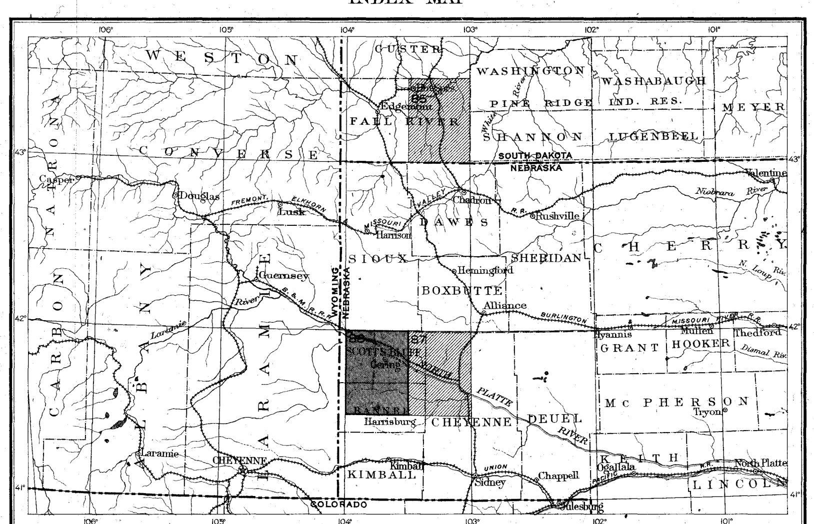
DEPARTMENT OF THE INTERIOR
UNITED STATES GEOLOGICAL SURVEY
CHARLES D. WALCOTT, DIRECTOR

GEOLOGIC ATLAS OF THE UNITED STATES

SCOTTS BLUFF FOLIO

NEBRASKA

INDEX MAP



SCALE: 40 MILES-1 INCH

AREA OF THE SCOTTS BLUFF FOLIO

AREA OF OTHER PUBLISHED FOLIOS

CONTENTS

DESCRIPTIVE TEXT
TOPOGRAPHIC MAP
ILLUSTRATION SHEET
AREAL GEOLOGY MAP
COLUMNAR SECTION SHEET

LIBRARY EDITION

SCOTTS BLUFF FOLIO
NO. 88

WASHINGTON, D. C.
ENGRAVED AND PRINTED BY THE U. S. GEOLOGICAL SURVEY
GEORGE W. STOSE, EDITOR OF GEOLOGIC MAPS   S. J. KUBEL, CHIEF ENGRAVER
1903

EXPLANATION.

The Geological Survey is making a geologic map of the United States, which necessitates the preparation of a topographic base map. The two are being issued together in the form of an atlas, the parts of which are called folios. Each folio consists of a topographic base 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 horizontal outline, or contour, of all slopes, and to indicate their grade or degree of steepness. This is done by lines connecting points of equal elevation above mean sea level, the lines being drawn at regular vertical intervals. These lines are called *contours*, and the uniform vertical 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:

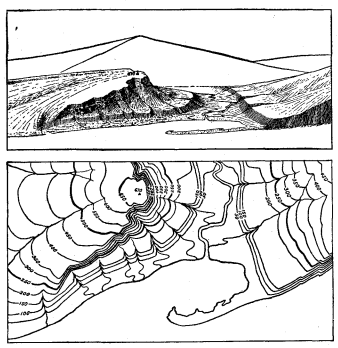


Fig. 1.—Ideal sketch and corresponding contour map.

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 in a precipice. Contrasted with this precipice is the gentle descent of the slope at 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 approximately a certain height above sea level. In this illustration the contour interval is 50 feet; therefore the contours are drawn at 50, 100, 150, 200 feet, and so on, above sea level. Along the contour at 250 feet lie all points of the surface 250 feet above sea; and similarly with any other contour. In the space between any two contours are found all 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 nearly all the contours are numbered. Where this is not possible, certain contours—say every fifth one—are accentuated and numbered; the heights of others may then be ascertained by counting up or down from a numbered contour.

2. Contours define the forms of slopes. Since contours are continuous horizontal lines conforming to the surface of the ground, they wind smoothly about smooth surfaces, recede into all reentrant angles of ravines, and project in passing about prominences. The 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 vertical 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 used 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.—Water courses are indicated by blue lines. If the streams flow the year round 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, and artificial details, are printed in black.

Scales.—The area of the United States (excluding Alaska) is about 3,025,000 square miles. On a map with the scale of 1 mile to the inch this would cover 3,025,000 square inches, and to accommodate it the paper dimensions would need to be 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 of "1 mile to an inch" is expressed by $\frac{1}{63,360}$. Both of these methods are used on the maps of the Geological Survey.

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 and corresponds nearly to 1 square mile; on the scale $\frac{1}{125,000}$ to about 4 square miles; and on the scale $\frac{1}{250,000}$ to about 16 square miles. At the bottom of each atlas sheet the scale is expressed in three different ways, one being a graduated line representing miles and parts of miles in English inches, another indicating distance in the metric system, and a third giving the fractional scale.

Atlas sheets and quadrangles.—The map is being published in atlas sheets of convenient size, which are bounded by parallels and meridians. The corresponding four-cornered portions of territory 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-quarter of a square degree; each sheet on a 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, respectively.

The atlas sheets, being only parts of one map of the United States, are laid out without regard to the boundary lines of the States, counties, or 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 sheet.—Within the limits of scale the topographic sheet is an accurate and characteristic delineation of the relief, drainage, and culture of the district represented. Viewing the landscape, map in hand, every characteristic feature of sufficient magnitude should be recognizable. It should guide the traveler; serve the investor or owner who desires to ascertain the position and surroundings of property to be bought or sold; save the engineer preliminary surveys in locating roads, railways, and irrigation ditches; provide educational material for schools and homes; and serve many of the purposes of a map for local reference.

THE GEOLOGIC MAP.

The maps representing areal geology show by colors and conventional signs, on the topographic base map, the distribution of rock formations on the surface of the earth, and the structure-section map shows their underground relations, as far as known and in such detail as the scale permits.

KINDS OF ROCKS.

Rocks are of many kinds. The original crust of the earth was probably composed of *igneous rocks*, and all other rocks have been derived from them in one way or another.

Atmospheric agencies gradually break up igneous rocks, forming superficial, or *surficial*, deposits of clay, sand, and gravel. Deposits of this class have been formed on land surfaces since the earliest geologic time. Through the transporting agencies of streams the surficial materials of all ages and origins are carried to the sea, where, along with material derived from the land by the action of the waves on the coast, they form *sedimentary rocks*. These are usually hardened into conglomerate, sandstone, shale, and limestone, but they may remain unconsolidated and still be called "rocks" by the geologist, though popularly known as gravel, sand, and clay.

From time to time in geologic history igneous and sedimentary rocks have been deeply buried, consolidated, and raised again above the surface of the water. In these processes, through the agencies of pressure, movement, and chemical action, they are often greatly altered, and in this condition they are called *metamorphic rocks*.

Igneous rocks.—These are rocks which have cooled and consolidated from a liquid state. As has been explained, sedimentary rocks were deposited on the original igneous rocks. Through the igneous and sedimentary rocks of all ages molten material has from time to time been forced upward to or near the surface, and there consolidated. When the channels or vents into which this molten material is forced do not reach the surface, it may consolidate in cracks or fissures crossing the bedding planes, thus forming dikes, or spread out between the strata in large bodies, called sheets or laccoliths, or form large irregular cross-cutting masses, called stocks. Such rocks are called *intrusive*. Within their rock inclosures they cool slowly, and hence are generally of crystalline texture. When the channels reach the surface the lavas often flow out and build up volcanoes. These lavas cool rapidly in the air, acquiring a glassy or, more often, a partially crystalline condition. They are usually more or less porous. The igneous rocks thus formed upon the surface are called *extrusive*. Explosive action often accompanies volcanic eruptions, causing ejections of dust or ash and larger fragments. These materials when consolidated constitute breccias, agglomerates, and tuffs. The ash when carried into lakes or seas may become stratified, so as to have the structure of sedimentary rocks.

The age of an igneous rock is often difficult or impossible to determine. When it cuts across a sedimentary rock it is younger than that rock, and when a sedimentary rock is deposited over it the igneous rock is the older.

Under the influence of dynamic and chemical forces an igneous rock may be metamorphosed. The alteration may involve only a rearrangement of its minute particles or it may be accompanied by a change in chemical and mineralogic composition. Further, the structure of the rock may be changed by the development of planes of division, so that it splits in one direction more easily than in others. Thus a granite may pass into a gneiss, and from that into a mica-schist.

Sedimentary rocks.—These comprise all rocks which have been deposited under water, whether in sea, lake, or stream. They form a very large part of the dry land.

When the materials of which sedimentary rocks are composed are carried as solid particles by water and deposited as gravel, sand, or mud, the deposit is called a mechanical sediment. These may become hardened into conglomerate, sandstone, or shale. When the material is carried in solution by the water and is deposited without the aid of life, it is called a chemical sediment; if deposited with the aid of life, it is called an organic sediment. The more important rocks formed from chemical and organic deposits are limestone, chert, gypsum, salt, iron ore, peat, lignite, and coal. Any one of the above sedimentary deposits may be separately formed, or the different materials may be intermingled in many ways, producing a great variety of rocks.

Sedimentary rocks are usually made up of layers or beds which can be easily separated. These layers are called *strata*. Rocks deposited in successive 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 over wide expanses, and as it rises or subsides the shore lines of the ocean are changed: areas of deposition may rise above the water and become land areas, and land areas may sink below the water and become areas of deposition. If North America were gradually to sink a thousand feet the sea would flow over the Atlantic coast and the Mississippi and Ohio valleys from the Gulf of Mexico to the Great Lakes; the Appalachian Mountains would become an archipelago, and the ocean's shore would traverse Wisconsin, Iowa, and Kansas, and extend thence to Texas. More extensive changes than this have repeatedly occurred in the past.

The character of the original sediments may be changed by chemical and dynamic action so as to produce metamorphic rocks. In the metamorphism of a sedimentary rock, just as in the metamorphism of an igneous rock, the substances of which it is composed may enter into new combinations, or new substances may be added. When these processes are complete the sedimentary rock becomes crystalline. Such changes transform sandstone to quartzite, limestone to marble, and modify other rocks according to their composition. A system of parallel division planes is often produced, which may cross the original beds or strata at any angle. Rocks divided by such planes are called slates or schists.

Rocks of any period of the earth's history may be more or less altered, but the younger formations have generally escaped marked metamorphism, and the oldest sediments known, though generally the most altered, in some localities remain essentially unchanged.

Surficial rocks.—These embrace the soils, clays, sands, gravels, and bowlders that cover the surface, whether derived from the breaking up or disintegration of the underlying rocks by atmospheric agencies or from glacial action. Surficial rocks that are due to disintegration are produced chiefly by the action of air, water, frost, animals, and plants. They consist mainly of the least soluble parts of the rocks, which remain after the more soluble parts have been leached out, and hence are known as residual products. Soils and subsoils are the most important. Residual accumulations are often washed or blown into valleys or other depressions, where they lodge and form deposits that grade into the sedimentary class. Surficial rocks that are due to glacial action are formed of the products of disintegration, together with bowlders and fragments of rock rubbed from the surface and ground together. These are spread irregularly over the territory occupied by the ice, and form a mixture of clay, pebbles, and bowlders which is known as till. It may occur as a sheet or be bunched into hills and ridges, forming moraines, drumlins, and other special forms. Much of this mixed material was washed away from the ice, assorted by water, and redeposited as beds or trains of sand and clay, thus forming another gradation into sedimentary deposits. Some of this glacial wash was deposited in tunnels and channels in the ice, and forms characteristic ridges and mounds of sand and gravel, known as osars, or eskers, and kames. The material deposited by the ice is called glacial drift; that washed from the ice onto the adjacent land is called modified drift. It is usual also to class as surficial rocks the deposits of the sea and of lakes and rivers that were made at the same time as the ice deposit.

AGES OF ROCKS.

Rocks are further distinguished according to their relative ages, for they were not formed all at one time, but from age to age in the earth's history. Classification by age is independent of origin; igneous, sedimentary, and surficial rocks may be of the same age.

