the southeast of Spirit Mound and northeast of Big Spring, and a less definitely known area lies southeast of Dalesburg. These are shown in fig. 4. In the loess area water can be obtained by tubular wells from any of the water-bearing strata described under the heading "Springs." The first water likely to be struck is below the till, where that is present, or below the gray clay in other localities, but here and there water is obtained in considerable quantity above the till. A third source of water for tubular wells, especially in the southwest corner of the quadrangle, is the Tertiary sand. The depth at which these water-bearing formations are encountered varies greatly according to the location of the well. In general it is greater at higher levels, where wells may be sunk 150 to 200 feet before a permanent water supply is obtained.

On the bottom lands of Missouri River, beneath the water-bearing bed which supplies the shallow wells, there is generally a layer of clay, below which another bed of water-bearing sand occurs. This second water sand is 30 to 40 feet below the surface and affords an abundance of fairly good water. A third supply of water is generally available on these bottom lands at a depth of 100 feet. There is an abundance of water at this horizon, but it is usually charged with mineral salts derived largely from the underlying Cretaceous shales. In the bottom lands of Big Sioux and Vermilion rivers and Aowa, South, and Brule creeks a similar succession of water-bearing beds is found, except that the lowest horizon is missing at many places, especially along the smaller streams. A few wells along the Big Sioux obtain their water supply from the Greenhorn limestone. Perhaps the most reliable source of water in this quadrangle in case other sources fail is the upper part of the Dakota sandstone, which is described in detail in the next section. A list of representative nonflowing wells is given on page 8.

ARTESIAN WELLS.

General statement.—In drilling wells water that is under pressure in any stratum 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. Flowing wells are found only in a narrow belt in the Elk Point quadrangle. The locations of representative artesian wells are shown on the artesian water sheet. They derive their supply mainly from the Dakota sandstone, but some wells southeast of the quadrangle obtain water from Paleozoic rocks.

The Dakota sandstone 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 water efficiency to four factors—first, its great extent, for it underlies most of the Great Plains from the Rocky Mountains eastward to about the ninety-fifth meridian; second, its highly elevated western edge, which is located in the moist region of the mountains and is crossed by numerous mountain streams; third, the fact that it is extensively covered along its eastern margin by the overlapping clays of the Benton group, or, where they are absent, by the glacial till sheet; and fourth, the cutting of wide valleys, especially in South Dakota, by preglacial streams, so as to bring the land surface below the pressure height, or head, generated by the elevation of the western border of the formation.

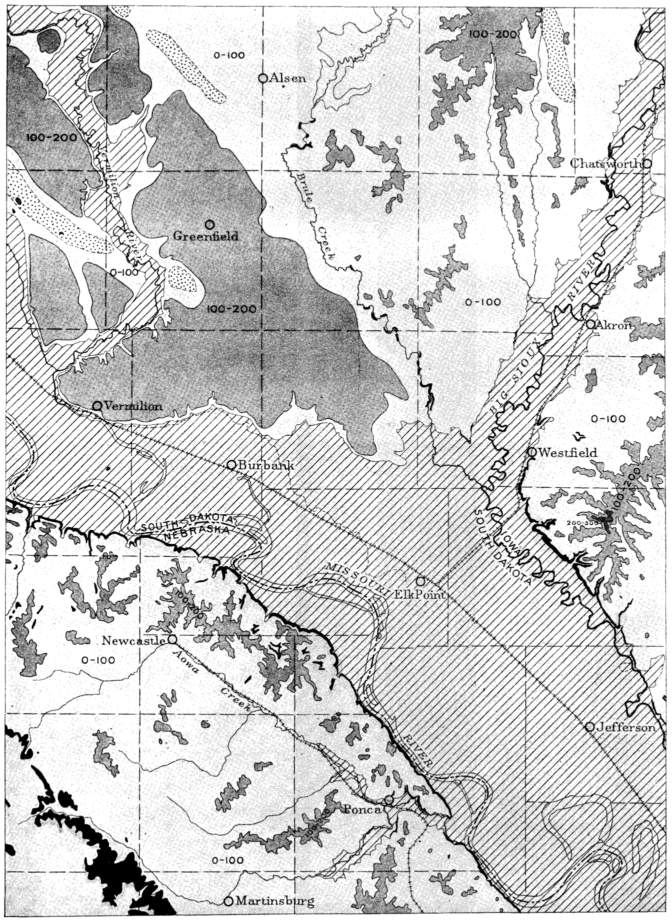


FIG. 4.—Sketch map of Elk Point quadrangle, showing approximate depths to sand at base of glacial till, from which water under pressure can usually be obtained. Depth indicated by numbers on tinted areas. Stippled areas, glacial clay not underlain by water-bearing sand. Ruled areas, glacial clay absent and water-bearing alluvium rests directly on Cretaceous rocks. Black areas, outcrops of Tertiary and Cretaceous rocks.

