DEPARTMENT OF THE INTERIOR

UNITED STATES GEOLOGICAL SURVEY

GEORGE OTIS SMITH, DIRECTOR

GEOLOGIC ATLAS

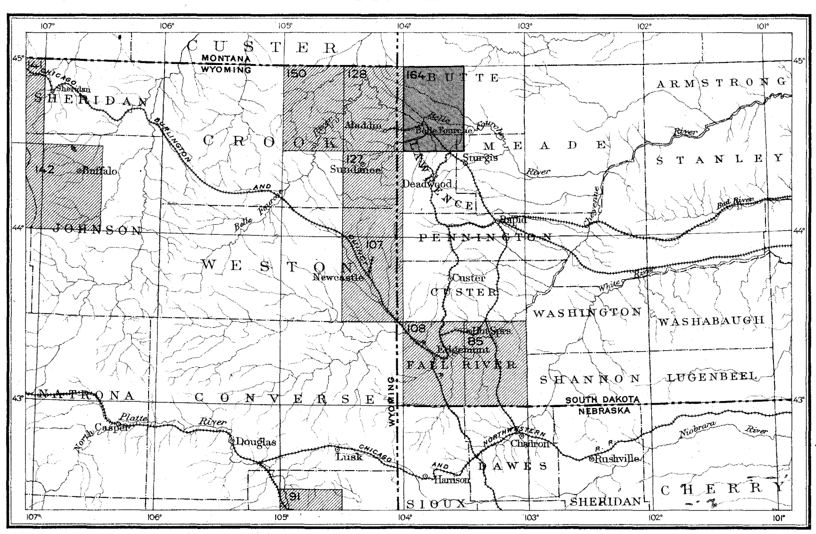
OF THE

UNITED STATES

BELLE FOURCHE FOLIO

SOUTH DAKOTA

INDEX MAP



SCALE: 40 MILES-1 INCH

BELLE FOURCHE FOLIO

OTHER PUBLISHED FOLIOS

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WASHINGTON, D. C.

ENGRAVED AND PRINTED BY THE U. S. GEOLOGICAL SURVEY

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

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GEOLOGIC ATLAS OF THE UNITED STATES.

The Geological Survey is making a geologic atlas of the United States, which is being issued in parts, called folios. Each folio includes topographic and geologic maps of a certain area, together with descriptive text.

THE TOPOGRAPHIC MAP.

The features represented on the topographic map are of three distinct kinds—(1) inequalities of surface, called *relief*, as plains, plateaus, valleys, hills, and mountains; (2) distribution of water, called *drainage*, as streams, lakes, and swamps; (3) the works of man, called *culture*, as roads, railroads, boundaries, villages, and cities.

Relief.—All elevations are measured from mean sea level. The heights of many points are accurately determined, and those of the most important ones are given on the map in figures. It is desirable, however, to give the elevation of all parts of the area mapped, to delineate the outline or form of all slopes, and to indicate their grade or steepness. This is done by lines each of which is drawn through points of equal elevation above mean sea level, the vertical interval represented by each space between lines being the same throughout each map. These lines are called *contour lines* or, more briefly, *contours*, and the uniform vertical distance between each two contours is called the *contour interval*. Contour lines and elevations are printed in brown. The manner in which contour lines express altitude, form, and grade is shown in figure 1.

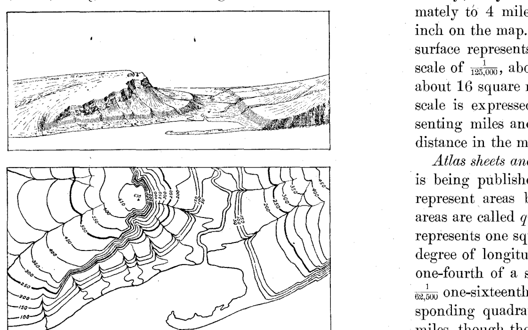


FIGURE 1.—Ideal view and corresponding contour map.

The sketch represents a river valley between two hills. In the foreground is the sea, with a bay that is partly closed by a hooked sand bar. On each side of the valley is a terrace. The terrace on the right merges into a gentle hill slope; that on the left is backed by a steep ascent to a cliff, or scarp, which contrasts with the gradual slope away from its crest. In the map each of these features is indicated, directly beneath its position in the sketch, by contour lines. The map does not include the distant portion of the view. The following notes may help to explain the use of contour lines:

1. A contour line represents a certain height above sea level. In this illustration the contour interval is 50 feet; therefore the contour lines are drawn at 50, 100, 150, and 200 feet, and so on, above mean sea level. Along the contour at 250 feet lie all points of the surface that are 250 feet above the sea—that is, this contour would be the shore line if the sea were to rise 250 feet; along the contour at 200 feet are all points that are 200 feet above the sea; and so on. In the space between any two contours are all points whose elevations are above the lower and below the higher contour. Thus the contour at 150 feet falls just below the edge of the terrace, and that at 200 feet lies above the terrace; therefore all points on the terrace are shown to be more than 150 but less than 200 feet above the sea. The summit of the higher hill is marked 670 (feet above sea level); accordingly the contour at 650 feet surrounds it. In this illustration all the contour lines are numbered, and those for 250 and 500 feet are accentuated by being made heavier. Usually it is not desirable to number all the contour lines. The accentuating and numbering of certain of them—say every fifth one—suffices and the heights of the others may be ascertained by counting up or down from these.

2. Contour lines show or express the forms of slopes. As contours are continuous horizontal lines, they wind smoothly about smooth surfaces, recede into all reentrant angles of ravines, and project in passing around spurs or prominences. These relations of contour curves and angles to forms of the landscape can be seen from the map and sketch.

3. Contour lines show the approximate grade of any slope. The vertical interval between two contours is the same, whether they lie along a cliff or on a gentle slope; but to attain a given height on a gentle slope one must go farther than on a steep slope, and therefore contours are far apart on gentle slopes and near together on steep ones.

A small contour interval is necessary to express the relief of a flat or gently undulating country; a steep or mountainous country can, as a rule, be adequately represented on the same scale by the use of a larger interval. The smallest interval used on the atlas sheets of the Geological Survey is 5 feet. This is in regions like the Mississippi Delta and the Dismal Swamp. For great mountain masses, like those in Colorado, the interval may be 250 feet and for less rugged country contour intervals of 10, 20, 25, 50, and 100 feet are used.

Drainage.—Watercourses are indicated by blue lines. For a perennial stream the line is unbroken, but for an intermittent stream it is broken or dotted. Where a stream sinks and reappears the probable underground course is shown by a broken blue line. Lakes, marshes, and other bodies of water are represented by appropriate conventional signs in blue.

Culture.—The symbols for the works of man and all lettering are printed in black.

Scales.—The area of the United States (exclusive of Alaska and island possessions) is about 3,027,000 square miles. A map of this area, drawn to the scale of 1 mile to the inch would cover 3,027,000 square inches of paper and measure about 240 by 180 feet. Each square mile of ground surface would be represented by a square inch of map surface, and a linear mile on the ground by a linear inch on the map. The scale may be expressed also by a fraction, of which the numerator is a length on the map and the denominator the corresponding length in nature expressed in the same unit. Thus, as there are 63,360 inches in a mile, the scale "1 mile to the inch" is expressed by the fraction $\frac{1}{63,360}$.

Three scales are used on the atlas sheets of the Geological Survey; they are $\frac{1}{250,000}$, $\frac{1}{125,000}$, and $\frac{1}{62,500}$, corresponding approximately to 4 miles, 2 miles, and 1 mile on the ground to an inch on the map. On the scale of $\frac{1}{62,500}$ a square inch of map surface represents about 1 square mile of earth surface; on the scale of $\frac{1}{125,000}$, about 4 square miles; and on the scale of $\frac{1}{250,000}$, about 16 square miles. At the bottom of each atlas sheet the scale is expressed in three ways—by a graduated line representing miles and parts of miles, by a similar line indicating distance in the metric system, and by a fraction.

Atlas sheets and quadrangles.—The map of the United States is being published in atlas sheets of convenient size, which represent areas bounded by parallels and meridians. These areas are called *quadrangles*. Each sheet on the scale of $\frac{1}{250,000}$ represents one square degree—that is, a degree of latitude by a degree of longitude; each sheet on the scale of $\frac{1}{125,000}$ represents one-fourth of a square degree, and each sheet on the scale of $\frac{1}{62,500}$ one-sixteenth of a square degree. The areas of the corresponding quadrangles are about 4000, 1000, and 250 square miles, though they vary with the latitude.

The atlas sheets, being only parts of one map of the United States, are not limited by political boundary lines, such as those of States, counties, and townships. Many of the maps represent areas lying in two or even three States. To each sheet, and to the quadrangle it represents, is given the name of some well-known town or natural feature within its limits, and at the sides and corners of each sheet are printed the names of adjacent quadrangles, if the maps are published.

THE GEOLOGIC MAPS.

The maps representing the geology show, by colors and conventional signs printed on the topographic base map, the distribution of rock masses on the surface of the land and, by means of structure sections, their underground relations, so far as known and in such detail as the scale permits.

KINDS OF ROCKS.

Rocks are of many kinds. On the geologic map they are distinguished as igneous, sedimentary, and metamorphic.

Igneous rocks.—Rocks that have cooled and consolidated from a state of fusion are known as *igneous*. Molten material has from time to time been forced upward in fissures or channels of various shapes and sizes through rocks of all ages to or nearly to the surface. Rocks formed by the consolidation of molten material, or magma, within these channels—that is, below the surface—are called *intrusive*. Where the intrusive rock occupies a fissure with approximately parallel walls it is called a *dike*; where it fills a large and irregular conduit the mass is termed a *stock*. Where molten magma traverses stratified rocks it may be intruded along bedding planes; such masses are called *sills* or *sheets* if comparatively thin, and *laccoliths* if they occupy larger chambers produced by the pressure of the magma. Where inclosed by rock molten material cools slowly, with the result that intrusive rocks are generally of crystalline texture. Where the channels reach the surface the molten material poured out through them is called *lava*, and lavas often build up volcanic mountains. Igneous rocks that have solidified at the surface are called *extrusive* or *effusive*. Lavas generally cool more rapidly than intrusive rocks and as a rule contain, especially in their superficial parts, more or less volcanic glass, produced by rapid chilling. The outer parts of lava flows also are usually porous, owing to the expansion of the gases originally present in the magma. Explosive action, due to these gases, often accompanies volcanic eruptions, causing ejections of dust, ash, lapilli, and larger fragments. These materials, when consolidated, constitute breccias, agglomerates, and tuffs.

Sedimentary rocks.—Rocks composed of the transported fragments or particles of older rocks that have undergone disintegration, of volcanic ejecta deposited in lakes and seas, or of materials deposited in such water bodies by chemical precipitation are termed *sedimentary*.

The chief agent in the transportation of rock débris is water in motion, including rain, streams, and the water of lakes and of the sea. The materials are in large part carried as solid particles, and the deposits are then said to be mechanical. Such are gravel, sand, and clay, which are later consolidated into conglomerate, sandstone, and shale. Some of the materials are carried in solution, and deposits of these are called organic if formed with the aid of life, or chemical if formed without the aid of life. The more important rocks of chemical and organic origin are limestone, chert, gypsum, salt, iron ore, peat, lignite, and coal. Any one of the kinds of deposit named may be separately formed, or the different materials may be intermingled in many ways, producing a great variety of rocks.

Another transporting agent is air in motion, or wind, and a third is ice in motion, or glaciers. The most characteristic of the wind-borne or eolian deposits is loess, a fine-grained earth; the most characteristic of glacial deposits is till, a heterogeneous mixture of bowlders and pebbles with clay or sand.

Sedimentary rocks are usually made up of layers or beds which can be easily separated. These layers are called *strata*, and rocks deposited in such layers are said to be stratified.

The surface of the earth is not immovable; over wide regions it very slowly rises or sinks, with reference to the sea, and shore lines are thereby changed. As a result of upward movement marine sedimentary rocks may become part of the land, and most of our land areas are in fact occupied by rocks originally deposited as sediments in the sea.

Rocks exposed at the surface of the land are acted on by air, water, ice, animals, and plants, especially the low organisms known as bacteria. They gradually disintegrate and the more soluble parts are leached out, the less soluble material being left as a *residual* layer. Water washes this material down the slopes, and it is eventually carried by rivers to the ocean or other bodies of water. Usually its journey is not continuous, but it is temporarily built into river bars and flood plains, where it forms *alluvium*. Alluvial deposits, glacial deposits (collectively known as *drift*), and eolian deposits belong to the *surficial* class, and the residual layer is commonly included with them. Their upper parts, occupied by the roots of plants, constitute soils and subsoils, the soils being usually distinguished by a notable admixture of organic matter.

Metamorphic rocks.—In the course of time, and by various processes, rocks may become greatly changed in composition and in texture. If the new characteristics are more pronounced than the old such rocks are called *metamorphic*. In the process of metamorphism the constituents of a chemical rock may enter into new combinations and certain substances may be lost or new ones added. A complete gradation from the primary to the metamorphic form may exist within a single rock mass. Such changes transform sandstone into quartzite and limestone into marble and modify other rocks in various ways.

From time to time during geologic ages rocks that have been deeply buried and have been subjected to enormous pressures, to slow movement, and to igneous intrusion have been afterward raised and later exposed by erosion. In such rocks the original structures may have been lost entirely and new ones substituted. A system of planes of division, along which the rock splits most readily, may have been developed. This structure is called *cleavage* and may cross the original bedding planes at any angle. The rocks characterized by it are *slates*. Crystals of mica or other minerals may have grown in the rock in such a way as to produce a laminated or foliated structure known as *schistosity*. The rocks characterized by this structure are *schists*.

As a rule, the oldest rocks are most altered and the younger formations have escaped metamorphism, but to this rule there are many important exceptions, especially in regions of igneous activity and complex structure.

FORMATIONS.

For purposes of geologic mapping rocks of all the kinds above described are divided into *formations*. A sedimentary formation contains between its upper and lower limits either rocks of uniform character or rocks more or less uniformly varied in character, as, for example, an alternation of shale and limestone. Where the passage from one kind of rocks to another is gradual it may be necessary to separate two contiguous formations by an arbitrary line, and in some cases the distinction depends almost entirely on the contained fossils. An igneous formation contains one or more bodies of one kind, of similar occurrence, or of like origin. A metamorphic formation may consist of rock of uniform character or of several rocks having common characteristics or origin.

When for scientific or economic reasons it is desirable to recognize and map one or more specially developed parts of a varied formation, such parts are called *members*, or by some other appropriate term, as *lentils*.

AGES OF ROCKS.

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

The sedimentary formations deposited during a period are grouped together into a *system.* The principal divisions of a system are called *series.* Any aggregate of formations less than a series is called a *group.*

Inasmuch as sedimentary deposits accumulate successively the younger rest on those that are older, and their relative ages may be determined by observing their positions. In many regions of intense disturbance, however, the beds have been overturned by folding or superposed by faulting, so that it may be difficult to determine their relative ages from their present positions; under such conditions fossils, if present, may indicate which of two or more formations is the oldest.

Many stratified rocks contain *fossils,* the remains or imprints of plants and animals which, at the time the strata were deposited, lived in bodies of water or were washed into them, or were buried in surficial deposits on the land. Such rocks are called fossiliferous. By studying fossils it has been found that the life of each period of the earth's history was to a great extent different from that of other periods. Only the simpler kinds of marine life existed when the oldest fossiliferous rocks were deposited. From time to time more complex kinds developed, and as the simpler ones lived on in modified forms life became more varied. But during each period there lived peculiar forms, which did not exist in earlier times and have not existed since; these are *characteristic types,* and they define the age of any bed of rock in which they are found. Other types passed on from period to period, and thus linked the systems together, forming a chain of life from the time of the oldest fossiliferous rocks to the present. Where two sedimentary formations are remote from each other and it is impossible to observe their relative positions, the characteristic fossil types found in them may determine which was deposited first. Fossil remains in the strata of different areas, provinces, and continents afford the most important means for combining local histories into a general earth history.

