DEPARTMENT OF THE INTERIOR

UNITED STATES GEOLOGICAL SURVEY

CHARLES D. WALCOTT, DIRECTOR

GEOLOGIC ATLAS

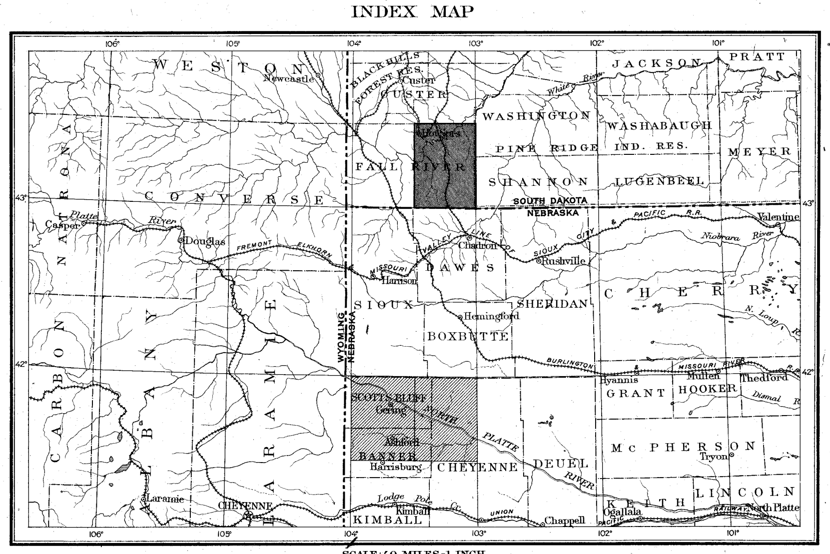
OF THE

UNITED STATES

OELRICHS FOLIO

SOUTH DAKOTA - NEBRASKA

INDEX MAP



SCALE: 40 MILES-1 INCH

AREA OF THE OELRICHS FOLIO

AREA OF OTHER PUBLISHED FOLIOS

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LIBRARY EDITION

OELRICHS FOLIO
NO. 85

WASHINGTON, D. C.

ENGRAVED AND PRINTED BY THE U. S. GEOLOGICAL SURVEY

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

1902

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:

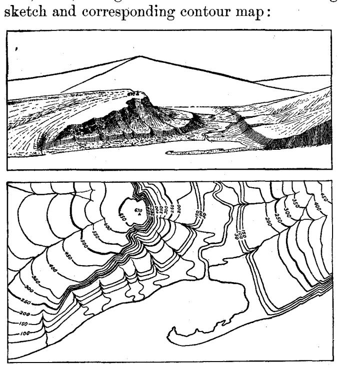


Fig. 1.—Ideal sketch and corresponding contour map.

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	Æ	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:

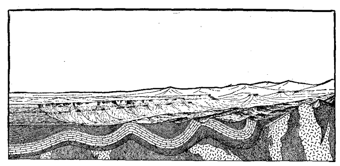


Fig. 2.—Sketch showing a vertical section in the front of the picture, with a landscape beyond.

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:

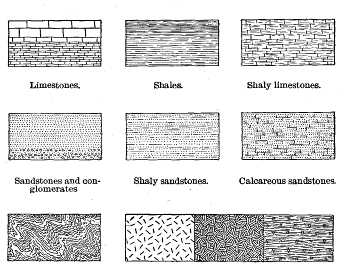


Fig. 3.—Symbols used to represent different kinds of rock.

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 OELRICHS QUADRANGLE.

By N. H. Darton.

GEOGRAPHY.

Position and extent.—The Oelrichs quadrangle embraces the quarter of a square degree which lies between parallels 43° and 43° 30′ north latitude and meridians 103° and 103° 30′ west longitude. It measures approximately 34½ miles from north to south and 25¼ miles from east to west, and its area is 871 square miles. It comprises the eastern half of Fall River County, S. Dak., with a strip of Custer County on the north and a little of Dawes County, Nebr., on the south. The northwest corner of the quadrangle lies on the slopes of the Black Hills, but the larger portion belongs to the Great Plains, although these plains are lower here than in the greater part of adjoining portions of Nebraska and Wyoming. The district is crossed by the South Branch of Cheyenne River and in greater part lies in the drainage basin of that stream, but tributaries of White River rise in the southeast corner.

Being part of the Black Hills and the Great Plains, this quadrangle illustrates many features which they present, but as its area is small, a general account of these provinces will be given before the detailed description is taken up.

THE GREAT PLAINS PROVINCE.

General features.—The Great Plains province is that part of the continental slope which extends from the foot of the Rocky Mountains eastward to the valley of the Mississippi, where it merges into the prairies on the north and the low plains adjoining the Gulf Coast and the Mississippi embayment on the south. The plains present wide areas of tabular surfaces traversed by broad, shallow valleys of large rivers rising mainly in the Rocky Mountains, and they are more or less deeply cut by narrower valleys of the lateral drainage. Smooth surfaces and eastward-sloping plains are the characteristic features, but in portions of the province there are buttes, extended escarpments, and local areas of bad lands. Wide districts of sand hills surmount the plains in some localities, notably in northwestern Nebraska, where sand dunes occupy an area of several thousand square miles. The province is developed on a great thickness of soft rocks, sands, clays, and loams, in general spread in thin but extensive beds sloping gently eastward with the slope of the plains. These deposits lie on relatively smooth surfaces of the older rocks. The materials of the formations were derived mainly from the west and were deposited, layer by layer, either by streams on their flood plains or in lakes and, during earlier times, in the sea. Aside from a few very local flexures, the region has not been subjected to folding, but has been broadly uplifted and depressed successively. The general smoothness of the region to-day was surpassed by the almost complete planations of the surface during earlier epochs. Owing to the great breadth of the plains and their relatively gentle declivity, general erosion has progressed slowly notwithstanding the softness of the formations, and as at times of freshets many of the rivers bring out of the mountains a larger load of sediment than they carry to the Mississippi, they are now building up their valleys rather than deepening them.

Altitudes and slopes.—The Great Plains province as a whole descends to the east about 10 feet in each mile from altitudes approaching 6000 feet at the foot of the Rocky Mountains to about 1000 feet above sea near Mississippi River. The altitudes and rates of slopes vary considerably in different districts, particularly to the north, along the middle course of Missouri River, where the general level has been greatly reduced. West of Denver the central plains have an altitude of 6200 feet at the foot of the Rocky Mountains, and this elevation is sustained far to the north along the foot of the Laramie Mountains. High altitudes are also attained in Pine Ridge, a great escarpment which extends from near the north end of the Laramie Mountains eastward through Wyoming, across the northwest corner of Nebraska, and for many miles into southern South Dakota. Pine Ridge marks the northern margin of the higher levels of the Great Plains, and presents cliffs and steep slopes descending a thousand feet into the drainage basin of Cheyenne River, one of the most important branches of the Missouri. From this basin northward there is a succession of other basins with relatively low intervening divides, which do not attain the high level of the Great Plains to the south. It is in this lower portion of the plains that the Oelrichs quadrangle is situated.

Drainage.—The northern portion of the Great Plains above described is drained by the middle branches of Missouri River, of which the larger members are Yellowstone, Powder, Little Missouri, Grand, Cannonball, Moreau, Cheyenne, Bad, and White rivers. On the summit of Pine Ridge not far south of the escarpment is Niobrara River, which rises in the midst of the plains some distance east of the northern end of the Laramie Mountains. To the south are Platte River with two large branches heading far back in the Rocky Mountains, the Rio Grande, and Arkansas River, which crosses the plains to the southeast and affords an outlet for the drainage from a large watershed of mountain and plains. Between the Rio Grande and the Arkansas are Cimarron River and numerous smaller streams heading in the western portion of the plains. Between Arkansas and Platte rivers is Republican River, rising near the one hundred and fifth meridian, and an extended system of local drainage in eastern Kansas and Nebraska.

THE BLACK HILLS.

General features.—In western South Dakota and eastern Wyoming a small group of mountains known as the Black Hills rises several thousand feet above the plains. Having abundant rainfall, it constitutes, through its vegetation and streams, an oasis in the semiarid region. The hills are carved from a dome-shaped uplift of the earth's crust, and consist largely of rocks which are older than those forming the surface of the Great Plains and which contain valuable minerals. The length of the more elevated area is about 100 miles, and its greatest width is 50 miles. The hills rise abruptly from the plains, although the flanking ridges are of moderate elevation. The salient features are an encircling hogback ridge, constituting the outer rim of the hills; next a continuous depression, the Red Valley, which extends completely around the uplift; then a limestone plateau with infacing escarpment, and, finally, a central area of high ridges culminating in the precipitous crags of Harney Peak at an altitude of 7216 feet. Two branches of Cheyenne River nearly surround the hills and receive many tributaries from them.

The central area.—The central area of the Black Hills comprises an elevated basin, eroded in crystalline schists and granite, in which scattered rocky ridges and groups of mountains are interspersed with park-like valleys. The wider valleys are above the heads of canyons of greater or less size, which become deeper and steeper sided as they extend outward to the northeast, east, and south.

The limestone plateau.—The limestone plateau forms an interior highland belt around the central hills, rising considerably above the greater part of the area of crystalline rocks. Its western portion is much more extensive than its eastern and is broad and flat, sloping gently downward near its outer margin, but being level near its eastern inner side, which presents a line of cliffs many miles long and often 800 feet high above the central valleys. It attains altitudes surpassing 7000 feet, locally almost equaling the height of Harney Peak, and carries the main divide of the Black Hills. The streams which flow down its western slope are affluents of Beaver Creek to the southwest and of the Belle Fourche to the northwest. Rising in shallow, park-like valleys on the plateau, they sink into deep canyons with precipitous walls of limestone often many hundred feet high. The limestone plateau extending south swings around to the eastern side of the hills, where, owing to the steeper dip of the strata, it narrows to a ridge having a steep western face. This ridge is interrupted by water gaps of all the larger streams in the southeastern and eastern portion of the hills, which rise in the high limestone plateau, cross the region of crystalline rocks, and flow through canyons in the flanking regions of the eastern side to Cheyenne River. All around the Black Hills the limestone plateau slopes outward, but near its base there is a low ridge of Minnekahta limestone with a steep infacing escarpment from 40 to 50 feet high, surmounted by a bare rocky incline which descends several hundred feet into the Red Valley. This minor escarpment and slope is at intervals sharply notched by canyons, which on each stream form a characteristic narrows or "gate."

The Red Valley.—The Red Valley is a wide depression that extends continuously around the hills, with long, high limestone slopes on the inner side and the steep hogback ridge on the outer side. It is often 2 miles wide, though it is much narrower where the strata dip steeply, and is one of the most conspicuous features of the region, owing in no small degree to the red color of its soil and the absence of trees, the main forests of the Black Hills ending at the margin of the limestone slopes. The larger streams flowing out of the hills generally cross it without material deflection, and between divides which are usually so low as to give the valley the appearance of being continuous, but in its middle eastern section it is extensively choked with Oligocene deposits.

The hogback rim.—The hogback range constituting the outer rim of the hills is usually a single-crested ridge of hard sandstone, varying in prominence and in steepness of slope. At the north and south and locally along the middle western section it spreads out into long, sloping plateaus. It nearly always presents a steep face toward the Red Valley, above which the crest line rises several hundred feet, but on the outer side it slopes more or less steeply down to the plains that extend far out from the Black Hills in every direction. The hogback rim is crossed by numerous valleys or canyons, which divide it into level-topped ridges of various lengths. At the southern point of the hills Cheyenne River has cut a tortuous valley through the ridge for several miles, and the Belle Fourche does the same toward the northern end of the uplift.

GEOGRAPHIC FEATURES OF THE QUADRANGLE.

Features pertaining to the Black Hills.—The Oelrichs quadrangle presents some of the characteristic features of the Black Hills topography, from the lower slopes of the eastern limestone ridge to the hogback rim, and a wide area of rolling plains to the east and south. The limestone slope in the extreme northwest corner of the quadrangle is trenched deeply by the gorge of Hot Brook and more or less cut into by minor canyons. The Red Valley is a prominent feature, having a width of somewhat over a mile and an undulating surface, which reaches the altitude of 3800 feet, but sinks to the deep gorge of Fall River, in which is built the greater part of the town of Hot Springs. The hogback range lying next east is not a single-crested rim, but a wide zone of high ridges rising abruptly from 450 to 500 feet above the Red Valley, along a north-northeast and south-southwest course. The canyons of Fall River and Sheps Creek cross it from the Red Valley, and Cheyenne River cuts a gorge diagonally across it, while several other deep canyons begin near the western crest of the range and extend eastward. In most cases these are box canyons having walls about 200 feet high. The total width of the range averages about 4 miles, and its higher portions rise to from 4300 to 4431 feet, the latter being the height of Battle Mountain, a summit east of Hot Springs. The eastern slope usually presents a characteristic hogback, consisting of a monoclinal ridge of hard sandstone pitching down about 300 feet, more or less steeply, to the low lands on the east. Cheyenne River cuts into this portion of the range a short distance above Cheyenne Falls, and passes out again 2 miles north. The falls are due to a bed of limestone and are about 25 feet high.