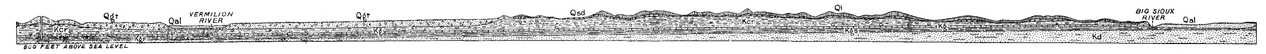


FIG. 5.—Sketch section across Elk Point quadrangle along the line A–A on areal geology map.

Horizontal scale: 1 inch = 2 miles. Vertical scale: Exaggerated 5 times.

Kd, Dakota sandstone; Kgs, Graneros shale; Kg, Greenhorn limestone; Kcr, Carlile shale; Qsd, earlier stratified drift and till; Ql, loess; Qgt, Wisconsin glacial till; Qal, alluvium.

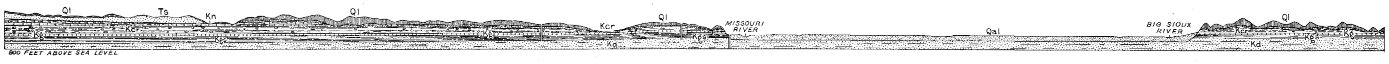


FIG. 6.—Sketch section across Elk Point quadrangle along the line B–B on areal geology map.

Horizontal scale: 1 inch = 2 miles. Vertical scale: Exaggerated 5 times.

Kd, Dakota sandstone; Kgs, Graneros shale; Kg, Greenhorn limestone; Kcr, Carlile shale; Kn, Niobrara formation; Ts, Tertiary sand and silt; Ql, loess; Qal, alluvium.

The Dakota sandstone is exposed along the larger streams in the southeastern part of the Elk Point quadrangle, where it dips at a slight angle toward the west and north. The depth to the top of the sandstone in different parts of the quadrangle is shown on the artesian water sheet. Although the formation is generally filled with water throughout eastern South Dakota, doubtless in the Elk Point quadrangle much of this water escapes by leaks underneath the surface of Missouri River and its bottom lands, causing the pressure and head to decrease at a regular rate toward the southeast. It should be remembered that the Dakota formation consists largely of deposits of sand separated by sheets of clay or shale. The different sand layers are of an uneven thickness and texture and some of them may be sufficiently consolidated to be impervious to water. In the cross sections (figs. 5 and 6) the general arrangement and character of the Dakota and overlying formations are shown, and details at certain localities are given in the well records.

The area in which flowing wells may be obtained is shown on the artesian water map. It is confined to the river bottoms along the western border of the quadrangle, and is known to extend eastward nearly to Burbank, but theoretically flowing wells should be obtainable in the Missouri River channel as far east as the longitude of Ponca, as shown on the map. Flowing wells may be obtained also on the Vermilion bottom land to and beyond the northern boundary of the quadrangle. In this area the first stratum furnishing a flow is struck at 175 to 250 feet, the depth depending on the degree of consolidation of the upper strata and the presence of layers affording communication between the Dakota sandstone and beds of sand in the overlying Benton. In some localities the first horizon does not furnish a sufficient supply of water and it is necessary to go 150 to 250 feet deeper, a maximum pressure and flow being then generally reached.

Outside of the areas of flowing wells the same water horizon may generally be reached at an elevation above sea level that gradually increases toward the east, as shown in figs. 5 and 6. In the troughs of Missouri and Big Sioux rivers, however, the depths diminish, as 150 feet or more of the upper beds have been removed. In the nonflowing area the height to which the water rises gradually diminishes to the southeast.

Amount of flow.—The flows of the artesian wells of this area vary considerably, ranging from 1 to 30 gallons a minute. As compared with the larger wells, the smaller ones afford a much smaller supply than their diameters would indicate, because of the greater friction in the smaller pipes. It is a common impression that the flow varies according to pressure, but such is not the case, unless the character and thickness of the beds contributing water to the wells are the same. The porosity of the water-bearing rock and the amount of surface contributing water to the well are important factors which affect flows. A fine-grained rock may furnish water slowly, even under high pressure, whereas a coarse-grained water-bearing bed may supply water freely with only a small head. Other things being equal, the water discharged from a stratum 4 feet thick will be about twice that from a 2-foot bed.