It is many places difficult or impossible to determine the age of an igneous formation, but the relative age of such a formation can in general be ascertained by observing whether an associated sedimentary formation of known age is cut by the igneous mass or is deposited upon it. Similarly, the time at which metamorphic rocks were formed from the original masses may be shown by their relations to adjacent formations of known age; but the age recorded on the map is that of the original masses and not that of their metamorphism.

Symbols, colors, and patterns.—Each formation is shown on the map by a distinctive combination of color and pattern and is labeled by a special letter symbol.

Patterns composed of parallel straight lines are used to represent sedimentary formations deposited in the sea, in lakes, or in other bodies of standing water. Patterns of dots and circles represent alluvial, glacial, and eolian formations. Patterns of triangles and rhombs are used for igneous formations. Metamorphic rocks of unknown origin are represented by short dashes irregularly placed; if the rock is schist the dashes may be arranged in wavy lines parallel to the structure planes. Suitable combination patterns are used for metamorphic formations known to be of sedimentary or of igneous origin. The patterns of each class are printed in various colors. With the patterns of parallel lines, colors are used to indicate age, a particular color being assigned to each system.

The symbols consist each of two or more letters. If the age of a formation is known the symbol includes the system symbol, which is a capital letter or monogram; otherwise the symbols are composed of small letters.

The names of the systems and of series that have been given distinctive names, in order from youngest to oldest, with the color and symbol assigned to each system, are given in the subjoined table.

Symbols and colors assigned to the rock systems.

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

SURFACE FORMS.

Hills, valleys, and all other surface forms have been produced by geologic processes. For example, most valleys are the result of erosion by the streams that flow through them (see fig. 1), and the alluvial plains bordering many streams were built up by the streams; waves cut sea cliffs and, in cooperation with currents, build up sand spits and bars. Topographic forms thus constitute part of the record of the history of the earth.

Some forms are inseparably connected with deposition. The hooked spit shown in figure 1 is an illustration. To this class belong beaches, alluvial plains, lava streams, drumlins (smooth oval hills composed of till), and moraines (ridges of drift made at the edges of glaciers). Other forms are produced by erosion. The sea cliff is an illustration; it may be carved from any rock. To this class belong abandoned river channels, glacial furrows, and peneplains. In the making of a stream terrace an alluvial plain is first built and afterward partly eroded away. The shaping of a marine or lacustrine plain is usually a double process, hills being worn away (*degraded*) and valleys being filled up (*aggraded*).

All parts of the land surface are subject to the action of air, water, and ice, which slowly wear them down, and streams carry the waste material to the sea. As the process depends on the flow of water to the sea, it can not be carried below sea level, and the sea is therefore called the *base-level* of erosion. Lakes or large rivers may determine local base-levels for certain regions. When a large tract is for a long time undisturbed by uplift or subsidence it is degraded nearly to base-level, and the fairly even surface thus produced is called a *peneplain.* If the tract is afterward uplifted, the elevated peneplain becomes a record of the former close relation of the tract to base-level.

THE VARIOUS GEOLOGIC SHEETS.

Areal geology map.—The map showing the areas occupied by the various formations is called an *areal geology map.* On the margin is a *legend,* which is the key to the map. To ascertain the meaning of any color or pattern and its letter symbol the reader should look for that color, pattern, and symbol in the legend, where he will find the name and description of the formation. If it is desired to find any particular formation, its name should be sought in the legend and its color and pattern noted; then the areas on the map corresponding in color and pattern may be traced out. The legend is also a partial statement of the geologic history. In it the names of formations are arranged in columnar form, grouped primarily according to origin—sedimentary, igneous, and crystalline of unknown origin—and within each group they are placed in the order of age, so far as known, the youngest at the top.

Economic geology map.—The map representing the distribution of useful minerals and rocks and showing their relations to the topographic features and to the geologic formations is termed the *economic geology map.* The formations that appear on the areal geology map are usually shown on this map by fainter color patterns and the areas of productive formations are emphasized by strong colors. A mine symbol shows the location of each mine or quarry and is accompanied by the name of the principal mineral mined or stone quarried. If there are important mining industries or artesian basins in the area special maps to show these additional economic features are included in the folio.

Structure-section sheet.—In cliffs, canyons, shafts, and other natural and artificial cuttings the relations of different beds to one another may be seen. Any cutting that exhibits those relations is called a *section,* and the same term is applied to a diagram representing the relations. The arrangement of rocks in the earth is the earth's *structure,* and a section exhibiting this arrangement is called a *structure section.*

The geologist is not limited, however, to natural and artificial cuttings for his information concerning the earth's structure. Knowing the manner of formation of rocks and having traced out the relations among the beds on the surface, he can infer their relative positions after they pass beneath the surface and can draw sections representing the structure to a considerable depth. Such a section is illustrated in figure 2.

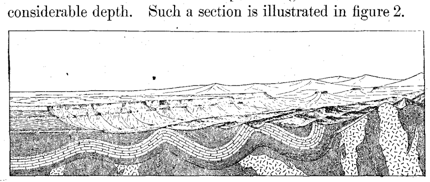


FIGURE 2.—Sketch showing a vertical section at the front and a landscape beyond.

The figure represents a landscape which is cut off sharply in the foreground on a vertical plane, so as to show the underground relations of the rocks. The kinds of rock are indicated by appropriate patterns of lines, dots, and dashes. These patterns admit of much variation, but those shown in figure 3 are used to represent the commoner kinds of rock.

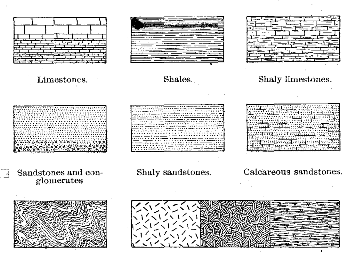


FIGURE 3.—Symbols used in sections to represent different kinds of rocks.

The plateau shown at the left of figure 2 presents toward the lower land an escarpment, or front, which is made up of sandstones, forming the cliffs, and shales, constituting the slopes. The broad belt of lower land is traversed by several ridges, which are seen in the section to correspond to the outcrops of a bed of sandstone that rises to the surface. The upturned edges of this bed form the ridges, and the intermediate valleys follow the outcrops of limestone and calcareous shale.

Where the edges of the strata appear at the surface their thickness can be measured and the angles at which they dip below the surface can be observed. Thus their positions underground can be inferred. The direction of the intersection of a bed with a horizontal plane is called the *strike.* The inclination of the bed to the horizontal plane, measured at right angles to the strike, is called the *dip.*

In many regions the strata are bent into troughs and arches, such as are seen in figure 2. The arches are called *anticlines* and the troughs *synclines.* As the sandstones, shales, and limestones were deposited beneath the sea in nearly flat sheets, the fact that they are now bent and folded is proof that forces have from time to time caused the earth's surface to wrinkle along certain zones. In places the strata are broken across and the parts have slipped past each other. Such breaks are termed *faults.* Two kinds of faults are shown in figure 4.

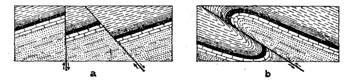


FIGURE 4.—Ideal sections of strata, showing (a) *normal* faults and (b) a *thrust* or *reverse* fault.

At the right of figure 2 the section shows schists that are traversed by igneous rocks. The schists are much contorted and their arrangement underground can not be inferred. Hence that portion of the section delineates what is probably true but is not known by observation or by well-founded inference.

The section also shows three sets of formations, distinguished by their underground relations. The uppermost set, seen at the left, is made up of sandstones and shales, which lie in a horizontal position. These strata were laid down under water but are now high above the sea, forming a plateau, and their change of elevation shows that a portion of the earth's mass has been uplifted. The strata of this set are parallel, a relation which is called *conformable.*

The second set of formations consists of strata that have been folded into arches and troughs. These strata were once continuous, but the crests of the arches have been removed by erosion. The beds, like those of the first set, are conformable.

The horizontal strata of the plateau rest upon the upturned, eroded edges of the beds of the second set shown at the left of the section. The overlying deposits are, from their position, evidently younger than the underlying deposits, and the bending and eroding of the older beds must have occurred between their deposition and the accumulation of the younger beds. The younger rocks are *unconformable* to the older, and the surface of contact is an *unconformity.*

The third set of formations consists of crystalline schists and igneous rocks. At some period of their history the schists were folded or plicated by pressure and traversed by eruptions of molten rock. But the pressure and intrusion of igneous rocks have not affected the overlying strata of the second set. Thus it is evident that a considerable interval elapsed between the formation of the schists and the beginning of deposition of the strata of the second set. During this interval the schists were metamorphosed, they were disturbed by eruptive activity, and they were deeply eroded. The contact between the second and third sets is another unconformity; it marks a time interval between two periods of rock formation.

The section and landscape in figure 2 are ideal, but they illustrate actual relations. The sections on the structure-section sheet are related to the maps as the section in the figure is related to the landscape. The profile of the surface in the section corresponds to the actual slopes of the ground along the section line, and the depth from the surface of any mineral-producing or water-bearing stratum that appears in the section may be measured by using the scale of the map.

Columnar section.—The geologic maps are usually accompanied by a *columnar section,* which contains a concise description of the sedimentary formations that occur in the quadrangle. It presents a summary of the facts relating to the character of the rocks, the thickness of the formations, and the order of accumulation of successive deposits.

The rocks are briefly described, and their characters are indicated in the columnar diagram. The thicknesses of formations are given in figures that state the least and greatest measurements, and the average thickness of each formation is shown in the column, which is drawn to scale. The order of accumulation of the sediments is shown in the columnar arrangement—the oldest being at the bottom, the youngest at the top.

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

GEORGE OTIS SMITH,
Director.

May, 1909.

DESCRIPTION OF BELLE FOURCHE QUADRANGLE.

By N. H. Darton and C. C. O'Harra.

GEOGRAPHY.

POSITION AND EXTENT OF THE QUADRANGLE.

The Belle Fourche quadrangle embraces the quarter of a square degree which lies between parallels 44° 30′ and 45° north latitude and meridians 103° 30′ and 104° west longitude. It measures 34½ miles from north to south and 25 miles from east to west and its area is 849.46 square miles. It comprises part of the southwest corner of Butte County, the northern portion of Lawrence County, and a small portion of Meade County, South Dakota. The greater part of the quadrangle is drained by Belle Fourche River, but its northeast corner extends across the divide into the head of the basin of South Fork of Owl River. The quadrangle lies mainly in the Great Plains, but its southern third extends up on the northern flanks of the Black Hills. It therefore exhibits many features of both these provinces and a general account of them will be given as an introduction to the detailed description of the quadrangle.

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 that rise mainly in the Rocky Mountains, and they are more or less deeply cut by narrower lateral valleys. 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 badlands. 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 that slope gently eastward with the slope of the plains. These deposits lie upon relatively smooth surfaces of 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 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 can 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 toward the east at the rate of about 10 feet in each mile, from altitudes approaching 6000 feet at the foot of the Rocky Mountains to about 1000 feet above sea level near Mississippi River. The altitudes and rates of slope 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 plains rise to an altitude of 6200 feet at the foot of the Rocky Mountains and maintain this elevation 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 a point 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.

Drainage.—The northern portion of the Great Plains above described is drained by the middle branches of Missouri River, the larger of which are Yellowstone, Powder, Little Missouri, Grand, Cannonball, Owl, Cheyenne, Bad, and White rivers. On Pine Ridge not far south of the escarpment is Niobrara River, which rises in the midst of the plains some distance east of the north 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 cross the plains to the southeast and afford an outlet for the drainage from a large area of mountains 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 that are older than those forming the surface of the Great Plains and that 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 slates, schists, and granite, in which scattered rocky ridges and groups of mountains are interspersed with parklike 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 area, which is much more extensive than its eastern portion, is broad and flat, with a gentle downward slope near the outer margin, but level near the eastern, inner side, which presents a line of cliffs many miles long, in places rising 800 feet above the central area. Locally it attains altitudes of slightly more than 7000 feet, almost equaling Harney Peak in height, and forms 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, parklike valleys on the plateau, they sink into deep canyons with precipitous walls of limestone, in some places many hundred feet high.

The limestone plateau, extending southward, swings around to the east side of the hills, where, owing to the steeper dip of strata, it narrows to a ridge having a steep western face. This ridge is interrupted by the water gaps of all the larger streams in the southeastern and eastern portions of the hills. These streams rise in the high limestone plateau, cross the region of crystalline rocks, and flow through canyons in the flanking regions of the east 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 are 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. In places it is 2 miles wide, though it is much narrower where the strata dip steeply. It 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, passing between divides which are usually so low as to give it 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 for the most part 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. Nearly everywhere it 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 has done the same toward the north end of the uplift.

TOPOGRAPHIC FEATURES OF THE QUADRANGLE.

Features pertaining to the Black Hills.—The Belle Fourche quadrangle presents some characteristic features of the Black Hills topography from the lower slopes of the limestone plateau to the hogback rim. The plateau projects into the southwest corner of the quadrangle on the axis of a prominent anticline and consists mostly of Minnekahta limestone, which dips steeply into the Red Valley a few miles south of Redwater River. This ridge reaches a maximum altitude of slightly over 4400 feet, and is the highest area in the quadrangle. It presents extensive areas of sloping plateaus deeply cut by numerous small canyons. The Red Valley is a prominent feature in the southwestern portion of the quadrangle, where it occupies a rudely rectangular area of about 50 square miles. Redwater and Spearfish creeks flow across it. The altitudes in the valley range from 3280 feet at the mouth of Spearfish Creek to 3600 feet on the east side of the stream a few miles above the mouth. On the north and east sides of the Red Valley is the hogback range, which presents a prominent face of sandstone cliffs toward the Red Valley but slopes gently to the plains on the opposite side. Hay and Redwater creeks trench it widely and deeply; and several smaller streams, notably False Bottom and Whitewood creeks, have cut canyons through it. The hogback range rises to an altitude of 4440 feet in the northwest corner of T. 6 N., R. 3 E., but north of Redwater Creek the elevation of its highest summits is from 3600 to 3800 feet. These ridges and the intervening valleys illustrate the close relation between stratigraphy and topography in the Black Hills region. The ridges follow the strike of the hard rocks; the valleys are excavated in the softer rocks.

Features pertaining to the Great Plains.—The northerly and northeasterly dips of the Dakota sandstone in the hogback range carry it beneath the soft shales that underlie the wide surrounding region. This region has the characteristic topography of the Great Plains, with long, gentle slopes and wide valleys. Here and there hard beds give rise to low escarpments or steep-sided ridges, but these are insignificant when compared with the higher ridges and mountains of the adjoining Black Hills. The most conspicuous topographic features in this portion of the quadrangle are the ridges east and north of St. Onge, which rise to an altitude somewhat over 3600 feet, and the line of ridges on the divide north of Indian Creek, one peak of which has an altitude of 3741 feet. The general altitude, however, for ridges and valleys in this region is from 2800 to 3300 feet, and the ordinary range between valley bottom and hilltop is in few places over 200 feet.

The principal stream is Belle Fourche River, which flows from west to east across the southern portion of the area. The higher slopes of the Black Hills drain into the Belle Fourche, most of the streams flowing northward except Hay Creek, which flows from the west through the hogback range. Whitewood Creek, which flows northeastward in a wide valley, is entirely in the plains area in this quadrangle. The streams in the region north of Belle Fourche River flow in shale valleys having southeasterly courses closely parallel to the strike of the rocks. Indian, Owl, and Crow creeks are principal streams; Willow, Lonetree, Horse, Hilderbrand, and Middle creeks drain areas of moderate size mostly within the quadrangle.

The Belle Fourche–Owl River divide passes diagonally across the northeast corner of the quadrangle. It consists of a low ridge on which rise several buttes and short ridges separated by wide gaps, most of them about 3250 feet in altitude. The most prominent of these buttes are in the ridge of which Two Top Peak is one of the summits. The west end of the ridge has an altitude of 3741 feet, or nearly 500 feet above the adjacent gaps.