When the predominant material of a rock mass is essentially the same, and it is bounded by rocks of different materials, it is convenient to call the mass throughout its extent a *formation*, and such a formation is the unit of geologic mapping.

Several formations considered together are designated a *system*. The time taken for the deposition of a formation is called an *epoch*, and the time taken for that of a system, or some larger fraction of a system, a *period*. The rocks are mapped by formations, and the formations are classified into systems. The rocks composing a system and the time taken for its deposition are given the same name, as, for instance, Cambrian system, Cambrian period.

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

Strata often contain the remains of plants and animals which lived in the sea or were washed from the land into lakes or seas or were buried in surficial deposits on the land. Rocks that contain the remains of life are called fossiliferous. By studying these remains, or fossils, it has been found that the species of each period of the earth's history have to a great extent differed from those 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 formations are remote one from the 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 rocks of different areas, provinces, and continents afford the most important means for combining local histories into a general earth history.

Colors and patterns.—To show the relative ages of strata, the history of the sedimentary rocks is divided into periods. The names of the periods in proper order (from new to old), with the colors and symbol assigned to each, are given in the table in the next column. The names of certain subdivisions and groups of the periods, frequently used in geologic writings, are bracketed against the appropriate period names.

To distinguish the sedimentary formations of any one period from those of another the patterns for the formations of each period are printed in the appropriate period-color, with the exception of the one at the top of the column (Pleistocene) and the one at the bottom (Archean). The sedimentary formations of any one period, excepting the Pleistocene and the Archean, are distinguished from one another by different patterns, made of parallel straight lines. Two tints of the period-color are used: a pale tint is printed evenly over the whole surface representing the period; a dark tint brings out the different patterns representing formations. Each formation is furthermore given

Period.		Symbol.	Color.
Cenozoic	Pleistocene	P	Any colors.
	Neocene (Pliocene, Miocene)	N	Buffs.
	Eocene, including Oligocene	E	Olive-browns.
Mesozoic	Cretaceous	K	Olive-greens.
	Juratrias (Jurassic, Triassic)	J	Blue-greens.
Paleozoic	Carboniferous, including Permian	C	Blues.
	Devonian	D	Blue-purples.
	Silurian, including Ordovician	S	Red-purples.
	Cambrian	Є	Pinks.
	Algonkian	A	Orange-browns.
	Archean	AR	Any colors.

a letter-symbol composed of the period letter combined with small letters standing for the formation name. In the case of a sedimentary formation of uncertain age the pattern is printed on white ground in the color of the period to which the formation is supposed to belong, the letter-symbol of the period being omitted.

The number and extent of surficial formations, chiefly Pleistocene, render them so important that, to distinguish them from those of other periods and from the igneous rocks, patterns of dots and circles, printed in any colors, are used.

The origin of the Archean rocks is not fully settled. Many of them are certainly igneous. Whether sedimentary rocks are also included is not determined. The Archean rocks, and all metamorphic rocks of unknown origin, of whatever age, are represented on the maps by patterns consisting of short dashes irregularly placed. These are printed in any color, and may be darker or lighter than the background. If the rock is a schist the dashes or hachures may be arranged in wavy parallel lines. If the metamorphic rock is known to be of sedimentary origin the hachure patterns may be combined with the parallel-line patterns of sedimentary formations. If the rock is recognized as having been originally igneous, the hachures may be combined with the igneous pattern.

Known igneous formations are represented by patterns of triangles or rhombs printed in any brilliant color. If the formation is of known age the letter-symbol of the formation is preceded by the capital letter-symbol of the proper period. If the age of the formation is unknown the letter-symbol consists of small letters which suggest the name of the rocks.

THE VARIOUS GEOLOGIC SHEETS.

Areal geology sheet.—This sheet 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 particular colored pattern and its letter-symbol on the map 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 symbols and names are arranged, in columnar form, according to the origin of the formations—surficial, sedimentary, and igneous—and within each group they are placed in the order of age, so far as known, the youngest at the top.

Economic geology sheet.—This sheet represents the distribution of useful minerals, the occurrence of artesian water, or other facts of economic interest, showing their relations to the features of topography and to the geologic formations. All the formations which appear on the historical geology sheet are shown on this sheet 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 symbol for mines is introduced at each occurrence, accompanied by the name of the principal mineral mined or of the stone quarried.

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 name 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 the formation of rocks, and having traced out the relations among beds on the surface, he can infer their relative positions after they pass beneath the surface, draw sections which represent the structure of the earth to a considerable depth, and construct a diagram exhibiting 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:

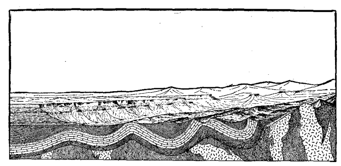


Fig. 2.—Sketch showing a vertical section in the front of the picture, with a landscape beyond.

The figure represents a landscape which is cut off sharply in the foreground by a vertical plane, so as to show the underground relations of the rocks.

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

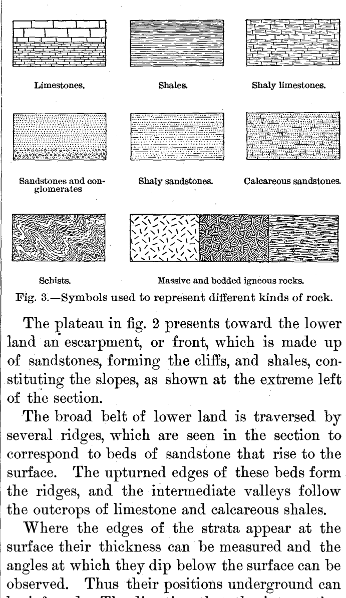


Fig. 3.—Symbols used to represent different kinds of rock.

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 beds of sandstone that rise to the surface. The upturned edges of these beds form the ridges, and the intermediate valleys follow the outcrops of limestone and calcareous shales.

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*.

When strata which are thus inclined are traced underground in mining, or by inference, it is frequently observed that they form troughs or arches, such as the section shows. 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 regarded as proof that forces exist which 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 slipped past one another. Such breaks are termed *faults*.

On the right of the sketch 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.

In fig. 2 there are three sets of formations, distinguished by their underground relations. The first of these, seen at the left of the section, is the 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 swelled upward 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 strata thus rest upon an eroded surface of older strata 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 this pressure and intrusion of igneous rocks have not affected the overlying strata of the second set. Thus it is evident that an interval of considerable duration 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, marking a time interval between two periods of rock formation, is another unconformity.

The section and landscape in fig. 2 are ideal, but they illustrate relations which actually occur. The sections in the structure-section sheet are related to the maps as the section in the figure is related to the landscape. The profiles of the surface in the section correspond 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 rock formations which occur in the quadrangle. It presents a summary of the facts relating to the character of the rocks, the thicknesses of the formations, and the order of accumulation of successive deposits.

The rocks are described under the corresponding heading, and their characters are indicated in the columnar diagrams by appropriate symbols. The thicknesses of formations are given in figures which state the least and greatest measurements. The average thickness of each formation 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 is placed at the bottom of the column, the youngest at the top, and igneous rocks or surficial deposits, when present, are indicated in their proper relations.

The formations are combined into systems which correspond with the periods of geologic history. Thus the ages of the rocks are shown, and also the total thickness of each system.

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

CHARLES D. WALCOTT,
Director.

Revised January, 1902.

DESCRIPTION OF THE SCOTTS BLUFF QUADRANGLE.

By N. H. Darton.

GEOGRAPHY

Position and extent.—The Scotts Bluff quadrangle embraces the quarter of a square degree which lies between parallels 41° 30′ and 42° north latitude and meridians 103° 30′ and 104° west longitude. It measures nearly 34.5 miles from north to south and about 25.8 miles from east to west, and has an area of about 892 square miles. It includes the greater part of Scotts Bluff County and the northwestern and north-central part of Banner County, Nebraska, and lies entirely within the broad valley of North Platte River, which traverses its northern half from west-northwest to east-southeast.

Relation to Great Plains.—The region is a portion of the Great Plains, which in general present wide tabular surfaces sloping eastward, with isolated buttes and outlying ridges, and with shallow river valleys margined by irregular and often deeply incised slopes. The topographic features, however, vary considerably, and it is difficult to make concise statements that will apply to the entire province.

The plains are due partly to extensive erosion to a uniform slope, but they also owe much of their flatness to the great sheets of sedimentary deposits which have been spread over them. In western Nebraska they rise to altitudes of from 5000 to 5300 feet. They are traversed by the broad valleys of the North Platte, South Platte, and Republican rivers, and are cut away around the Black Hills uplift by White River and by the South Fork of Cheyenne River in South Dakota. Their northern edge in northwestern Nebraska is a high escarpment known as Pine Ridge, at the foot of which lies the wide valley extending across to the southern margin of the Black Hills. In this region they are built up largely by wide-spread Tertiary deposits, which were laid down on a relatively irregular floor of Cretaceous formations. These deposits cover nearly all of western Nebraska and extend across eastern Wyoming to the foot of the Rocky Mountains and through western Kansas, far to the south. In valleys cut through these deposits in Pleistocene time the Cretaceous rocks are bared, especially the wide depression adjoining the Black Hills. Alluvial formations of moderate extent are spread over the valley bottoms. The smooth, tabular divides of the Plains in central-northwestern Nebraska are covered for thousands of square miles by vast accumulations of sands, which were derived largely from the loosely bedded sandy members of the Tertiary formations, which, being spread by wind, formed sand dunes. It is possible also that a portion of the sand-hill area was originally occupied by earlier Pleistocene sands constituting a portion of the *Equus* beds, as the *Equus* fauna is found in this region.

Local topographic features.—In the Scotts Bluff quadrangle few of the typical features of the Great Plains remain, the North Platte and its branches having eroded wide areas to a depth of several hundred feet, as may be seen along the southern margin of the quadrangle, where, facing northward, is the eroded margin of the original high plain, which thence extends far southward. A remnant of the High Plains, completely isolated by erosion, constitutes the narrow summit of the prominent ridge between Pumpkin and North Platte valleys. Other remnants are found on the summits of the buttes west of Scotts Bluff. The valley of North Platte River lies from 900 to 1200 feet below the average level of the adjoining uplands, which in general rise to the west, toward the mountains, and to the southwest, away from the river valley. The altitude of the river at the eastern margin of the quadrangle is 3818 feet and at its western margin 4010 feet, the fall being nearly 7 feet to the mile. Along the river is a low, level plain having a width of from 1 to 2 miles on either side of the stream and extending on the north to a low but distinct escarpment rising about 40 feet to a wider, higher terrace, which slopes gradually upward to the hills 2 or 3 miles beyond. On the south side of the river the bottom is more irregularly distributed and varies considerably in width. There is very little of the higher terrace, on account of the nearness of the hill slopes, which at Scotts Bluff rise abruptly from the river bank. In Mitchell Bottom the river flat expands to a width of 2 miles for some distance, but it narrows again northwest of Mitchell. The river shows a marked disposition to cut toward the southern and southwestern side of the valley.

A line of high buttes, cut off on the south by a branch of Cedar Canyon Creek, terminates in Scotts Bluff, which rises about a half mile back from the river out of a terrace of moderate height cut up into intricate "badlands." The bluff and associated features are very prominent and form a conspicuous landmark for many miles along the river, some aspects of which are shown in figs. 18, 19, 21, and 23 of the Illustration sheet. Scotts Bluff reaches an altitude of 4662 feet, which is about 800 feet higher than the river at its foot. It is level topped for a short distance and then slopes rapidly southward into Mitchell Pass, which has an altitude of 4200 feet. Dome Rock and the line of buttes to the west, between which are low passes, are the remnants of a high ridge. Next south is the elevated divide extending eastward from Signal Butte to beyond the eastern margin of the quadrangle, and separating North Platte Valley from Pumpkin Creek Valley. The central axis of this ridge is parallel to the North Platte and is relatively straight. On the higher summits in its western portion this divide has an altitude of nearly 4850 feet; to the east it declines to about 4500 feet. On a branch ridge to the south are Hogback and Wildcat mountains, which are 5082 and 5038 feet high respectively. The main ridge is deeply incised by steep-sided canyons and is characterized by precipitous walls surmounting slopes which rise gently from the adjoining valleys. The high promontories lying between these canyons are of irregular contour and present a great variety of striking scenery, some features of which are shown in figs. 18 and 19 on the Illustration sheet.