Decline of pressure.—The term pressure as used here means closed pressure, or that which exists when a well is completely closed except at the bottom, where the water enters. Of course in order to obtain this pressure, it is necessary that there be no leak in the casing. Any escape of water from the pipe above the surface can be readily detected, but it is not always possible to determine the existence of leaks below ground. If two wells near together, supplied with water from the same stratum, vary widely in closed pressures, it is safe to assume that the one showing less pressure leaks. Again, if the well is closed and the pressure then declines, it indicates that the water has probably found another channel of escape. In such cases the well should be opened as soon as possible. Subterranean leakage of a well may occur through an imperfect joint in the pipe, or outside of the pipe from one stratum to another. It is conceivable that in some wells the hole may be made too large for the pipe and so the water escapes from a lower stratum where there is higher pressure to a higher stratum where there is less pressure, or no water.

There are three principal water-bearing horizons in the Dakota sandstone of this quadrangle. In regions farther north the pressure of water from the upper horizons is often much less than from the lower. This may be due in part to freer leakage from the upper beds. The same difference of pressure doubtless exists in this region, though not in so marked a degree.

Since artesian water was first obtained in the Elk Point quadrangle, about 1890, there has been a gradual decline in head, or pressure. At Vermilion this decline in head is estimated at about 11 feet. Some of the wells on the higher levels have ceased to flow, and others lower down in the valley show a slight decrease.

Usually soon after the opening of an artesian well in this region, its flow shows a slight decrease, which is more perceptible in the larger wells. In some wells, however, there is an increase in flow at first, caused probably by the washing out of a cavity, which increases the delivering surface of the water-bearing rock, or by the breaking in of a new flow. A decline may be due to one of various causes or to a combination of causes. Probably the most common cause of decrease in flow is friction in the water-bearing stratum, which prevents the water gathering in the well as rapidly as it could be delivered by the pipe. As a result the pressure in the well rapidly declines, sometimes several pounds in a few days. This increases the flow of water toward the bottom of the well until a nearly uniform flow is established which may be maintained indefinitely with slight diminution. Experiments and observations have demonstrated the rate at which water percolates through sands of different degrees of fineness. Through coarse sand it flows, when under a head of 100 feet to the mile, at the rate of 1 mile a year. The sands of the Dakota are in general very fine and the average gradient or head is in few places as much as 10 feet to the mile. Hence the normal flow from these sands to or past any given point is small. When wells are multiplied in a locality till their circles of influence intersect, they interfere with each other's supply and all of them begin to decline in flow. When, therefore, several wells, either flowing or nonflowing, are needed for any purpose within a comparatively small area, they should be as remote from each other as possible.

Fluctuations in pressure.—Wells in this region generally are perceptibly affected by variations in the atmospheric pressure. This phenomenon is of course slight and not even noticeable except where the pressure is low, when it frequently attracts attention. It is more apparent in wells of the Elk Point quadrangle than in those farther northwest. Some wells here are known to flow more abundantly shortly before a storm, or when there is a south wind, which usually brings low barometer. On the other hand the same wells are sluggish during a north wind, and the flow may stop entirely for a few hours when the barometer is unusually high. As cold weather brings denser air and higher barometer, together with a slight shortening of the column of water in the well from cooling, some wells cease to flow during the winter months. If such wells are unused there is sometimes an accumulation of sediment in the bottom which is sufficient to prevent the resumption of flow in the spring, unless the well is pumped until it has cleared itself.

Another interesting variation of pressure has been observed in this area. When the rivers rise, there is a corresponding rise of pressure in the wells near them. This has caused some to believe that these wells are supplied with water from the rivers, but it is evident that there is a leakage into the bed of the river from the strata supplying the wells. Greater depth of water in the river produces greater pressure, and thus hinders the leakage into the river and causes more water to escape into the well.

The pressure of some wells varies from year to year for reasons not well understood. In the spring of 1897 there was a general rise in the wells near Vermilion, followed by a decrease in their flow in the following year. It is possible that such changes are the result of variation of supply in the mountains, although a decrease at the wells would not take place for a long time after the decrease at the point where the sands receive the water.

SOILS.

The soils of this quadrangle have not been studied in detail, and only the most obvious characteristics are noted below.

STONY SOILS.

Stony soils cover only small areas, mainly on the rougher surface of the moraines and along the edges of the terraces that skirt the principal streams.