One of the most remarkable features of the area is the great width and depth of the valleys of Indian and Owl creeks as compared with that of Belle Fourche River. This condition is an important factor in the reclamation project by which the water of the river is to be carried across a low ridge and held in a large reservoir in the Owl Creek valley. From this reservoir ditches will convey water to an extensive area of the adjacent wide, low valleys. The reason for this difference in altitude in the valleys is that the present Belle Fourche River is of very recent development. Originally its headwaters flowed northward across Stoneville Flats into the Little Missouri, and the present stream was very small above the mouth of Redwater Creek. Before the change of course was effected Indian and Owl creeks were the principal streams of the region, and owing to this fact and to the further fact that they traverse softer materials than the Belle Fourche they have cut deep and wide valleys.

DESCRIPTIVE GEOLOGY.

GENERAL OUTLINE.[a]

The Black Hills uplift is an irregular, dome-shaped anticline, embracing an oval area 125 miles long and 60 miles wide, with its longer dimension trending nearly northwest and southeast. It is situated in a wide area of almost horizontal beds and has brought above the general level of the plains an area of pre-Cambrian crystalline rocks about which there is upturned a nearly complete sequence of sedimentary formations ranging in age from middle Cambrian to later Cretaceous, all dipping away from the central nucleus. There are also extensive overlaps of the Tertiary deposits that underlie much of the adjoining plains area. The region affords most excellent opportunities for the study of stratigraphic relations and variations. Many of the rocks are hard, and the streams flowing out of the central mountain area have cut canyons and gorges, in the walls of which the formations are extensively exhibited. The structure along the sides of the uplift is that of a monocline dipping toward the plains. The oldest sedimentary rocks constitute the escarpment facing the crystalline rock area, and each stratum passes beneath a younger one in regular succession outward toward the margin of the uplift. The sedimentary formations consist of a series of thick sheets of sandstones, limestones, and shales, all of which are essentially conformable in attitude, with the exception of the overlapping Tertiary deposits, which extend across the edges of the older rocks. The stratigraphy presents many points of similarity to that of the Rocky Mountains in Colorado and Wyoming, but possesses numerous distinctive local features.

The Cambrian system is represented by the Deadwood sandstone, which reaches a thickness of 450 feet in the northern hills, but decreases to 4 feet or possibly less in the region southwest of Hermosa. There is everywhere a basal sandstone, generally conglomeratic, lying on a nearly smooth eroded surface of the Algonkian schists and granites. Where the formation is thin it consists entirely of this member, but as it thickens to the north it includes also overlying gray shales and slabby sandstones, partly glauconitic. These beds grade locally into slabby limestones, mostly in the form of a flat-pebble intraformational conglomerate. Next above is a persistent and prominent member of 5 to 30 feet of gray to reddish-buff massive sandstone. It is overlain by 20 to 40 feet of green fissile shale, regarded as the top of the formation. The Deadwood carries an Acadian ("Middle Cambrian") fauna.

The Ordovician system is represented by the Whitewood limestone, which occupies small areas near Deadwood and in the Bearlodge uplift. On Whitewood Creek its thickness is 80 feet, but it thins rapidly to the south. The rock is a massive tough limestone of buff color, with brownish spots or mottlings. It is overlain by several feet of greenish shale of unknown age.

In the Black Hills region the Carboniferous system comprises several formations apparently representing continuous deposition throughout the period. Limestone predominates, but some sandstones also occur in the higher formations. Everywhere at the base is the Englewood limestone, 25 to 50 feet thick. It consists of slabby beds of pinkish or buff color, with Chouteau or earlier Kinderhook fossils. The Englewood grades up into the Pahasapa limestone, so named from the Indian term for the Black Hills. The formation is a massive light-colored limestone 300 feet thick in the southern and central hills, 400 to 500 feet thick about Deadwood, and 700 feet thick on Spearfish Creek. It gives rise to prominent cliffs in the great limestone escarpment and in many canyons. It carries Mississippian fossils, and is equivalent to the Madison limestone of Wyoming and Montana. Next above, and apparently conformable, is the Minnelusa sandstone, which also outcrops completely around the Black Hills uplift in a broad zone on the outer slope of the limestone ridge. The rocks of this formation are mainly sandstones, buff and reddish in color, with local interbedded limestones. At the top there is invariably a thick member of massive, cross-bedded, coarse, granular, moderately hard sandstone, varying in color as a rule from white to buff, but locally reddish. Lower down the sandstones are mostly slabby, and in places brecciated. A thin but persistent body of red shale occurs at the base. On the west side of the hills the formation is more than 600 feet thick, but the amount diminishes to about 400 feet on the east side. There is much lime in the formation, mostly as matrix in the sandstone. Fossils are rare, but a few impressions in the upper beds indicate Pennsylvanian age. The upper sandstone is supposed to represent the Tensleep sandstone, and the middle and lower sandstones and limestones the Amsden formation, of the Bighorn and other uplifts in Wyoming.

Lying upon the Minnelusa sandstone are the red slabby sandstones and sandy shales of the Opeche formation, 100 to 150 feet thick in the southern hills and about 70 feet thick in the northern hills. The formation yields no fossils. It is overlain by the Minnekahta limestone, long known as the purple limestone, which constitutes the slope rising on the inner side of the Red Valley. This limestone is thin, averaging about 50 feet in thickness, but on account of its hardness extends widely up many of the slopes and presents cliffs in many canyons. The rock is light colored and partly magnesian. Its thin bedding is characteristic, but the laminæ are so tightly cemented together that the ledges appear massive. On weathering the rock breaks into slabs. The few fossils which this rock has yielded are believed to be Permian, in the sense in which that term has been used in the Mississippi Valley.

The thick mass of red shales with gypsum deposits lying on the Minnekahta limestone has been designated the Spearfish formation. It has been supposed to be of Triassic age, but presents no direct evidence as a basis for classification. Its thickness ranges from 350 to 695 feet,the latter amount being indicated by a boring at Fort Meade. The gypsum deposits are in places more than 30 feet thick and the most persistent bed occurs about 100 feet above the base of the formation. This bed is not continuous, and local deposits also occur at other horizons, notably at the top of the formation near Cambria.

Overlying the Spearfish red beds unconformably, but with no discordance of dip, is the Sundance formation, representing part of the later Jurassic. This formation outcrops along the lower inner slopes of the hogback range. It varies from 225 to 350 feet in thickness and consists mainly of gray shales, with a persistent bed of buff sandstone 40 feet thick about 50 feet above the bottom. In most regions the sandy shales above this sandstone are of reddish color. At some localities there are deposits of coarse sandstone at the base of the formation. The Sundance contains large numbers of marine fossils, mostly in thin limestone layers in the shale. In the southeastern portion of the uplift the formation is overlain by 100 to 225 feet of massive fine-grained Unkpapa sandstone, in greater part of pure white or bright-pink color. This sandstone thins out and is absent on the west side of the hills, but it extends far to the north on the east side, although thin and showing few exposures. It has yielded no fossils and its inclusion in the Jurassic is purely arbitrary.

In the Black Hills uplift the Cretaceous system comprises about 4000 feet of strata, apparently in continuous succession and representing practically all of Cretaceous time. The first formation is the Morrison shale, which is provisionally assigned to this system. It consists of massive shale, generally from 100 to 150 feet thick, but is apparently absent in the southeastern portion of the uplift. The predominating color is pale greenish gray, but maroon, pink, and chocolate tints appear in places. Thin beds of light-colored sandstone and thin local layers of impure limestone are included in the formation. It carries a few fresh-water shells and many bones of dinosaurs; the latter are classed as Jurassic by some paleontologists. The Lakota sandstone follows the Morrison, but overlaps the Unkpapa in the southeastern portion of the hills. It is mostly a hard, coarse-grained, cross-bedded, massive sandstone, 200 to 300 feet thick in the southern hills and 100 feet or less in the northern hills. Generally it constitutes the crest of the hogback range. Local bodies of shale are included in it. The upper member near Buffalo Gap and Fall River is a dull yellow sandstone which is overlain by the local Minnewaste limestone. This limestone is 25 feet thick, and Cheyenne River falls over a ledge of it 20 feet high. The next formation is the Fuson, which consists mostly of gray to purple shale, with local beds of sandstone. Its thickness averages 65 feet. The Fuson and Lakota beds contain an extensive Lower Cretaceous flora. The Dakota sandstone, which lies on the Fuson formation throughout the uplift, is mostly a hard, massive buff sandstone, slabby at the top. It exceeds 100 feet in thickness in most localities, but decreases to about half that amount in the northeastern part of the hills. Locally, the Dakota sandstone extends to the crest of the hogback range, but ordinarily it outcrops on the outer slope. It contains an Upper Cretaceous (Dakota) flora. The Dakota is followed by the thick series of dark-colored shales—Graneros, Carlile, and Pierre, which underlie the plains at the foot of the hogback range. The Graneros shale, from 900 to 1150 feet thick, includes the hard Mowry shale member, which weathers light gray and is full of fish scales. There are also local sandstones, one of which occurs just under the Mowry shale and is the "oil sand" in the Newcastle region. The Greenhorn limestone, 35 to 50 feet thick, caps the Graneros shale all around the Black Hills, giving rise to a low but distinct ridge. It is filled with characteristic *Inoceramus labiatus* and weathers out in thin slabs. The Carlile shale, from 500 to 650 feet thick, usually contains two thin beds of sandstone and near the top large numbers of lens-shaped concretions, many of which are fossiliferous. Next above are the impure chalk and gray calcareous shale of the Niobrara formation, averaging 200 feet thick and weathering to a bright straw color. This formation contains aggregations of *Ostrea congesta*, which are distinctive. The Pierre shale, overlying the Niobrara, attains a thickness of 1400 feet. Toward the top there is a horizon of scattered limestone masses filled with *Lucina occidentalis*, which weather out as "tepee buttes." These also occur locally at a lower horizon. Many smaller oval concretions occur in the shale, filled with molluscan remains. The sandstone of Fox Ridge extends westward to the margin of the Black Hills uplift, capping low ridges of Pierre shale.

The Tertiary system in the Black Hills region is represented by remnants of formations of the White River group, and originally these deposits extended far westward from the Big Badlands and covered all the lower slopes of the hills. Large areas remain on the divides from Rapid Creek to Beaver Creek, and there are outliers on the ridges as far west as the central area of crystalline rocks. Other outliers occur about Lead and on the Bearlodge Range. The Brule and Chadron formations are recognized by their characteristic clay, fuller's earth, sand, and sandstone, containing mammalian remains.

DESCRIPTION OF THE ROCKS.

The strata that come to the surface in the Belle Fourche quadrangle have a thickness of about 5000 feet. The order of occurrence and general character of limestones, sandstones, and shales are shown on the columnar section sheet. The rocks are all sedimentary, and range in age from Carboniferous to Quaternary. Rocks of Cretaceous age occupy nearly 90 per cent of the surface. Beneath the surface, as shown in the structure sections, are early Carboniferous, Ordovician, Cambrian, and Algonkian rocks.

CARBONIFEROUS SYSTEM.

Limestones and sandstones of Carboniferous age, which constitute a large portion of the Black Hills uplift, extend only a short distance into the southwest corner of the Belle Fourche quadrangle. The formations exposed are the Minnelusa sandstone, Opeche formation, and Minnekahta limestone.

MINNELUSA SANDSTONE.

Outcrops and character.—The Minnelusa sandstone is exposed in portions of the slopes of the high ridge in the southwest corner of the quadrangle and in several deep canyons cut through the Minnekahta limestone slopes on the northeast side of that ridge. The exposures are small and obscure and include only about 100 feet of the upper portion of the formation. The most extensive outcrops are in Higgins Gulch and the two larger gulches 1 and 2 miles to the northwest. As in other portions of the northern Black Hills, the rock is a moderately coarse grained sandstone, not very hard and mostly massively bedded in its upper portion. The colors are mainly gray, but some portions are buff and red. The lowest beds exposed are in part slabby, to some extent cross-bedded, and of white, gray, and buff color. Part of the red color in some of the exposures is due to red clay washed from the overlying formation. The name Minnelusa is derived from the Dakota Indian name of Rapid Creek.

Age.—These upper beds of the Minnelusa are believed to belong in the Pennsylvanian series, but they have yielded no fossils in the northern Black Hills region. From the character of the rock and its relations to the adjoining formation it is believed to represent the Tensleep sandstone of the Bighorn Mountain region, which is known to be of Pennsylvanian age.

OPECHE FORMATION.

Character and outcrops.—The thin series of red shale and sandstone beds lying next above the Minnelusa sandstone is known as the Opeche formation, from the Indian name for Battle Creek, its type locality. It is exposed in the numerous small canyons cut into the limestone ridge in the southwest corner of the quadrangle. Its thickness is 85 feet in the walls of Higgins Gulch, and the amount appears to be slightly greater, or nearly 100 feet, in the canyons adjoining Crow Creek. It outcrops in the slopes beneath an escarpment of the Minnekahta limestone, but is in many places covered by talus

[a]For a detailed account of the geology of the Black Hills, see Darton, N. H., Geology and underground water resources of the central Great Plains: Prof. Paper U. S. Geol. Survey No 32, 1905, 433 pp.; Preliminary description of the geology and water resources of the southern half of the Black Hills and adjoining regions in South Dakota and Wyoming: Twenty-first Ann. Rept. U. S. Geol. Survey, pt. 4, 1901, pp. 489–599; Geology and water resources of the northern portion of the Black Hills and adjoining regions in South Dakota and Wyoming: Prof. Paper U. S. Geol. Survey No. 65 (in press); Jagger, T. A., jr., Laccoliths of the Black Hills: Twenty-first Ann. Rept. U S. Geol. Survey, pt. 3, 1901, pp. 163–303; Darton, N. H., and others, Oelrichs, Newcastle, Edgemont, Sundance, Aladdin, and Devils Tower folios (Nos. 85, 107, 108, 127, 128, 150), Geol. Atlas U. S., U. S. Geol. Survey; 1902–1907.

or sod. In this area the formation is made up of soft red sandstone mainly in beds from 1 to 4 inches thick interbedded with red sandy shale, all evenly laminated. At the top of the formation is shale, which invariably has a deep purple color. Ordinarily the formation is somewhat more massively bedded in its lower portion. It lies conformably on the Minnelusa sandstone, but begins with an abrupt change in material.

Age.—The age of the Opeche formation has not been definitely determined, as it has yielded no fossils. The overlying Minnekahta limestone contains fossils of supposed Permian age, and the underlying sandstone is believed to be Pennsylvanian.

MINNEKAHTA LIMESTONE.

Outcrop.—The Minnekahta limestone, about 35 feet thick, constitutes the slopes and crest of the high ridge lying between Crow and Spearfish valleys in the southwest corner of the quadrangle. It rises steeply from the surrounding Red Valley and is mostly bare and rocky except for scattered bushes and pines. The formation is cut through by various canyons and has been removed by erosion along portions of the slope of the higher part of the ridge near Crow Creek. In these places it presents precipices from 30 to 40 feet in height, and at the mouths of the canyons it usually causes a narrow place, or "gate," which is a characteristic feature. The type locality of the formation is at the Minnekahta Springs, near Hot Springs, in the southern Black Hills.

Character.—The rock is of light-gray color, but in general it has a light pinkish or purple tinge from which the old name "Purple limestone" was derived. In the cliffs it appears to be massive, but close examination shows that the layers are thin and clearly defined by slight differences of color. On weathering it breaks into slabs, generally from 2 to 3 inches in thickness. It consists largely of carbonate of lime, a considerable proportion of carbonate of magnesia, and a small but variable admixture of clay and sand.

Fossils and age.—Fossils obtained in the Minnekahta limestone at various localities in the Black Hills indicate a probable Permian age, in the sense in which that term is used in the Mississippi Valley.

TRIASSIC (?) SYSTEM.

All the rocks that are regarded as possibly of Triassic age in the Black Hills are included in the Spearfish formation. The type locality is at Spearfish, just south of this quadrangle.

SPEARFISH FORMATION.