The broad valley of Pumpkin Creek occupies a large area south of the ridge above described. The creek is a small one, with many branches heading in the adjacent slopes. It heads in a wide depression near longitude 104° which extends to the west and northwest through low saddles to the valleys of Horse Creek and North Platte River, and it is apparent that Horse Creek at one time passed over the southernmost of these saddles and down Pumpkin Creek Valley. Long slopes extend southward from Pumpkin Creek to the base of a steep escarpment that rises to the level of the High Plains and is deeply incised by numerous canyons at the heads of branches of Pumpkin Creek. This escarpment averages about 300 feet in height and the altitude of the plain at its top increases gradually from 4740 feet in the southeastern corner of the quadrangle to 5285 feet in the southwestern corner—about 20 feet to the mile, a rate nearly three times as great as that of the Platte Valley. The High Plains are very smooth in contour, but their greater portion lies south of the quadrangle, extending for many miles to the valley of Lodgepole Creek, in the southern part of the State.

The region lying beyond the terraces north of North Platte River is a slope extending to the foot of a high plateau, which is capped by sand hills north of the quadrangle and is traversed by the valleys of Winter Canyon, Spottedtail Creek, and Sheep Creek, and surmounted by a number of low gravel-capped ridges of moderate elevation.

Surface waters.—North Platte River is a flowing stream which occupies a bed averaging a half mile in width, and covers it to a depth of several feet for a portion of the late spring and early summer, but dwindles in the later summer until there are only a few shallow channels among sand banks.

For several years a gaging station was maintained by the United States Geological Survey at Gering, where daily readings were made of the river heights from April to October, and from these the volume of flow is calculated. The averages since June, 1897, are as follows:

Estimated discharge of North Platte River at Gering, Nebr., 1897 to 1900.

Month.	Maximum.		Minimum.		Mean, 1897–1900.
	Year.	Sec.-feet.	Year.	Sec.-feet.	Sec.-feet.
April	1899	14,080	1898	1,000	3,046
May	1898	18,500	1898	3,400	11,215
June	1899	23,500	1900	5,400	11,914
July	1899	18,000	1898	500	4,425
August	1899	5,200	1898	100	1,237
September	1899	13,000	1898	50	466
October	1899	23,000	1898	100	670

As a large volume of water is taken out of the river at intervals by the various irrigation canals in Nebraska and Wyoming, the records of flow at the gaging station do not indicate the total volume of water which flows down the valley. It should be borne in mind also that under the bed of the river there is a considerable thickness of coarse sand which contains an underflow of greater volume than that flowing over the surface in the long period of dry weather.

The valleys emptying into the river from the north are mostly dry in summer, except the so-called Winter Springs, which flow for a few miles to one of the irrigation canals.

Pumpkin Creek, which is at best of small and variable volume, contains water only east of the center of Banner Township. It receives no flowing branches at the surface, although possibly there is some underground seepage from tributary ravines, many of which receive more or less spring water at various points. Nearly all the canyons along the southern margin of this quadrangle contain springs of considerable size, but the water from them flows only a few rods and sinks into the alluvial deposits in the valleys.

Horse Creek is a flowing stream when its waters are not diverted into irrigation ditches; it empties into North Platte River 2 miles north of Caldwell.

Timber.—This region contains but little timber, but there is a sufficient supply for local use. On the ridge north of the Pumpkin Valley and on the slopes rising to the high table in the southern margin of the quadrangle there remains a scattered growth of pine. This tree is the Rocky Mountain pine (*Pinus ponderosa*), and it attains a diameter of from 1 to 2 feet where the conditions are most favorable. A moderate number of young pine trees start at some localities on the ridges, but few of them attain maturity. The zone of cottonwoods, so characteristic of most western streams, is absent along North Platte River, and there are only occasional small trees and bushes; but the valley of Pumpkin Creek contains scattered cottonwoods. The principal deciduous growths are found in some of the ravines, where they comprise cottonwood, box elder, wild plum, and a few other varieties.

Climate.—Western Nebraska has a climate of typical Plains character. It is dry and hot in summer, moderately moist in late spring, and cold with a little snow in winter. There is considerable variability in climatic features from year to year, more than is found farther south or north, and some local variations from point to point, particularly in rainfall. The following table gives average monthly rainfall from 1886 to 1897,

Table of average rainfall in western Nebraska, 1886 to 1897.

[In inches.]

Month.	1886.	1887.	1888.	1889.	1890.	1891.	1892.	1893.	1894.	1895.	1896.	1897.
January	0.50	1.33	1.06	1.00	0.63	1.42	1.29	1.19	1.10	1.00	1.00	1.70
February	1.00	1.50	1.33	1.00	1.00	1.17	1.08	1.20	1.25	1.25	1.00	1.35
March	1.00	1.00	1.33	1.33	1.25	1.66	1.00	1.50	1.25	1.75	2.20	2.00
April	1.33	2.00	1.25	2.33	2.25	1.66	4.00	1.40	3.00	2.00	2.00	1.80
May	1.92	3.66	5.50	2.66	2.00	3.00	3.60	1.25	2.40	2.50	3.00	3.20
June	2.58	2.00	2.75	3.00	2.00	3.30	5.30	1.75	2.66	3.80	3.95	2.40
July	3.00	2.66	2.50	2.75	2.50	3.33	1.75	1.20	2.33	1.80	2.40	3.50
August	2.17	3.33	2.25	2.40	1.79	2.00	2.00	1.80	1.33	1.00	1.60	2.60
September	1.33	2.67	0.50	1.00	0.75	1.50	1.25	1.00	1.25	1.20	2.20	1.25
October	1.25	5.00	1.00	1.50	1.00	0.83	4.00	1.33	1.50	0.80	1.00	1.25
November	2.33	2.00	1.00	0.80	1.50	1.17	1.00	1.25	1.00	1.00	1.00	1.20
December	1.33	1.00	0.94	1.19	1.00	1.16	1.00	1.00	1.12	0.90	0.50	1.40

calculated from observations made at Kimball, Fort Sidney, Alliance, Gering, Fort Robinson, and Hay Springs, Nebr.

GEOLOGY.

STRATIGRAPHY.

The formations appearing at the surface in the Scotts Bluff quadrangle are clays, sands, soft sandstones, conglomerates, calcareous grits, limestones, volcanic ash, loams, and mixtures of sand and gravel. They are all sedimentary deposits—that is, they were laid down in water—except a few sand dunes heaped up by the winds. In greater part these deposits are in sheets lying one above another and having a general downward slope to the east. Valleys having been eroded through or into these formations, their contacts are exposed

Table of geologic formations in the Scotts Bluff quadrangle.

Age.		Name.	Predominant characters.	Thickness.
				Feet.
Pleistocene		Dune sand	Loose, light-gray sand	0–40
		Alluvium	Gravel and sand	40
		Upland gravels, loam, and sand	Sand and loam, pebbly in places	20–60
Neocene	Pliocene ?	Ogallala formation	Calcareous grit, sandy clay, and conglomerate	0–100
	Miocene	Arikaree formation	Gray sand with beds of pipy concretions; contains much volcanic ash and several old channels filled with conglomerate	100–470
		Gering formation	Coarse sand, soft sandstone, and conglomerate	0–200
Eocene	Oligocene	Brule clay	Pinkish clay, hard, massive, and more or less arenaceous, with local sandstone lenses near bottom	500+
		Chadron formation	Gray sand and sandstone, and sandy clay	70+

with more or less sinuous and complex outlines, but the order of superposition is simple. In the valleys there are thin sheets of materials recently brought down by the streams and spread over the eroded surface of the older formations. The sand dunes are mainly of very local extent. The formations are of relatively modern age, geologically, the earliest being Oligocene. The accompanying table is a list of the formations in the order of their age, with a brief statement of their general character and thickness.

It will be seen that the most extensive formation in the section (fig. 1) is the Brule clay, which is several hundred feet thick. This lies on the Chadron formation, the exact thickness of which in this region is not known, but it is somewhat over 70 feet. Doubtless all or part of the quadrangle is underlain by the Laramie formation, which rises to the surface a short distance west of it. Lying on the Brule clay and separated from it by unconformity is a lens-shaped mass of sands and soft sandstones, termed the Gering formation, which is most extensively developed in the high ridge lying between Pumpkin Creek and the North Platte River. Next above comes the Arikaree formation, which constitutes the greater part of the same high ridge. This formation is thinner to the south and southeast, where it is exposed in the face of the escarpment of the High Plains along the southern margin of the quadrangle. These plains are capped by the Ogallala formation, which also caps a few high points north of Pumpkin Valley, including Wildcat and Hogback mountains. The Pleistocene deposits in the larger valleys lie on the bottoms and terraces. The deposits on the higher terraces are coarser, and the more recent deposits along the streams are fine silts or sands and loams. On most of the slopes are talus deposits of varying thickness and of recent origin.

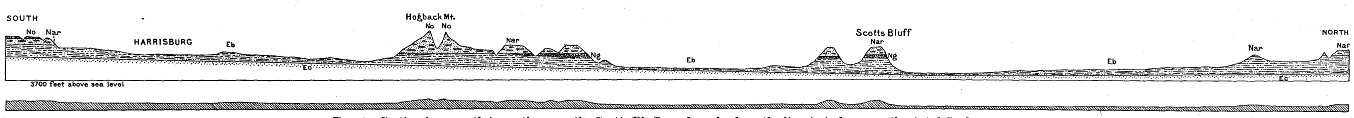


FIG. 1.—Section from north to south across the Scotts Bluff quadrangle along the line A–A shown on the Areal Geology map.

No, Ogallala formation; Nar, Arikaree formation; Ng, Gering formation; Eb, Brule clay; Ec, Chadron formation.

Horizontal scale, 1 inch = 3 miles; vertical scale, 1 inch = 3000 feet, approximately. Natural profile is shown in shaded drawing below section.

EOCENE PERIOD.

OLIGOCENE EPOCH.

Chadron formation.—The Chadron formation underlies the Platte Valley above Scotts Bluff, but it is extensively covered by alluvium, above which it rises for a short distance northwest of Mitchell, south of the river. It consists of greenish-gray and reddish sandstones, with greenish-pink and maroon sandy clays. It contains bones and teeth of *Titanotherium*, which have been found in exposures along the Mitchell canal northwest of Mitchell. The lowest outcrop of the formation in this district is in a small blowout, a hollow swept out by wind, a mile and a quarter north-northwest of Mitchell, on the south side of the river, where the material is a light-pink, sandy clay, with faint tints of green. In a hill a half-mile southeast are some higher beds of the same character rising above the surrounding alluvial plain. Farther west the formation is seen in the cuts of the Mitchell canal and on the slopes immediately adjoining. The total thickness exhibited is about 60 feet, limited below by overlap of alluvium and above by the Brule clay. In the northern part of sec. 36, T. 23 N., R. 57 W., and sec. 31, T. 23 N., R. 56 W., the cuts for the canal expose pale greenish-gray sandstone 12 to 15 feet thick. The succession of beds at the east line of range 57 is as follows:

Section at east line of range 57.

	Feet.
Pink and green clay	12
Greenish sandstone and pink clay	6
Greenish sandstone, iron stains	4
Pink and greenish clay	1
Greenish cross-bedded sandstone	6
Greenish clay, iron stains	15
Greenish sandstone and clay	6
Green clay	5

The stratigraphy varies considerably in this region, but the sandstone is a conspicuous feature throughout, and it was found to contain remains of *Titanotherium* at many points, while in the pink clays of the Brule formation a short distance higher up the slope were found bones and teeth of *Merycoidodon* and *Poëbrotherium*. In sec. 35, T. 23 N., R. 57 W., there is a low knoll north of the canal consisting of green and maroon sandy clays of the Chadron formation, which are exposed also at intervals to the west line of the section, where they contain lenses of sandstone.