Most of the morainic surfaces carry bowlders, which must be removed to permit ordinary cultivation. The localities where stony soils are found are on high points bordering both sides of Big Sioux River, on the east side of Clay Creek, and at lower levels along Vermilion River.

SANDY SOILS.

Sandy soils are present over very extensive areas in the Elk Point quadrangle, lying mainly in the Missouri River valley and in the Tertiary area southwest of Daily Branch. Along the Missouri they occur on old bars of the streams and in certain overflow channels where the choking of the velocity of the water in time of flood has caused rapid deposition of sand, while the clay has been washed away. In the Tertiary area much of the soil is too sandy for cultivation and can be used only for pasture.

CLAYEY SOILS.

The clayey soils are popularly known as gumbo. They occupy the lower portions of the Missouri and Vermilion bottom lands, particularly in old channels, and throughout the till area they occur in basins or lake beds. The soil is black and fertile, but during droughts it cakes into clods and often shows an efflorescence of mineral salts known as alkali. Clayey soil covers small areas where Cretaceous clay forms the subsoil, on the lower slopes of the Big Sioux and its tributaries, and along some of the tributaries of Missouri River.

LOAMY SOILS.

By far the larger portion of the quadrangle is covered by loamy soil. The loess is a typical loam when loosened by tillage and has many valuable qualities. It is light colored and fertile, affords perfect underdrainage, and yet has an unusual power to resist drought. The material is porous and fine grained, so that water passes downward readily but rises again by capillary action. Roots of plants penetrate this soil deeply, which is an important feature in resisting drought. The loamy soil therefore combines the easy tillage of sand with the moisture and fertility of clay. Though the soil is generally fertile in loess areas, the surface is in many places so uneven that tillage is impracticable. Soil of this kind is subject to rapid erosion by both rain and wind, so that on prominent points or steep slopes it is too thin to support crops. On the lower slopes and lowlands this soil is deep, black, and fertile. Loamy soils on the till closely resemble the lowland soils of the loess region. Similar soils are also present on the bottom lands of the larger streams, usually in the higher portions of the valleys and near the main channels.

July, 1907.

List of representative tubular wells in the Elk Point quadrangle.