Features pertaining to the Great Plains.—Immediately east of the hogback range, which forms the limit of the Black Hills, there is a valley occupied for some distance by Cheyenne River and having a width of from 1 to 4 miles. It is bordered on the east by a low escarpment, in general 50 to 100 feet high, due to a thin but hard bed of limestone, which is cut through by the Cheyenne 2 miles southeast of Evans's quarry. Thence the river flows northeast in a flat-bottomed valley, across which it meanders in long loops, cutting first into the hills on one side and then into those on the other. About a hundred feet above the river bottom there are broad, sloping terraces which on either side merge into low hills and faintly defined ridges extending southward, which constitute the divide between the basins of Cheyenne and White rivers, and have an altitude of 300 to 400 feet above the rivers on either side. South and east of the Cheyenne there are extensive sand-dune areas extending back from the valley, in the case of those north of Oelrichs to a distance of 16 miles. The principal branches of Cheyenne River east of the hogback range are Beaver and Lame Johnny creeks on the north and Horsehead and Sand creeks on the south. These streams all flow in wide valleys and are bordered by long slopes of rounded hills. Horsehead Creek drains a considerable area southwest of Oelrichs, where the principal branches are from the west. To the east lies a low divide at the head of the basin containing branches of Blacktail and Slim Butte creeks, which empty into White River some distance east of the quadrangle. Several buttes of moderate prominence occur at intervals along the top of ridges near the head of the White River drainage, the most notable among them being Limestone Butte, which has an altitude of 3500 feet; Hay Canyon Butte, 3440 feet; and Lone Butte, a little more than 3400 feet high.

GEOLOGY.

The general sedimentary record.—The rocks appearing at the surface within the limits of the Oelrichs quadrangle are mainly of sedimentary origin—that is, they were deposited by water. They consist of sandstone, shale, limestone, sand, loam, and gravels, all presenting more or less variety in composition and appearance. The principal materials of which they are composed were originally gravel, sand, or mud, derived from the waste of older rocks, or chemical precipitates from salty waters.

These rocks afford a record of physical geography from later Carboniferous time to the present, and other sediments which underlie them extend it back to early Cambrian epochs. The composition, appearance, and relations of strata indicate in some measure the conditions under which they were deposited. Sandstones ripple-marked by waters and cross-bedded by currents, and shales cracked by drying on mud flats are deposited in shallow water; pure limestones suggest clear marine seas and scarcity of land-derived sediment. The fossils which strata contain may belong to species known to inhabit waters which are fresh, brackish, or salt, warm or cold, muddy or clear. The character of the adjacent land may be shown by the character of the sediments derived from its waste. The quartz sand and pebbles of coarse sandstones and conglomerates, such as are found in the Lakota formation, whatever their original source in crystalline rocks, have been repeatedly redistributed by streams and concentrated by wave action on beaches. Red shales and sandstones such as make up the "Red Beds" usually result directly from the revival of erosion on a land surface long exposed to rock decay and oxidation and hence covered by a deep residual soil. Limestones, on the other hand, if deposited near the shore, indicate that the land was low and that its streams were too sluggish to carry off coarse sediments, the sea receiving only fine sediment and substances in solution. The older formations exposed by the Black Hills uplift were laid down from seas which covered a large portion of the central-western United States, for many of the rocks are continuous over a vast area. The land surfaces were probably large islands of an archipelago, which was to some degree coextensive with the present Rocky Mountain province, but the peripheral shores are not even approximately determined for any one epoch, and the relations of land and sea varied greatly from time to time. Pursuing these general ideas more in detail, one finds that the strata brought to view by the Black Hills uplift record many local variations in the ancient geography and topography of the continent.

BRIEF GEOLOGIC HISTORY.

Cambrian submergence.—One of the great events of early North American geologic history was the wide expansion of an interior sea over the western-central region. The submergence reached the Rocky Mountain province during the early Cambrian and for a time the central portion of the Black Hills remained as one of the islands rising above the waters. From the ancient crystalline rocks, streams and waves gathered and concentrated sands and pebbles, which were deposited as a widespread sheet of sandstone and conglomerate, on sea beaches, partly in shallow waters off-shore, and partly in estuaries. Abutting against the irregular surface of the crystalline rocks which formed the shore are numerous exposures of these sediments containing much local material. Subsequently, the altitude being reduced by erosion and the area possibly being lessened by submergence, the islands yielded the finer grained muds now represented by the shales which occur in the upper portion of the Cambrian in some areas. In many regions the land surface of crystalline rocks was buried beneath the sediments.

Silurian-Devonian conditions.—From the close of Cambrian to early Carboniferous time the Black Hills area presents a scanty geologic record, the Silurian and Devonian being absent to the south, and only a portion of the Silurian being present to the north. This is probably because there was an extensive but very shallow sea, or land so low as to leave no noticeable evidence of erosion. Whether it remained land or sea, or alternated from one to the other condition, the region shows no evidence of having undergone any considerable uplift or depression until early in Carboniferous time, when there was a decided subsidence, that established relatively deep-water and marine conditions, not only over the Black Hills area, but generally throughout the Rocky Mountain province.

Carboniferous sea.—Under the marine conditions of the early Carboniferous there were laid down calcareous sediments, which are now represented by several hundred feet of nearly pure limestone, known as the Pahasapa limestone. As no coarse deposits occur, it is probable that no crystalline rocks were exposed above water in this region, although elsewhere the limestone, or its stratigraphic equivalents, was deposited immediately upon them. In the latter part of the Carboniferous the conditions were so changed that fine sand was brought into the region in large amount and deposited in thick but regular beds, apparently with much calcareous precipitate, and more or less ferruginous material, as is indicated by the color of many beds of the Minnelusa formation. Minnelusa deposition is believed to have been followed by an uplift which appears to have resulted in ponding saline water in lakes, in which accumulated the bright-red sands and sandy muds of the Opeche formation. The Minnekahta limestone, which is the next in sequence, was deposited from sea water, and from its fossils we know with a fair degree of certainty that it is a representative of the latest Carboniferous or Permian time. It was laid down in thin layers, but to a thickness now represented by only 40 feet of the limestone, yet the very great uniformity of this formation over the entire Black Hills area is an impressive feature, probably indicative of widespread submergence.

Red gypsiferous sediments.—A great change of conditions, began, apparently at once, at the close of the epoch represented by the Minnekahta limestone, and resulted in the deposition of the great mass of red shales constituting the Spearfish red beds, which probably were laid down in vast salt lakes, resulting possibly from extensive uplift and aridity. The mud accumulated in thin layers to a thickness of 500 feet, as now represented by the formation, and it is so uniformly of a deep-red tint that this is undoubtedly the original color. It is present not only throughout the extent of the formation, but also through its entire thickness, as is shown by deep borings, and therefore is not due to later or surface oxidation. Either the original material of the sediments was red, or it was colored during deposition by the precipitation of iron oxide. At various times, which were not synchronous throughout the region, accumulation of clay was interrupted by chemical precipitation of comparatively pure gypsum in beds ranging in thickness from a few inches to 30 feet, and free from mechanical sediment. It is believed that these beds are the products of evaporation during an epoch of little or no rainfall and consequently of temporarily suspended erosion; otherwise it is difficult to understand their nearly general purity. The Spearfish red beds have been supposed to represent the Triassic, but there is no direct evidence of this, and they may be Permian. Their deposition appears to have been followed by extensive uplift without local structural deformation, but with general planation and occasional channeling, which represents a period of Triassic time of unknown duration, and was succeeded by the deposition of the Jurassic series.

Jurassic sea.—In the Black Hills region the Jurassic was a period of varying conditions, shallow and deep waters and marine and fresh waters alternating. The materials are nearly all fine grained and indicate waters without strong currents. In the southeastern Black Hills region some of the earliest deposits are thin masses of coarse sandstone, indicating shore conditions, but generally there is shale lying directly on the red beds, which was deposited in moderately deep water. It is followed by the ripple-marked sandstone, evidently laid down in shallow water and probably the product of a time when sedimentation was in excess of submergence, if not during an arrest of submergence. The red color of the upper part of the medial sandy series in some portions of the Black Hills appears to show a transient return to arid conditions similar to those under which the Spearfish red beds were laid down. An extensive marine fauna and limestone layers in the upper shales of the Sundance formation are indicative of the deeper water which followed. After this stage marine conditions gave place to fresh-water bodies, probably through widespread uplift. The new products were the thick body of fine sand of the Unkpapa sandstone, now a prominent feature in the southeastern portion of the Black Hills but absent elsewhere, and the Morrison formation, a widespread mantle of sandy shales, which is absent to the southeast, although probably originally deposited there to a greater or less thickness and then removed by erosion in consequence of the uplift which initiated the next epoch. The extent of this degradation is not known, but it has given rise to a general erosional unconformity at the base of the Lakota sandstone, the next succeeding deposit.

Cretaceous seas.—During the Cretaceous period deposits of various kinds, but generally uniform over wide areas, gathered in a great series, beginning with such as are characteristic of shallow seas along a coastal plain, passing into sediments from deep marine waters, and changing toward the end to fresh-water sands and clays with marsh vegetation. The earliest coastal and possibly estuarine deposit—the Lakota formation—consists mainly of coarse sands spread by strong currents in beds 30 to 40 feet thick, but includes several thin partings of clay and local accumulations of vegetal material. There was deposited next a thin calcareous series, represented by the Minnewaste limestone, but apparently it was laid down in a local basin in the southern portion of the Black Hills. It was followed by a thin but widely extended sheet of clays of the Fuson formation. After the deposition of these clays there was a return to shallow waters and strong currents, as in Lakota times, and coarse sands of the Dakota formation were accumulated. At the beginning of the Benton there was everywhere in the region a rapid change of sediment from sand to clay.

During the great later Cretaceous submergence marine conditions prevailed, throughout the Benton, Niobrara, and Pierre epochs, and several thousand feet of clay were deposited. In Benton time there were occasional deposits of sand, two of them in the later part of the epoch that were general over the greater part of the Black Hills region, and one, earlier, that was local and produced the lenses of sandstone which are now found in the vicinity of Newcastle and elsewhere. Another marked episode was that which resulted in the general deposition of the thin Greenhorn limestone in the middle of the Benton sediments. The shale of the Benton was followed by several hundred feet of impure chalk, now constituting the Niobrara formation, and this in turn by over 1200 feet of Pierre shale, deposited under very uniform conditions. The retreat of the Cretaceous sea corresponds with the Fox Hills epoch, during which sands were spread in an extensive sheet over the clay beds, and resulted in the development of extensive bodies of brackish or fresh water, which received the sands, clays, and marsh deposits of the Laramie. Whether these two last-named groups of sediments were deposited over the area now occupied by the Black Hills is not definitely known, but it is possible that they were, as they are upturned around two sides of the uplift.

Early Tertiary mountain growth.—The Black Hills dome developed early in Tertiary time—or possibly in latest Cretaceous time—to a moderate height, and the larger topographic outlines of the region were established before the Oligocene epoch, the dome being truncated and its larger old valleys excavated in part to their present depths, as is indicated by the occurrence in them of White River (Oligocene) deposits, even in some of their deeper portions. 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 it is possible that they are represented, at least in part, in the Laramie deposits, as in the region adjoining the Bighorn Mountains.

Oligocene fresh-water deposits.—Oligocene deposits were laid down by streams and in local lakes and finally covered the country to a level now far up the flanks of the Black Hills. Erosion has removed them from most of the higher regions where they formerly existed, especially along the western side of the hills, where the deposits apparently were thin, but in the vicinity of Lead small outliers remain at an altitude of over 5200 feet, and on the north end of the Bear Lodge Mountains they are seen a thousand feet higher. In many places on the slopes of the uplift there is clear evidence of superimposition of drainage due to a former capping of Oligocene formations.

Middle Tertiary mountain growth.—Following the Oligocene epoch the dome was raised several hundred feet higher and more extensively eroded. No representatives of the succeeding Loup Fork group—the Arikaree and Ogallala formations—have been discovered in the immediate vicinity of the Black Hills, but they are extensively developed in Pine Ridge on the south and remain in portions of the area of high buttes to the north in the northwestern corner of South Dakota. There was probably slow but continuous uplift during the Loup Fork epoch, and materials were contributed by the higher slopes of the Black Hills at that time, but whether the formations ever were deposited in the immediate vicinity of the hills is not ascertained.

Uplift, erosion, and stream adjustment.—During the early portion of the Pleistocene period there was widespread denudation of the preceding deposits, and many of the old valleys were revived, with much rearrangement of the drainage, which on the eastern side of the Black Hills was mainly caused by increased tilting to the northeast. Some of the streams superimposed upon the Oligocene deposits cut across old divides, in some cases connecting a valley with its next neighbor to the north—changes clearly indicated by southeastward-flowing streams in pre-Oligocene valleys abruptly turning north into canyons of post-Oligocene age, numerous elevated saddles being left to mark the original southeasterly course of the valleys. Some of the offsetting in the present drainage has been largely increased by early Pleistocene erosion and recent stream robbing.

There was apparently still further uplift in late Pleistocene time, for the present valleys, below the level of the earlier Pleistocene high-level deposits, seem to be cut more deeply than they would be in simply grading their profiles to the level of the Missouri and Cheyenne rivers. Wide, shallow valleys have developed in the soft deposits, and canyons of moderate extent and depth in the harder rocks. Erosion has progressed without aggradation in the main, but in some cases, with the shifting of channels, there have been accumulations of local deposits on small terraces at various levels.

DESCRIPTION OF THE ROCKS.

The strata coming to the surface in the Oelrichs quadrangle have a thickness of about 5000 feet. The order of succession of the limestones, sandstones, and shales, and their general characters are given on the Columnar Section sheet.

CARBONIFEROUS PERIOD.