Outcrop.—The Spearfish formation, formerly called the "Red Beds," consists of red sandy shale with intercalated beds of gypsum. It averages 650 feet thick. It outcrops in an area of considerable size in the southwest corner of the quadrangle, where it underlies portions of the valleys of Redwater, Spearfish, and Crow creeks. A few outlying areas occur on the limestone ridge east of Crow Creek. Along Redwater, Spearfish, and Crow creeks and their larger branches the formation is covered by wide deposits of alluvium, and on some of the intervening ridges it is covered by terrace deposits. Outcrops, however, are numerous on the slopes, and as a rule they are conspicuous on account of the bright-red color of the shale and the snowy whiteness of the gypsum. In places the formation rises in high bluffs, especially along the Redwater, Crow, and Spearfish valleys.

Character.—The sedimentary material is almost entirely sandy red shale, generally thin bedded, evenly laminated, and without any marked stratigraphic features. The gypsum occurs at several horizons in beds varying in thickness from 15 feet to less than an inch. Some of these beds are continuous throughout the outcrop zone, notably one near the top and another 100 feet or more above the base of the formation. Most of the gypsum is pure white, but some of it is gray to dirty blue. It is nearly all massive in structure. The formation averages 650 feet in thickness but in the Redwater Valley near the western border of the quadrangle the thickness is approximately 680 feet. A boring a mile east of Spearfish which began considerably below the top of the formation penetrated red beds to a depth of 453 feet, reaching a limestone supposed to be the underlying Minnekahta. The exposure of the upper part of the formation on the north side of Redwater Valley near the mouth of Crow Creek exhibits the following beds:

Section of upper part of Spearfish formation in Redwater Valley.

	Feet.
Greenish-gray sandy shale	14.
Red sandy shale	14
Massive white sandstone merging into gypsum	3
Green sandy shale mottled with red	2
Red sandy shale	20
Gypsum	2
Red sandy shale and soft red sandstone	225

Below these beds are 395 feet of red sandy shale and argillaceous sandstone containing a 5-foot bed of gypsum 120 feet above the base of the formation. In places this gypsum occurs in two or three beds separated by thin deposits of red shale. East and northeast of the town of Spearfish the upper gypsum beds increase in prominence, and one bed which is extensively exposed reaches a thickness of 18 to 20 feet in the high ridge on the east side of the valley. In this locality the following section is presented:

Section of upper portion of Spearfish formation near Spearfish.

	Feet.
Pink and green shales with some gypsum	12
Light-red sandy shale	2
Massive gypsum	2
Light-red and green sandy shale	4
Gypsum	$\frac{2}{3}$
Light-red sandy shale	3
Gypsum	$\frac{1}{3}$
Light-red sandy shale	4
Massive gypsum	12
Deep-red shale down to alluvial flat	100

The gypsum in both these sections is white or mottled gray and of crystalline, massive nature and nearly free from impurities. Veinlets of recrystallized gypsum ramifying through the red shale are not uncommon, but few of them are thicker than one-half to three-fourths of an inch.

Age.—The Spearfish deposits are sharply distinguished from the Permian Minnekahta limestone below by an abrupt change of material, but no evidence of unconformity is presented. No fossils have been discovered in the Spearfish formation, and its precise age is unknown. From the fact that it lies between the Permian below and the marine Jurassic above it has been regarded as Triassic in age, but a part of it at least may prove to be Permian. It is separated from the Sundance formation by a planation unconformity without discordance of dip, representing all of earlier Jurassic and probably part at least of Triassic time.

JURASSIC SYSTEM.

The rocks of Jurassic age in the Black Hills are comprised in the Sundance formation and the Unkpapa sandstone.

SUNDANCE FORMATION.

Outcrop.—The Sundance formation, consisting of sandstone and shales, outcrops along the north and east sides of the Red Valley, mostly in the lower portion of the slopes which rise into the hogback range. It extends across the divide between Redwater and Hay creeks in the vicinity of meridian 104°, and underlies the terrace deposits and alluvium in an area of considerable extent near the junction of Spearfish and Redwater creeks. A small area is exposed on a branch of Whitewood Creek 6 miles southeast of St. Onge. The most extensive exposures are in the high slopes northeast of Spearfish and along the north side of Redwater Valley in R. 1 E. The type locality is above Sundance, not far southeast of this quadrangle.

Character.—The formation consists mainly of shale, partly sandy, and of sandstones, and varies in thickness from 250 feet on the west to about 225 feet on the east. There are several members which are persistent throughout, although considerable local variation is presented in the different sections. At the base there are dark-gray or greenish-gray shales 50 feet or more thick, overlain by buff fine-grained sandstone of moderate hardness from 30 to 40 feet thick. This sandstone is a very characteristic, conspicuous, and persistent member of the formation, outcropping in cliffs 20 to 30 feet high. It is of buff or slightly reddish tint, varies from massive to slabby in bedding, and contains some strongly ripple-marked layers—all characteristic features of this member throughout the Black Hills. Its upper part merges into sandy shales of buff to gray color, and these into soft impure sandstone or sandy shale mostly of a pronounced reddish tint and from 25 to 50 feet thick.

Next follows a member consisting of dark-gray and greenish-gray shales about 100 feet thick, containing local thin beds or lenses of highly fossiliferous limestone. Thin beds of sandstone also occur in these shales, which in most places grade upward into a few feet of buff sandstone at the top of the formation. The reddish member in the middle of the formation is a pronounced feature throughout, and is especially conspicuous in the slopes east of Spearfish; in places along the Redwater Valley it is somewhat less prominent. The following section near the western margin of the quadrangle illustrates the principal features of the formation:

Section of Sundance formation in Redwater Valley.

	Feet.
Greenish and yellowish shales, with a few sandstone layers at the top and near the middle and several very fossiliferous layers near the top	40
Dark-gray to black shales with some harder layers containing belemnites; and a few layers of lime nodules	60
Greenish and yellow shales with thin sandstones; some belemnites	10
Soft sandstone	$\frac{1}{2}$
Green shale	2
Soft sandstone	14
Massive, very soft gray sandstone	2
Light-red, somewhat sandy shale	16
Massive, soft pinkish-gray sandstone	4
Soft pinkish to buff sandstone	14
Soft grayish-buff massive sandstone	18
Greenish shale and thin sandstone	4
Massive grayish-buff sandstone	3
Flaggy, ripple-marked grayish-buff sandstone	4
Thin-bedded grayish-buff sandstone with thin partings of greenish shale, all soft	12
Massive grayish-buff sandstone and greenish-gray shale with thin sandstone containing a thin fossiliferous bed	16
Gray slabby sandstone lying on Spearfish formation	2
	$221\frac{1}{2}$

Fossils.—Fossils are abundant in all the exposures. One of the most conspicuous and abundant is *Belemnites densus*, a cigar-shaped form of heavy, hard carbonate of lime, smooth on the outside but having a radiate structure within. They occur mostly in sandy layers in the upper shale member and weather out on the surface in such numbers as to be a notable feature in most of the outcrops. The upper shale also contains the following species:

Ostrea strigilecula.	Tancredia corbuliformis
Avicula mucronata.	Tancredia bulbosa.
Camptonectes bellistriatus.	Tancredia postica.
Astarte fragilis.	Dosinia jurassica.
Trapezium bellefourchensis.	Saxicava jurassica.
Trapezium subæqualis.	Ammonites cordiformis.
Pleuromya newtoni.	Lingula brevistriatus.
Tancredia inornata.	

In places in the northwestern portion of the area layers of fossiliferous limestone occur in the lower shales. The fossil forms reported in these beds are as follows:

Ostrea strigilecula.	Psammobia prematura.
Camptonectes bellistriatus.	Belemnites densus.
Pseudomonotis curta.	

All these species are of later Jurassic age. The Sundance formation is believed to be equivalent to the Ellis formation of Montana and the Yellowstone Park region.

UNKPAPA SANDSTONE.

The Unkpapa sandstone is much less extensively developed in the northern Black Hills than in the southern part of the uplift, but it is probably present, at least locally, in the middle inner slopes of the hogback range. There are many places where it is not exposed, owing to its softness and to the presence of talus from the slopes above. Ordinarily the rock is a massive fine-grained sandstone varying in color from white to purple and buff and presenting more or less cross-bedding, but in this quadrangle most of the material is slabby and of yellowish color. It is not clearly separable from the slabby sandstones at the top of the Sundance formation, and is therefore not mapped; it gives place abruptly, though without evidence of unconformity, to the overlying Morrison shale. Its thickness appears to range between 10 and 25 feet and is usually near the smaller amount. The age of the sandstone is not known, but from its close association with the Sundance formation it is believed to belong in the Jurassic system. It may be a product of latest Jurassic sedimentation. The type locality is in the ridges east and south of Hot Springs, in the southern Black Hills, where it reaches a thickness of more than 250 feet. The name is from Unkpapa Peak, near Buffalo Gap.

CRETACEOUS SYSTEM.

Rocks of Cretaceous age constitute the outer rim of the Black Hills and the wide area of adjoining plains. They cross the Belle Fourche quadrangle in a broad belt comprising the Morrison shale, Lakota sandstone, Fuson formation, Dakota sandstone, Graneros shale, Greenhorn limestone, Carlile shale, Niobrara formation, Pierre shale, and Fox Hills (?) sandstone.

MORRISON SHALE.

Outcrop. — The Morrison formation consists mostly of massive shale of fresh-water origin which outcrops in the upper portion of the slopes below cliffs of Lakota sandstone. Owing to the softness of its materials and the talus from the cliffs above outcrops are few and generally not complete. The most extensive exposures are in the high ridge between the Redwater and Hay Creek valleys, near the western margin of the quadrangle; along the north side of the Redwater Valley below the mouth of Spearfish Creek; and at intervals along the high ridge northeast of Spearfish. The formation crosses False Bottom Creek about 3 miles south of St. Onge and it also appears in the uplift 6 miles southeast of St. Onge on the southern margin of the quadrangle. An outlying area occurs on the ridge a mile northeast of the northern part of Spearfish.

Character. — The prevailing color of the formation on weathered slopes is greenish gray or yellowish gray, but pink and purple tints are not uncommon and in places the color is maroon or pink. Some exposures show decidedly darker shades and at a number of localities the upper beds are black and carbonaceous. Thin layers of calcareous clay nodules are common, and locally these develop into thin beds of impure limestone. Sandstone beds are present in most places but are as a rule not conspicuous. There are many local variations in character, but the massive character and chalky appearance of the shale serve to distinguish it from the Sundance formation. The thickness toward the southeast is about 50 feet. Along the slopes north of the Redwater Valley it is 50 feet and on the small outlier northeast of Spearfish it appears to be nearly 100 feet. In general the formation presents the characteristics which it has in the type locality about Morrison, Colo.

Fossils and age.—Numerous bones of large dinosaurs have been obtained from the Morrison formation at many places in the Black Hills and elsewhere. They have been regarded as of late Jurassic age, but some eminent paleontologists now believe that they are early Cretaceous. As the stratigraphic relations in some regions sustain this view the formation is here provisionally assigned to the Cretaceous. The thin limestone layers in the formation in some areas contain fresh-water shells and algæ.

LAKOTA SANDSTONE.

Outcrop.—The Lakota sandstone appears in cliffs at or near the summit of the hogback range which extends across the southwestern portion of the quadrangle. These cliffs surmount rounded slopes of the Sundance and Morrison formation and are in places of considerable extent and prominence. The sandstone constitutes the crest and a portion of the eastern slope of the ridge extending from a point east of False Bottom Creek to Redwater Creek, but west of the Redwater, where the crest of the range consists of Dakota sandstone, the Lakota appears as a cliff in the middle slopes. The Lakota also appears in the uplift 6 miles southeast of St. Onge, and small outliers cap the high summits a mile northeast of the northern part of Spearfish. Other outliers occur on the ridge between the Redwater and Hay Creek valleys near the western margin of the quadrangle. The type locality of the formation is Lakota Peak, a summit on the hogback range 4 miles northwest of Hermosa.

Character.—The sandstone varies from massive to flaggy, but much of it is coarse grained, hard, and to some extent cross-bedded. Its color ranges from gray to buff. In many places there are three members—an upper massive, gray to buff, coarse sandstone, with fragments of petrified wood; a middle gray sandstone, mostly soft and flaggy, in part quartzitic, and containing much petrified wood; and a lower massive, gray to buff sandstone containing no petrified wood but otherwise closely resembling the upper member. The middle member generally contains some clay in pebbles or irregular masses in its upper part. Generally either the upper or the lower portion is well exposed, although sections are not uncommon in which both are prominent. Few complete sections are presented. In the ridge north of False Bottom Creek, where the thickness is 90 feet, the formation consists of 20 feet of flaggy buff sandstone at the top, 25 feet of soft dark sandstone in the middle, and 45 feet of massive, gray to buff sandstone merging downward into a fine-grained conglomerate at the base. Near the mouth of Polo Creek similar features are presented, but the thickness is somewhat less. In the ridge north of Redwater Creek opposite the mouth of Lake Creek the total thickness is about 60 feet, and this amount is the average thickness for some distance eastward. In the uplift southeast of St. Onge the following section was measured:

Section of Lakota sandstone 6 miles southeast of St. Onge.

	Feet.
Massive buff sandstone	25
Soft flaggy sandstone, in part quartzitic; streaks of conglomerate with moderately large quartz pebbles; clay pebbles and masses near top; petrified wood	30
Soft flaggy sandstone, irregularly bedded	15
	70

From its character and fossils the Lakota sandstone is believed to be of fresh-water origin.

Fossils and age.—In the middle and upper portions of the Lakota sandstone a large amount of petrified wood occurs. Numerous cycads have been obtained in the formation at several localities in the northern Black Hills, but none were observed in this area. Fossil leaves of several species, which are of Lower Cretaceous age, occur abundantly along Hay Creek, west of this quadrangle.

FUSON FORMATION.

Character and outcrop.—Lying between the massive sandstones of the Lakota and Dakota formations is a series of fresh-water shales and thin-bedded soft sandstones which has been designated the Fuson formation, from Fuson Canyon, near Buffalo gap. Much of the material is a massive sandy shale or clay, largely of purplish color, with thin sandstone layers. Its thickness ranges from 60 to 70 feet or more. Owing to its softness the formation is generally concealed by talus or wash from the overlying sandstone, but as a rule its position is indicated by a well-defined slope between the sandstone cliffs. The outcrop zone follows the outer slope of the hogback range crossing the southwestern portion of the quadrangle, and the formation also appears extensively in the anticline southeast of St. Onge. On the divide between Redwater and Hay creeks there are numerous exposures in the canyons, and others appear at intervals in the ridge extending southward from the mouth of False Bottom Creek. The sandstone layers in this formation thicken locally so as to become moderately prominent. They resemble the Lakota and Dakota sandstones in color and texture. The following section is presented near the main road about 4 miles southeast of St. Onge.

In the western portion of the quadrangle the formation is about 80 feet thick and the upper beds consist of shale, which weathers to a distinct yellow tint. Near the road 4 miles south of Belle Fourche the formation consists largely of dark-gray shale weathering to yellow in the upper part and to drab and purple lower down.

Section of Fuson formation 4 miles southeast of St. Onge.

	Feet.
Yellowish sandy shale	18
Dark shale, weathering to light purple	20
Dark-gray or black shale, iron stained, weathering to dark purple	10
Sandy fire clay with conchoidal fracture, carbonaceous near bottom	12
Concealed	10
	70

Fossils.—Extensive collections of leaves have been made from sandy shale of the Fuson formation in the Hay Creek coal field, west of this quadrangle. They are of Lower Cretaceous age.

DAKOTA SANDSTONE.