Owner.	Location.	Depth. Feet.	Remarks.
N. Thomas	SW. ¼ sec. 12, T. 30 N., R. 4 E.	265	Begun in the loess, passed through Tertiary into Niobrara formation. Water from lower part of Tertiary sand.
S. Thomas	NW. ¼ sec. 24, T. 30 N., R. 4 E.	156	Begun in loess, penetrated Tertiary deposits for 56 feet. Water from sand in upper part of the Tertiary.
—— Brinks	NE. ¼ sec. 1, T. 21 N., R. 4 E.	366	Begun in loess, passed through Carlile and Greenhorn, nearly to base of Graneros formation.
John Rahn	NE. ¼ sec 34, T. 30 N., R. 5 E.	301	Begun in loess, passed through Carlile, Greenhorn, and Graneros formations, and penetrated the Dakota for 29 feet. Water from Dakota sandstone.
—— Cady	SW. ¼ sec. 14, T. 30 N., R. 4 E.	177	Begun in loess, penetrated Tertiary sand for 85 feet. Water from Tertiary sand.
—— Gilliand	SE. ¼ sec. 30, T. 30 N., R. 5 E.	135	Begun in loess, passed through 20 feet of blue clay (till ?) and penetrated Tertiary clay and sand for 75 feet. Water from Tertiary gravel at base.
J. H. Johnson	NE. ¼ sec. 14, T. 31 N., R. 4 E.	142	Begun in loess, passed through 67 feet of Tertiary and 10 feet of Niobrara formation. Water from sand near middle of Tertiary.
Robert Howell	SE. ¼ sec. 14, T. 31 N., R. 4 E.	80	Passed through 44 feet of loess and 36 feet of Niobrara chalk rock. Water from sand at base of chalk rock.
—— Rickett	SE. ¼ sec. 23, T. 30 N., R. 4 E.	152	Passed through 12 feet of sand, 139 feet of yellow clay, and 1 foot of sand and gravel, all Tertiary. Water from sandstone at base.
—— Joderson	NW. ¼ sec. 11, T. 29 N., R. 4 E.	155	Passed through 10 feet of loess and 145 feet of Tertiary beds. Water from a sand at base of Tertiary.
W. S. Mills	W. ½ sec. 13, T. 91 N., R. 49 W.	--------	Passed through Graneros formation and 127 feet of Dakota. Water from middle of Dakota.