Minnelusa sandstone.—The lowest formation exposed in the Oelrichs quadrangle, the Minnelusa sandstone, appears in an anticline west of Hot Springs, where it is cut across by Hot Brook and Cold Brook. In the high cliff rising above the railroad track in the center of the anticline on Hot Brook there is one of the finest exposures of the formation in the Black Hills, comprising somewhat more than two-thirds of it, consisting of massive sandstones of brilliant colors above and buff and gray sandstones below, with several beds of limestone and one of bright-purple clay. The upper sandstones are brilliant red, brown, and orange, and in certain layers bright yellow, and are surmounted by the dark red Opeche sandstone, which is capped by purplish gray Minnekahta limestone. The tints in some of the beds are due in part to staining from the overlying strata, but several of the sandstones are colored throughout. The thickness exposed is 400 feet, and in detail the strata are as follows:

Section on Hot Brook, South Dakota.

	Feet.
Opeche red sandstone.	
Gray limestone	10
Soft red sandstone	20
Limestone breccia, red to buff matrix	15
Yellow arenaceous limestone	15
Red limestone	5
Yellow arenaceous limestone	5
Red arenaceous limestone	5
Gray limestone breccia, red matrix	15
Red sandstone	25
Greenish-gray limestone	5
Soft red sandstone	50
Gray limestone	10
Red sandstone	10
Gray sandstone	10
Red sandstone	6
Red shale	30
Pale-red sandstone with thin coaly shale partings	20
Light-buff and gray sandstones	15
Breccia	3
Reddish-gray sandstone	25
Green shale	1
Gray to buff sandstone	12
Black shale	2
Light-buff, soft sandstone	15
Dark shale	2
Soft white sandstone	15
Gray calcareous sandstone with coaly shale partings	30
Total	376

The section comprises about two-thirds of the formation brought up by a local anticline of considerable height. The uppermost layer is a nearly pure limestone in which, in an adjoining canyon, were discovered *Productus semireticulatus* and

Chonetes (?). The formation has not elsewhere yielded fossils, but these suggest that its age is upper Carboniferous. In its unweathered condition many of the Minnelusa beds contain much carbonate of lime, as may be seen in borings from deep wells in various portions of the Black Hills. The lime weathers out near the surface and porous sandstone remains.

Opeche formation.—The Opeche formation is a series of red beds, consisting of soft red sandstone, mainly thin bedded and containing variable amounts of clay, which lies between the Minnelusa sandstone and the Minnekahta limestone. It presents extensive exposures along the canyons of Hot Brook and Cold Brook, rising high on the anticline in the gorge of Hot Brook west of Hot Springs, and it outcrops in numerous shallow canyons cut in the slope of the Minnekahta limestone. The top of the formation, for the first few feet below the Minnekahta limestone, consists of shales which invariably have a deep-purple color, and the basal layers are red sandstones, varying in thickness from 4 to 15 inches. On Cold Brook, 4 miles northwest of Hot Springs, the total thickness is 115 feet, with purple shale at the top, 50 feet of red sandy clay below, and at the bottom 60 feet of deep-red sandstone in beds 1 to 4 feet thick, with red clay partings. Farther down Cold Brook, at a point 1½ miles from Hot Springs, a thickness of 135 feet is exhibited. The age of the Opeche formation has not been definitely determined, as it has yielded no fossils, but it is assigned to the Permo-Carboniferous for the reason that the overlying Minnekahta limestone is of that epoch and red sediments occur in the upper part of the corresponding series in Kansas and eastern Nebraska.

Minnekahta limestone.—The Minnekahta limestone, formerly known as the "Purple limestone," is a prominent member of the Black Hills series, but it occupies only a limited area in the northwestern corner of this quadrangle. It averages only 50 feet in thickness, but through its hardness it gives rise to prominent topographic features, being exposed usually on wide dip slopes and in transverse escarpments and being distinguished by sinkholes and caves which are numerous within its area. The limestone is ordinarily massive in appearance in cliff faces, but on close examination it is found to consist of thin layers, differing slightly in color, and on weathering it breaks into slabs, usually 2 to 3 inches in thickness. The color as a whole is light gray, but there is always a slight pinkish or purplish tinge, from which the name "Purple" limestone originated. Its composition varies somewhat, mainly in the percentage of magnesia, which is usually present in considerable proportion, and in clay, which is a constant ingredient. An analysis of a typical sample is as follows:

Analysis of Minnekahta limestone.

	Per cent.
Lime	31.51
Magnesia	19.85
Alumina, iron, etc	.36
Water	1.25
Carbonic acid	44.66
Sulphuric acid (SO_3)	.07
Silica	1.12
Manganese, soda, and potash	none
Total	98.82

On the eastern side of the hills this formation dips generally to the east or slightly south of east at a very moderate angle, but there are frequent variations in the amount and direction of dip, as the limestone is a thin, relatively hard bed of homogeneous rock lying between masses of softer red beds, and consequently was much affected by local conditions of pressure. The thinnest layers are often minutely crumpled and faulted, but considering the large amount of deformation to which the formation has been subjected, the flexures are but little broken.

This formation is termed the Minnekahta limestone because of its characteristic development in the region of the Hot Springs, originally known as the "Minnekahta" by the Indians. The springs rise through crevices in the limestone just west of the town of Hot Springs, the water being of a temperature of about 92° and flowing in very large volume. The formation is classified as Permo-Carboniferous from fossils which were found in it not far west of Hot Springs. These are inconspicuous little shells, comprising *Bakewellia*, *Edmondia*, and *Nuculana*.

JURATRIAS PERIOD.

Spearfish shale.—The Spearfish shale, formerly appropriately called the "Red Beds," consists of red, sandy shale with intercalated beds of gypsum, the total thickness of the formation being about 400 feet. It outcrops across the northwestern corner of the Oelrichs quadrangle, in the broad treeless Red Valley, in which is the town of Hot Springs, and usually presents wide, bare slopes and high buttes of bright-red clay with outcrops of snowy white gypsum in striking contrast. The sedimentary material is almost entirely of sandy red shale, generally thin bedded, and without any special features except the gypsum, which occurs in beds at various horizons, sometimes extending continuously over wide areas. There are also throughout the formation small veins of gypsum due to secondary deposition. The gypsum is a prominent feature about Hot Springs, and its occurrence on Cold Brook is shown in fig. 2. The principal beds, which are here about 60 feet above the base of the formation, have a thickness of 33½ feet, exclusive of a 10-foot parting of shale between them, but the thickness diminishes slightly northward, and rapidly southward. Near the mouth of Cold Brook the gypsum was at one time worked to some extent for plaster. At Hot Springs a considerable portion of the formation has been cut away and overplaced by gravel, sand, and conglomerate of Pleistocene age.

The Spearfish formation has not yielded fossils in this vicinity, but it has been regarded as of Triassic age because it lies uncomformably beneath marine Jurassic deposits and is underlain by the Minnekahta limestone, which is known to be Permo-Carboniferous.

Sundance formation.—The Sundance formation lies uncomformably upon the Spearfish red beds and constitutes the slope which rises from the eastern side of the Red Valley at the western base of the hogback rim. It comprises shales and sandstones in alternating sequence, certain members being of general occurrence and others less persistent. The shales are mainly dark green and the sandstones pale buff, but there is an intermediate member of sandy shales and soft sandstones of reddish color, and often a local basal member of massive red sandstone which frequently attains a thickness of 25 feet. The succession common throughout the area consists of a dark shale at the base, a slabby, buff, ripple-marked sandstone next above, then a reddish, sandy shale or soft sandstone, and an upper green shale with fossiliferous limestone layers. The upper shales usually include thin layers of limestone, which are always highly fossiliferous, and the sandstones also contain fossils. They are all typical marine Jurassic forms. The thickness of the formation varies from 200 to 250 feet.

In the section of the Sundance formation exposed in the slopes southeast of Hot Springs the following beds occur.

Section of the Sundance formation near Catholicon Springs Hotel, South Dakota.

	Feet.
Unkpapa sandstone.	
Green shales with belemnites, etc	80
Red sandy shales	80
Greenish shales and thin sandstones	8
Buff, slabby, ripple-marked sandstones	15
Limestone filled with *Ostrea*	10
Green shales, very sandy	21
Soft, thin-bedded sandstone, fish-bearing layer	4
Buff sand	2
Spearfish red beds.	
Total	220

The buff sand lies on a slightly eroded surface of the Spearfish red beds, and, thickening northward and southward, it becomes a conspicuous bed of red to buff sandstone. A typical contact of this sandstone is shown in fig. 8, on the Illustration sheet. The limestone with *Ostrea* is a local lens not found elsewhere. The fish-bearing layer is also local; it has yielded some new and interesting fish remains, which were found about 10 inches above the top of the buff sand. Farther north, in the slopes east of Hot Springs, the following average section was observed, but there is considerable local variation in stratigraphy.

Fossils are very abundant, both in the calcareous layers in the upper green shales and in the buff and ripple-marked sandstones. They occur in some of the other beds, but in much less number. The most characteristic fossil is *Belemnites densus*, which occur in cigar-shaped masses varying in size from an inch or less to 4 inches in length, of dark color and radiate structure when seen in transverse section. This fossil occurs mainly in the upper green shales.

Section near Hot Springs, South Dakota.

	Feet.
Unkpapa sandstone.	
Green shales, with belemnites, etc	90
Red sandy shales and sandstones	80
Green shales	8
Buff, slabby, ripple-marked sandstones	30
Dark shales	9
Red massive sandstones	25
Spearfish red beds.	
Total	242

Unkpapa sandstone.—The Unkpapa sandstone is a massive, fine-grained deposit of remarkably uniform texture, varying from white to purple and buff, and always clearly separable both from the Sundance shales below and the Lakota sandstone above. Its greatest development in the Black Hills region is in the hogback range east of Hot Springs, where the exposures are very striking in their coloring of brilliant pink, purple, and pure white. The greatest thickness, 225 feet, is in Sheps Canyon, southeast of Hot Springs; the thickness diminishes toward the north, and at the line between Custer and Fall River counties it is not over 140 feet. The formation outcrops principally along the middle slopes on the western side of the hogback range overlooking the Red Valley, but is exposed for a greater or less distance in the gaps which extend eastward, as well as in Elm Creek and Odell canyons, on the eastern slope, where its thickness is about 180 feet, and where it has been quarried to some extent for building stone. In Odell Canyon most of the rock is glistening white and other portions are of deep red color. In Elm Creek Canyon portions are beautifully banded with various colors, yellow, buff, purple, and pink, in part along the stratification planes, but often diagonal to them. At one point west of Buffalo Gap these banded beds exhibit minute faulting. The contact of the Unkpapa sandstone on the Sundance beds is sharp, but presents no sign of unconformity, whereas at the top there is unmistakable unconformity by erosion, giving rise to an irregular surface on which the Lakota sandstone lies. A typical contact of this sort is shown in fig. 7, on the Illustration sheet. No fossils have been found in the Unkpapa sandstone, but from its association with the Sundance formation it is provisionally classed in the Jurassic.

CRETACEOUS PERIOD.

Lakota formation.—The Lakota formation, consisting mainly of sandstone, gives rise to the western crest and many of the broader features of the hogback range lying east of the Red Valley. The sandstones are hard, coarse grained, cross bedded, and massive, with thin partings of shale. In some portions of the Black Hills the formation includes coal, but none has been found in the Oelrichs quadrangle. The thickness in this quadrangle ranges from 230 to 300 feet, with frequent local variations. The formation lies unconformably on the Unkpapa sandstone and is abruptly limited above by the Minnewaste limestone. In the canyon of Fall River the beds of sandstone are very massive, but they are separated by greenish-gray shales 15 to 20 feet thick, which occur at several horizons. The uppermost member, a dull-yellow sandstone, is immediately overlain by the Minnewaste limestone, of which the relations are shown in fig. 4, on the Illustration sheet, representing a fine exposure just west of Evans's quarry, near the mouth of the canyon. It exhibits the greater part of the Lakota formation, the Minnewaste limestone, a steep slope of talus on the Fuson shale, and a thick capping of massive buff sandstone of the Dakota formation, in which is Evans's quarry. In the high ridges and their numerous deep canyons east of Hot Springs, the Lakota formation is the most prominent feature. Many of the surfaces of the ridges are strewn with fragments of fossil trees which have been weathered out of the sandstone and appear to characterize a horizon that is high in the formation over a considerable area in the southern portion of the Black Hills, and at which cycads also usually occur, although none have yet been discovered in this quadrangle. Fossil bones have been observed in considerable number in the region west of Buffalo Gap, and there have been found, at a number of points, plant remains which, together with the cycads, appear to indicate that the formation is of early Cretaceous age.

Minnewaste limestone.—The Minnewaste limestone is a formation of restricted occurrence in the Black Hills, its principal area being between the vicinity of Cascade Springs and Buffalo Gap. Its average thickness is only 25 feet, but it is conspicuous on the hogback range east of Hot Springs and extends far up the slopes on some of the higher divides. Some of its features are shown in fig. 4, on the Illustration sheet. The rock is a nearly pure, light-gray limestone, presenting a uniform character throughout. An extended search has failed to detect any fossils in it, but it is supposed to be of lower Cretaceous age because it lies considerably below the Dakota sandstone. One of the most extensive exposures is at the falls of Cheyenne River, where the water flows over a ledge about 20 feet high, and the name Minnewaste is given from the Dakota Indian name for Cheyenne River, meaning good water. Extensive exposures may be seen in the anticline 2 miles east of Hot Springs, where the rock covers a wide area of the western slope of the anticlinal ridge.