Brule clay.—Nearly the entire area of the Scotts Bluff quadrangle is underlain by clays of the Brule formation, which extends widely under western Nebraska and adjoining regions. In its typical development it is a pale-buff or flesh-colored sandy clay of compact texture and massive structure, and is often locally called "hardpan." In exceptional cases the formation is slightly more sandy than usual, and locally it contains beds of sand or sandstone and near its base a thin layer of limestone. There are extensive exposures of Brule clay in the northern face of Scotts Bluff, where, from the base of the overlying Gering beds to the river, there is a vertical interval of 500 feet of continuous outcrop, and the formation has a small additional thickness below the level of the river. The appearance of this exposure is shown in figs. 18, 19, 21 and 23 of the Illustration sheet. The badland topography is a characteristic feature of most exposures of the Brule clay, and is extensively developed in the area at the foot of Scotts Bluff. The massive structure of the formation gives it the necessary solidity to preserve details of configuration, its softness permits of ready carving by the rain and rivulets, and the slight variations in hardness of its beds give rise to unequal slopes. The formation is exhibited extensively along the lower slopes of the ridges, canyons, and buttes of the elevated region lying between the North Platte and Pumpkin valleys, and again in the base of the escarpment which rises to the high plains along the southern margin of the quadrangle. It is also seen, but to much less extent, on the slopes lying behind the higher terraces north of North Platte River.

The basal portion of the Brule formation locally includes a thin bed of limestone and some irregular masses of sandstone, all of which are seen along the Platte River above Scotts Bluff and in the slopes on the east side of Cedar Valley. Probably they underlie the alluvium at Mitchell Bottom and elsewhere along the river and are at no great distance beneath the base of Scotts Bluff. The greatest developments of the limestone are seen near Caldwell, near Sunflower, south of Gering, and northwest of Larissa. It is a very thin bed of compact, cream-colored rock lying on a series of pinkish and greenish clays. In the vicinity of Caldwell the first outcrops are seen in sec. 32, T. 23 N., R. 57 W., where the limestone is from 6 inches to a foot thick, and caps some low hills lying north of the Mitchell canal, with only a small portion of the underlying pinkish clay exposed beneath it. Occurring at intervals to the west for several miles, it is seen on the slopes above Kiowa Creek, where the section consists of 15 inches of limestone on 15 feet of greenish and pinkish sandy clays, underlain by 5 feet of nearly pure volcanic ash. At the base are a few feet of greenish clays which may belong to the Chadron formation. In the terrace slope just north of Sunflower there are exposures of the limestone, 20 to 22 inches thick, for a short distance. At one point a higher layer, 2 inches thick, is separated from the thicker layer by 2 feet of green and pink clay. Under the 20-inch bed there are 25 feet of pink and green clays, which are further exposed at intervals along the low bluffs west to beyond the margin of the quadrangle, where they are seen to be underlain by sandstones of the Chadron formation. No fossils were found in the clays below the limestone in this part of the Platte Valley, but from the evidence of bones found in apparently the same beds south of Gering, they belong to the Brule formation. Some bone fragments found in the limestone just north of Sunflower are too fragmentary for precise determination. The lower members of the Brule formation lying on the Chadron formation northwest of Mitchell are pink clays without the limestone layer, and some distance above there are several thin beds of sandstone and some layers of greenish and reddish clay resembling Chadron deposits in some respects, but containing bones of later age. There is some unconformity by erosion at the base of the formation. A limestone similar to the one at Sunflower and Caldwell, associated with similar beds of clay, makes its appearance in the lower parts of the canyons south of Gering and is seen at intervals to the east and northeast to the north slope of the 4100-foot hill southwest of Larissa. Above are alternations of typical Brule clays with thin beds of soft sandstones for some distance, and below are the pinkish and greenish clays which in the region due south of Gering are underlain by a mass of conglomeratic sandstone, lying on pink clays of typical Brule character, which at one point in the lowest horizon exposed include a thin bed of gray sandstone. In all these beds were found bones which indicate that they belong to the Brule formation. The sandstones first make their appearance in a ravine in the southwest corner of Gering Township, and outcrop conspicuously farther east, interbedded with pink clay of typical Brule character, but their thickness and stratigraphic relations vary considerably, and they occur both above and below the thin layer of limestone. The most extensive exposures of the lower sandstone are in ravines and slopes 6 miles due south of Gering, as shown in part in fig. 22 of the Illustration sheet. This view represents a lens of coarse conglomeratic sandstone 25 feet thick, containing clay fragments and pebbles of feldspar and granite, cross bedded, and lying on an irregular surface of typical Brule clay. Next above are 12 feet of greenish and pinkish clays and then a 4-inch layer of compact cream-colored limestone, followed by 80 feet of pink clays, a layer of sandstone 15 to 20 feet thick, and pink clays extending to the base of the Gering formation, a thickness in all of about 200 feet from the limestone to the base of the Gering formation. The sandstone caps the 4100-foot knoll in sec. 26, T. 21 N., R. 55 W., as an outlier. It is a hard gray rock which has proved useful for building. In the hollow to the east are 100 feet of pink clay containing a 6-foot layer of sandstone near its lower part. Remains of animals found in the lower clays are typical of the Brule clay. The sandstones are again seen in limited exposures to the northeast. At a point 2 miles due northwest of Larissa ledges of limestone are seen, the bed being about 4 inches thick. Eighty feet lower down the slope there are many fragments of limestone which suggest another horizon of the rock. The intervening pink clay contains a 15-foot and a 6-foot bed of soft gray sandstone. On the north end of the next ridge, at a point about 3½ miles northwest of Larissa, the limestone is seen again, giving rise to a small shelf at an altitude of about 4070 feet. Its thickness is from 6 to 10 inches and it thins out in some places. As in the other localities, it is underlain by pinkish and greenish clays and overlain by more massive pink clays, with a 3-foot layer of soft gray sandstone capping the 4100-foot summit. The 12 to 15-foot pinkish and greenish clay series, which is always found underlying the limestone, can be traced for 6 or 8 miles along the east slopes of Cedar Valley, but the limestone occurs in discontinuous lenses.

The limestone south and southeast of Gering is only about 200 feet below the Gering formation, which is much less than in the region farther west. This suggests that it may be at a higher horizon, but the relations may result from greater local uplift and erosion of the Brule formation in this vicinity prior to the deposition of the Gering formation. As the limestone in this vicinity has a stronger dip to the northwest than usual the latter suggestion is not without evidence to support it. The rate of rise from the direction of Scotts Bluff is also relatively rapid, for in Scotts Bluff 500 feet of Brule clays are exhibited in the steep slopes from the water's edge to the Gering contact. If the limestone here is at the same horizon as that of Sunflower and Caldwell the underlying series is here much thicker, for the clays and sandstones exposed below the limestone south of Gering have a thickness of about 140 feet without exhibiting the Chadron formation.

Beds of volcanic ash occur in the Brule clay, some of them of wide extent and apparently at constant horizons. One which is conspicuous in many outcrops lies from 60 to 70 feet below the top of the formation in the district south and southeast of Gering, and about 150 feet below at Scotts Bluff, a position which it preserves to the west end of the ridge north of Roubedeau Township. It varies in thickness from 6 to 12 feet, is often nearly pure, and its white color and sharp-edged glittering flakes are distinctive features. It merges into the pink sandy clay. In Scotts Bluff and vicinity another bed of volcanic ash occurs about 110 feet below the upper one. It is thinner and usually more intermixed with the pink clay. On the flanks of Funnel Rock it is 140 feet below the upper bed, has a thickness of 3 to 4 feet, and consists of about equal parts of silt and volcanic ash. Under the microscope the volcanic ash is seen to consist of very small, thin flakes and shreds of glassy volcanic rock, mostly sharp edged and angular in outline. It was ejected apparently at several periods from volcanoes, probably in the Rocky Mountain region, carried far by the wind, and deposited in the water where the Brule clays were being laid down. It is possible, however, that, in whole or part, it may have been brought by streams from some distance and deposited like the other sediments.

The thickness of Brule clay presented in Scotts Bluff, 500 feet, appears to be maintained throughout the region to the south and east without exhibiting the basal beds. To the west, where the Chadron formation rises, there is a vertical interval of 550 feet or more between the top of the Chadron and the base of the Gering without evidence of much dip in the long intervening land slopes. Ascending the Platte Valley the formation rises at a rate of about 20 feet to the mile, but the rise is much greater to the southwest.

Fossil bones of various mammals and turtles characteristic of the Oligocene occur in the Brule clay. The principal species collected were *Merycoidodon gracilis*, *M. culbertsonii*, *Palæolagus haydeni*, *Cynodictis gregarius*, *Poëbrotherium wilsoni*, *Elotherium mortoni*, *Hyracodon nebraskensis*, *Leptomeryx evansi*, *Miohippus bairdi*, *Cænopus occidentalis*, and *Stylemys*. These forms were determined by F. A. Lucas of the National Museum.

NEOCENE PERIOD.

Gering formation.—Overlying the Brule clay in a portion of the quadrangle there are coarse sands and soft sandstones which have been designated the Gering formation. It has been recognized only in the ridge lying between North Platte River and Pumpkin Creek, where it appears to be the deposit of an early Miocene predecessor of North Platte River in a channel cut in the Brule clay. Its average thickness is about 100 feet, but locally it reaches 200 feet; and away from the central portion of the area it appears to thin out entirely. It has not been recognized north of the North Platte or in the base of the escarpment south of Pumpkin Creek Valley. It is separated from the Brule clay by a distinct erosional unconformity, but appears to merge upward into the Arikaree formation through a few feet of passage beds.

The greatest development of the Gering formation is in the high bluff 6 miles south-southwest of Gering, in the northwest corner of T. 20 N., R. 55 W., where there are several members having an aggregate thickness of 200 feet. The features of the section at this locality are shown in fig. 8 of the Columnar Section sheet. There are four beds of sands or soft sandstones, some of them containing considerable clay admixture and others carrying numerous pebbles, separated by slight but distinct erosional unconformities. One of the beds contains a 4-foot bed of white, nearly pure volcanic ash in coarse vesicular flakes, which extends along the bluff for about a quarter-mile. At the top of the Gering deposits there is an abrupt change to Arikaree beds, without unconformity, whereas at the base the unconformity with Brule clay is a strong one, showing considerable shallow channeling.

A mile south of the exposure shown in fig. 8 the Gering beds have the character and relations illustrated in fig. 9, which shows the manner in which the deposit thins to the southward. At this locality the Gering formation may have a thickness of only 40 feet, extending up to an altitude of 4480 feet, where there is a marked unconformity, but it is probable that the overlying dark-gray sand, with thin streaks of conglomerate, should be included in the formation. This upper member merges rapidly into typical Arikaree formation. A layer of nearly pure volcanic ash, 6 inches thick, occurs at an altitude of 4500 feet.

East of the exposures shown in figs. 8 and 9 the formation presents many variations in composition and thickness. In bluffs 7 miles due south of Gering there is seen the section shown in fig. 10. The formation consists mainly of sandy clay, with intercalated sandy streaks and a basal conglomerate lying unconformably on Brule clay, with an intervening bed of pure volcanic ash, 2 feet thick at several points.

In the high butte south of west of Larissa the formation apparently thins out northward, as shown in fig. 11 of the Columnar Section sheet. In this section the formation has a thickness of 25 feet in the south side of the butte, consisting of laminated sands or soft sandstones. On the north side there are pink clays of rather sandy nature, but apparently of the Brule formation, which appear to be immediately overlain by Arikaree beds without noticeable unconformity. In the ridge south of this point the formation presents the relations shown in fig. 12.

To the west, in a portion of this section, the typical Gering sandstones appear to become gradually finer grained, the basal unconformity becomes indistinct, and for some distance the formation, although undoubtedly continuous, is not sufficiently characteristic to be identified. Possibly the relations shown in fig. 11, and at many other places where the Gering formation appears to be absent, are due to a local change similar to the one just described.

The section shown in fig. 13 is about a half-mile east of the one shown in fig. 12. Here the Gering sands and sandstones have a thickness of 130 feet, with an erosional unconformity in the center. The basal beds lying unconformably on the Brule clay are cross-bedded conglomerates and soft sandstones, with clay pebbles and a thin, discontinuous layer of nearly pure, fine-grained volcanic ash. The second unconformity is 50 feet above the first, at the base of laminated soft sandstones with some massive beds and considerable cross bedding and pebbly admixture in its basal portion. Some of the pebbles are of pink clay. The top member is coarse sandstone with streaks of conglomerate, about 20 feet thick, overlain by typical Arikaree beds, which begin abruptly.