J. L. Anderson	SE. ¼ sec. 4, T. 93 N., R. 52 W.	360	Begun in till, passed through 30 feet of Niobrara chalk rock, also Carlile, Greenhorn, and a part of Graneros formations. Water from sandstone in lower part of Graneros.
Louis Ofstad	SW. ¼ sec. 25, T. 94 N., R. 50 W.	41	Alluvium to bottom of well.
B. S. Payne	NW. ¼ sec. 7, T. 92 N., R. 50 (?) W.	165	Passed through 145 feet of till and 20 feet of sand. Water from sand at base of till.
—— Holst	SW. ¼ sec. 4, T. 94 N., R. 49 W.	220	Passed through 90 feet of loess, 80 feet of blue clay or till, and 50 feet of sand, probably Quaternary. Water from sand.
B. Dugan	SE. ¼ sec. 29, T. 92 N., R. 48 W.	290	Passed through 40 feet of loess, 100 feet of Carlile shale, 30 feet of Greenhorn limestone, 110 feet of Graneros shale, and 10 feet of Dakota sandstone. Water from Dakota sandstone.
J. Bergsten	SW. ¼ sec. 20, T. 93 N., R. 49 W.	142	Passed through 60 feet of loess, 55 feet of till, and 27 feet of sand, all Quaternary. Water from sand at bottom.
C. A. Erickson	NW. ¼ sec. 13, T. 94 N., R. 49 W.	365	Passed through 20 feet of loess, 52 feet of till, and 292 feet of shale belonging to the Benton group. No water.
Otto Wallin	Sec. 33, T. 94 N., R. 49 W.	375	Passed through 40 feet of loess, 150 feet of Carlile, 30 feet of Greenhorn, 155 feet of Graneros, and 1 foot of Dakota sandstone. Water from Dakota sandstone.
E. W. Ericson	SE. ¼ sec. 3, T. 94 N., R. 49 W.	145	Passed through 33 feet of loess, 110 feet of blue clay or till, and 2 feet of sand and gravel, all Quaternary. Water from 2-foot layer of sand and gravel.
O J. Anderson	NE. ¼ sec. 33, T. 32 N., R. 4 E.	167	Passed through 130 feet of loess and 37 feet of sand and clay. Water from sand under the loess.
George Mattison	NE. ¼ SW. ¼ sec. 20, T. 31 N., R. 6 E.	517	Passed through 100 feet of alluvium and 417 feet of Dakota sandstone. Water obtained 100 feet below top of Dakota.

U.S. GEOLOGICAL SURVEY
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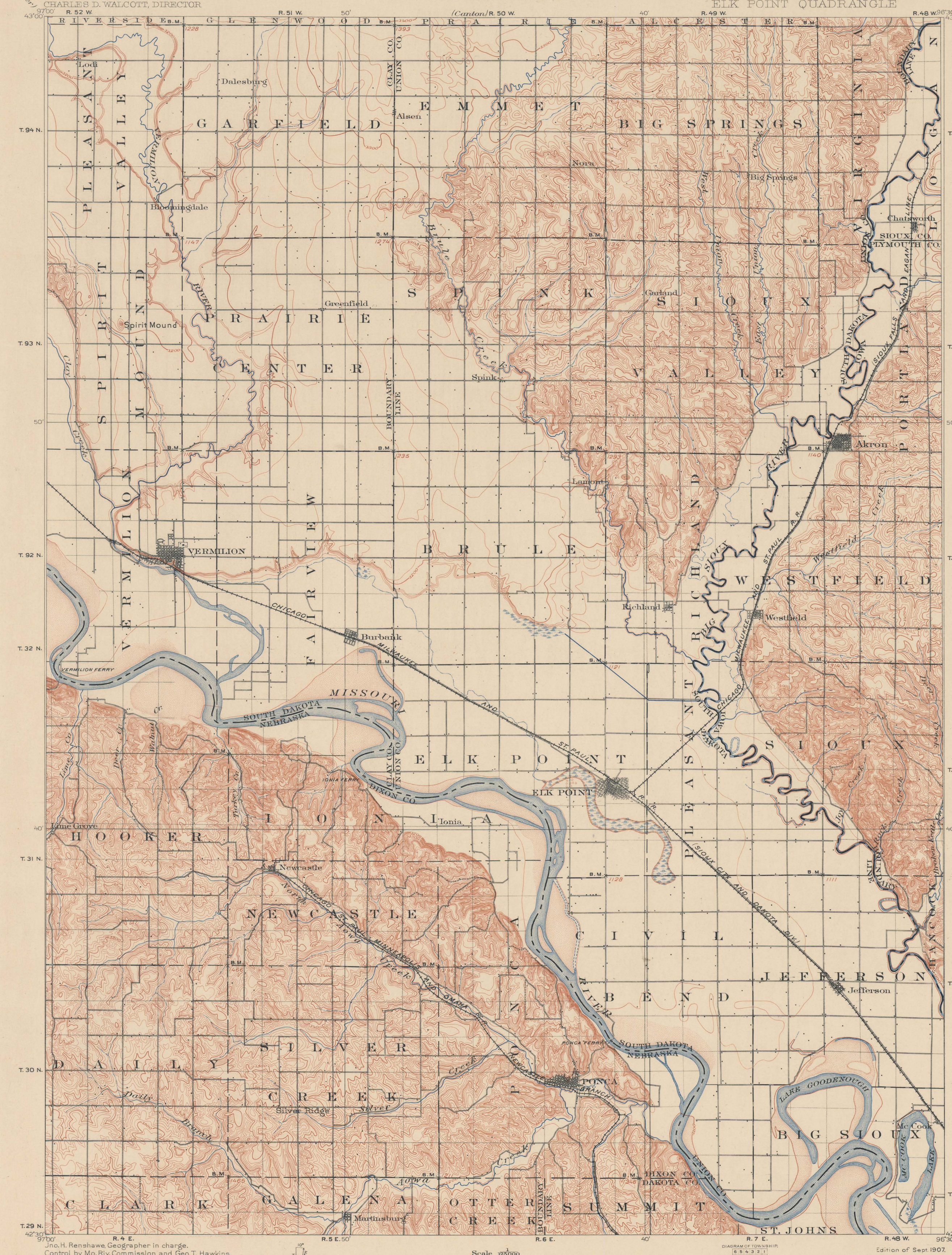
TOPOGRAPHY