Character and outcrop.—The Dakota sandstone is the uppermost member of the series formerly designated "Dakota sandstone" in the Black Hills and other regions. It has been separated from the underlying shale and sandstones because of its later Cretaceous flora, similar to that which occurs at the type locality, Dakota City, Nebr., and elsewhere. The Dakota sandstone is thin, generally being less than 80 feet thick, and usually it outcrops along the lower outer slopes of the hogback range. West and north of the Redwater Valley, however, it constitutes both the crest and the northern slope of that range. West and south of St. Onge, where the range is double crested, it constitutes the eastern crest and slopes. It appears prominently also in the uplift southeast of St. Onge, where its thickness varies from 40 to 50 feet. Farther west the amount increases to 60 and 80 feet and in wells at Belle Fourche it is 100 feet or more. The sandstone ranges from massive to flaggy and from grayish buff to brownish in color. Much of it is cross-bedded, moderately coarse grained, and hard, and in places it is quartzitic. Considerable iron oxide is present in thin beds, lenses, nodules, and admixtures with the sandstone. Ordinarily the lower beds of the formation are massive and outcrop in cliffs of reddish color, many of which show a characteristic rude columnar structure. The following section in the ridge north of the Redwater Valley is representative:

Section of Dakota sandstone 2 miles west of the mouth of Spearfish Creek.

	Feet.
Shaly and slabby sandstone	20
Massive cross-bedded quartzitic sandstone, in part pinkish on fresh fracture	16
Massive to flaggy gray sandstone	4
Flaggy to shaly sandstone of pinkish tint	8
Shaly sandstone, much stained yellow and red	4
Soft shaly sandstone, brown stains	8
Sandstone, mostly thin-bedded with a few ironstone layers and nodules	20
	80

East of this section the sandstone is less hard and portions of the hogback slope consist of sandy surfaces. North of Hay Creek the formation commonly presents three members, consisting of harder sandstone at the top and bottom separated by a middle portion of softer sandstone. The thickness in that area is 80 feet.

Fossils.—Fossil leaves occur in the Dakota sandstone in various portions of the Black Hills. They are mostly dicotyledons and are all of Upper Cretaceous age.

GRANEROS SHALE

Character and outcrop.—As in the type locality in southeastern Colorado, the Graneros shale is in this quadrangle the lowest member of the Benton group. It consists of dark shale, averaging about 1000 feet in thickness, and underlies a belt of rolling plains about 10 miles wide extending diagonally from northwest to southeast across the middle of the quadrangle. Although the formation is covered by extensive areas of alluvium and high terrace deposits, it constitutes many low ridges and slopes in which the exposures are continuous for long distances.

Toward the lower portion of the formation there is a persistent member of harder shale and thin-bedded, very fine grained sandstone known as the Mowry shale member, which is shown by a separate pattern on the geologic map. It has a thickness of about 250 feet and lies 250 feet above the base of the formation. The beds weather grayish white and contain large numbers of fish scales, both characteristic features. Owing to the hardness of the Mowry shale it rises in ridges of moderate prominence, notably in Baldy and St. Onge peaks. It also forms both the banks of Belle Fourche River near Belle Fourche and for a long distance westward. In places the Mowry shale is underlain by a thin deposit of soft, gray to buff, massive, coarse-grained sandstone. The greatest thickness of this sandstone observed was near St. Onge Peak, where it is 8 feet. A small outcrop of Mowry shale appears in the bed of Redwater Creek at the bridge in the eastern part of the village of Belle Fourche.

The lower shales of the Graneros formation are mostly of dark color, especially near their base. They contain a few thin beds of sandstone and scattered lens-shaped concretions and are separated rather sharply from the Dakota sandstone, but without evidence of unconformity. A short distance above the Mowry shale there is usually a thin bed of bentonite, a white or gray clay which has great capacity for absorbing water. This bed is 3 feet thick in the slopes north of Belle Fourche River near the western margin of the quadrangle and lies 8 feet above the Mowry shale. The thick mass of shale overlying the Mowry shale varies in thickness from 500 to 600 feet, as nearly as can be ascertained. In its middle portion there is an extensive bed of flaggy, sandy limestone averaging about 1 foot in thickness, containing shells and fish remains. This bed is sufficiently hard to be a ridge maker, and constitutes the crest of the distinct ridge extending northwestward from Belle Fourche on the northeast side of Middle Creek. Another ridge due to this bed is seen a mile and a half southeast of Susie Peak and at Haystack Buttes and the adjoining ridges on the high summits southeast of Snoma. Above and below this limestone layer, particularly above, there are numerous ferruginous, calcareous concretions which on weathering give a decided yellowish-brown color to the inclosing shale.

GREENHORN LIMESTONE.

The Graneros shale is overlain by a thin body of impure limestone believed to represent the Greenhorn limestone of the type locality in southeastern Colorado. It outcrops in the low but distinct escarpment that extends from southeast to northwest across the middle of the quadrangle. This escarpment attains considerable prominence in the ridge north of Snoma at and near Susie Peak, and extends from the middle of R. 3 E. to and along the north side of the Crow Creek valley. It is hidden by alluvium along Belle Fourche River and Whitewood Creek.

The thickness of the formation varies from 25 to 35 feet. The rock contains a variable amount of clay and sand and in its unweathered condition is of gray color and is only moderately hard. It becomes harder on weathering, and in the outcrops appears as thin pale-buff slabs covered with impressions of a distinctive fossil. In the eastern portion of the quadrangle many of the weathered fragments are covered with a white incrustation of carbonate of lime which makes the outcrop especially conspicuous. The limestone beds are separated by shale layers from one-half inch to 3 inches thick in greater part. The limestone is characterized by the occurrence of large numbers of impressions of *Inoceramus labiatus*, a fossil which is of rare occurrence in the adjoining formations. At its base the formation is in most places clearly distinct from the dark shales of the Graneros formation, but without suggestion of unconformity. Its upper portion appears to grade into the Carlile shale through 6 to 8 feet of passage beds. The formation has been penetrated by some of the artesian wells, whose records ordinarily report it as "rock," so that evidently it is sufficiently hard underground to be noticeable as a definite stratum in the inclosing softer shales.

CARLILE SHALE.

The Carlile formation consists mainly of dark-gray shale with numerous ferruginous limestone concretions. It outcrops in a belt varying in width from 2 to 5 miles, extending from southeast to northwest across the quadrangle. It widest outcrops are in the region of irregular ridges lying between the valleys of Owl and Crow creeks north of Belle Fourche, and between Indian and Crow creeks in Rs. 3 and 4 E. The thickness varies from 600 feet on the east and west sides of the area to about 800 feet north of Belle Fourche. The shale beds merge into those of the adjoining formation through a few feet of beds of passage.

The shales are mostly dark gray, but some are black, and they are generally fissile. In places thin beds of sandstone are included in the formation, and one almost continuous bed of this rock from 1 to 6 feet thick about 100 feet above the base is conspicuous in some of the outcrops. About 5 miles due north of Belle Fourche this bed is represented by a thin layer of conglomerate containing many sharks' teeth. It is 4 inches thick and outcrops only in a small area. The pebbles range in size up to 1 inch in diameter.

The formation contains numerous biscuit-shaped concretions in sizes mostly from 3 to 5 feet, but some of them are considerably larger. Many of them exhibit cone-in-cone structure in part. They are scattered through regular layers and accumulate on the surface as the soft shale is removed by erosion, forming a conspicuous feature about the heads of Slate, Prairiedog, Bull, and Roundout creeks. Ordinarily the concretions are traversed by cracks filled with calcite, and their surfaces are yellow to yellowish red from the oxidation of the iron. The concretions are less numerous and mostly of grayish color in the upper portion of the formation. Some of them are highly fossiliferous, notably on the north side of Owl Creek near the center of T. 9 N., R. 4 E., where they yield specimens of *Inoceramus* up to a foot in length, *Prionocyclus*, and other forms of the typical upper Benton fauna.

NIOBRARA FORMATION.

The light-yellow outcrops of the Niobrara formation are a conspicuous feature along the valleys of Owl and Indian creeks and in the divide east of Twin Buttes. Owing to the softness of the formation it is largely covered by alluvium, wash, and sod, especially in the Indian Creek–Owl Creek valley in Rs. 3, 4, and 5 E. Extensive exposures appear in the Owl Creek valley above the mouth of Salt Creek, in Miller Butte, and along the banks of Belle Fourche River east of Twin Buttes. In the last-named locality the formation constitutes the river bank in cliffs rising 30 feet or more above the water.

The Niobrara consists of mixtures of clay and carbonate of lime in various proportions, in greater part constituting an impure chalk grading into and interbedded with calcareous shale. Its thickness is between 150 and 200 feet. The color of the fresh material is mostly light gray to pale buff, but on weathering this changes to a rich chrome yellow, which is a characteristic feature of the formation. It includes here and there thin masses made up of irregular aggregates of *Ostrea congesta*, a species distinctive of the formation. This fossil also occurs scattered through the shale. A few bone fragments were observed and several small ammonites were obtained from some large limestone concretions near the top of the formation at a point several miles east of Twin Buttes. The type locality of this formation is on Missouri River at the mouth of the Niobrara.

PIERRE SHALE.

Many square miles of the northern portion of the Belle Fourche quadrangle are occupied by the soft dark-gray Pierre shale. This formation begins along the north side of the valley of Owl and Indian creeks and extends far to the north, underlying a region of rolling plains with low ridges and wide valleys. To the east it extends to and beyond Pierre, the type locality. The only interruptions are the alluvial deposits in some of the valleys and the caps of later sandstone along the Owl River divide.

Owing to low dips and width of outcrop it is difficult to ascertain the thickness of the Pierre shale, but apparently it is about 1400 feet. The formation consists of a monotonous succession of dark-gray fissile pure shale beds with many calcareous iron-stained concretions, some of which are surrounded by a shell of cone-in-cone. In the upper portion of the formation the weathering of the concretions does not stain the shale materially, and it is mostly dark gray or black. Near the bottom of the formation, however, where the shale is lighter in color, the iron stain causes a general yellowish appearance on the weathered surfaces. Small scattered fragments of concretions are also a general feature of the surface throughout the Pierre area. At a horizon about 400 feet below the top of the formation there are lenses of porous dull-gray limestone, mostly from 3 to 6 feet in diameter, containing large numbers of *Lucina occidentalis* and other fossils. Most of these lenses project above the general surface as steep, rounded hills which are known as "tepee buttes." These buttes occur at intervals in the ridge between Willow and Horse creeks, and one that is especially prominent appears in the northeast corner of sec. 2, T. 11 N., R. 3 E.

FOX HILLS (?) SANDSTONE.

The sandstone beds capping some of the high buttes on the Belle Fourche–Owl River divide appear to be at the same horizon as the similar sandstones of Fox Ridge—the typical Fox Hills. The thickest masses cap the high ridge of which Two Top Peak is one of the summits, where about 140 feet of beds remain. Two miles northeast of Two Top Peak is another mass of considerable size, and on other summits, including Antelope Peak, smaller amounts are left. Most of the smaller areas consist of scattered blocks, the remnants of larger masses.

The rocks consist of soft pale-buff slabby sandstone at the bottom, merging upward into massive soft pinkish to yellow sandstone. Many fragments of conglomerate appear on the extensive talus slopes, some of the blocks being 10 by 12 by 6 feet in size. At no point was this material observed in place, and it is believed to be the debris of an upper member removed by erosion. The pebbles of the conglomerate are commonly of the size of wheat grains, but some of them reach one-half inch or more in diameter. The formation appears to merge down into the Pierre shale through a few feet of beds of passage. No fossils were observed in it.

SANDSTONE DIKE.

At a point 4 miles south of Antelope Butte and 1 mile southwest of the road ranch on Hilderbrand Creek a weathered dike of soft sandstone may be traced for about 100 yards. It is 6 inches wide and traverses the Pierre shale with a general direction of S. 10° W. It is approximately vertical.

QUATERNARY SYSTEM.

Quaternary deposits occur in all but the smallest valleys of this area and on numerous terraces adjoining the valleys. They fall into two categories—high terrace deposits and alluvium.

HIGH TERRACE DEPOSITS.

Remnants of old terrace deposits occur at various heights above the stream bottoms, especially in the slopes descending from the Black Hills. They mark the course of old streams which have since cut to lower levels, and undoubtedly they were originally more extensive. With the erosion of the country a large amount of such material has been removed or widely scattered, especially in areas where it was thin. The deposits consist mainly of sands, loams, gravels, and bowlders. The coarse materials are largely made up of quartz or quartzite, evidently derived from the higher portions of the Black Hills. The most extensive deposits are on the ridge east and southeast of Belle Fourche and along the sides of the Spearfish Valley. A wide area of high terrace heavily capped by gravel lies south of Whitewood Creek in the southeast corner of the quadrangle, and there are smaller areas on the north side of Belle Fourche River north of Snoma. Few of these terraces reach an altitude of more than 300 feet above the present streams, and many of them slope downward to the margin of the alluvial flats. Some are considerably higher, however, notably the capping of the high ridge north of Hay Creek, the remnants on the high ridge east of St. Onge, including Baldy and St. Onge peaks, and small remnants on Haystack, Twin, and Miller buttes. Small remains of these deposits at high levels occur also along the flanks of the limestone ridge in the southwest corner of the quadrangle. There is a conspicuous line of high terrace deposits along the north side of the Indian Creek valley, mostly in R. 4 E. The deposits mentioned above generally vary in thickness from 12 to 15 feet.

ALLUVIUM.

Alluvial deposits extend along all the valleys of the quadrangle except in some of the steeper canyons and along the many smaller draws in the higher region where erosion is greater than deposition. Belle Fourche River is bordered by alluvial bottom lands which are from 1 to 2 miles wide below Belle Fourche but mostly less than half a mile wide in the new part of the valley above that city. The alluvial area is especially wide along Indian Creek below the mouth of Hilderbrand Creek, and this area extends southward across the divide and down the Owl Creek valley in the center of T. 9 N., R. 4 E. The alluvium averages about a mile in width in the Redwater, Spearfish, and Whitewood valleys. In the valley of False Bottom Creek there is a notable widening near St. Onge. These alluvial areas vary in height from water level to about 30 feet above the streams, and there are a few high banks in which the stream has cut through to the underlying formation. The thickness of the alluvial deposits averages 25 feet in the larger valleys, but it varies irregularly from place to place and in many localities can not be ascertained.

The alluvium consists mainly of local materials and merges into hillside wash on the slopes adjoining the valleys. Along Redwater and Spearfish creeks there is considerable reddish material derived from the red shale of the Spearfish formation. Along the greater part of Owl and Indian creeks it is pale yellowish to gray owing to the presence of carbonate of lime derived from the chalky shales of the Niobrara. The alluvium along Whitewood Creek, which originally was mostly gray loam, is now capped by extensive deposits of gray tailings brought down from the mines and mills of Lead and vicinity, in the Black Hills. In places there are beds of gravel and sand in the alluvium, especially along Belle Fourche River near Snoma, where a deposit on the north side of the river is being extensively utilized in making concrete for the reclamation dam on Owl Creek.

Lake Creek, a tributary of Redwater Creek, is now depositing calcareous tufa, and accumulations of this material several feet in thickness may be observed in various places, particularly along the roadside a short distance south of the mouth of the creek. The tufa shows the usual porous structure with numerous casts of weeds and grass. The creek is fed by springs near Cox Lake that probably dissolve carbonate of lime from the Minnekahta limestone, which lies at no great depth.

GEOLOGIC STRUCTURE.

Structure of the Black Hills uplift.—The Black Hills uplift, if not eroded, would present an irregular dome rising on the north end of an anticlinal axis which extends northward from the Laramie Range of the Rocky Mountains. (See fig. 1.) It is elongated to the south and the 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 east side of the uplift. The most notable are the one extending northward from Crow Peak, another extending from Runkel northward by Whitewood to the valley of Indian Creek north of Belle Fourche, and a third just west of Hot Springs. These subordinate flexures are characterized by steeper dips on their west sides and gentler dips to the east. They branch from the general dome and die out with declining pitch under the plains. In the northern hills there are numerous local domes and flexures, due mainly to laccolithic igneous intrusions, but they are of small extent as compared with the general uplift. No similar features are indicated by the structure of the southern hills.