In the high bluff 3 miles due south of Larissa the Gering formation presents the components shown in fig. 14 of the Columnar Section sheet. The formation is here 120 feet thick and consists of two members separated by unconformity. Both members are conglomeratic toward the base, and the lower one contains a 2½-foot bed of nearly pure volcanic ash.

At Castle Rock, 4 miles to the southeast, the Gering formation is difficult to separate, unless it is represented by the pinkish sandy clays lying next below a thin bed of white clay at the base of the Arikaree beds (fig. 16). In the ridge north and along the slopes west of Castle Rock the formation is more distinct, as is shown in fig. 15. Here, below the thin white clay bed shown in fig. 16, there are 65 feet of stratified sands and soft sandstones, with a thin bed of volcanic ash 30 feet above the pronounced unconformity at the base of the formation.

In the region northeast and north of Ashford the formation is usually well characterized, but in the ridge extending northwest from Funnel Rock it is either absent or not distinguishable. It begins to be conspicuous again northeast of Dorrington, extending along the foot of the ridge for about 4 miles, but not attaining a thickness of more than 60 feet. Fig. 3 shows typical features of the formation in this region.

In Signal Butte and adjoining slopes it is about 30 feet thick. At Signal Butte the relations are as shown in fig. 2. The formation is thin in the Roubedeau Pass region and to the east. In the bluff at the north side of the mouth of Cedar Canyon are found the relations shown in fig. 5. Farther up Cedar Canyon the formation is thicker and more characteristic, as shown in fig. 4.

On the south side of the ridge extending eastward from Roubedeau Pass to Scotts Bluff the Gering formation appears to thin out or to lose its distinctiveness (see fig. 6), but on the north side, although it is thin, it is well defined. It extends to Dome Rock, where it underlies a small cap of Arikaree, and it is an obvious feature in Scotts Bluff, as is shown in fig. 7. A view showing the relations in Scotts Bluff is reproduced in fig. 18, on the Illustration sheet. In the bluff the formation presents very strong erosional unconformity on the Brule clay at an altitude of 4380 feet, and is well defined at its upper limit of 4440 feet. A bed of volcanic ash occurs near its base.

The Gering formation contains fossil bones of animals of various kinds, and although they are not numerous they were obtained at many localities. They afford a base for definitely fixing the age of the formation as earliest Miocene. The species collected comprise *Deinictis major*, *Merycochoerus rusticus*, *Leptauchenia decora*, *L. nitida*, *Aceratherium platycephalum* and rhinoceros, according to determination by F. A. Lucas of the National Museum.

Arikaree formation.—The Arikaree formation caps the high ridges lying between the North Platte and Pumpkin Creek valleys and the higher buttes adjoining the upper portion of Winter Canyon. It underlies the Ogallala deposits in the high plateau along the southern margin of the quadrangle. It consists mainly of fine sands characterized by included layers of hard, fine-grained, dark-gray concretions usually consisting of long, irregular, cylindrical, pipe-shaped masses joined side by side. These for convenience have been called "pipy concretions." They vary in thickness from a few inches to several feet, but from 10 to 15 inches is a fair average. Their trend is east-northeast and west-southwest, with most surprising regularity. The layers are often many yards in area. Local lenses of coarse conglomerate and layers and admixtures of volcanic ash are the other components of the Arikaree deposits. The sands of the Arikaree formation are loose or moderately compact; some are argillaceous; and their color is uniformly light gray. Owing to the presence of the hard concretions, the formation generally gives rise to ridges of considerable prominence, with steep slopes and high walls. These rise above the Gering deposits in the greater part of the ridge lying between the North Platte and Pumpkin Creek valleys, but elsewhere they lie immediately above the Brule clay. Usually there is an abrupt change in the character of the materials as the coarse beds of the Gering formation give place to the fine, massive Arikaree sand containing pipy concretions. There is a possibility that the Gering formation is a basal portion of the Arikaree formation deposited along the course of the channel of a stream or stronger current of the earlier part of the Arikaree epoch. In the areas in which the Arikaree formation appears to lie directly on the Brule clay there is usually only a faint suggestion of erosional unconformity between the two formations, or simply a rapid change from sandy, pinkish Brule clay, with some small concretions, to fine gray sands with the typical character and pipy concretions of the Arikaree formation. Many of the relations are shown in figs. 2 to 16. The Arikaree formation has a thickness of 500 feet on Hogback and Wildcat mountains, where it is capped by the Ogallala formation, but the average thickness remaining in the ridge north is seldom over 250 feet, as its surface has been more or less eroded. In the escarpment of the High Plains near the southern margin of the quadrangle the formation has a thickness of about 100 feet to the east and gradually increases to 200 feet to the west.

Volcanic ash is a general component of the Arikaree formation, mainly as an admixture with the sand, but also as beds of varying degrees of purity. These beds do not appear to lie at any regular horizons, but have different local relations. Some of the beds are shown in figs. 7, 9, and 11, the thickest being a bed of pure ash 15 feet thick, shown in fig. 11. On the high ridge culminating in Wildcat Mountain there are several thin beds, and one of pure ash, 8 feet thick, lies 140 feet below the Ogallala grit. Considerable ash occurs in the last 20 feet of beds next below the Ogallala capping. In some of the high cliffs 7 miles due south of Gering 80 or 90 feet of massive Arikaree beds contain nearly 50 per cent of volcanic ash mixed with pure sand and clay, with diatoms and sponge spicules in some layers.

Conglomerate in the Arikaree formation occupies a narrow channel or channels on the high ridge south of the North Platte Valley. It lies from 50 to 100 feet above the base of the formation, but in places there are deeper channels extending down to and into the Gering. The greatest developments of the deposit are south of Larissa, where prominent ledges of the conglomerate extend for several miles along the escarpment of the ridge and along some of the canyon sides. Other exposures are found at intervals westward to beyond Cedar Canyon along the north face of the ridge, and an outlying mass outcrops near the western end of the ridge 3 miles southwest of Dorrington. Some of the relations of these conglomerates are shown in figs. 9, 14, 17, and 20. In fig. 14 are represented the salient features on the bluffs south of Larissa.

The conglomerate consists of pebbles and bowlders of gray sandstone, generally firmly cemented by siliceous matrix. Many of the bowlders are 6 and 8 inches in diameter, but the average size is considerably less than 6 inches.

The Arikaree formation contains numerous remains of the smaller forms of several species of *Dæmonelix* (a fossil plant), occasional fresh-water molluscan fossils, and several species of vertebrate remains which are regarded as Miocene in age.

Ogallala formation.—The Ogallala formation is the uppermost division of the Neocene deposits of this region. It extends northward a short distance into the Scotts Bluff quadrangle from southern Nebraska, where it covers the wide area of high plains lying south of Pumpkin Valley. It is also probably represented by a few thin masses capping the high summits of Wildcat and Hogback mountains. It rests on the Arikaree formation with some evidence of unconformity. The material is an impure calcareous grit or sand cemented by carbonate of lime. At its base there often are beds of conglomerate with pebbles consisting mainly of gray sandstone or limestone and throughout its mass are streaks of pebbly sand, thin ledges of sandstone, and scattered pebbles of crystalline rocks derived apparently from the Rocky Mountains. The harder calcareous beds are white or cream color, and outcrop in prominent cliffs, which are high and rugged along the northern edge of the high plains near the southern margin of the quadrangle. The thickness of the formation in the greater part of this section varies from 80 to 120 feet, its surface having been eroded to a considerable extent. The outlying masses on Wildcat Mountain and adjacent high points are massive calcareous grits of white color with intercalations of sand, and masses of white conglomerate with limestone pebbles at their base. The thickness at the summit of Wildcat Mountain is 30 feet, and the amount is about the same on the summit of Hogback Mountain. The Ogallala formation has not yet yielded any fossils of sufficiently distinctive character to indicate its age, but it is supposed to represent the early Pliocene.

PLEISTOCENE PERIOD.

Alluvial deposits.—The broad zone of bottom lands adjoining the North Platte River is covered with a thick sheet of alluvial materials deposited in relatively recent times by the river. The maximum depth of the deposit is not known, but it may be 70 or 80 feet in some places, judging by a few deep wells. The alluvium consists mainly of sandy loams with occasional masses of gravel and beds of clay, but, owing to the low level at which it lies, only its upper part is exposed, and the character of the deposits is ascertainable chiefly from well borings. On the north side of the river the bottom lands are from 1½ to 2 miles in width, except near Sunflower, where they are much narrower. The surface rises gradually to a low escarpment, which is surmounted by broad expanses of higher terraces, which are nearly level, and are covered by a mantle of alluvial gravel somewhat coarser than that which forms the bottom lands. The gravels consist mainly of rocks from the Rocky Mountains, comprising granites of many kinds, quartzites, chalcedonic veinstones, and a small variety of igneous rocks varying in size from coarse sands to moderately large bowlders. Still coarser deposits lie higher and farther back, capping low, narrow ridges or lines of knobs. The deposits vary in thickness from 20 to 40 feet and are cut through by Winter Canyon and Sheep Creek. South of North Platte River there are low flats which have a width of 2 miles in Mitchell Bottom, but are narrow elsewhere, for the river has a tendency to hug its southern bank. South of the river, mainly between Mitchell and Caldwell, there are a few small areas of higher terrace capped by coarse sand and gravel. The badlands at the foot of Scotts Bluff are cut out of a small, sloping terrace, but one which did not receive a great amount of gravel at the period of high-level deposition. The terraces at this locality are shown in figs. 19 and 21 on the Illustration sheet.

There are alluvial deposits at low levels along Pumpkin Creek Valley, but they are narrow and thin. On the higher slopes lying farther south, extending to the foot of the escarpment of the High Plains, there are extensive deposits of coarse alluvial material representing the same period of deposition as the mantle on the higher terraces north of North Platte River. They lie on an irregular surface and their continuity is broken somewhat by the extensive later erosion of the many streams and draws which run northward out of the highlands. The deposits are coarse sands and gravels, containing a great variety of crystalline rocks and veinstones from the Rocky Mountains.

All of the smaller valleys in the quadrangle contain alluvial deposits or washes of greater or less extent and thickness, but only the larger of these are represented on the geologic map. There are also alluvial materials on the slopes, constituting wash and talus. These are often sufficiently thick to hide the underlying formations, but they are too variable in relations and thickness to be represented adequately on the map.

Sand dunes.—Sand dunes, an inconspicuous feature in the Scotts Bluff quadrangle, occur at intervals along the valleys of Pumpkin Creek and North Platte River. The largest area is a capping on the divide at the west end of the ridge northwest of Dorrington. Several dunes, from a half mile to 2 miles in length, extend along the south side of Platte River between Caldwell and Mitchell. The sands are of recent origin and in many places are still loose and travel before the wind. They have been derived mainly from the alluvial deposits along the valleys and are in no case more than a few feet thick. The dunes, which are built up against and over slight obstructions, usually lie with their longer diameters from northwest to southeast, as the prevailing stronger winds of the region are from the northwest.

PRE-EOCENE ROCKS.