Fuson formation.—The Fuson formation is a fine-grained deposit lying between the Dakota sandstone and the Minnewaste limestone, with an average thickness of about 100 feet, consisting of a mixture of fine sand and clay, which is usually massively bedded and weathers out in small cylindrical fragments like dry starch. It includes some local beds of coarse sandy rock, especially at its base, and also beds of nearly pure shale. The predominant color is white or gray, but buff, purple, and maroon tints are often conspicuous. As the formation is relatively soft, as compared with the adjoining sandstones and limestones, it usually lies along the base of the Dakota sandstone cliffs and is often buried under the talus of sandstone blocks. One of the most extensive exposures is at the falls of Cheyenne River, where it shows the following section:

Section of the Fuson formation at Cheyenne Falls, South Dakota.

	Feet.
Dakota sandstone.	
Dark sandy shale	4
Soft, gray, slabby sandstone; plants	6
Compact white massive shale	8
Dark-green clay	1
Dark-gray, compact, massive shale	25
Very compact white mudstone	2½
Gray massive shale	6
Harder, white massive shale	9
Purple shale	1
White fine-grained sandstone	5 to 12
Purple shale	6 to 8
Light-buff massive sandstone	25
Dark-buff coarser sandstone, much honeycombed by weathering	25
Minnewaste limestone.	
Total	132½

The large amount of sandstone in the lower part of this section is a very unusual feature, but the layer which becomes honeycombed by weathering is a characteristic member for several miles northward. Outcrops of the formation are considerably obscured by talus along Fall River, but there are extensive exposures in the side canyons in that vicinity, notably in the canyon on the steep side of the anticline 2 miles due east of Hot Springs, where much of the material is bright purple and strongly resembles a shale which has been baked by intrusive igneous rock. No fossils have been found in this formation, so that there is no evidence as to its precise age.

Dakota sandstone.—The Dakota sandstone constitutes all of the eastern slope of the hogback range, being prominent in the steep rise from the valley underlain by the Graneros shale. It caps many of the higher summits along the western crest, including Battle Mountain and the summits just north. The formation rarely exceeds 150 feet in thickness and is thus much thinner than the Lakota sandstone. It generally consists of a thick bed of buff sandstone weathering brown, massive in structure and hard in texture, overlain and underlain by thinner bedded sandstone. The massive bed, shown in fig. 4, on the Illustration sheet, forms the ledge over which Fall River passes in a series of picturesque cascades just below Evans's quarry, at which it is worked to some extent, as well as at other places. In the overlying thinner bedded sandstone there have been discovered fossil plants of the Dakota flora, of upper Cretaceous age.

Graneros shale.—This shale is the lowest formation of the Benton group and is believed to be the precise equivalent of the Graneros shale of southeastern Colorado, as it lies between the Dakota sandstone and the Greenhorn limestone, which in both regions is characterized by numerous remains of the same inoceramus. The shale is of dark color and in greater part breaks up into thin flakes. It contains numerous concretions, ranging in diameter from a few inches to several feet, and usually lens shaped. Its thickness averages about 900 feet, so far as could be ascertained from several cross-section measurements made with rather uncertain dip determinations. The outcrop is mostly along a valley, a mile or two wide, which skirts the base of the hogback range, and the most extensive exposures are along Cheyenne River southeast of Evans's quarry, but as the formation is very barren its surface is generally bare.

At several localities the Graneros shale is traversed by dikes or masses of sandstone occupying fissures. The most extensive of these are west and southwest of Tepee Creek, where sands derived from the underlying Dakota sandstone extend for some distance through the lower beds of the shale. The largest of the dikes at this locality is 20 feet wide, and they have a linear arrangement in the narrow zone about a mile in length having a north-northeast and south-southwest direction. Several small dikes were observed on the north bank of Cheyenne River, a little more than a mile southeast of Evans's quarry.

Greenhorn limestone.—In the plains immediately adjoining the Black Hills one of the most prominent features is a low but distinct escarpment, which is due to the hard Greenhorn limestone, in the middle of the Benton group. It usually lies 1 to 4 miles outside the hogback range of the Dakota sandstone, toward which it faces. The limestone is thin but persistent and is characterized by a large number of impressions of *Inoceramus labiatus*, a fossil which is of infrequent occurrence in the adjoining formations. It contains a considerable amount of clay and some sand, and appearing to harden on exposure, it breaks out into hard, thin, pale-buff slabs, covered with impressions of the distinctive fossil. Its thickness averages about 50 feet, including some shaly beds in its upper portion. At its base it is distinctly separated from the black shales of the Graneros formation, and its upper beds grade into the Carlile shales through 6 or 8 feet of passage beds. Its most extensive exposures are in the escarpment in the high hills south of the head of Tepee Creek and near Cheyenne River below the mouth of Fall River. The formation is covered by dune sands in the portion of the region adjoining the mouth of Horsehead Creek and north of Horse Camp Draw for a few miles, but elsewhere the escarpment is distinct.

Carlile formation.—The Carlile formation consists mainly of shales, but includes two thin, hard beds of sandstone, the upper one calcareous, and at the top several layers containing oval concretions. Its thickness averages between 430 and 590 feet. Two typical sections are given in the following tables.

Fossils of typical upper Benton molluscan forms occur in considerable abundance in some of the beds in the Carlile.

Niobrara formation.—The Niobrara formation is a soft, shaly limestone or impure chalk, containing more or less clay and fine sand, and often including thin beds of hard limestone, which

Section of Carlile formation near Buffalo Gap, South Dakota.

	Feet.
Niobrara chalk.	
Shales, with large buff concretions	150
Hard, slabby sandstone	2
Gray shale	130
Thin, coarse sandstone	4
Gray shale	75
Concretions in gray shale	2
Gray shale	40
Calcareous beds, with *Ostrea*, etc	4
Shale and talus	180
Greenhorn limestone.	
Total	587

Section of Carlile formation 1½ miles southeast of the falls of Cheyenne River, South Dakota.

	Feet.
Niobrara chalk.	
Gray shale, with large buff concretions	50
Gray shale	70
Light-gray sandstone	4
Dark-gray shale, with thin sandy layers	160
Sandstone	2
Gray shales	150
Greenhorn limestone.	
Total	436

consist of aggregations of *Ostrea congesta*. In unweathered exposures it is usually light gray, but weathered outcrops are bright yellow, and therefore conspicuous, although, as the rock is soft, it rarely gives rise to noticeable ridges. The most extensive exposures occur along the valley of Dry Creek and at intervals from Cheyenne River northward to Buffalo Gap station. In the region adjoining the mouth of Horsehead Creek and Horse Camp Draw the formation is widely covered by sand dunes. The thickness of the Niobrara is about 225 feet.

Pierre shale.—Many thousand square miles of the plains adjoining the Black Hills are occupied by the Pierre shale, a thick mass of dark bluish-gray color, which weathers light brown and is relatively uniform in composition throughout. It gives rise to a dreary, monotonous landscape of low, rounded hills sparsely covered with grass and not useful for agriculture. The thickness of the formation is about 1200 feet, so far as can be ascertained, but it is only rarely that it can be measured, and where the dip is gentle it is almost impossible to do so. At a horizon about a thousand feet above its base the formation includes scattered lenses of limestone which usually contain numerous shells of *Lucina occidentalis*. They vary in size from 2 to 3 cubic feet to masses 20 feet in diameter and 6 or 8 feet thick, usually of irregular lens shape, and occur typically as shown in fig. 10, on the Illustration sheet. Owing to their hardness they give rise, when uncovered by erosion, to low conical buttes resembling in form a very squat tepee, which accordingly have been designated "tepee buttes." The form is shown in fig. 10, on the Illustration sheet. Tepee buttes occur in large numbers in the vicinity of Oelrichs, rising from 10 to 150 feet above the surrounding slopes, and are distributed very irregularly over the plain, according to the grouping of the lenses. Similar limestone masses, also containing *Lucina occidentalis*, occur near the base of the Pierre shale, but they have been observed only in the high hills south of the head of Dry Creek and in small number. Numerous concretions occur in the Pierre shales at various horizons and usually contain large numbers of distinctive fossils, of which the more abundant are of the following species: *Baculites compressus, Inoceramus sagensis, Nautilus dekayi, Placenticeras placenta, Heteroceras nebrascense*, and an occasional *Lucina occidentalis*. They are generally of small size and break into small pyramidal fragments which are scattered more or less abundantly all over the surface of the shale. At the base of the formation, overlying the Niobrara chalk, there is always a very distinct black, splintery, fissile shale, about 150 feet thick, which has been included in the Pierre formation, although it has not yet been found to contain characteristic fossils. It usually occurs in a slope, often rising steeply above the low lands eroded in the Niobrara chalk, and at three horizons it contains concretions which exhibit a regular sequence. The lower ones are biscuit shaped, hard, and siliceous. Those in the layers next above are similar in shape and composition, but are traversed in every direction by deep cracks filled with calcite and sometimes contain scattered crystals of barite. Next above are two or three layers of large, lens-shaped, highly calcareous concretions, of light-straw color, showing beautifully developed cone-in-cone structure.

EOCENE PERIOD.

Chadron sand.—The Chadron sand consists of sands and sandy clays, lying upon the Pierre shale, but separated from it by an unconformity which represents a long period of time, there being in this vicinity none of the latest Cretaceous or early Eocene deposits. The occurrences within this quadrangle consist of a narrow belt in a shallow syncline, extending southeast from the vicinity of Limestone Butte east of Oelrichs, and some small patches on the divides north of Blacktail Creek, which are outliers of the great areas of Tertiary formations giving rise to the Big Bad lands a short distance east and south of the margin of the quadrangle. In Limestone Butte the section is 135 feet thick, the butte being capped by thin but hard limestone layers which are supposed to be the lower portion of the Brule formation. At the base are 75 feet of pale-green sandy clays with a thin bed of pebbles at the bottom, and ascending there occur in order 30 feet of pink sandy clays, 1 foot of gray limestone, 18 feet of light-gray sandy clay, 1¼ feet of compact limestone, 4 feet of pink clay, and finally a thin bed of hard limestone at the top. Similar components are seen in the extension of the formation eastward and in numerous small outlying masses. Hay Canyon Butte is capped by the lower limestone, which is again exposed in two buttes slightly more than 2 miles east by south from it. An outlier consisting of the green sandy clay is exposed 5 miles northeast of Oelrichs on the 3563-foot summit. A short distance east of the South Fork of Blacktail Creek, in the southeastern part of the quadrangle, the formation contains, near its base, a thin bed of volcanic ash, and this material also occurs mixed with the sands at various places. This volcanic ash is found, under the microscope, to consist of fine particles of volcanic glass in thin, sharp-edged flakes of irregular but mostly very angular outlines, colorless and without crystalline structure or inclusions. An occasional small bubble of air is seen in some of the flakes. These particles of glass are the fragments of volcanic rock or pumice blown out of some volcano during an explosive eruption. The location of the volcano is not known. Much of the surface of the Chadron formation is bare of vegetation, giving rise to incipient bad lands, and the light color of the material is in striking contrast to the underlying Pierre shale, which just below the sands is usually of a bright brownish-red color, owing to the oxidation of the iron in it.

Brule clay.—The Brule clay occupies two small areas southeast of Oelrichs, lying northwest and northeast of Lone Butte, in a shallow syncline, surrounded by Chadron sands. The material is a sandy clay of light-buff color, in greater part compact and massive. It is eroded into small bad lands similar in form to those of the region east of this quadrangle. Fossil bones of typical White River animals of the horizon of the Oreodon beds of the Big Bad lands occur in considerable abundance. The thickness of the Brule clay in this area is about 150 feet.

PLEISTOCENE PERIOD.

Residual gravel.—The oldest surficial deposits in this region are residual gravels, apparently remnants of the basal gravels of the Chadron formation, which are but slightly moved from their original position, some of them being in close proximity to the larger Chadron deposits, though others are now widely isolated. One of the largest areas is in the southwest corner of the quadrangle, where all the higher divides are sprinkled over with such gravel, lying on the Pierre clay and varying greatly in abundance. At no point does it form a continuous coating, being spread on sloping surfaces down which it works as erosion of the underlying shale progresses. It has been observed in this region as far north as the divide next south of Beef Creek, where a few small areas are thinly sprinkled with pebbles. Other occurrences are northwest of Oelrichs, and east of Horsehead Valley they are more numerous, one of the largest being that which is on the ridge 2 miles west of Lone Butte. Much of the region lying about the headwaters of Blacktail Creek and its branches contains more or less gravel of this sort, of which the more conspicuous areas are shown on the geologic map. The gravel is largely of vein quartz, including much chalcedonic material. The age of these residual deposits is indefinite, as they result from a cycle of erosion which began in pre-Pleistocene time and has been continued to the present.

Terrace deposits.—The valley of Cheyenne River contains terraces which are about 100 feet above the river and are covered by alluvial deposits They are most extensive in the region south and southeast of Buffalo Gap, where they have a width of several miles, and were formed when Cheyenne River occupied a broad valley a hundred feet above its present level and received a large stream from the northwest, flowing out at at Buffalo Gap and joining it near the present mouth of Beaver Creek. Through this affluent a considerable proportion of pink loam from the Red Valley was added to the alluvium, and it indicates very clearly the course of the ancient drainage channel, which flowed southwest from the town of Buffalo Gap and thence down the valley of the Cheyenne River. The principal deposits of these high terraces are gravel and sand, and their aggregate thickness is usually from 15 to 30 feet. They are smoothly spread and the surface slopes gently toward the river, but ends in cliffs. The broad terrace extending along the south side of the river from the mouth of Slate Springs Draw to the mouth of Hay Canyon has an average width of 2 miles and to the south abuts against slopes of Pierre shale. It bears some areas of dune sand. Above the mouth of Slate Springs Draw the high terrace deposits are smaller in area and more widely scattered. The largest area now remaining begins a mile south of the falls of Cheyenne River and extends for 3 miles along the west bank, at an elevation of about 75 feet above water level.