Faults are rarely observed; only a few have been found whose vertical displacement amounts to more than a few feet, and these are short breaks due to igneous intrusion. Most of the Algonkian rocks are extensively metamorphosed and more or less flexed, but these structures do not extend up into the overlying Paleozoic rocks. Metamorphism of this kind is greatest in the southern part of the Black Hills.

Structure of the Belle Fourche quadrangle.—The Belle Fourche quadrangle embraces a portion of the northeastern margin of the Black Hills uplift, with rocks dipping toward the northeast at low angles. There are local irregularities in this monoclinal structure, consisting mainly of variations of strike and dip and the presence of several low diagonal undulations of the strata. The rate of dip averages 150 feet to the mile but it ranges in many places between 100 and 200 feet, and in the southwest corner of the area there are zones of steeper dip. In the northeast corner the strata are inclined at very low angles and north of Willow Creek they appear to be nearly horizontal.

The monocline is traversed by three distinct anticlines. One of these, which gives rise to the prominent ridge of Minnekahta limestone in the southwest corner of the quadrangle, extends southward to the Crow Peak intrusive mass in the Deadwood quadrangle and may possibly be due to an extension underground of the laccolith which appears in Crow Peak. This anticline is peculiar in having steep slopes on the sides and a relatively flat top, except that in the southwestern portion a still higher dome rises on its side exposing the Minnelusa sandstone to some extent. The summit of this subordinate anticline is also flat, as shown by the flatness of the Minnekahta limestone which forms its crest. The dips on the sides of this flexure vary from 10° to 35° in greater part, the steepest dip being on the southwest side.

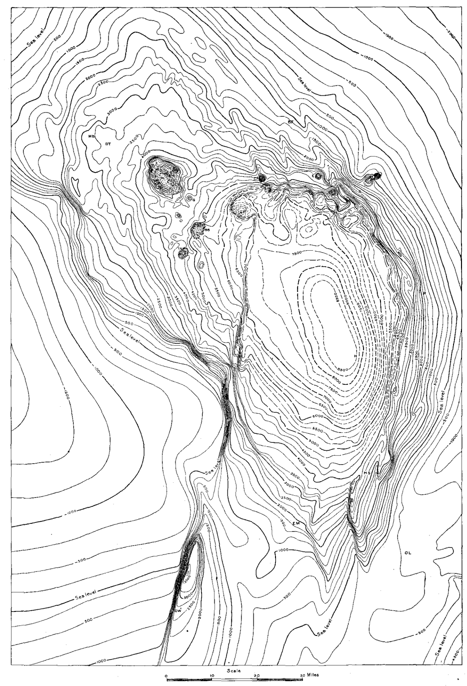


FIG. 1.—The Black Hills uplift represented by contours on the surface of the Minnekahta limestone. Where the Minnekahta limestone has been removed by erosion, the calculated position of the contours is shown by broken lines; where all sedimentary rocks have been removed, the dashes are short. Contour interval, 250 feet.

B, Bear Butte; BB, Black Butte; BF, Belle Fourche; BL, Bear Lodge Mountain: C, Crook Mountain; CP Crow Peak; D, Deadwood; DT, Devils Tower; E, Elkhorn Ridge; EM, Edgemont; G, Green Mountain; H, Harney Peak; HS, Hot Springs; IN, Inyankara Mountains; MB, Little Missouri Buttes; N, Nigger Hill; OL, Oelrichs; OW, Old Woman Creek; R, Rapid; S, Sturgis.

Another anticline extends along the front of the hogback ridge east of Spearfish Creek and is exhibited mostly in the Spearfish and Sundance formations. It extends northward a short distance beyond Belle Fourche, where it dies out in the Carlile and Niobrara formations. For the greater part of its course the dips are steeper on the west than on the east. Dakota and Fuson beds near the road 4 miles south of Belle Fourche dip to the west at angles of 30° to 70°. In the syncline on the west side of this anticline the lower shale of the Graneros extends far up the slope of the hogback ridge 4 miles south-southwest of Belle Fourche. It is in this syncline also that the Sundance formation is spread out widely in the area lying southeast of the mouth of Spearfish Creek.

The third anticline extends into the quadrangle from the south on the west side of Whitewood Creek. It trends nearly due north-northwest, passing a short distance east of St. Onge and Susie peaks. It pitches down and is lost in the broad area of Pierre shale near Mud Buttes. It causes the prominent deflection of the outcrop of Greenhorn limestone about Susie Peak and the wide area of the lower shale of the Graneros between St. Onge and Baldy peaks. Southeast of the village of St. Onge its presence is marked by a ridge of Dakota and Fuson formations, and along its axis near the southern margin of the quadrangle a small area of the Sundance formation is exposed. The dips in the slopes of the flexure vary from 3° to 20°. Two miles southeast of St. Onge they are 15° to 20°. In the syncline on the west side of this anticline the upper shale of the Graneros and the Mowry shale project far southward, the outcrop of the Mowry terminating in St. Onge Peak.

No faults have been discovered in this quadrangle except a few very small slips along joint planes which doubtless are not deep seated.

GEOLOGIC HISTORY.

General sedimentary record.—The rocks appearing at the surface within the Belle Fourche quadrangle are mainly of sedimentary origin. 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 middle Cambrian time to the present. The composition, appearance, and relations of the 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 open seas and scarcity of land-derived sediment. The fossils which the strata contain may belong to species known to inhabit waters that 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 in coarse sandstones and conglomerates, such as are found in the Lakota sandstone, had their original source in the crystalline rocks, but have been repeatedly redistributed by streams and concentrated by wave action on beaches. Red shales and sandstones, such as make up the Spearfish formation, result as a rule directly from the revival of erosion on a land surface long exposed to rock decay and oxidation and hence covered by 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 material, the sea receiving only fine sediment and substances in solution. The older formations exposed by the Black Hills uplift were laid down in seas that covered a large portion of the west-central 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 in a general way 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. The strata brought to view by the Black Hills uplift record many local variations in the geography and topography of the ancient land.

Cambrian submergence.—One of the notable events of early North American geologic history was the wide expansion of an interior sea over the west-central region. The submergence reached the Rocky Mountain province in the Cambrian period, 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 offshore and partly in estuaries. Abutting against the irregular surface of the crystalline rocks which formed the shore are sediments containing much local material. Subsequently, the altitude being reduced by erosion and the area possibly lessened by submergence, the islands yielded the finer-grained muds now represented by the shales that occur in the upper portion of the Cambrian in some areas. In many regions the surface of crystalline rocks was buried beneath the sediments.

Ordovician-Devonian conditions.—The Black Hills area presents a scanty geologic record of the vast period from the close of Cambrian to the beginning of Carboniferous time, the Ordovician, Silurian, and Devonian rocks being absent in the south and only a portion of the Ordovician being present in the north. This meager record is probably due to the fact that during these periods there was in this region 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 Carboniferous time. Then there was a decided subsidence, which 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 early Carboniferous time there were laid down in the Black Hills calcareous sediments that are now represented by several hundred feet of nearly pure limestone, the greater part of which is known as the Pahasapa limestone. As no coarse deposits of this age occur, it is probable that no crystalline rocks were then exposed above water in this region, although elsewhere the limestone, or some stratigraphic equivalent, was deposited immediately upon them. In the later 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. The presence of iron is indicated by the color of many beds of the Minnelusa sandstone. The deposition of the Minnelusa is believed to have been followed by an uplift that 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 its fossils show with a fair degree of certainty that it is a representative of the latest Carboniferous (Permian) time. It was laid down in thin layers, to a thickness now represented by only 40 feet of the limestone. 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.—At the close of the epoch represented by the Minnekahta limestone there was a resumption of red bed deposition, and the great mass of red sandy clay constituting the Spearfish formation was accumulated. This material probably was laid down in vast salt lakes that resulted from extensive uplift and aridity. The mud accumulated in thin layers to a depth of nearly 700 feet, as is now attested by the thickness of the formation. The Spearfish beds are so uniformly of a deep-red tint that this was undoubtedly the original color. This color is present not only wherever the formation outcrops but also through its entire thickness, as shown by deep borings, and therefore is not due to later or surface oxidation. Doubtless the original material of the sediments was red. At various times the accumulation of red 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. These beds are believed to be 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. It has been supposed that the Spearfish red beds are Triassic, but there is no direct evidence that they are of this age, and they may be Permian. Their deposition appears to have been followed by extensive uplift, without local structural deformation but with some planation and occasional channeling, which represents a portion of Triassic-Jurassic time of unknown duration. This uplift was succeeded by the deposition of later Jurassic sediments.

Jurassic sea.—In the Black Hills region the Jurassic was a period of varying conditions, shallow and deep marine waters alternating. The materials then laid down are nearly all fine grained and indicate waters without strong currents. In parts of the Black Hills some of the earliest deposits are thin masses of coarse sandstone, indicating shore conditions, but generally shale lies directly on the Spearfish red beds. Upon this shale lies a widespread body of ripple-marked sandstone, evidently laid down in shallow water and probably at 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 formation was laid down. An extensive marine fauna and the limestone layers in the upper shale of the Sundance formation indicate that deeper water followed. After this stage widespread uplift gave rise to fresh-water bodies. The first product was the thick body of fine sand of the Unkpapa sandstone, now a prominent feature along the east side of the Black Hills but thinner or absent elsewhere.

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 and estuaries along a coastal plain, passing into sediments from marine waters, and changing toward the end to fresh-water sands and clays with marsh vegetation. The earliest of these deposits, beginning possibly in late Jurassic time, constitutes the Morrison formation, a widespread mantle of sandy shale. The absence of this shale in the southeast corner of the uplift is due either to a local land area of Unkpapa sand, or to slightly increased local uplift, causing increased erosion in the uplift which initiated the next epoch. The extent of this degradation is not known, and although it has given rise to a general erosional unconformity at the base of the Lakota sandstone, the next succeeding deposit, it is believed to have continued for a very short time only.

The materials of the Lakota consist mainly of coarse sands spread by strong currents in beds 20 to 60 feet thick, but include several thin partings of clay and local accumulations of vegetal material. Next there was deposited a thin calcareous series, represented by the Minnewaste limestone, but apparently it was laid down only in a local basin in the southern portion of the Black Hills. Over this was spread a thin but widely extended sheet of clay of the Fuson formation. After the deposition of this clay there was a return to shallow waters and strong currents, as in Lakota time; and coarse sands of the Dakota formation were accumulated. At the beginning of the Benton epoch there was everywhere in the region a rapid change of sediment from sand to clay.

During the great later Cretaceous submergence, throughout the Benton, Niobrara, and Pierre epochs, marine conditions prevailed 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 thin but widespread, and one, earlier, that was local and produced the lenses of sandstone which now underlie the Mowry at several localities. Another marked episode was that which resulted in the general deposition of the thin Greenhorn limestone somewhat above the middle of the Benton sediments. The clay of Benton time was followed by several hundred feet of impure chalk, now constituting the Niobrara formation, and this in turn by more than 1400 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 next epoch. Whether the Fox Hills and overlying sediments were deposited over any of 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 major topographic outlines of the region were established before the Oligocene epoch. The dome was then 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 the deeper portions. Where the great mass of eroded material was carried is not known, for in the lower lands to the east and southeast there are no early Eocene deposits nearer than those of the Gulf coast and Mississippi embayment and those of the Denver Basin.

Oligocene fresh-water deposits.—Oligocene deposits were laid down by streams and in local lakes or bayous 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 west side of the hills, but in the vicinity of Lead small outliers remain at an altitude of over 5200 feet, and on the north end of the Bearlodge Mountains they are 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.—After the Oligocene epoch the dome was raised several hundred feet higher and was more extensively eroded. No representatives of the succeeding Miocene and Pliocene—the Arikaree and Ogalalla formations—have been discovered in the immediate vicinity of the Black Hills, but they are extensively developed in Pine Ridge, to the south, and remain on the high buttes to the north in the northwest corner of South Dakota. There were probably extensive uplifts during these epochs, and much material was eroded from the higher slopes of the Black Hills, but whether the formations were ever deposited in the immediate vicinity of the hills has not been ascertained.

Quaternary uplift and erosion.—During the early portion of the Quaternary 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 east side of the Black Hills was caused mainly by increased tilting to the northeast. This rearrangement has caused several streams superimposed upon the Oligocene deposits to cut across old divides, in some places connecting a valley with its neighbor to the north. Such streams flow southeastward for some distance in pre-Oligocene valleys and then turn abruptly northward into canyons of post-Oligocene age, leaving elevated saddles which mark the southeastward course of the old valleys. Some of the offsetting in the present drainage has been largely increased by early Quaternary erosion and recent stream robbery.

There was apparently still further uplift in later Quaternary time, for the present valleys, below the level of the earlier Quaternary high-level deposits, seem to be cut more deeply than they would be in simply grading their profiles to the level of Missouri and Cheyenne rivers. Wide, shallow valleys have developed in the soft deposits, and canyons of moderate extent and depth in the harder rocks. Later erosion has progressed with but little local deposition, but in some places the shifting of channels has been accompanied by accumulations of local deposits on small terraces at various levels.

ECONOMIC PRODUCTS.

With the exception of the underground water, the economic products found in this quadrangle are of no great value. They are described under the following headings—soils, gypsum, bentonite, limestone, clay, coal, building stone, surface water, underground water.

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 where they are formed as alluvial deposits in the larger valleys. In the process of disintegration residual soil develops more or less rapidly on the 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 sandstone, 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 in many places a deep soil. If the calcareous cement is present in small proportion only, it may be leached out far below the surface, the rock retaining its form but becoming soft and porous, as has 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 rock is pure but very thick in many places where the rock contains much insoluble matter. The amount of soil remaining on the rocks depends on the vigor of erosion, for on many slopes the erosion is sufficient to remove the soil as rapidly as it forms, leaving bare rock surfaces. Crystalline schists and granitic rocks decompose mostly by kaolinization 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, and thus by softening and washing give rise to soils. Where they are sandy, sandy soils result, and where they are composed of relatively pure clay, a very clayey soil is the product. The character of the soils 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—shales and sandstones, for instances, alternating with limestone. Such alternations produce abrupt transitions in the character of the disintegration products, and soils that differ widely in composition and agricultural capabilities occur 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 on steep slopes where soils derived from rocks higher up the slopes have washed down and mingled with or covered the soils derived from the rocks lying immediately beneath. Soils of this class are known as overplaced, and a special map of large scale would be required to show their distribution.

Distribution.—The arable lands of the Belle Fourche quadrangle are underlain mainly by shale and alluvium. Most of the shale gives rise to a clay soil which is not only barren in itself but is acid from decomposing pyrites and rather sticky for agricultural use. It is covered by grass which originally afforded excellent pasturage but in some areas has been grazed down by excessive herding. As the soil is not rich and the climate is semiarid sod develops slowly, and after close grazing the grass requires some time to regain its former thickness.

In almost all the wide valleys in the shale region there are alluvial deposits which are generally very fertile. The widest areas of such soils are in the valley of Indian Creek, in the east-central portion of the quadrangle, along Belle Fourche River below the town of Belle Fourche, and along portions of the valleys of Spearfish, Owl, Whitewood, False Bottom, and Redwater creeks. When the dam and canals now in course of construction by the United States Reclamation Service are completed a wide area of alluvial lands in the east-central portion of the area will be irrigated. Considerable irrigation is already practiced along the Spearfish, Redwater, Whitewood, and Belle Fourche valleys. The alluvial soils vary somewhat in composition from predominantly sandy to predominantly clayey, but in greater part they consist of loam well suited for tillage. The soils in the Red Valley are mostly alluvial, but on the slopes along the outcrops of the red beds the soil is in the main thin and nearly barren. On the hogback range the soil is thin and sandy and much of the surface is scarcely level enough for agriculture. The soils derived from the Sundance formation are usually fertile, but some of them contain much clay and most of the outcrop area presents very irregular topography. On the limestone ridge in the southwest corner of the quadrangle the soil is thin and much interrupted by rock ledges, but it is fertile and in some areas has yielded crops of the hardier grains.

GYPSUM.