Formations not outcropping in quadrangle.—There is a great thickness of sedimentary deposits underlying the formations which outcrop in the Scotts Bluff quadrangle. They lie in nearly level sheets and have a floor of granite or metamorphic rocks. The district is in the zone in which the formations change considerably between the mountains on the west and the Missouri and Mississippi valleys on the east, and there is, in consequence, some uncertainty as to the precise thickness and succession of some of the beds, but of the others the relations are more regular. The Chadron formation undoubtedly underlies the whole of the quadrangle, except at a few points in the western portion, where it abuts against the Laramie sandstone. It lies at no great distance below the bottom of North Platte Valley and Pumpkin Valley. The extent of the Laramie formation eastward is not known, but from its occurrence in the northeast corner of Colorado there is probability that it underlies all of the quadrangle, or at least the portion south of North Platte River. The thickness of the formation is not known, but probably it is not over 200 or 300 feet. There is no question that the quadrangle is underlain by the next succeeding formation, the Pierre shale, for the formation is known to underlie all of western Nebraska, northwestern Kansas, eastern Colorado and Wyoming, and the greater part of the Dakotas. It is about a thousand feet thick, and consists throughout of a dark clay or soft shale, with occasional harder shale layers and thin beds of iron pyrite. Owing to its plasticity it is extremely difficult to penetrate in well-boring operations. It is underlain by 200 feet of light blue-gray chalk rock and limy shale, known as the Niobrara formation. This is succeeded by a series of shales, probably considerably over 500 feet thick, of the Benton formation, which has in its middle a thin but persistent series of limestones containing large numbers of a characteristic shell known as *Inoceramus labiatus*. Next below is the Dakota sandstone and possibly the underlying Lakota sandstone—several hundred feet of coarse gray to buff sandstones which carry water available for artesian wells. The depth of this sandstone in the North Platte Valley is probably about 2000 feet, but it may be considerably more. In eastern Nebraska the Dakota sandstone lies on Carboniferous limestone, but in the Black Hills and Rocky Mountains it is separated by clays and shales and a thick mass of Red Beds, and there is no evidence as to how far these intervening formations extend under western Nebraska. The Carboniferous limestones doubtless have a thickness of several hundred feet under the Scotts Bluff quadrangle, and are separated from granites or other old crystalline rocks by a sheet of sandstone of Cambrian age.

BRIEF GEOLOGIC HISTORY OF THE CENTRAL GREAT PLAINS REGION.

The sedimentary rocks of the Camp Clarke quadrangle, including those underground, afford a record of physical geography from Cambrian time to the present, but, owing to lack of knowledge of the relations of some of the deeply buried rocks, the geologic history of the region can not be outlined as completely as in the adjacent mountain regions where all the beds are uplifted and exposed at the surface. There were undoubtedly many marine submergences, and several periods of emergence in which the surface was sculptured by running waters, especially in the later epochs. The basal sedimentary member, the Cambrian sandstone, which is widespread in the United States and is brought to view in nearly every uplift, lies on and against granites and other old crystalline rocks. It marks one of the great events in North American geologic history, the wide expansion of an interior sea over the western-central region. Its first products were coarse deposits, gathered by the streams and waves and laid down on sea beaches, partly in shallow waters offshore and partly in estuaries. The later products of the submergence were finer grained and are now represented by the Cambrian shales and limestones. From the close of the Cambrian to early Carboniferous time the central region presents a scanty record, the Silurian and Devonian being absent or thin in the greater part of the uplifts to the west and north.

In early Carboniferous times there was widespread transgression of the ocean over the region, and there accumulated great deposits of carbonate of lime, represented by limestones many hundred feet thick. In the later portion of the period a gradual general uplift diminished the depth and extent of submergence, and coarser sediments began to appear. This epoch is represented by alternations of sandstones and limestones, sandy limestones, and red shales. In Permian times there was still further emergence, resulting in a shallow basin which extended across the western portion of the central Plains region and far to the northwest. In this basin there were laid down the great mass of red shales of the "Red Beds" with their extensive interbedded deposits of gypsum, products of an arid climate. The sandy clay of the gypsiferous Red Beds accumulated in thin layers to a thickness of 500 feet or more, as now represented by the formation, and it is so uniformly of a deep-red tint that this is undoubtedly the original color. This color is present not only throughout the extent of the formation, but through its entire thickness, with the exception of an occasional lighter colored bed, as is also shown by deep borings, and therefore is not due to later or surface oxidation. This deposition of red mud was interrupted from time to time by chemical precipitation of comparatively pure gypsum in beds ranging in thickness from a few inches to 30 feet, and often free from mechanical sediment. It is apparent that these beds are the products of evaporation while mechanical sedimentation was temporarily suspended, a condition indicative of greatly diminished rainfall; otherwise it is difficult to understand their nearly general purity. Whether this deposition of the Red Beds extended into or through Triassic times in the central Plains region is not known, but it is thought that the uplift to which they were due finally brought the region above the water at the close of the Permian, and that during most if not all of the Triassic there was no deposition and probably some slight erosion, during an epoch which extended well into Jurassic time.

In later Jurassic time there was a sea that covered the region in which the Laramie and Bighorn mountains and the Black Hills now rise, and doubtless extended for some distance over the northwest corner of Nebraska. The conditions varied somewhat from shallow to deep waters, but marine waters prevailed. The materials are nearly all fine grained and indicate waters without strong currents, except along some portions of the shores, where coarse sandstones were laid down, some of them of bright-red color, which probably derived their sediments from adjacent land surface of the Red Beds. Generally, however, clay was the first sediment, and it was followed by ripple-marked sandstone, evidently laid down in shallow water and probably the product of a time when sedimentation was in excess of subsidence, if not during an arrest of subsidence. The red color in the medial part of the Jurassic deposits in some districts may represent a transient return to arid conditions similar to those under which the gypsiferous Red Beds were laid down. The thick mass of shales with thin limestones which followed is indicative of deeper waters. After this stage there was widespread uplift, which, in the northern-central area, marked the beginning of Cretaceous time. There were fresh waters in which the principal deposit was the widespread clay of the Morrison formation, now extending from Montana to Oklahoma, where it gives place to marine sediments of the Lower Cretaceous. Probably the Morrison deposition extended over the western part of Nebraska, but its eastern margin is not located. It was succeeded by a period of shallower waters with shore conditions and strong currents, marked by the coarse sands of the Lakota formation in the region of the Black Hills and to the northwestward; and later, under similar conditions, there was deposited the wide sheet of Dakota sandstone which extends over the entire central and northern Plains region. Several hundred feet of these sands are exposed along the Rocky Mountain front, and in the Black Hills, Bighorns, and region northwestward, and they appear in eastern South Dakota and eastern Nebraska, and extend in a broad belt at or not far under the surface in southeastern Colorado and southern and central Kansas.

Following the deposition of this great sheet of sandy sediments there was a rapid change to clay deposition, of which the first representative is the Benton shale, a formation even more extensive than the underlying Dakota sandstone. This was the later Cretaceous submergence, in which marine conditions prevailed, and it continued until several thousand feet of clays were deposited during the Benton, Niobrara, and Pierre epochs. In Benton times there were occasional deposits of sand, and one thin but very widespread lime stratum of the Greenhorn limestone in the middle of the Benton sediments. The shale of the Benton is followed by several hundred feet of impure chalk, now constituting the Niobrara formation, and this in turn by many hundred feet of Pierre shale, which thickens rapidly to the westward, attaining 1200 feet or more in western South Dakota and over 7000 feet adjacent to the Rocky Mountains in a limited area west of Denver.

The retreat of the Cretaceous sea corresponds with the Foxhills epoch, during which sands were spread in an extensive sheet over the clay beds. It resulted in extensive bodies of brackish waters, and then of fresh waters, which deposited the sands, clays, and marsh material of the Laramie and earliest Tertiary. Apparently these last-mentioned formations were not laid down much east of longitude 101° in Nebraska, for they thin rapidly to the east, although, as we do not know the extent of post-Laramie erosion, their former limits can only be conjectured.

In earlier Tertiary times the domes of the Black Hills and other mountains lying farther west were uplifted, but this uplift appears not to have affected the strata in the central Plains region. Where the great mass of eroded material was carried is not known, for in the lower lands to the east and south there are no early Eocene deposits nearer than those on the Gulf Coast and Mississippi embayment, but in small part they are represented by the sandstones and conglomerates overlying the Laramie formation in the vicinity of the mountains.

Later in Tertiary time, after the outlines of the great mountain ranges to the north and west had been carved, there was a long period in which streams of moderate declivity flowed across the central Great Plains region; these, with frequently varying channels and extensive local lakes, due to damming and the sluggish flow of the waters, laid down the widespread mantle of Oligocene or White River deposits. These begin with the sands of the Chadron formation, which show clearly the course of old currents, by channels filled with coarse sandstone, and areas of slack water and overflow in which fuller's earth and other clays were laid down. The area of deposition of this series extended across eastern Colorado and Wyoming and western Nebraska and South Dakota, and probably also farther northward, for the deposits have been found in western Canada. Doubtless the original extent was much wider than the area in which we now find the formation, for much has been removed by erosion. The White River epoch was continued by the deposition of the Brule clays under conditions in which the currents were less strong and local lakes and slack-water overflows were more extensive. The Brule clay which resulted has about the same area as the Chadron, and originally it was much more extensive than it is at present.

At the beginning of Miocene time the general conditions had not changed materially, but doubtless for a while an extensive land surface existed in the central Plains area. In the stream channels extending across this surface the Gering formation was laid down, one channel extending across this quadrangle. Next came the deposition of a widespread sheet of sands derived from the mountains to the west, probably spread over the entire central Plains region by streams, aided to a minor extent by the winds. The streams of this time shifted their courses across the plains, spreading the débris from the mountains in a sheet which in some portions of the area attained a thickness of 1000 feet. This is the Arikaree formation, and it buried some of the lower ranges of the uplifts, as shown by its high altitude on the slopes of Rawhide Butte and along the front of the Laramie Range. It has been so widely eroded since the time of its deposition that we do not know its original extent, but doubtless it covered most of the central Plains far to the east. It was followed by uplift and erosion, erosion which removed the Arikaree and parts of underlying formations from the south and east, leaving the thickest mass of the deposit in western Nebraska and eastern Wyoming. Next came the epoch in which the streams began depositing the thin mantles of sands of the Ogallala and other late Pliocene formations, especially in southern Colorado, southern Nebraska, Kansas, and regions farther south. The deposition at this time appears to have been mainly in the southern region above described, erosion probably predominating in the district lying farther north.

These alternating conditions of later Tertiary deposition and erosion, first in the north and next in the south, were undoubtedly determined by differential uplift, the uplifted region suffering erosion and the depressed or stationary region receiving deposits from streams which did not have sufficient declivity to carry off their loads. This condition also is a feature of the semi-arid climate of the Plains, the mountain torrents and resulting vigorous erosion furnishing large amounts of débris which the streams of low declivity and constantly diminishing volume on the Plains were unable to carry to the sea. Even if such a region is traversed by valleys cut during a time of uplift or increased rainfall, when cutting ceases these valleys will soon be filled by sediments, and when they are full the streams at times of freshet, and to a less extent in the dry portion of the year, will shift their courses so as finally to spread a wide mantle of deposits over the entire area in which there is sluggish drainage.

During the early portion of the Pleistocene period there was uplift and increased precipitation, which resulted in widespread denudation of the preceding deposits, so that they were entirely removed in the eastern portion of the area, where there were glacial floods, and widely and deeply trenched in the western portion. To the west there extended to the foot of the mountains a great high plain, of wonderful smoothness, mantled mostly by the Arikaree to the north and by the Ogallala and possibly some later deposits, the product of later Tertiary deposition to the south. As the Black Hills dome rose somewhat higher than the general uplift, there was deep erosion around it, so that the High Plains, whatever their extent may have been in that region, were largely removed, and now their northern edge is presented toward that uplift in the great escarpment of Pine Ridge. Farther south, across Nebraska, Colorado, Kansas, and Texas, the High Plains present wide areas of tabular surface, but the streams of Pleistocene time have cut into them deeply and removed them widely. Erosion is still in progress, especially in the smaller streams, where the water has sufficient declivity to carry away its load; but in the larger streams the valleys are building up, as in the later Tertiary periods, for the volume of water is not adequate to carry away the waste from the adjoining slopes. Without further uplift the valleys will in this way be filled, the streams will again wander over the divides, and the Great Plains will receive a new mantle similar to those of whose remnants they consist.

ECONOMIC GEOLOGY.

UNDERGROUND WATERS.