Terrace conglomerate.—At an earlier stage in its history Fall River excavated a canyon across the Red Valley, which later it filled with a narrow deposit of coarse gravel, from the mouth of the gorge through the Minnekahta limestone eastward to the hogback range; but more recently it has cut an inner gorge from 75 to 100 feet deep through the deposit, presenting walls of conglomerate. The old valley was about one-half mile wide; the present one is a few hundred yards. The conglomerate lies mainly on the Spearfish red beds, which rise above the level of its surface to the north and south, and to the west it abuts against the limestone slope. The deposit forms a smooth plain merging into the undulating topography of the Red Valley on either side. Its thickness averages about 50 feet in the center of the valley and its base is somewhat irregular in con tour. The material consists of bowlders, pebbles, and angular masses of Minnekahta limestone, Minnelusa sandstone, and varied detritus from the other rocks along the valleys of Hot Brook and Cold Brook, all tinted more or less reddish by clay from the red beds, and cemented by calcareous precipitates, probably from the waters of the warm springs. The conglomerate is mostly very compact, but it merges into loose materials containing only a small amount of cement or cemented only in layers, as may be seen in excavations in the eastern part of the new town of Hot Springs. The several stages of cutting and filling in the valley of Fall River are so related to recognized cycles of erosion as to make possible a definite statement that they are Pleistocene.

Alluvial deposits.—Along Cheyenne River there are alluvial flats of recent material, of greater or less extent, which is distributed during spring freshets, and similar flood plains, proportionate in size to that of the strream, border nearly all of the creeks. That of Horsehead Creek, below the mouth of Blackbank Creek, has an average width of about a mile, the stream meandering from side to side and cutting into the shale banks to a greater or less extent. In the canyon below Cheyenne Falls the flat is very narrow and discontinuous, as the river is cutting in hard rock, and the same is true in the gorge west of the mouth of Tepee Creek. The streams crossing the hogback ridge flow in relatively narrow canyons, where there is but little room for alluvial accumulation, and this is also the case with those in the Minnekahta limestone area. One of the most interesting recent deposits is that of calcareous sinter, now accumulating at various points along Fall River below Hot Springs, and deposited mostly on vegetation growing in the stream, so that the forms are casts of the plants. Great masses of this material are found in the gorge below the town, notably for a short distance about 1½ miles above Evans's quarry.

Dune sand.—Extending from the valley of Cheyenne River there are extensive accumulations of dune sand, which have been derived from the alluvial deposits on the river flats and blown southeastward by the stronger prevailing winds. Along the valley of Horsehead Creek, where they are most extensive, they reach east to a point 2 miles northeast of Oelrichs, and in the valley of Sand Creek they reach beyond Smithwick. The deposits are not thick, but they give rise to typical sand-hill topography, consisting of dunes and blowouts. The sand is fine and rounded and there are many portions of the area in which it bears little or no grass and the material is free to move whenever the wind blows. It travels over the divides and along the hollows, but in the larger valleys, such as that of Horsehead Creek, it is mostly removed by the stream at times of freshet.

STRUCTURAL GEOLOGY.

Structure of the Black Hills uplift.—The Black Hills uplift, if not eroded, would present an irregular dome rising on the northern end of an anticlinal axis extending northward from the Laramie or Front Range of the Rocky Mountains. It is elongated to the south and northwest, has steep slopes on the sides, is nearly flat on top and is subordinately fluted. The greatest vertical displacement of the strata, as indicated by the height at which the granite and schist floor is now found, amounts to about 9000 feet. The minor flutings of the dome are mainly along the eastern side of the uplift, the most notable ones being in the ridge of the Minnekahta limestone just west of Hot Springs. Another of considerable prominence occurs 3 miles east of Hot Springs. These subordinate flexures are characterized by steeper dips on their western side and gentler dips to the east. They merge into the general dome to the north and run out with declining pitch to the south. In the northern hills there are numerous local domes and flexures due mainly to laccolithic igneous intrusions, but no similar features are indicated by the structure of the southern hills.

Faults are rarely observed and none have been detected which amount to more than a few feet in vertical displacement.

Structure sections.—The sections on the Structure Section sheet represent the strata as they would appear in the sides of a deep trench cut across the country. Their position with reference to the map is on the line at the upper edge of the blank space. The vertical and horizontal scales are the same, so that the actual form and slope of the land and the actual but generalized relations of the rocks are shown, the structure where buried being inferred from the position of the strata observed at the surface.

Structure of the Oelrichs area.—The principal structural features of this quadrangle are illustrated by the five structure sections on the Structure Section sheet. Under the plains the strata lie in gentle undulations, but where they extend across a portion of the southeastern margin of the Black Hills dome they rise about 4500 feet in a distance of 10 miles, on a monocline dipping east and south, the strike curving around to the south-east and south. The monocline bears a subordinate crenulation which crosses it diagonally just east of Hot Springs as an anticline with very steep western limb, and another anticline enters the region west of Hot Springs and soon dies in the Red Valley to the northeast. In fig. 1 is shown the contour of the principal structural features of the area, representing the altitude of the surface of the Dakota sandstone, which is supposed to be restored in the northwestern corner of the quadrangle, from which it has been removed by erosion.

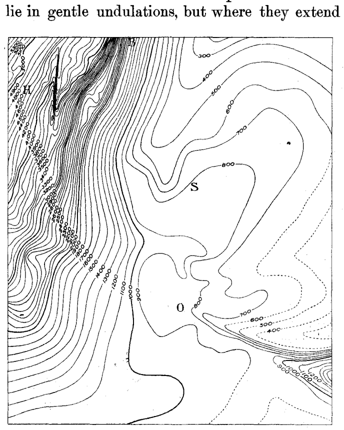


FIG. 1.—Diagram showing contour of surface of Dakota sandstone in the Oelrichs quadrangle. The lines represent altitudes above sea level and are 100 feet apart vertically. O, Oelrichs; S, Smithwick; H, Hot Springs; B, Buffalo Gap.

It will be seen from this diagram that the monocline begins to rise a short distance west of the longitude of Oelrichs, at first with a gentle inclination and then steeply. The steepest dips are along the hogback range, particularly west of the town of Buffalo Gap, where they are 35°. Next west are found gentler dips, and it is in this portion of its rise that the monocline bears the crenulation east of Hot Springs. In Red Valley in the vicinity of Hot Springs the dips are relatively low, but the strata continue to rise steadily toward the west. North of Gypsum Butte there is a prominent anticline trending northeast and southwest and pitching down rapidly to the northeast so that it is soon lost under the Red Valley. Cold Brook passes across this anticline, which here has a moderate elevation, and the Minnelusa sandstones are cut through. The anticline is high on Hot Brook, where a considerable thickness of the Minnelusa beds are exposed above the gorge cut across the arch. In the hogback range east of Hot Springs the formations are at first nearly horizontal so that relatively thin beds of the Dakota sandstones, Fuson formation, and Minnelusa limestones are spread out over wide areas. South of Fall River these low dips continue east for some distance, but with numerous local variations of direction and amount. At the falls of Cheyenne River the Dakota sandstones and underlying beds are nearly flat and extend some distance east of the average line of the hogback slope. It is owing to this cause that Cheyenne River cuts into the range, its course having been established at a time of higher level, when the sandstones were deeply buried beneath the overlying shales. North of Fall River there is found, in the middle of the range, a very prominent anticline, which is traversed by a branch valley of Fall River for several miles. The Dakota sandstone rises high on the ridge east of this valley, presenting a prominent escarpment to the west, and at its base there is a shelf of Minnewaste limestone dipping eastward. A short distance west this limestone passes over the crest of an anticline and dips steeply west down the slope into the bottom of the valley, in which it constitutes a syncline, rising again to the west to outcrop 500 feet higher in the western face of Battle Mountain. This prominent flexure soon dies out to the south on the south side of Fall River, but it is continued southward as a noticeable flattening of dip in the monocline, passing out of the range at Cheyenne Falls. To the north it extends across the head of Odell Canyon with considerable prominence and passes thence with diminished height to beyond Buffalo Gap. In the latitude of Oelrichs the monocline of the Black Hills changes its trend to the west to pass around the point of one of the great anticlines at the southern end of the uplift. The change in structure is exhibited in the gorge of Cheyenne River west of the mouth of Tepee Creek, in the high escarpment of the Greenhorn limestone west of the head of Dry Creek, and in the curve of the Niobrara outcrop at the head of Dry Creek. The structure east of the monoclinal region above described has been determined from the attitude of the tepee zone in the Pierre shale as indicated by the distribution of the tepee buttes. The principal horizon of the lenses of limestone giving rise to these tepee buttes is 1000 feet above the top of the Dakota sandstone, and the configuration shown in fig. 1 is based on the assumption that this upper horizon is uniform in stratigraphic position throughout. It will be seen that the structure indicated is that of a very gently undulating area having a broad, flat anticline in the region northeast of Smithwick and a steep-sided syncline extending east of Oelrichs, a syncline which is well defined by the basin of Oligocene formations which it contains. The Chadron sand along the eastern margin of this flexure exhibits relatively steep dips to the north. Along Slim Butte Creek there is an anticline which gains prominence to the east and which east of the margin of the quadrangle brings the Niobrara limestone to the surface.

ECONOMIC PRODUCTS.

SOILS.

Derivation.—The soils in this region are closely related to the underlying rocks, from which they are residual products of decay and disintegration except when they are formed as alluvial deposits in the larger valleys or are spread by winds. In the process of disintegration, residual soil develops more or less rapidly on the several rocks of the region according to the character of the cement holding the particles together. Siliceous cement dissolves most slowly, and rocks in which it is present, such as quartzite and sandstones, are extremely durable and produce but a scanty soil. Calcareous cement, on the other hand, is more readily dissolved by water containing carbonic acid, and on its removal clay and sand remain to form, often, a deep soil. If the calcareous cement is present in small proportion only, it is often leached out far below the surface, the rock retaining its form, but becoming soft and porous, as in the case of the Minnelusa sandstone. If, as on the limestone plateaus, the calcareous material forms a greater part of the rock, the insoluble portions collect on the surface as a mantle, varying in thickness with the character of the limestone, being thin where the latter is pure, but often very thick where the rock contains much insoluble matter. Of course the amount of soil remaining on the rocks depends on erosion, for where there are slopes the erosion is often sufficient to remove the soil as rapidly as it forms, leaving bare rock surfaces. Crystalline schists and granitic rocks decompose mostly by hydration of a portion of the contained feldspar, and the result is usually a mixture of clay, quartz grains, mica, and other materials. Shales are disintegrated in consequence of changes of temperature, by frost, and by water, thus by softening and washing giving rise to soils. If they are sandy, sandy soils result, and if they are composed of relatively pure clay, a very clayey soil is the product. The character of the soil thus derived from the various geologic formations being known, their distribution may be approximately determined from the map showing the areal geology, which thus serves also as a soil map. It must be borne in mind that some of the geologic formations present alternations of beds of various materials, such, for instance, as shales and sandstones alternating with limestone. These give abrupt transitions in the character of their disintegration products, soils which differ widely in composition and agricultural capabilities occurring side by side. The only areas in which the boundaries between different varieties of soil do not coincide with the boundaries of the rock formations, are in the river bottoms, in the sand dunes, in the areas of high-level gravels, in the smaller valleys, and upon steep slopes, where soils derived from rocks higher up the slope have washed down and mingled with or covered the soils derived from the rocks below. Soils of this class are known as overplaced, and a special map of large scale would be required to show their distribution.

Distribution.—The larger portion of the Oelrichs quadrangle is underlain by Pierre shale, which consists mainly of clay and gives rise to a stiff "gumbo," which is not only very barren in itself, but is acid from decomposing pyrites and too sticky for suitable working. It is covered with grass, which originally afforded excellent pasturage, but in some areas it has been grazed down by excessive herding, and as the soil is not rich, the grass will require some time to regain its former growth. Some areas of the Pierre shale are traversed by wide valleys with overplaced soils of considerable fertility. This is notably the case along the bottom through which Cheyenne River flows, and in flats in the valley of Horsehead Creek. In the area covered by sand hills, the soils usually are too dry and sandy for cultivation, but much of the surface supports a growth of coarse but nutritious grasses.

The Niobrara beds are calcareous and fertile, but are not favorably located for farming. In the valley of Dry Creek, where the surface is wide and level, no water is available for irrigation. The Graneros shale valley, which extends along the front of the hogback range, is barren except in the portion traversed by Cheyenne River, where there are fertile alluvial flats at intervals. The hogback range has a generally rocky surface, with a sandy soil which supports a growth of grass and scattered pines. Slopes covered by the Minnewaste limestone are usually as bare and barren as the sandstone areas. The Red Valley is favorably situated for agriculture but its soil is barren and there is general absence of water excepting in the gorge of Fall River. The slopes of Minnekahta limestone present extensive rock outcrops and are generally covered with the margin of the pine forest of the Black Hills, but on some of the more level plains there is scanty soil which supports a fine growth of grass. The alluvial soils at a few points in the valley of Fall River below Hot Springs and on Cold Brook above the town, have been cultivated by the aid of irrigation and yield fine crops of garden truck for local use. The Brule and Chadron areas southeast of Oelrichs are mostly cut into bad lands or sandy slopes which are dry and barren. The higher gravel and loam terraces east-northeast of Oral and southeast of Buffalo Gap are mostly level, fertile land which has been farmed to a considerable extent, but, not being irrigated, profitable crops have been obtained from it in only a few of the moister years.