The Spearfish formation carries deposits of gypsum, a hydrous sulphate of lime, throughout its extent, and the mineral occurs in beds sufficiently thick and pure to be of value if it were nearer to market. When gypsum is calcined at a moderate heat to drive off the greater portion of the chemically combined water, and is then ground, the product is plaster of Paris. The principal gypsum deposit in the Belle Fourche quadrangle is in the upper portion of the Spearfish formation exposed in the ridges east and northeast of Spearfish. One bed reaches a thickness of 18 to 20 feet but has an average thickness of 12 feet in an area of several square miles. It is mostly white or light gray in color, massive in structure, and nearly pure. Another bed which occurs 120 feet above the bottom of the formation is about 5 feet thick and outcrops in all the slopes adjoining the limestone ridge in the southwest corner of the quadrangle. The mineral has not yet been utilized in this region but it has been worked to some extent at other localities in the Black Hills, where, however, the distance from market has proved to be too great to make the industry profitable.

BENTONITE.

Bentonite is a light-colored clay which has the peculiarity of being highly absorbent. When dry the material is a soft massive rock of light-gray or very pale greenish color, with conchoidal structure when broken. Owing to its absorptive quality small fragments adhere strongly when placed on the tongue. When wet the material becomes a paste like glue or soft soap, and miry pits known as "soap holes" occur at some points along its outcrop. The bentonite occurs as a bed in the Graneros shale a short distance above the top of the Mowry shale member. It varies in thickness from a thin layer to 3 feet or possibly more, but appears in nearly all portions of the area. The most extensive exposures are in the ridge extending along the north side of Belle Fourche River west of Belle Fourche, where the deposit has a thickness of about 3 feet and lies 8 feet above the top of the Mowry shale. Bentonite is mined at various localities in Wyoming, and its value is such that it can be shipped to long distances. It is used as an absorbent packing for horse's hoofs, as a filling for paper, as a medium in certain drugs, and as an adulterant.

LIMESTONE.

Limestone for lime or other purposes can be obtained in abundance from the Minnekahta limestone in the southwest corner of the quadrangle, but as the rock usually contains a considerable proportion of magnesia its usefulness is limited. The "tepee buttes" in the Pierre shale consist largely of carbonate of lime, but no test has yet been made of their quality. The Niobrara formation is made up of a mixture of carbonate of lime and clay, and possibly some portions of the rock could be used for making cement.

CLAY.

Large amounts of clay for bricks and other purposes are available in nearly all portions of the quadrangle, mainly in the alluvium, and most of the shales consist almost entirely of clay. The deposits have been used only to a slight extent for brickmaking. Some of the Fuson formation appears to be fire clay, but no test has yet been made in this area as to its fire-resisting qualities.

COAL.

Coal deposits of moderate extent in the lower portion of the Lakota sandstone are worked at Aladdin, a short distance west of this area. These deposits appear not to extend into the Belle Fourche quadrangle, although it is possible that some thin beds may yet be discovered. However, the coal horizon is extensively exposed, and no further evidence of carbonaceous deposition is presented than some thin carbonaceous streaks that give no promise of developing into workable coal beds. Some prospecting has been done in the lower black shales of the Graneros, but there is no probability whatever of finding coal at that horizon or in any of the overlying shales.

BUILDING STONE.

Large supplies of various kinds of building stone occur in the Black Hills, but they are not extensively utilized. Sandstone and limestone have been worked in small amount for underpinning for buildings, but no regular quarries have been opened. The Minnekahta limestone could easily be worked in slabs of suitable size for building; and many portions of the Dakota and Lakota sandstones are of good quality and color for coarse work. In the northern part of the quadrangle large supplies of rough rock may be obtained from the Fox Hills sandstone.

WATER SUPPLY.

SURFACE WATER.

General outline.—The average annual rainfall in the Belle Fourche region is probably somewhat less than 15 inches, except in the high ridge in the southwest corner of the quadrangle, where the amount may be slightly greater. Part of the precipitation is in the form of snow and the remainder falls mostly in heavy showers of short duration during the spring and early summer months. As most of the surface of the country has thin soil and as only small areas present porous rocks the water of rains and melting snows runs off rapidly, usually in freshets that follow storms or the melting of snow during warm spells in the spring. In the central and northern portions of the area there is as a rule no continuous snow cover for any considerable length of time. In consequence of these conditions the minor valleys contain but little running water during the greater portion of the year and springs are few and mostly small in the lower lands. A large amount of the local run-off in this region could be saved by dams and made available for stock and local irrigation. There are many suitable dam sites and at several places north of Belle Fourche considerable water has been impounded by small earth dams across draws. As evaporation of standing water in this region is about 6 feet a year, a large amount of water has to be collected to compensate for this loss.

The works in course of construction by the United States Reclamation Service below Belle Fourche will consist of a dam in secs. 18 and 19, T. 9 N., R. 4 E., and a canal to deflect the waters of Belle Fourche River at a point about a mile and a half below Belle Fourche. The dam will create a large reservoir, extending for some distance up the valleys of Owl and Dry creeks, into which the river water will be carried by the canal. By this means a water supply will be obtained for irrigating a large area in the valleys of Indian and Owl creeks and of Belle Fourche River north and east of the reservoir.

Belle Fourche River.—This river has a drainage basin above Belle Fourche and above the mouth of Redwater Creek of about 3250 square miles. The flow has been gaged at Belle Fourche above the mouth of Redwater Creek since 1903 and found to vary from a minimum of practically no flow in June, 1903, to a maximum of nearly 6000 second-feet in June, 1904. Ordinarily it ranges from 50 to 200 second-feet, but the mean for twenty-seven months in 1903 to 1906 was about 320 second-feet. In 1906 the river was gaged at the intake station of the United States Reclamation Service, 1½ miles below Belle Fourche and below the mouth of Redwater Creek. After the usual flood in May and June the flow at that place varied in August from 72 to 775 second-feet. The mean flow for August, September, October, and November ranged from 221 to 266 feet.

Redwater Creek.—This stream rises on the east slope of the Bearlodge Mountains and has a drainage basin of about 1020 square miles. It has a constant flow varying from 100 to 300 second-feet through most of the season and averaging 285 second-feet for twenty-seven months in the years 1903 to 1906. In some years its midsummer flow diminishes to less than 100 second-feet for a short period, and in time of flood the flow exceeds 1000 second-feet. In June, 1904, it reached 8050 feet. The stream has been regularly gaged for the past few years near its mouth in Belle Fourche. There is an additional flow in the Redwater ditch which varies greatly but averages about 40 second-feet, according to gagings from May to October, the months during which the canal is used, in 1904 to 1906.

Spearfish Creek.—Spearfish Creek drains part of the high limestone plateau and adjacent slopes in the northern Black Hills, with a catchment area of about 230 square miles above the gaging station at Spearfish. It carries a remarkably regular flow into Redwater Creek, which it joins at a point about 6 miles south-southwest of Belle Fourche. The flow of this Creek ordinarily varies from 50 to 100 second feet, and rarely diminishes to less than 50 second-feet or exceeds 150 second-feet. The average for thirty-five months in the years 1903 to 1906 was 100 second-feet. In June, 1904, a flood of 4150 second-feet was reported and in July, 1905, there was a flow of 517 second-feet.

Whitewood Creek.—Whitewood Creek, which crosses the southeast corner of the Belle Fourche quadrangle, drains an extensive area of highlands in the northern Black Hills. Its flow is large and constant and at times it is greatly swollen by freshets. No gagings are available.

False Bottom Creek.—False Bottom Creek drains a portion of the northern Black Hills west of Deadwood and has a constant flow of moderate volume. The only gaging reported is one of 7.4 second-feet on May 12, 1903.

Indian and Owl creeks.—Indian and Owl creeks drain basins of moderate size in the shale area of the Great Plains north of the Black Hills. They carry a flow of water throughout most years, but the volume is small.

UNDERGROUND WATERS.

GENERAL CONDITIONS.

Throughout the quadrangle there are prospects of water supplies from wells of greater or less depth. The series of formations, as shown in the columnar section, includes several beds of water-bearing sandstone which absorb surface waters in their outcrop zones in the higher ridges and slopes of the Black Hills. The sandstones pass underground on the sides of the uplift and, owing to the relative steepness of the dip, attain considerable depth within short distances. In most of the area water-bearing beds at one horizon or another lie at a depth that is within reach of the well borer. As the region is semiarid, with an inadequate supply of surface waters or with waters of bad quality in most localities, there is considerable need for underground waters. The principal water-bearing strata rise above the surface of the slopes of the Black Hills in regular succession, as already described. They outcrop in wide zones encircling the uplift and receive a large amount of water not only from the rainfall on their surface but from streams which at many points sink into them, wholly or partly, in crossing their outcrops. The sinking of the streams in this manner is observed in almost every valley leading out of the central area and few of the streams carry into the Belle Fourche or the Cheyenne more than a small proportion of the original run-off of their drainage brains. The greatest amount of water sinks in crossing the sandstones of the Minnelusa, Lakota, and Dakota formations. These water-bearing sandstones pass beneath thick deposits of impervious shale so that the water retains much of the head due to the high altitude at which it passes underground.

WATER-BEARING FORMATIONS.

Dakota and Lakota sandstones.—The Dakota and Lakota sandstones are the principal formations in which water supplies are to be expected in the northeastern half, or plains portion, of the Belle Fourche quadrangle. They pass beneath the overlying Graneros shale with dips which vary considerably in amount (see structure-section sheet), but which finally carry them to a depth of about 3500 feet in the northeast corner of the quadrangle. The depth to the top of the Dakota sandstone is indicated approximately on the artesian water sheet. In various portions of the country surrounding the Black Hills the Dakota and Lakota horizons have been reached by wells, most of which obtain flows of greater or less volume and as a rule of satisfactory quality.

In the shales of the Morrison and Sundance formations, underlying the Lakota sandstone, there are no prospects for water, although doubtless the sandstone layer in the lower portion of the Sundance formation may contain a small amount. The great mass of gypsiferous red shale of the Spearfish and Opeche formations is not water bearing. The Minnekahta limestone is too dense to carry water, notwithstanding the fact that in some places it is cavernous.

Minnelusa sandstone.—In its outcrops the Minnelusa formation appears to consist of very porous sandstone, likely to imbibe much surface water and to constitute a water-bearing formation available for deep wells. The numerous springs which locally emerge from the upper sandstone bed furnish a further indication of its properties in this regard. The formation was penetrated by a deep boring at Cambria, Wyo., and there found to consist of a very fine textured rock, with the sand grains so closely cemented by lime that the interstices were so nearly filled as to leave little room for water. The rock appears to be of much coarser grain and less calcareous in this region, especially the upper bed of white sandstone, which is conspicuous in the outcrops in the southwest corner of the quadrangle. It is therefore probable that the sandstone will yield water in this area. The depth to its top is shown on the artesian water sheet, which indicates that there is a considerable area in the southwestern portion of the quadrangle in which the formation can be reached by wells 200 to 1100 feet deep in a district not underlain by the Dakota and Lakota sandstones. As the Minnelusa sandstone rises high on the slopes of the central portion of the Black Hills the pressure or head of its water should be sufficient to afford a flow throughout the valleys in the southern and western portions of this quadrangle.

Pahasapa limestone.—The Belle Fourche quadrangle is underlain by the Pahasapa limestone, which, however, is probably too compact to yield water.

Deadwood sandstone.—Below the Pahasapa limestone is a series of shales and sandstones known as the Deadwood formation which probably contain water, but in most of the Belle Fourche quadrangle they lie too deep to be reached by ordinary boring operations. The depth of the formation ranges from 1100 to 1500 feet in the Red Valley, but rapidly increases toward the north, and at Belle Fourche its top is about 2700 feet below the surface. It lies at great depth in the central and northern portions of the quadrangle.

That the Deadwood sandstone contains a large amount of water under considerable pressure has recently been proved by the highly successful artesian well 2985 feet deep at Edgemont.

DEEP WELLS.

List of wells.—The following table gives a list of artesian wells and deep borings in the quadrangle, with their depth, diameter, yield, etc.

Artesian wells and deep borings in the Belle Fourche quadrangle.

	Depth.	Depth to main flow.	Diameter.	Yield per minute.	Pressure.
Belle Fourche city wells:	*Feet.*	*Feet.*	*Inches.*	*Gallons.*	*Pounds.*
No. 1	550	-------	-------	-------	55
No. 2	525	525	-------	200	45
No. 3	881	560	4	30	-------
Belle Fourche, many small wells	-------	([a])	1–2	1	-------
Belle Fourche, Craft's addition	897	[b] 560	-------	45	55
Land and Cattle Company, NW. $\frac{1}{4}$ sec. 11, T. 8, R. 2	635	[c] 635	1	Many.	55
Land and Cattle Company, NW. $\frac{1}{4}$ sec. 11, T. 8, R. 2	745	[d] 680	-------	15	40
F. A. Durst, NW. $\frac{1}{4}$ sec. 14, T. 8, R. 2	550	500	$4\frac{1}{2}$	100	26+
F. N. & G. S. Fuller, NW. $\frac{1}{4}$ sec. 6, T. 8, R. 3	835	[a] 800	2	30	15
J. A. Gilbert, SE. $\frac{1}{4}$ sec. 36, T. 9, R. 2	836	[e] 836	2	15	Flows.
Orman and Crook, NE. $\frac{1}{4}$ SW. $\frac{1}{4}$ sec. 19, T. 9, R. 4	1417	[f] 1325	3–2	50	-------
H. L. Barnett, SE. $\frac{1}{4}$ sec. 31, T. 9, R. 3	935	([a])	2	5	-------
J. Wichert, SE. $\frac{1}{4}$ sec. 24, T. 8, R. 2	381	[a] 300+	-------	2	30
Case ranch, SE. $\frac{1}{4}$ sec. 14, T. 8, R. 2	241	([a])	$1\frac{1}{4}$	2	-------
Case ranch, SE. $\frac{1}{4}$ sec. 14, T. 8, R. 2	355	([g])	$4\frac{1}{2}$	40	26
G. H. Ray, SE. $\frac{1}{4}$ sec. 12, T. 8, R. 2	818	[h] 760	2	5	-------
U. S. Reclamation Service, sec. 36, T. 9, R. 2	627	[i] 625	2	20	-------
U. S. Reclamation Service, SE. $\frac{1}{4}$ sec. 18, T. 9, R. 4	1388	1380	2	1	9+
Newland ranch, SW. $\frac{1}{4}$ sec. 4, T. 8, R. 3	1033	1013	2	15	15
Brant's road ranch, SE. $\frac{1}{4}$ sec. 23, T. 10 R. 2	2019	-------	-------	-------	Flows.
Fred Ross, NW. $\frac{1}{4}$ sec. 4, T. 9, R. 3	1858	([a])	$1\frac{1}{4}$	$3\frac{1}{2}$	-------
M. Snyder, SE $\frac{1}{4}$ sec. 13, T. 8, R. 4	$1096\frac{1}{2}$	[a] 1080	2	60	Flows.
J. A. Scotney, NE. $\frac{1}{4}$ sec. 20, T. 8, R. 2	330	-------	4	25	30
J. A. Scotney, NE. $\frac{1}{4}$ sec. 20, T. 8, R. 2	225	([j])	6	15	-------
S. Johnson, SW. $\frac{1}{4}$ sec. 13, T. 8, R. 2	330	-------	-------	-------	15
W. R. Glassie, NE. $\frac{1}{4}$ sec. 28, T. 8, R. 2	320	([k])	-------	-------	5
D. Richardson, Hay Creek, 6 miles west of Belle Fourche	220	-------	4	25	-------
T. Rawlins, SW. $\frac{1}{4}$ NE. $\frac{1}{4}$ sec. 17, T. 8, R. 2, $2\frac{1}{2}$ miles southwest of Belle Fourche	535	[l] 515	3	5	10+
H. M. Stearns, SE. $\frac{1}{4}$ NW. $\frac{1}{4}$ sec. 13, T. 8, R. 3	600	-------	-------	450	125
Schaffer ranch, SW. $\frac{1}{4}$ sec. 14, T. 9, R. 2	[m] 900	-------	-------	-------	-------
R. D. Evans, sec. 6, T. 8, R. 2	900	[n] 470	3	15	20
Wm. Barbour, NE. $\frac{1}{4}$ sec. 35, T. 9, R. 1	350±	-------	4	-------	-------

[a] First flow; soft water.
[b] Second flow; small flow at 340 feet.
[c] Second flow; hard water; first flow at 450 feet. In valley.
[d] Second flow; water also at 450 and 650 feet.
[e] Soft water; some water at 600 feet.
[f] Flow also at 1345 feet.
[g] Soft water.
[h] Hard water; water also at 500 feet.
[i] First flow at 567 feet.
[j] Hard water.
[k] Second flow.
[l] First flow at 330 feet.
[m] In progress, in shale.
[n] Soft water; water also at 274 feet.