SOUTH DAKOTA-NEBRASKA-IOWA
ELK POINT QUADRANGLE



LEGEND

RELIEF
printed in brown

1128
Figures
showing heights above mean sea level instrumentally determined

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

Depression contours

Sand bars

DRAINAGE
printed in blue

Streams

Intermittent streams

Canals and ditches

Lakes

Marshes

CULTURE
printed in black

Roads and buildings

Private and secondary roads

Railroads

Bridges

Ferries

U.S. township and section lines

State lines

County lines

Township lines

B.M.
×
Bench marks

Jno. H. Renshawe, Geographer in charge.
Control by Mo. Riv. Commission and Geo. T. Hawkins.
Mo. Riv., from surveys by Mo. Riv. Commission 1892.
Topography by Wm. H. Griffin.
Surveyed in 1898.

TRUE NORTH
MAGNETIC NORTH
10°
APPROXIMATE MEAN DECLINATION 1906.

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.

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

Edition of Sept. 1907.

U. S. GEOLOGICAL SURVEY
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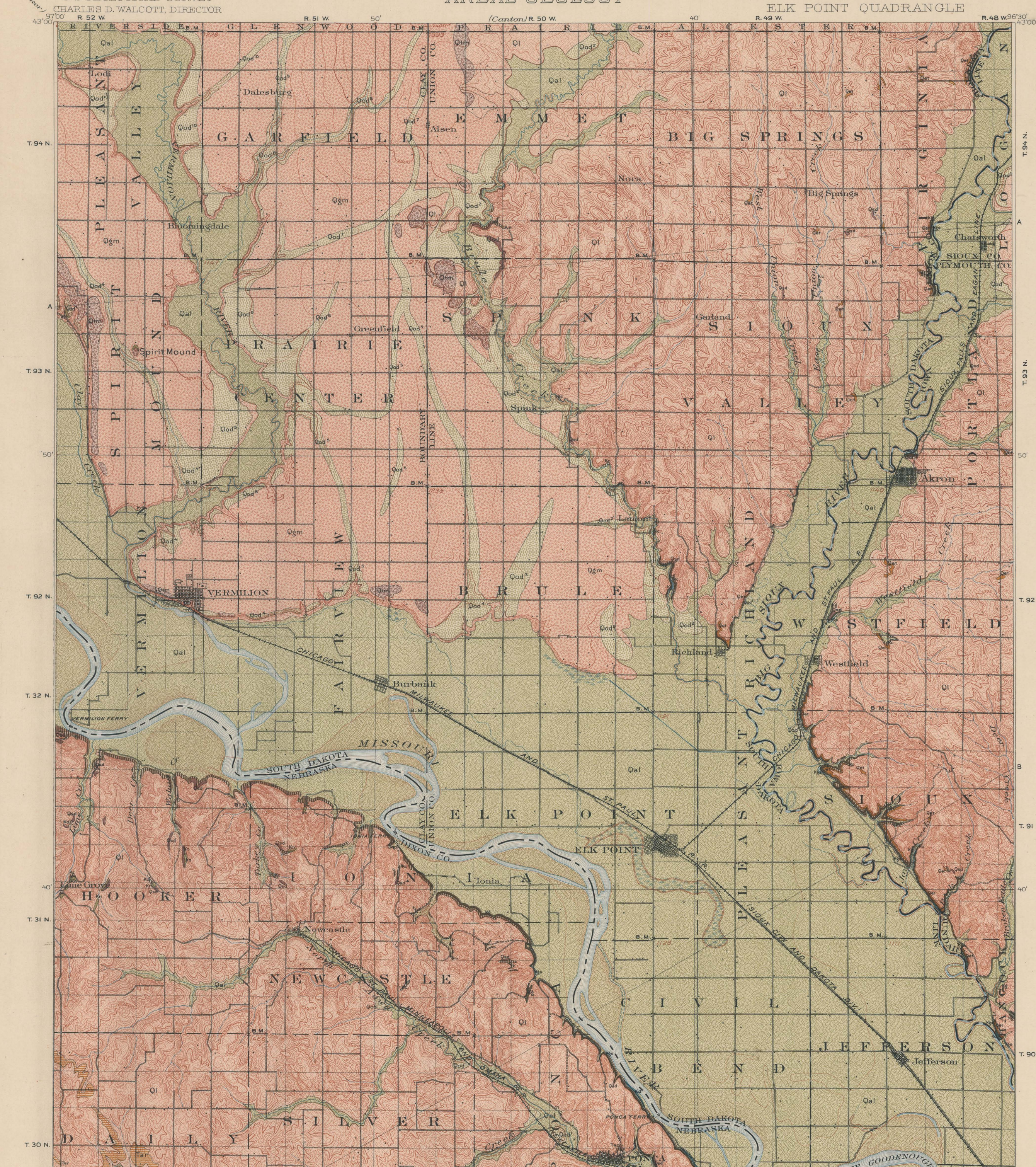
AREAL GEOLOGY

SOUTH DAKOTA-NEBRASKA-IOWA
ELK POINT QUADRANGLE



LEGEND

SEDIMENTARY ROCKS

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

QUATERNARY

Recent

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

Pleistocene — Wisconsin Stage

Qod — Old stream deposits *(occupying channels of glacial streams; chronologic order indicated by numbers)*

Qtm — Altamont terminal moraine *(clay, gravel, and bowlders)*

Qgm — Ground moraine *(unstratified clay, sand, gravel, and bowlders)*

Ql — Loess *(fine clayey sand cemented by lime and iron oxide)*

Pleistocene — Pre-Wisconsin

Qsd — Earlier stratified drift *(sand, gravel, and clay)*

Qet — Earlier glacial till

TERTIARY

Tar — Arikaree formation? *(sand and silt)*

CRETACEOUS

Kn — Niobrara formation *(chalky limestone and soft gray shale)*

Benton group

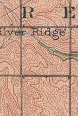
Kc — Carlile shale *(dark shale containing iron concretions, with sandstone near top)*

Kg — Greenhorn limestone *(thin-bedded limestone alternating with blue chalky shale)*

Kgs — Graneros shale *(dark shale containing sandstone and thin seams of lignite coal at base)*

Kd — Dakota sandstone *(light-brown sandstone and shale, with thin beds of lignite)*

Jno. H. Renshawe, Geographer in charge.
Control by Mo. Riv. Commission and Geo. T. Hawkins.
Mo. Riv. from surveys by Mo. Riv. Commission 1892.
Topography by Wm. H. Griffin.
Surveyed in 1898.



APPROXIMATE MEAN DECLINATION 1906.

Scale $\frac{1}{125000}$

Contour interval 20 feet.
Datum is mean sea level.
Edition of Mar. 1908.

DIAGRAM OF TOWNSHIP

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Geology by J. E. Todd,
under the supervision of N. H. Darton.
Surveyed in 1904.