UNDERGROUND WATERS.

The occurrence of underground water in the Oelrichs quadrangle is of interest mainly in the plains adjoining the Black Hills, under which there extend several thick sheets of water-bearing sandstone. Receiving water from rainfall at the surface in the hogback range, these sandstones conduct it underground on the eastward dip to a considerable depth within a comparatively short distance. Where the inclination of the strata diminishes away from the hills, as it generally does, there is a wide area beneath which the water-bearing beds lie at a depth that is within reach of the well borer. As the region is semi-arid and the surface water often contains much "alkali," there is great need for underground waters at most places. In the columnar section are shown the relations of the principal water-bearing horizons. The principal water supplies are to be expected in the Lakota sandstone, though there are doubtless other water-bearing beds at various higher horizons up to the top of the Dakota sandstone. These strata are exposed over a wide zone in the hogback range, where, by imbibition and by sinkage from streams, they receive a considerable proportion of the rainfall, which very slowly flows in the permeable sandstones completely under the State of South Dakota and emerges in great springs and general surface seepage in the outcrops of Dakota sandstone in the Missouri Valley in the southeastern corner of the State. The altitude at which this water enters the beds is from 3000 to 3500 feet above sea in greater part; it emerges at the surface to the eastward at an altitude of about 1200 feet, and under the intervening country its head gradually diminishes from source to outflow. In eastern South Dakota numerous wells have been sunk from 400 to 1000 feet, which furnish large volumes of water from the Dakota sandstone, and it is believed that this water is available under the region lying westward, up to the flanks of the Black Hills, under conditions which are set forth in the Artesian Water sheet of this folio. The depth of the uppermost water-bearing sandstone beneath the surface at any point is shown by patterns of color, each one of which includes between its limits a difference of 500 feet; thus one represents depths from 0 to 500 feet, the next from 500 to 1000 feet, and so on. In the area in which the head of water is sufficient to afford surface flow the patterns are printed in blue, and where a flow may not be expected they are printed in green. The area of flow, unfortunately, is relatively restricted, lying mostly within the immediate vicinity of the valley of Cheyenne River and some of its larger branches to the north. It will be noticed that the altitudes to which the water may be expected to rise increase to the northward, for in that direction the sources of supply are very much higher than they are to the south, where Cheyenne River crosses the hogback range. There are also shown on the sheet lines representing intervals of one hundred feet, which show the height to which the underground waters may be expected to rise above sea, or in other words, their head. These lines afford means for ascertaining how near the surface the water may be expected to rise in wells which do not afford a flow, and also the pressure of the water in the area of the flow. The depth below the surface at which water would stand in a well in the non-flowing area may be found by subtracting the feet of head from the feet of altitude, shown by the brown contour lines on the base map. At Oelrichs, for instance, which has an altitude of 3350 feet, and is midway between the 3100 and 3000 contour lines of head, the water should be expected to rise within 300 feet of the surface and, as is shown by the pattern, it would be necessary to sink a well about 2600 feet to reach the top of the Dakota sandstone. It is possible that it might be necessary to penetrate also the Fuson formation and Minnewaste limestone before a large volume of water could be obtained.

On the Columnar Section sheet are shown the formations which have to be penetrated, and these can be recognized by their characteristics as described in the table and by the fossils referred to below. From the Areal Geology sheet can be ascertained in which formation the well is started. Two of the most important fossils for determining the geologic horizon are *Ostrea congesta* and *Inoceramus labiatus* (see Illustration sheet), the former occurring crowded together and constituting thin layers of limestone in the upper portion of the Niobrara chalk beds, which, although bright yellow when exposed on the surface, are of a pale blue-gray color when first brought out by the well boring. *Inoceramus* is characteristic of the Greenhorn limestone, which is hard and of buff color on the surface, as seen in the many outcrops in the escarpment just east of the hogback range, but is of dark-gray color and soft texture underground. The zone of concretions and the thin layers of sandstone in the Carlile formation will be encountered by the well borer and recognized by their hardness and their stratigraphic relations.

BUILDING STONE.

For several years past the Dakota sandstone has been worked at Evans's quarry, southeast of Hot Springs. The beds are massive, easy to dress when freshly exposed, and reasonably accessible. The colors vary from white and buff to a delicate pink. The product has been used with satisfactory results in the town of Hot Springs, and a considerable quantity has been shipped to other places. The amount available is large, but the expense of long-distance shipment greatly restricts its use. The same ledge has recently been opened at Odell. The Unkpapa sandstone has been quarried for several years in Elm Creek Canyon and Odell Canyon, and to a less extent in the immediate vicinity of Hot Springs. The rock is massive and easy to dress, but it is rather soft. The colors are most attractive; some beds are a pale crimson and others present bandings and mottling of red, buff, purple and other tints. In a shallow canyon very near the county line 4 miles north of Hot Springs a portion of the Unkpapa sandstone is pure white, and as it is very soft would probably afford excellent glass sand. A small amount of limestone was quarried at Limestone Butte, near Oelrichs, for building in the vicinity. Some of the slabby layers in the lower part of the Sundance formation have been used locally at Hot Springs.

GYPSUM.

The Spearfish red beds carry deposits of gypsum (hydrous sulphate of lime) throughout their extent, and often the mineral occurs in very thick beds. These are relatively pure, and if nearer to good markets the deposits would be of great value. The only commercial operations so far have been at Hot Springs, but they are discontinued for the present owing to the expense of taking the product to market. The gypsum is calcined at a red heat, to drive off the chemically combined water, and is then ground and packed in barrels. The product is plaster of paris.

The gypsum deposits attain great thickness in the vicinity of Hot Springs. Near Cold Brook, three-quarters of a mile northwest of the station and a short distance north of the works above mentioned, is an exposure shown in fig. 9, on the Illustration sheet. The section there exhibited is shown in detail in fig. 2.

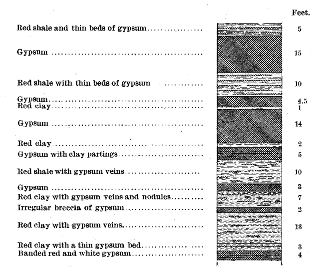


FIG. 2.—Section of gypsum deposits in Spearfish red beds on Cold Brook, three-fourths of a mile northwest of Hot Springs, South Dakota.

The following is an analysis of a typical gypsum from south of Hot Springs. It was made by Mr. Steiger in the laboratory of the United States Geological Survey.

Analysis of gypsum from south of Hot Springs, South Dakota.

	Per cent.
Lime, CaO	32.44
Magnesia, MgO	.33
Alumina, Al_2O_3	.12
Silica, SiO_2	.10
Sulphuric acid, SO_3	45.45
Carbonic acid, CO_2	.85
Water, H_2O	20.80
Total	100.09

LIMESTONE.

Limestone for lime or other purposes may be obtained in abundance from the Minnekahta and Minnewaste formations. Both of these beds have been burned to some extent for lime for building in and near Hot Springs. The two limestones are equally good for lime.

VOLCANIC ASH.

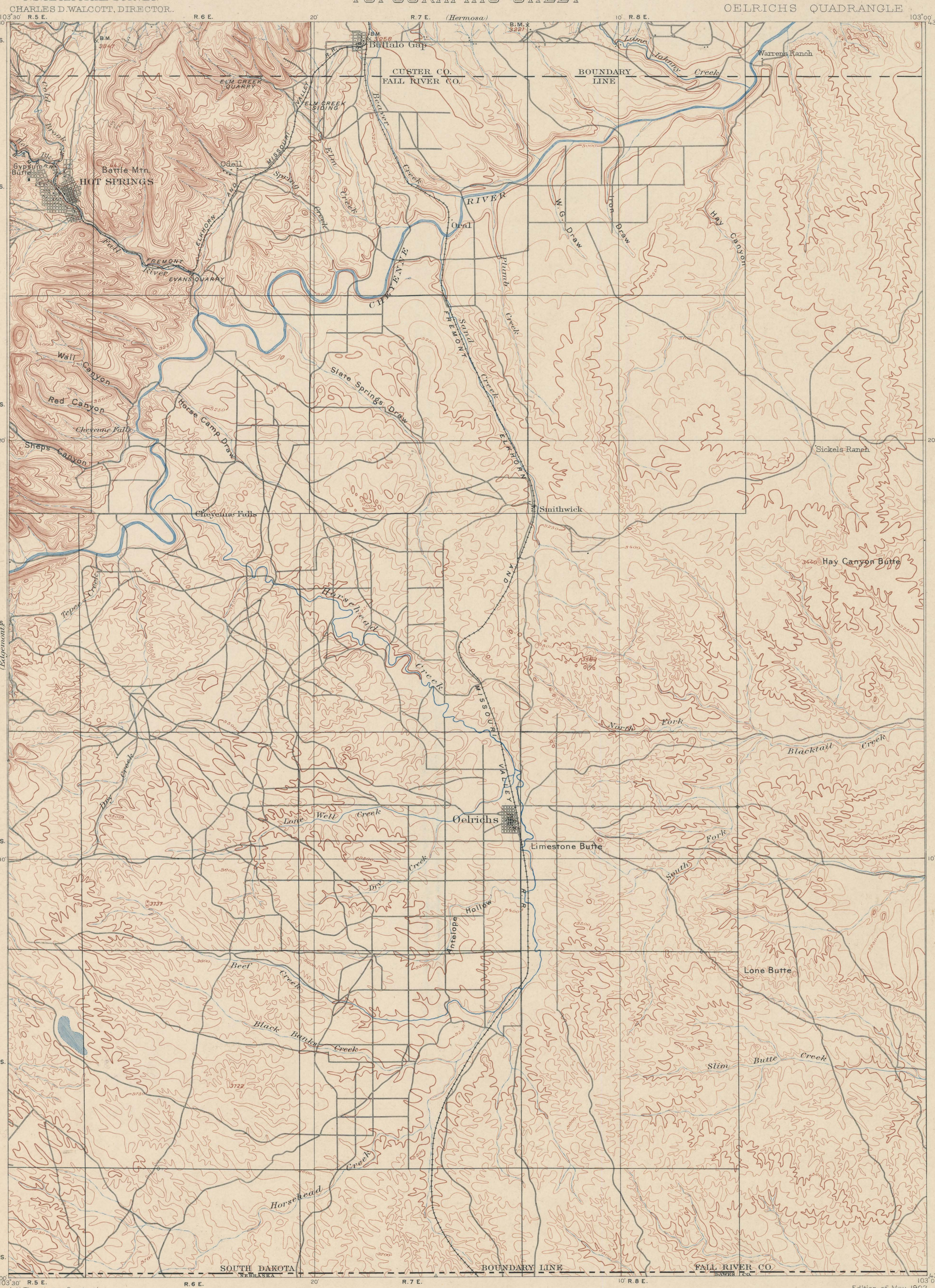
The Chadron formation contains a thin bed of volcanic ash which is of economic value as polishing powder. The exposure is in the steep beds on the south side of the syncline a short distance east of South Fork of Blacktail Creek. The bed is thin and apparently not extensive, but it is a particularly sharp-edged ash and is consequently very powerful as an abrasive.

June, 1901.

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

TOPOGRAPHIC SHEET

SOUTH DAKOTA–NEBRASKA
OELRICHS QUADRANGLE



LEGEND

RELIEF
(printed in brown)

Figures *(showing heights above mean sea level instrumentally determined)*

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

Depression contours

DRAINAGE
(printed in blue)

Streams

Intermittent streams

Intermittent lakes

CULTURE
(printed in black)

Roads and buildings

Private and secondary roads

Trails

Railroads

U.S. township lines

State lines

County lines

Triangulation stations

Bench marks

A. H. Thompson, Geographer.
E. M. Douglas, Topographer in charge.
Triangulation by E. M. Douglas.
Topography by T. M. Bannon.
Surveyed in 1893.