The principal supplies of underground waters in this region are in the alluvial deposits of the valleys, especially in the wide bottom lands along the North Platte. In the adjoining slopes and highlands the supply varies greatly in amount, and is seldom large, though many of the small depressions contain shallow deposits of loose materials in which more or less water accumulates, and additional supplies are often obtainable from crevices in the clays below. The slopes of the Brule clay are particularly barren of water, a fact which has seriously impeded the settlement of the region back from the river. On the broad bottom lands adjoining North Platte River there are numerous wells, varying in depth from 15 to 30 feet in greater part, the shallower wells usually being near the river. On Mitchell Bottom the depths are greater, varying mostly from 30 to 60 feet. The amount of available water varies somewhat, but it is nearly always adequate for domestic use. In Pumpkin Creek Valley wells have been sunk at short intervals and they usually yield moderate supplies of fairly good water at depths of from 20 to 40 feet. In Cedar Valley scanty supplies are found in crevices in the Brule clay at depths from 45 to 75 feet, but at some points the wells have been failures. This Brule clay is the surface formation, or lies a short distance below the surface, in a wide area on the slopes adjoining the North Platte and Pumpkin Creek valleys; it is known to the well drillers as "hardpan," and in most cases in these slopes wells are either unsuccessful or yield water of unsatisfactory quality. Numerous abandoned houses in this region indicate points at which prospective settlers have been unable to obtain water supplies or where they dug wells which at first yielded water but finally dried up. When water is found it is in crevices and fissures, and these are of such uncertain occurrence that the underground conditions can be determined only by trial wells. In much of the area the Brule clay is so thick that it can not be penetrated by dug wells, and usually after the first 50 or 60 feet the chances for finding water rapidly diminish. Some years ago a well was bored at Gering to a depth of 331 feet, which obtained a promising flow of water, probably from the Laramie sandstone, which underlies the Chadron formation. Owing to the small size of the pipe and certain accidents in boring, the well became clogged up and did not continue to flow. At Harrisburg, on the south slope of Pumpkin Valley, a boring made to a depth of 790 feet obtained only a moderate amount of water and no surface flow. Judging from the small samples of borings which were seen, the well passed through the Chadron formation and entered the Laramie formation for several hundred feet. This formation outcrops in Goshen Hole to the west and includes sandstones which should be expected to yield water under considerable pressure, but the experience of the Harrisburg deep boring appears to indicate that if it contains water-bearing beds under the Scotts Bluff quadrangle they lie deeper than 790 feet.

It is probable also that the Dakota sandstone may be within the reach of the well borer and possibly it would furnish flowing water in large amount and of good quality in the lower levels of the North Platte Valley. Its depth can not be estimated accurately, for the overlying formations vary in thickness under western Nebraska and there is no direct evidence as to their amount in this district. The sandstone is overlain by shales and chalk rock about 2000 feet thick, possibly considerably more. The shales are difficult to penetrate owing to their softness and plasticity, and necessitate experienced well borers, heavy casing, and occasional diminution in size of casing as the depth increases.

The Arikaree formation, owing to its very porous nature, collects much water from the rainfall and affords an important source of supply in the high plateau which extends far south from the southern margin of the quadrangle. The water collects in considerable volume in the lower beds of the formation, where it is reached by numerous wells 200 or 300 feet deep. The outcrop of these lower beds is usually marked by frequent springs, some of which yield a moderately large flow of fine water. Such springs occur at intervals along the base of the plateau a short distance south of the latitude of Harrisburg, notably at Gabe, Long, and Indian springs. There are similar springs in the canyons in the ridge lying between the North Platte and Pumpkin Creek valleys, but they are mainly from the Gering sandstones at their contact with the impervious Brule clay. Waters also seep out of the alluvial materials in the valleys, as at Mud, Willow, Winter, and Spottedtail springs, which are important sources of local supply.

IRRIGATION.

There is in this quadrangle a considerable acreage under cultivation with the assistance of irrigation. There are extensive canals along the valley of North Platte River, and the results of irrigation have been so satisfactory that increased facilities are being provided for obtaining water, and with the new railroad line in the region prospects of profitable farming are most encouraging. At present nearly all of the wide alluvial flat is provided with water by the Farmers, Enterprise, Winter, and Minatare canals on the north, and the Mitchell and Castle Rock canals on the south side of the river, which carry water to an area of about 90 square miles, only a portion of which is now being farmed. The soils of the valley are usually thick and rich and, although somewhat alkaline, respond satisfactorily to culture. The wide bottom lands are flat and easy of access and the water of the river supplies a large volume to the ditches. The principal crops are wild hay, alfalfa, corn, and wheat. Oats and garden vegetables are also irrigated extensively. The yield per acre of crops under irrigation is somewhat variable. Wheat usually harvests from 30 to 40 bushels per acre; potatoes, 150 to 200 bushels; and hay, 1½ tons. Alfalfa yields 2 tons to the cutting and is cut three times each season.

The cost of irrigation varies greatly; the average obtained from 7,500 acres is 40 cents an acre, varying mostly from 30 to 75 cents an acre. In many cases the water is paid for partly by labor.

VOLCANIC ASH.

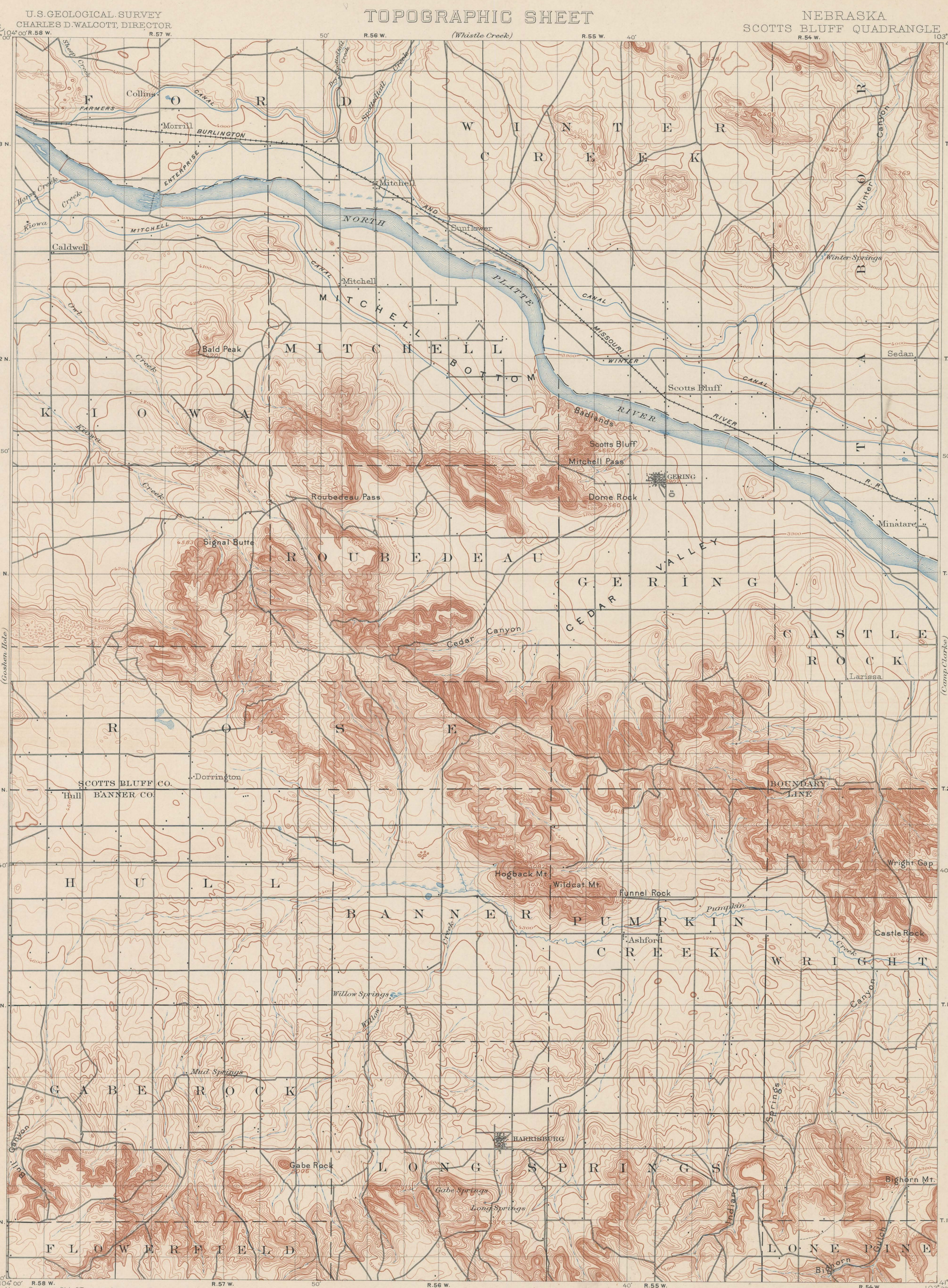
This material is mined at several points in the West for polishing powder, and the extensive deposits of ash in the Scotts Bluff quadrangle may possibly be of value at some time. The layer in the upper portion of the Brule clay outcrops for many miles in the region lying between the North Platte and Pumpkin valleys, and it usually consists of nearly pure ash in a bed 8 to 10 feet thick. A lower horizon of less pure ash occurs from 80 to 100 feet below the upper one. The Gering formation usually contains a thin bed of ash which is often sufficiently pure and thick to be of economic value. The Arikaree formation includes a bed at its base at many localities, and deposits of greater or less extent and local occurrence at higher levels, notably a 15-foot bed of pure ash 75 feet above the base of the formation in the butte 2½ miles west-southwest of Larissa, and an 8-foot bed 330 feet above the base in Wildcat Mountain.

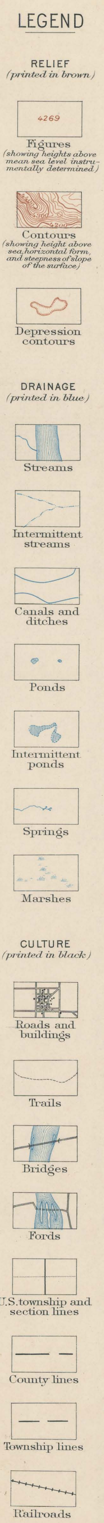
June, 1901.

U.S. GEOLOGICAL SURVEY
CHARLES D. WALCOTT, DIRECTOR

TOPOGRAPHIC SHEET

NEBRASKA
SCOTTS BLUFF QUADRANGLE





Henry Gannett, Chief Topographer.
Jno. H. Renshawe, Topographer in charge.
Control by E.M. Douglas, U.S. Engineer Corps, and General Land Office.
Topography by H.B. Blair.
Surveyed in 1895.

Scale $\frac{1}{125000}$

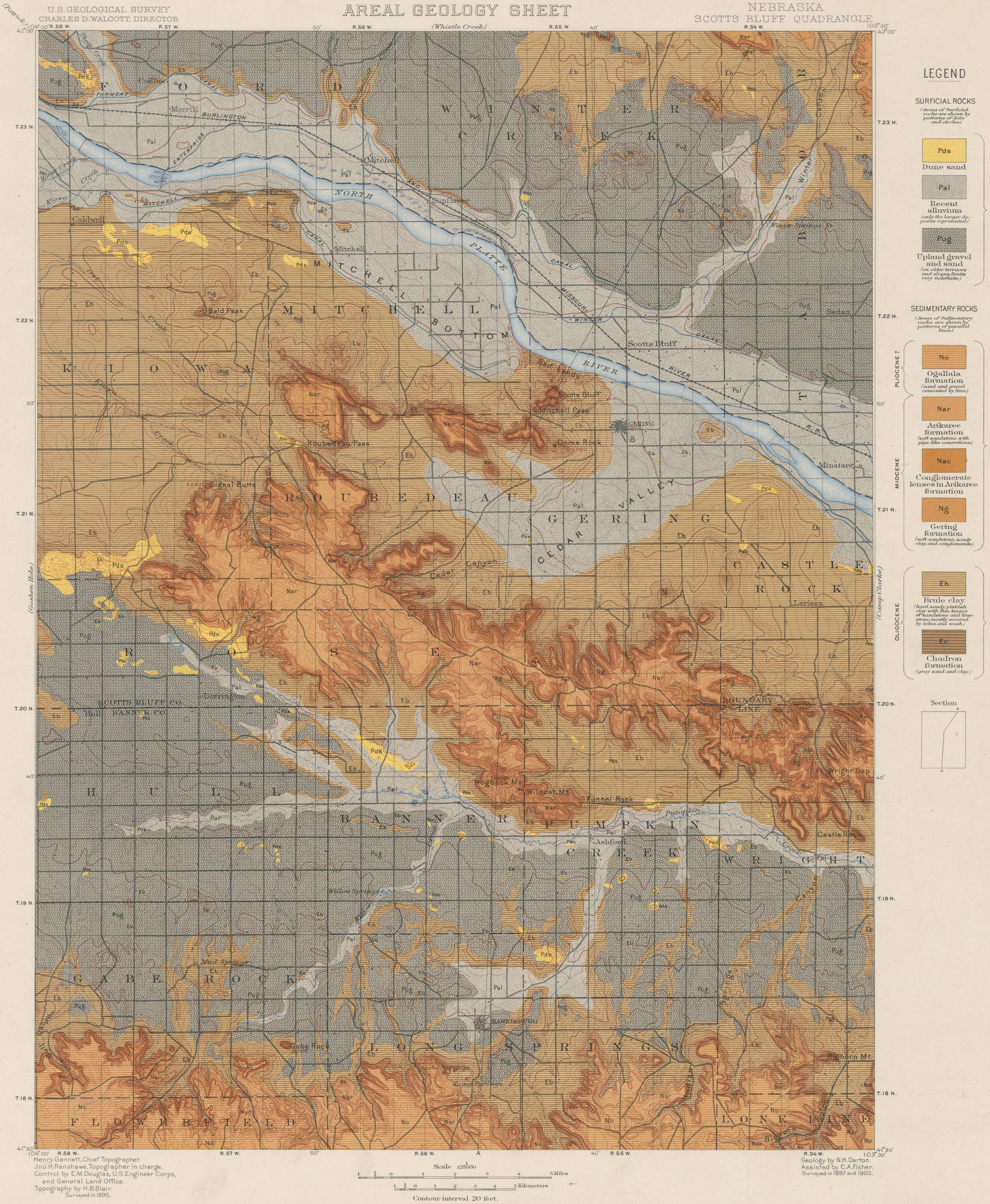
Contour interval 20 feet.
Datum is mean sea level.