(Parker)

U.S. GEOLOGICAL SURVEY
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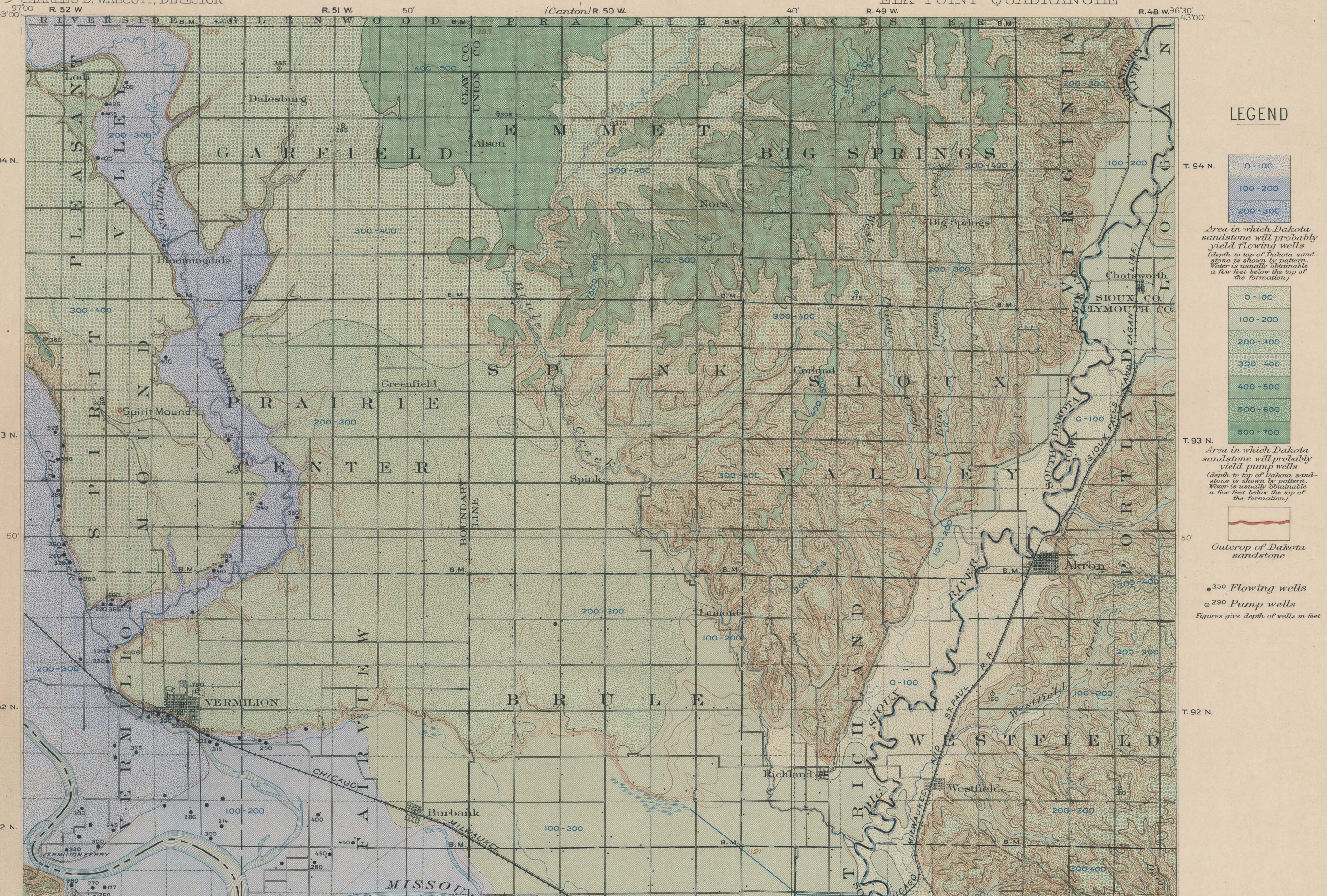
ARTESIAN WATER

SOUTH DAKOTA-NEBRASKA-IOWA
ELK POINT QUADRANGLE



Jno. H. Renshawe, Geographer in charge.
Control by Mo. Riv. Commission and Geo. T. Hawkins.
Mo. Riv., from surveys by Mo. Riv. Commission 1892.
Topography by Wm. H. Griffin.
Surveyed in 1898.

10°
TRUE NORTH
MAGNETIC NORTH
APPROXIMATE MEAN DECLINATION 1906.

Scale $\frac{1}{125000}$

1 ½ 0 1 2 3 4 5 Miles

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Contour interval 20 feet.
Datum is mean sea level.
Edition of Mar. 1908.

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