Scale 1/125000

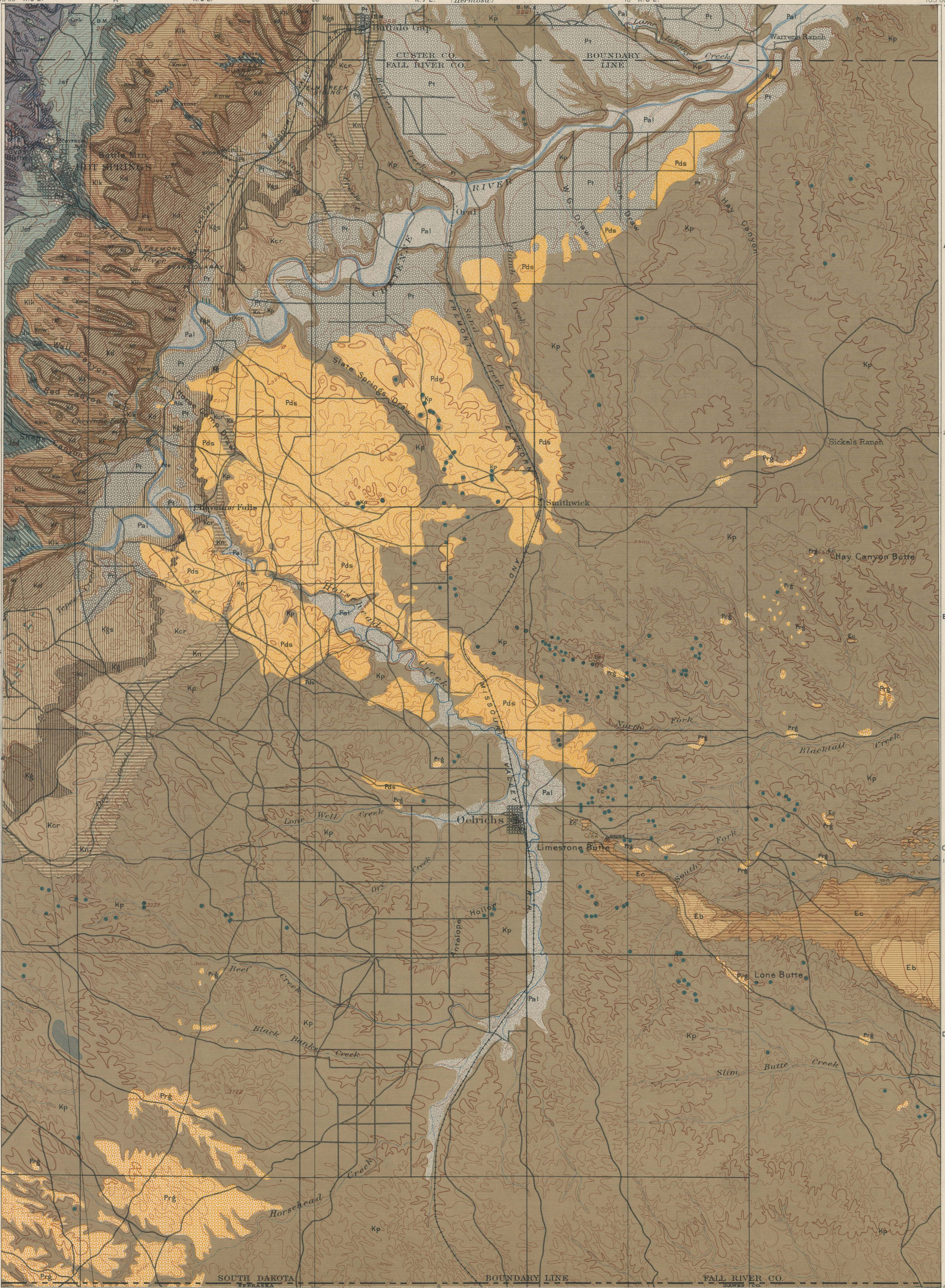
Contour interval 50 feet.
Datum is mean sea level.

Edition of May 1902.

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

AREAL GEOLOGY SHEET

SOUTH DAKOTA–NEBRASKA
OELRICHS QUADRANGLE



103°30′ R.5 E. E R.6 E. 20′ R.7 E. 10′ R.8 E. 103°00′

A.H.Thompson, Geographer.
E.M.Douglas, Topographer in charge.
Triangulation by E.M.Douglas.
Topography by T.M.Bannon.
Surveyed in 1893.

Scale $\frac{1}{125000}$

1 ½ 0 1 2 3 4 5 Miles

1 ½ 0 1 2 3 4 5 Kilometers

Contour interval 50 feet.

Datum is mean sea level.

Edition of June 1902.

Geology by N.H. Darton.
Surveyed in 1899.

LEGEND

SEDIMENTARY ROCKS
(continued)

CARBONIFEROUS

- Cmk — Minnekahta limestone *(very thin-bedded gray limestone in massive ledges)*
- Co — Opeche formation *(bright-red sandy shale; purplish at top)*
- Cml — Minnelusa sandstone *(red, yellow, and gray calcareous sandstone)*

Sandstone dikes in Graneros shale *(material derived from Dakota sandstone)*

Sections

Quarries

LEGEND

SURFICIAL ROCKS
(Areas of Surficial rocks are shown by patterns of dots and circles)

PLEISTOCENE

- Pds — Dune sand
- Pal — Alluvium *(only the larger deposits represented)*
- Pt — Older terrace deposits *(sand, gravel, and loam)*
- Ptc — Terrace conglomerate *(locally lithified gravel beds in older terrace deposits)*
- Prg — Residual gravel *(from Chadron sand)*

SEDIMENTARY ROCKS
(Areas of Sedimentary rocks are shown by patterns of parallel lines)

OLIGOCENE — EOCENE

- Eb — Brule clay *(massive, sandy, pale-pink and buff clay)*
- Ec — Chadron sand *(white to gray sand with thin limestone near top)*

CRETACEOUS

- Kp — Pierre shale *(dark-gray shale or clay with many concretions)*
- Limestone lenses in Pierre shale *(form "Tepee buttes")*
- Kn — Niobrara formation *(impure chalky limestone or calcareous clay; weathers light buff)*

Subdivisions of the Benton formation

- Kcr — Carlile formation *(gray shale and thin sandstone)*
- Kg — Greenhorn limestone *(impure slabby limestone)*
- Kgs — Graneros shale *(black fissile shale)*
- Kd — Dakota sandstone *(massive buff sandstone with thinner beds at top)*
- Kf — Fuson formation *(massive sandy clay of various colors)*
- Kmw — Minnewaste limestone *(massive gray limestone)*
- Klk — Lakota formation *(massive buff sandstone with clay intercalations)*

JURATRIAS

JURASSIC

- Ju — Unkpapa sandstone *(massive fine-grained sandstone, red, purple, white, yellow, and buff)*
- Jsd — Sundance formation *(buff sandstone and greenish shale)*

TRIASSIC

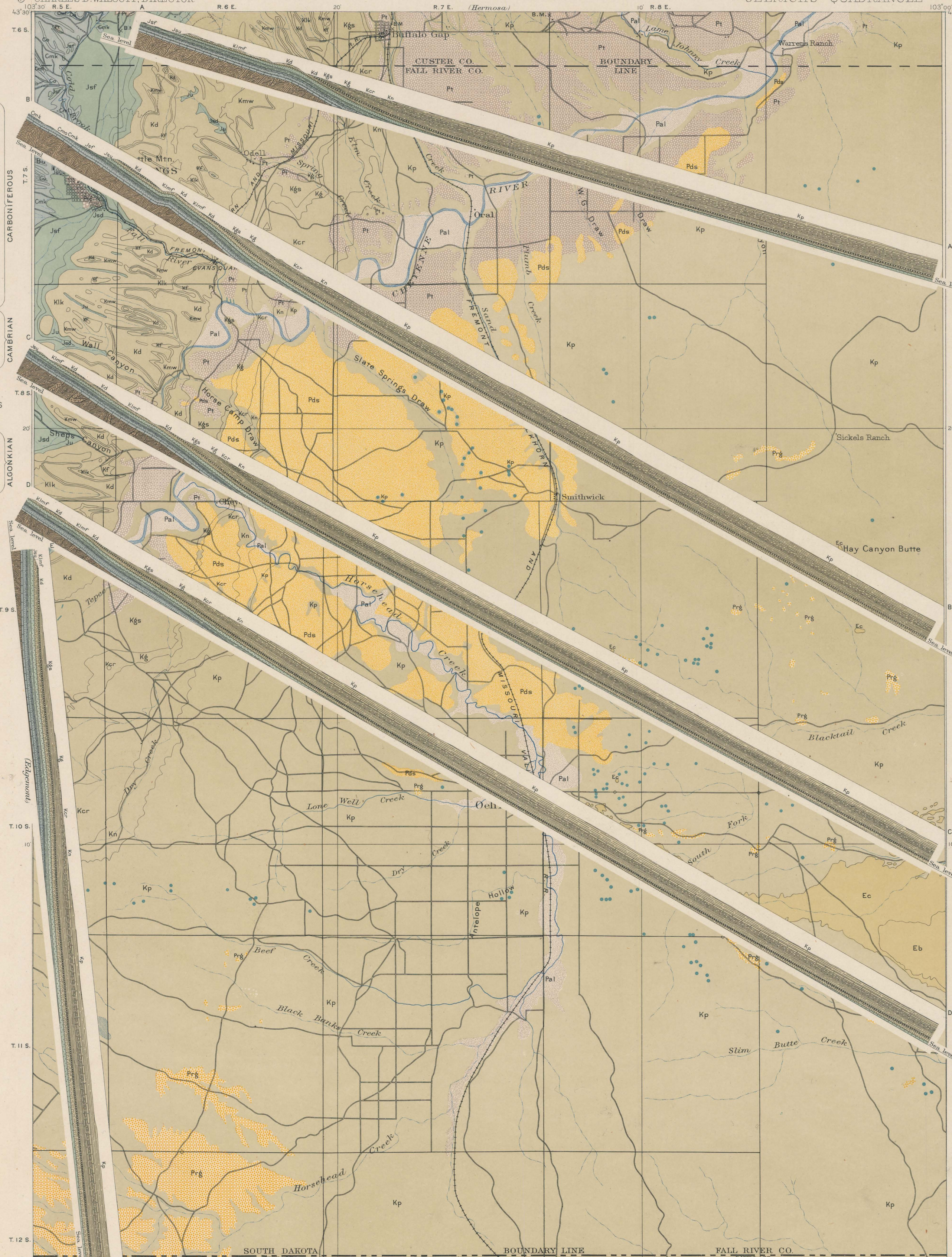
- Jsf — Spearfish shale *(red sandy shale)*

Legend is continued on the left margin.

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

STRUCTURE-SECTION SHEET

SOUTH DAKOTA–NEBRASKA
OELRICHS QUADRANGLE



LEGEND

SEDIMENTARY ROCKS (continued)

SHEET SYMBOL / SECTION SYMBOL

CARBONIFEROUS

- Cmk / Cmk — Minnekahta limestone (very thin-bedded gray limestone in massive ledges)
- Co — Combined with Minnelusa sandstone on sections — Opeche formation (bright red sandy shale; purplish at top)
- Cml / Cmo — Minnelusa sandstone (red, yellow, and gray calcareous sandstone)
- Pahasapa limestone

CAMBRIAN

- Pahasapa limestone and Deadwood sandstone (do not outcrop in this quadrangle)

ANCIENT CRYSTALLINE ROCKS

SECTION SYMBOL

ALGONKIAN

- Schist and granite (do not outcrop in this quadrangle)

Sandstone dikes in Graneros shale (material derived from Dakota sandstone)

LEGEND

SURFICIAL ROCKS

SHEET SYMBOL

PLEISTOCENE

- Pds — Dune sand
- Pal — Alluvium (only the larger deposits represented)
- Pt — Older terrace deposits (sand, gravel, and loam)
- Ptc — Terrace conglomerate (locally cemented gravel beds in older terrace deposits)
- Prg — Residual gravel (from Chadron sand)

SEDIMENTARY ROCKS

SHEET SYMBOL / SECTION SYMBOL

OLIGOCENE / EOCENE

- Eb — Brule clay (massive, sandy, pale pink and buff clay)
- Ec — Chadron sand (white to gray sand with thin limestone near top)

CRETACEOUS

- Kp / Kp — Pierre shale (dark gray shale or clay with many concretions)
- Limestone lenses in Pierre shale (form "Tepee buttes")
- Kn / Kn — Niobrara formation (impure chalky limestone or calcareous clay; weathers light buff)

Subdivisions of the Benton formation

- Kcr / Kcr — Carlile formation (gray shale and thin sandstones)
- Kg / Kg — Greenhorn limestone (impure slabby limestone)
- Kgs / Kgs — Graneros shale (black fissile shale)
- Kd / Kd — Dakota sandstone (massive buff sandstone with thinner beds at top)
- Kf — Combined with Lakota formation on sections — Fuson formation (massive sandy clay of various colors)
- Kmw — Combined with Lakota formation on sections — Minnewaste limestone (massive gray limestone)
- Klk / Klmf — Lakota formation (massive buff sandstone with clay intercalations)

JURATRIAS

JURASSIC

- Ju / Jsu — Unkpapa sandstone (massive fine-grained sandstone, red, purple, white, yellow, and buff)
- Jsd — Combined with Unkpapa sandstone on sections — Sundance formation (buff sandstone and greenish shale)

TRIASSIC

- Jsf / Jsf — Spearfish shale (red sandy shale)

A. H. Thompson, Geographer.
E. M. Douglas, Topographer in charge.
Triangulation by E. M. Douglas.
Topography by T. M. Bannon.
Surveyed in 1893.

Scale 1/125000
Miles; Kilometers

Edition of Sept. 1902.