Edition of July 1902.

U.S. GEOLOGICAL SURVEY
CHARLES D. WALCOTT, DIRECTOR

AREAL GEOLOGY SHEET

NEBRASKA
SCOTTS BLUFF QUADRANGLE



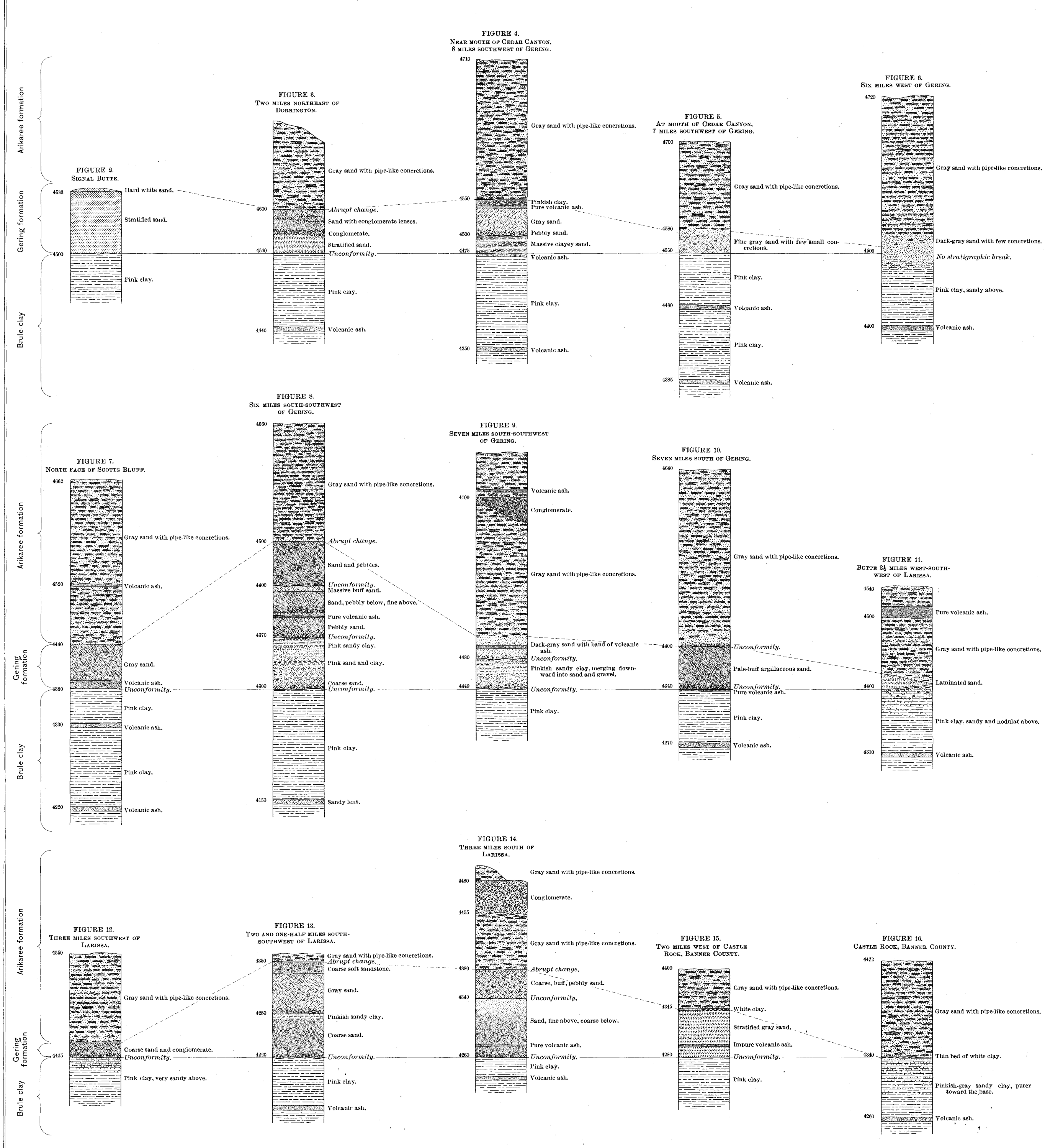
Henry Gannett, Chief Topographer.
Jno. H. Renshawe, Topographer in charge.
Control by E.M. Douglas, U.S. Engineer Corps, and General Land Office.
Topography by H.B. Blair.
Surveyed in 1895.

Edition of Aug. 1902.

Geology by N.H. Darton.
Assisted by C.A. Fisher.
Surveyed in 1897 and 1902.

COLUMNAR SECTION SHEET

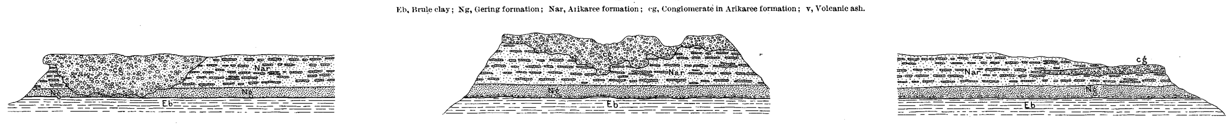
DETAILED COLUMNAR SECTIONS IN THE SCOTTS BLUFF QUADRANGLE.
SCALE: 1 INCH = 100 FEET.
(ALTITUDES IN FEET ON LEFT OF SECTIONS.)



SKETCH SECTIONS SHOWING VARYING RELATION OF CONGLOMERATE IN ARIKAREE FORMATION.
SCALE: 1 INCH = APPROXIMATELY 150 FEET.

FIGURE 17.
Eight miles south-southwest of Gering.

Eb, Brule clay; Ng, Gering formation; Nar, Arikaree formation; cg, Conglomerate in Arikaree formation; v, Volcanic ash.



N. H. DARTON,
Geologist.

ILLUSTRATION SHEET

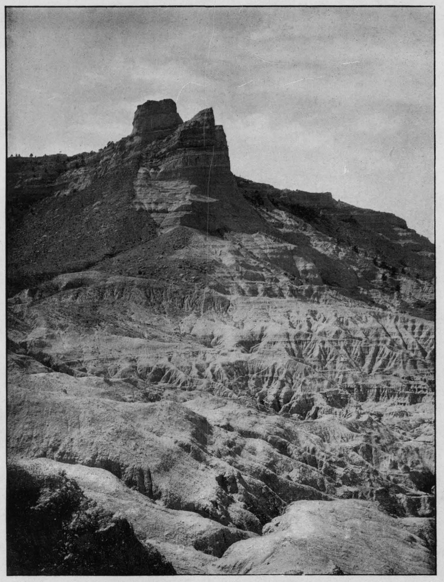


Fig. 18.—NORTH FACE OF SCOTTS BLUFF.

The upper cliffs are Arikaree formation. The lower slopes and bad lands are Brule clay.

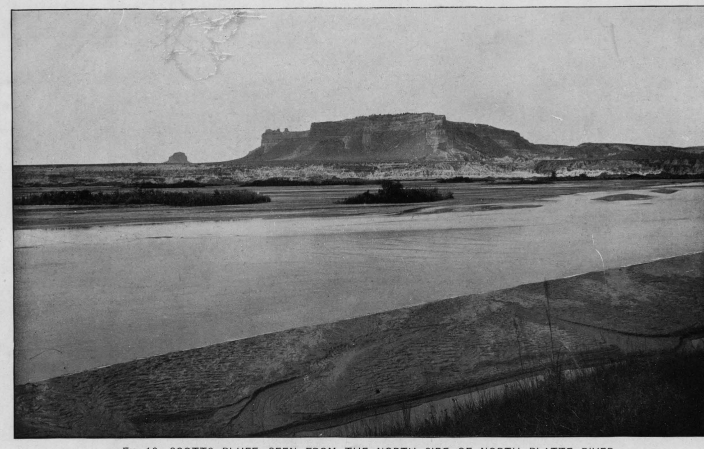


Fig. 19.—SCOTTS BLUFF, SEEN FROM THE NORTH SIDE OF NORTH PLATTE RIVER.

Shows the terrace at the foot of the bluffs, into which the bad lands are cut, and the broad river bottom. Dome Rock is seen on the left.

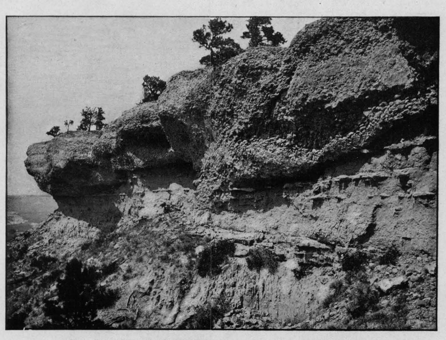


Fig. 20.—CONGLOMERATE IN ARIKAREE FORMATION.

Three miles southeast of Larissa, Nebr. Shows irregularities of the base of the conglomerate.

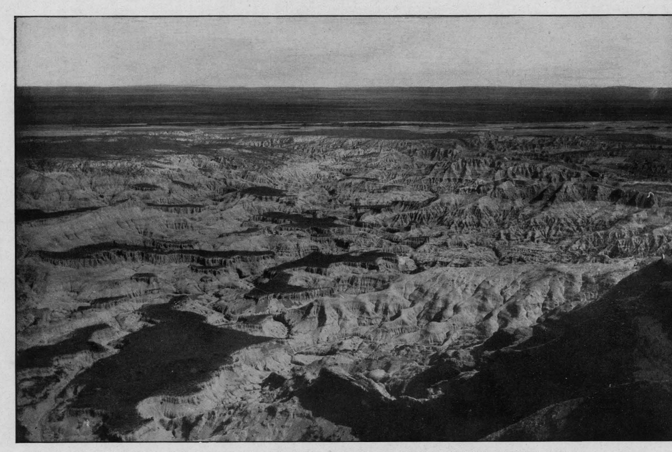


Fig. 21.—BAD LANDS IN THE BRULE CLAY AT THE FOOT OF SCOTTS BLUFF.

Looking north across North Platte River. Remnants of the terrace plain, into which the bad lands are cut, appear in the foreground.

Fig. 22.—SANDSTONE LENS IN BRULE CLAY.

Six miles south of Gering, Nebr.

Fig. 23.—DETAILS OF BAD LANDS IN BRULE CLAY AT FOOT OF SCOTTS BLUFF.

Looking north.

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