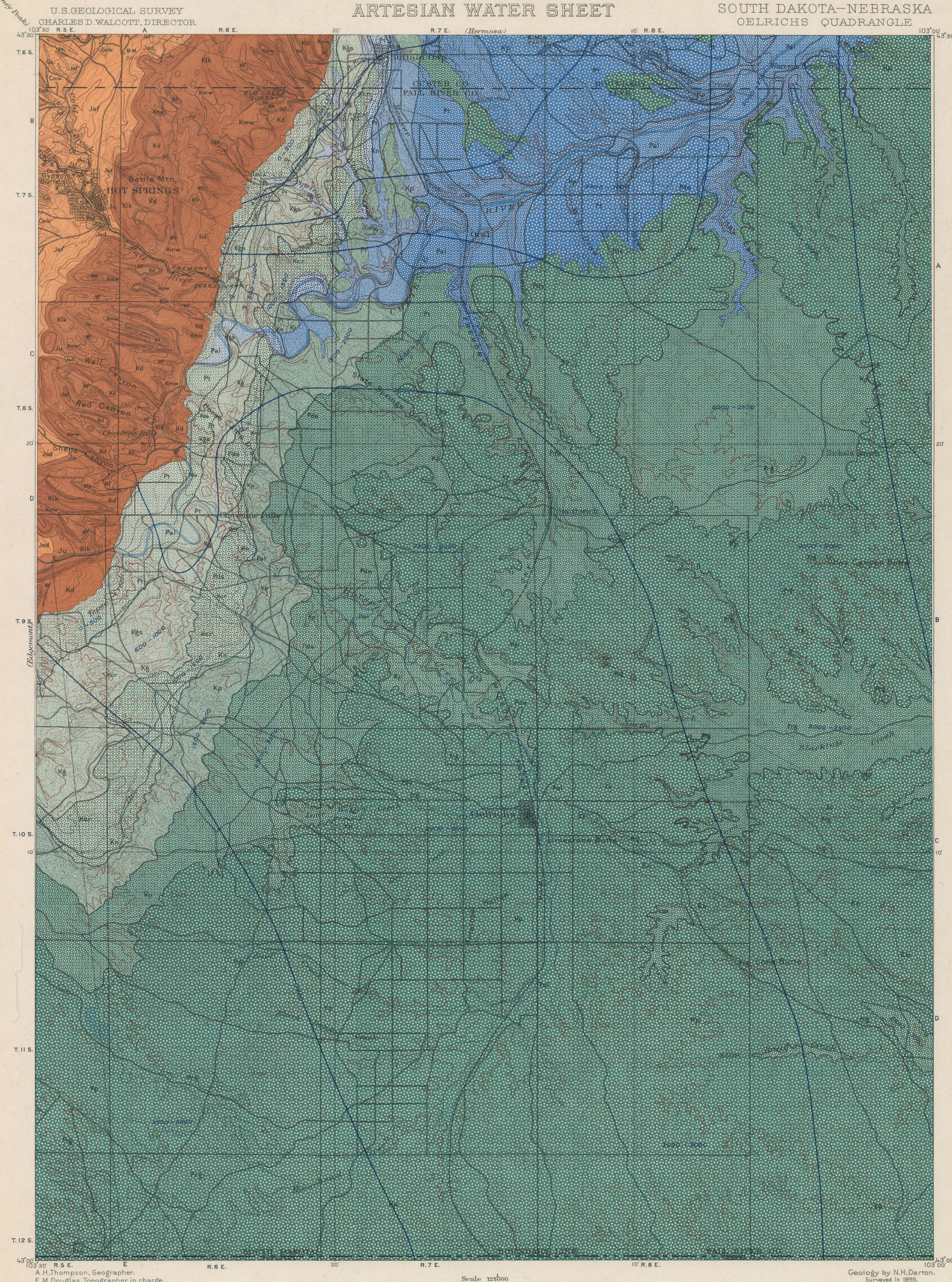
Geology by N. H. Darton.
Surveyed in 1899.

Legend is continued on the left margin.

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

ARTESIAN WATER SHEET

SOUTH DAKOTA–NEBRASKA
OELRICHS QUADRANGLE



LEGEND

0-500
500-1000
1000-1500
1500-2000
2000-2500
2500-3000

Area of artesian water which will probably yield flowing wells
(depth to top of Dakota sandstone indicated by pattern)

0-500
500-1000
1000-1500
1500-2000
2000-2500
2500-3000

Area of artesian water which will probably yield pumping wells
(depth to top of Dakota sandstone indicated by pattern)

Lines which show approximate depth to top of Dakota sandstone, the uppermost of a series of water-bearing sandstones. Interval is 500 feet. Figures show depth in feet

Area of outcrop of Dakota sandstone and associated artesian water formations

Area not containing Dakota sandstone and associated artesian water formations

Contour lines showing approximate altitude above sea to which the artesian water may rise

A.H. Thompson, Geographer.
E.M. Douglas, Topographer in charge.
Triangulation by E.M. Douglas.
Topography by T.M. Bannon.
Surveyed in 1893.

Scale $\frac{1}{125000}$

1 ½ 0 1 2 3 4 5 Miles

1 ½ 0 1 2 3 4 5 Kilometers

Contour interval 50 feet.

Datum is mean sea level.

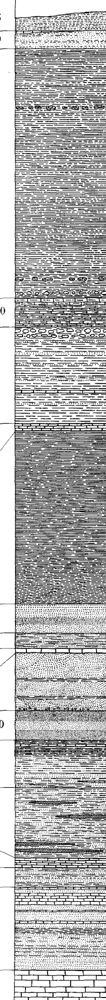
Edition of Sept. 1902.

Geology by N.H. Darton.
Surveyed in 1899.

COLUMNAR SECTION SHEET

GENERALIZED SECTION FOR THE OELRICHS QUADRANGLE.

SCALE: 1 INCH=500 FEET.



Period.	Formation Name.	Symbol.	Thickness in Feet.	Columnar Section.	Depth to Dakota Sandstone.	Character of Rocks.	Character of Topography and Soils.
EOCENE (OLIGOCENE)	Brule clay.	Eb	0–115			Pinkish-buff sandy clay.	Bad lands.
	Chadron formation.	Ec	0–100		3000	Sand and sandy clay with limestone at the top.	Bad lands.
CRETACEOUS	Pierre shale.	Kp	1300		2800 2600 2400 2200 2000 1800 1600	Principal horizon of limestone lenses, giving rise to "tepee buttes." Dark-gray shale or clay, weathering brown or buff and containing many fossiliferous concretions. Widely scattered concretions which give rise to "tepee buttes." Black fissile shale containing numerous concretions, in part cone-in-cone.	Small sharp hills, "tepee buttes." Wide rolling plains with shallow valleys and low ridges. Soil thin, clayey, and infertile. Supports thin growth of grass. Small sharp hills, "tepee buttes."
	Niobrara formation.	Kn	100–200			Gray calcareous shale, weathering yellow, and impure chalk filled with *Ostrea congesta* near the top.	Valleys or flats with fertile soil.
	Carlile formation.	Kcr	500		1400 1200 1000	Light-colored shale with numerous large concretions. Gray shale with sandy shale and thin sandstone layers. Bed of impure limestone.	Low rocky ridges and bare shale slopes.
	Greenhorn limestone.	Kg	35		800	Thin-bedded, hard limestone, weathering creamy white, and filled with *Inoceramus labiatus*.	Small bare ridges.
	Graneros shale.	Kgs	900		600 400 200 0	Dark shale, very fissile below, with scattered concretions.	Wide valleys with thin sterile soil except where covered by alluvium.
	Dakota sandstone.	Kd	150			Sandstone, thin bedded above, very massive below.	Rocky slopes and cliffs. Soil very thin.
	Fuson formation.	Kf	80			Massive, buff to purple, sandy shale.	Slopes below cliffs of sandstone.
	Minnewaste limestone.	Kmw	25			Light-gray limestone.	Even surfaces nearly bare.
	Lakota formation.	Klk	300			Massive, cross-bedded sandstone and shale.	Rocky slopes and high cliffs. Soil very thin.
JURATRIAS — JURASSIC	Unkpapa sandstone.	Ju	100–200			Fine-grained, massive sandstone, white, pink, purple, and buff.	Bare cliffs.
	Sundance formation.	Jsd	250			Greenish-gray shale with thin limestone beds. Red sandy shale, buff sandstone, and thin beds of limestone.	Long slopes with much talus cover.
TRIASSIC?	Spearfish shale. ("Red Beds.")	Jsf	400			Red sandy shale with gypsum beds.	Wide red valley with poor soil.
CARBONIFEROUS — PERMO-CARB.	Minnekahta limestone.	Cmk	50			Thin-bedded gray limestone.	Rocky slopes and cliffs.
	Opeche formation.	Co	100			Red sandy shale and red sandstone.	Slopes below cliffs.
	Minnelusa sandstone.	Cml	430			Reddish, buff, white, and gray sandstone, with some shale and limestone in upper portion.	Canyon walls.
	Pahasapa limestone.					Massive gray limestone.	Does not reach the surface.

N. H. DARTON,
Geologist.

ILLUSTRATION SHEET

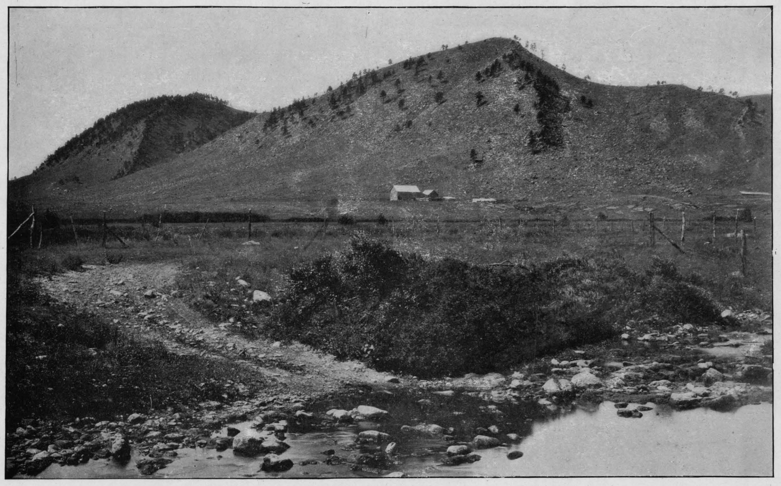


FIG. 3.—"HOGBACK" OF DAKOTA SANDSTONE.

Buffalo Gap, S. Dak.; looking southwest. The surfaces sloping steeply to the left are the bedding surfaces of the upturned Dakota sandstone.

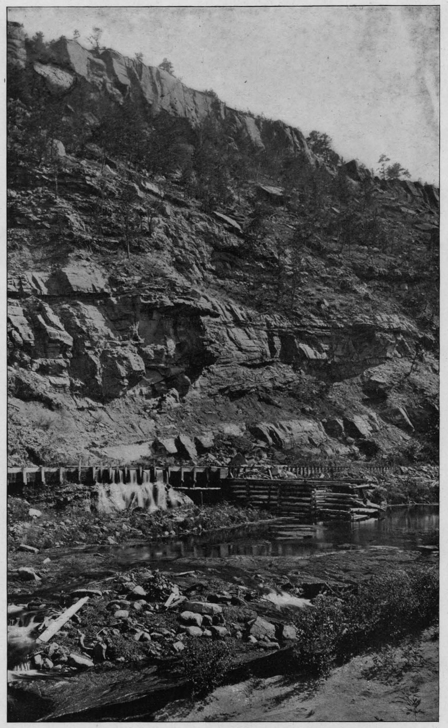


FIG. 4.—EXPOSURE OF DAKOTA SANDSTONE, FUSON FORMATION MINNEWASTE LIMESTONE, AND LAKOTA FORMATION.

At Evans quarry, south wall of Fall River Canyon, 4 miles below Hot Springs, S. Dak. The capping rock is Dakota sandstone.

FIG. 5.—AN AGGLOMERATE OF OSTREA CONGESTA SHELLS.

A typical fossil of the Niobrara formation.

FIG 6.—INOCERAMUS LABIATUS.

The typical fossil of the Greenhorn limestone.

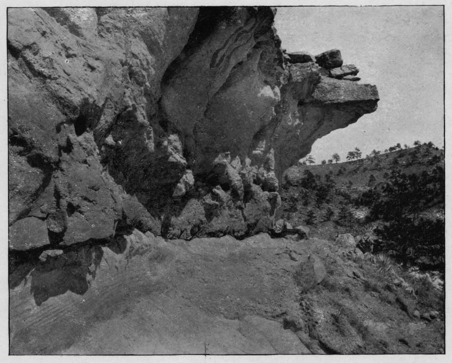


FIG. 7.—LAKOTA SANDSTONE LYING UNCONFORMABLY ON UNKPAPA SANDSTONE.

North wall of Sheps Canyon, south of Hot Springs, S. Dak.

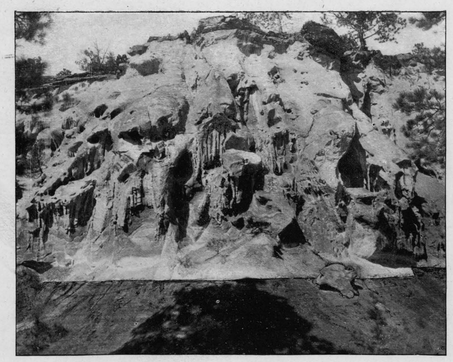


FIG. 8.—UNCONFORMABLE CONTACT OF SUNDANCE FORMATION ON SPEARFISH SHALE, "RED BEDS."

Seven miles south of Hot Springs, S. Dak.

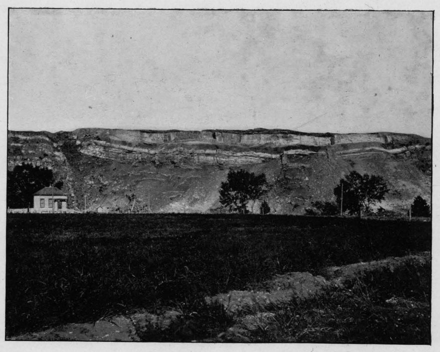


FIG. 9.—GYPSUM BEDS IN SPEARFISH SHALE.

Cliff on Cold Brook, near Hot Springs, S. Dak.

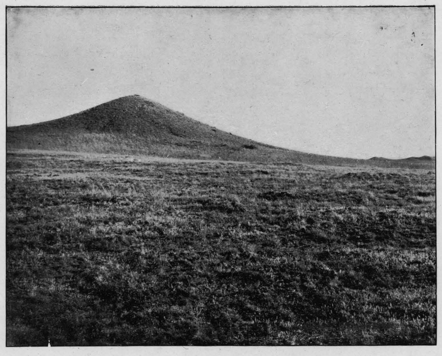


FIG. 10.—A TYPICAL "TEPEE BUTTE."

Due to a limestone lens, which contains numerous shells of Lucina occidentalis, in Pierre shale.

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