Belle Fourche and vicinity.—Since 1904 Belle Fourche has been supplied by water from artesian wells which penetrate the Dakota or underlying Lakota sandstone. The water in the deeper wells has sufficient pressure to flow into a tank 75 feet above the ground on a knoll just south of the railroad depot. Shallower wells afford supplies at a number of residences. The first well had a depth of $525\frac{1}{2}$ feet and flowed 60 gallons a minute, and originally the pressure was considerably more than 55 pounds to the square inch. The well finally got out of order, apparently owing to a break in the casing, and other wells were sunk which obtained additional supplies. The materials penetrated in the first well were as follows:

Record of first well at Belle Fourche.

	Feet.
Shale	0–207
Sandstone (Dakota), yielding a small flow at 245 feet	207–307
Soft clay (Fuson), containing a thin layer of sand yielding a small second flow	307–425
Sandstone (Lakota)	$425–525\frac{1}{2}$

The Lakota sandstone contained water at various horizons with gradually increasing volume and head, the maximum flow being at a depth of about 510 feet from the lower part of the formation. The second well on somewhat lower land near the center of the village had the following record:

Record of second well at Belle Fourche.

	Feet.
Shale	0–300
Hard sandstone (Dakota), small flow	300–330
Soft sandstone (Dakota), with flow at 410 feet	330–410
Red, white, and mottled clay (Fuson formation)	410–435
Gray sandy clay and sandstone with lignite fragments (Lakota)	435–470
Sandstone (Lakota)	470–525

A pressure of 45 pounds is reported in this well. A third well, bored in 1903 to a depth of 881 feet, found water-bearing strata at intervals from 297 to 560 feet. This well is 4 inches in diameter and has a flow of 30 gallons a minute. Several small wells in the village are supplied by the first flow at depths of 300 to 400 feet.

A well in Craft's Addition, three-fourths of a mile east-southeast of well No. 1, obtains water with a pressure of 55 pounds from the second flow at a depth of 560 feet. This well was drilled to 897 feet with no increase of flow below 560 feet.

There are two artesian wells on property of the Belle Fourche Land and Cattle Company in the NW. $\frac{1}{4}$ sec. 11, T. 8 N., R. 2 E., a mile north of Belle Fourche. The first, which was sunk in 1904, has a depth of 650 feet. It draws from the second flow, at 635 feet. The water is somewhat hard and the pressure is 55 pounds. A flow of softer water was found at a depth of 450 feet, which is the first flow. The following record is given:

Record of artesian well 1 mile north of Belle Fourche.

	Feet.
Shale	0-350
Sandstone (Dakota)	350–450
Shale and clay (Fuson)	450–550
Sandstone (Lakota)	550–650

A second well on a small knoll north of the river in the northwest quarter of the same quarter section has a depth of 744 feet. It yields a 15-gallon flow of soft water under a pressure of 40 pounds. A small flow was found at a depth of 650 feet in this well.

F. Durst has a well in the NE. $\frac{1}{4}$ NW. $\frac{1}{4}$ sec. 14, T. 8 N., R. 2 E., on a hill about 70 feet above Belle Fourche. It was sunk in 1906 and has a diameter of $4\frac{1}{2}$ inches and a depth of 550 feet. The main flow was reached at 500 feet and minor flows at 350 and 400 feet. The pressure is sufficient to raise the water 60 feet above the surface, with a volume of 100 gallons a minute. The water is fairly soft. The following record is supplied by the driller:

Record of Durst artesian well south of Belle Fourche.

	Feet.
Sand and gravel	0– 20
Black shale	20-220
Gray shale	220–320
Sandstone	320–332
Shale	332-422
Clay and shale	422–442
Hard close sandstone; no water	442–492
Soft white sandstone; much water	492-550

Two wells on the Case ranch, a mile farther south, have depths of 241 and 355 feet and yield good flows of soft water. The deeper well shows a pressure of 26 pounds.

Another shallow well just south of Minnesela, with a depth of 381 feet, has a 2-gallon flow of soft water under a pressure of 30 pounds.

The Gilbert, Barrett, and Fuller wells, on the south side of Belle Fourche River 2 to 3 miles below Belle Fourche, range from 835 to 935 feet in depth. They have large flows of soft water from the Dakota sandstone or "first flow." The well on the Newland ranch in the SW. $\frac{1}{4}$ sec. 4, T. 8 N., R. 3 E., with a depth of 1033 feet, reaches this flow at 1013 feet. This well is in the deeper part of the syncline that crosses Belle Fourche River 5 miles below Belle Fourche and had to penetrate nearly the entire thickness of Graneros shale.

Hay Creek valley.—There are deep wells at intervals up Hay Creek valley, most of which yield flows. At the Scotney ranch, in the northeast corner of sec. 20, T. 8 N., R. 2 E., there are two artesian wells, one 225 feet deep which flows 15 gallons, and another on slightly higher ground 330 feet deep which has a 28-gallon flow under a pressure of 30 pounds. The water is hard. At the Rawlins ranch, in the NE. $\frac{1}{4}$ sec. 16 of the same township, a boring 535 feet deep yields a 5-gallon flow and had a small first flow at 330 feet. The pressure is 10 pounds or more. At the Richardson place at the crossing 6 miles above Belle Fourche a well 220 feet deep has a 25-gallon flow. It begins in the Fuson formation and reaches water in the basal portion of the Lakota sandstone.

Chambers ranch.—On the Chambers ranch, in the SW. $\frac{1}{4}$ NW. $\frac{1}{4}$ sec. T. 8 N., R. 1 E., on the hogback ridge 9 miles west of Belle Fourche, a boring was made in 1899 to a depth of 700 feet. It obtained no flow and was finally abandoned. The following record is given:

Record of boring on Chambers ranch, 9 miles west of Belle Fourche.

	Feet.
Soil	0– 10
Sandstones and clay, with water rising to —100 feet at 180 feet	10-300
Clay, some sandstone	300–490
Reddish sandstone, with water rising to —100 feet in gray sandstone at base	490–540
Green shale and clay	540–580
Red sandstone	580-685
Red beds under hard ironstone layer	685-700

The boring began at the top of the Dakota sandstone and penetrated that formation and the underlying Fuson and Lakota formations within the first 200 feet. The water at a depth of 180 feet was in the Lakota sandstone, which affords the large flows in the valleys about Belle Fourche, but the boring was on land more than 100 feet too high for a flow. The reddish sandstone at 490–540 feet was in the Sundance formation, and the water at 540 feet was in the sandstone near the lower portion of that formation. The Spearfish red beds were entered at a depth of 580 feet and penetrated 120 feet.

Reclamation project.—The United States Reclamation Service has drilled two artesian wells in connection with the Belle Fourche project—one at the dam site on Owl Creek, in the SE. ¼ SE. ¼ sec. 18, T. 9 N., R. 4 E., the other at the intake of the diversion canal 1½ miles below Belle Fourche. The well at the dam site is 1380 feet deep and 2 inches in bore and has a 1-gallon flow under pressure sufficient to raise the water 20 feet or more above the surface. The boring was in Carlile and Graneros shales, with hard streaks at 250, 540, 640, 790, 900, and 1330 feet, that at 250 feet probably representing a portion of the Greenhorn limestone. The Dakota sandstone was entered near the bottom, so the well is supplied by the first flow.

The following analysis is given:

Analysis of water from well at dam site on Owl Creek.

	Parts per million.
Total solids	711
Calcium and magnesium carbonate	59
Sulphate radicle	0
Sodium carbonate	142
Undetermined	510

The well at the intake of the diversion canal is on the north bank of Belle Fourche River, in the SW. ¼ sec. 36, T. 9 N., R. 2 E. It is 627 feet deep and 2 inches in diameter, and obtains its supply from a depth of 625 feet. A first flow was found in the Dakota sandstone at a depth of 567 feet; shale (Fuson) separates the two flows. The following analysis of the water was made by F. M. Eaton:

Analysis of water of Reclamation Service artesian well at intake 1½ miles below Belle Fourche.

	Parts per million.
Total solids	482
Calcium (Ca)	9.7
Magnesium (Mg)	2.4
Sodium and potassium (Na+K)	154
Chlorine (Cl)	16
Sulphate radicle (SO_4)	141
Bicarbonate radicle (HCO_3)	222
Carbonate radicle	16
Nitrate radicle (NO_3)	0.04

Orman well.—The Orman well is in the NE. ¼ SW. ¼ sec. 19, T. 9 N., R. 4 E., at the south end of the Owl Creek dam. It was finished in October, 1906. The diameter of the well is 3 inches and the depth 1417 feet. The water-bearing bed was entered at a depth of 1325 feet and is a very coarse sandstone 40 feet thick. The flow at an altitude of 3017 feet, or 18 feet above the ground, is 50 gallons a minute, and 26 feet higher it is 32 gallons. The temperature of the water is 94°. Another well 6 inches in diameter is now being drilled on ground 45 feet higher a few rods farther south, and in May, 1907, it had reached a depth of 1100 feet. An analysis of the water from the 3-inch well by W. A. Converse is as follows:

Analysis of water from well at Orman.

	Parts per million.
Total solids	1107
Organic and volatile matter	.5
Silica (SiO_2)	13
Oxides of iron and aluminum ($Fe_2O_3+Al_2O_3$)	2.7
Calcium (Ca)	183
Magnesium (Mg)	57
Sodium and potassium (Na+K)	86
Bicarbonate radicle (HCO_3)	248
Sulphate radicle (SO_4)	640
Chlorine (Cl)	3.5
Nitrate radicle (NO_3)	0.00

Stearns well.—A well on the Stearns ranch, a mile northwest of Snoma postoffice, is 600 feet deep and yields a flow reported to be 450 gallons a minute under a pressure of 125 pounds.

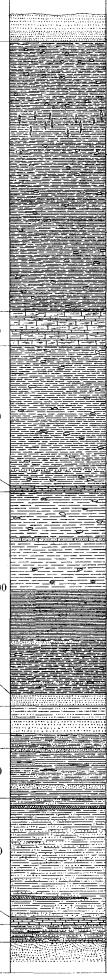
Area of flow.—The artesian water map shows the area in which flowing wells may be expected. The representation is based on the pressures reported in a number of wells and on the theoretical head which should be expected from the altitude of the outcrops of the water-bearing sandstone in the hogback ridge. Owing to the small amount of evidence available the boundaries of the flow area are only approximately ascertained, and it should be borne in mind that they vary somewhat for the different flows. Ordinarily the water from the basal beds of Lakota sandstone has the greatest pressure, so that it will afford flows at higher altitudes than the water from the Dakota sandstone, or "first flow." The pressures of the wells in Belle Fourche indicate that the head of the water is sufficient to raise it to an altitude of about 3150 feet, and a somewhat greater head is indicated by wells on higher lands to the south, although these wells have less surface pressure. The head indicated by the reported pressure in the Stearns well near Snoma is 3220 feet. The head diminishes toward the east, so that in the valley of Indian Creek it is less than 3000 feet. The well at the Ross ranch, however, indicates that the head is sufficient to afford a flow at altitudes somewhat over 2885 feet. The flow at Brant's road ranch, in the Owl Creek valley north of Belle Fourche, indicates that in that vicinity the water will rise to an altitude of more than 3060 feet. Unfortunately the pressure of this well was not ascertained, so that the maximum altitude of head can not be calculated. Flowing wells a short distance south of the southeast corner of the quadrangle afford data for determining the altitude of head in that direction, and the flowing well 2 miles south of St. Onge adds confirmatory evidence to the belief that flows may be obtained up to the base of the hogback range. Doubtless also the flow area will be found to extend up some of the valleys part way across the hogback range, to the line along which the base of the Lakota sandstone passes underground.

It is probable that artesian flows may be obtained from the upper part of the Minnelusa sandstone in the Red Valley area and adjoining slopes, as explained in a previous paragraph.

April, 1907.

GENERALIZED SECTION FOR THE BELLE FOURCHE QUADRANGLE.

SCALE: 1 INCH = 500 FEET.



System.	Series.	Formation Name.	Symbol.	Thickness in Feet.	Columnar Section.	Depth to Top of Dakota Sandstone.	Character of Rocks.	Character of Topography and Soils.
CRETACEOUS	UPPER CRETACEOUS	Fox Hills sandstone.	Kfh	140		3400	Sandstone, light colored and slabby below, massive and yellowish to pinkish above.	Caps rocky buttes. Thin sandy soils.
		Pierre shale.	Kp	1400		3200 3000 2800 2600 2400 2200 2000	Limestone concretions that give rise to "tepee buttes." Dark-gray shale with numerous concretions.	Wide rolling plains. Clay soil, mostly well sodded.
		Niobrara formation.	Kn	150–200		1800	Soft impure limestone or chalk and limy shale with thin limestone masses composed of *Ostrea congesta*.	Valleys, mostly covered by alluvium. Fertile soil.
		Carlile shale.	Kcr	650–800		1600 1400 1200	Gray fissile shale with numerous ferruginous limestone concretions. Thin sandstone near bottom.	Irregular ridges of moderate height. Clay soil.
		Greenhorn limestone.	Kg	25–35			Impure gray slabby limestone with shale intercalations.	Low ridges or benches on shale slopes. Thin soil.
		Graneros shale.	Kgs	1000–1100		1000 800 600 400 200	Gray fissile shale with scattered concretions. Thin bed of sandy limestone near middle and bentonite near base. Mowry shale member, composed of hard gray shale and fine-grained sandstone, weathering light gray and containing numerous fish scales. Local bed of sandstone. Dark fissile shale with concretions and thin sandstone layers near base.	Wide valleys and rolling ridges. Clayey soil, mostly sodded.
		Dakota sandstone.	Kd	40–80		0	Gray to brown sandstone, mostly massive below, slabby above.	Rocky ridges and sloping plateaus. Thin sandy soil on hogback ridges.
	LOWER CRET	Fuson formation.	Kf	60–80			Gray to purple sandy shale and thin sandstones.	Outer slopes of hogback ridges. Sand and clay soil.
		Lakota sandstone.	Klk	60–90			Gray to buff sandstone, massive to flaggy, mostly hard.	Crests of hogback ridges. Thin sandy soil.
CRETACEOUS OR JURASSIC		Morrison shale.	Km	50–100			Massive sandy shale, greenish gray to maroon.	Inner slopes of hogback ridges. Clay soil.
JURASSIC		Sundance formation.	Jsd	225–250			Greenish-gray shale with lenticular limestones; buff sandstone near base, reddish sandy beds near middle, and fine massive white, buff, and purple sandstone, probably Unkpapa, at the top.	Slopes and low ridges. Sand and clay soils, mostly fertile.
TRIASSIC?		Spearfish formation.	Ћs	600–650			Red sandy shale and soft red sandstone with gypsum deposits.	Wide red valley with thin barren soils.
CARBONIFEROUS	PERMIAN?	Minnekahta limestone.	Cmk	35			Gray limestone, thinly laminated.	Sloping plateaus and cliffs in canyon walls. Thin but fertile soils.
		Opeche formation.	Co	85–100			Red sandy shale and red sandstone.	Slopes in canyons.
	PENN.	Minnelusa sandstone.	Cml	100			Massive gray to buff cross-bedded sandstone.	Cliffs in canyon walls.

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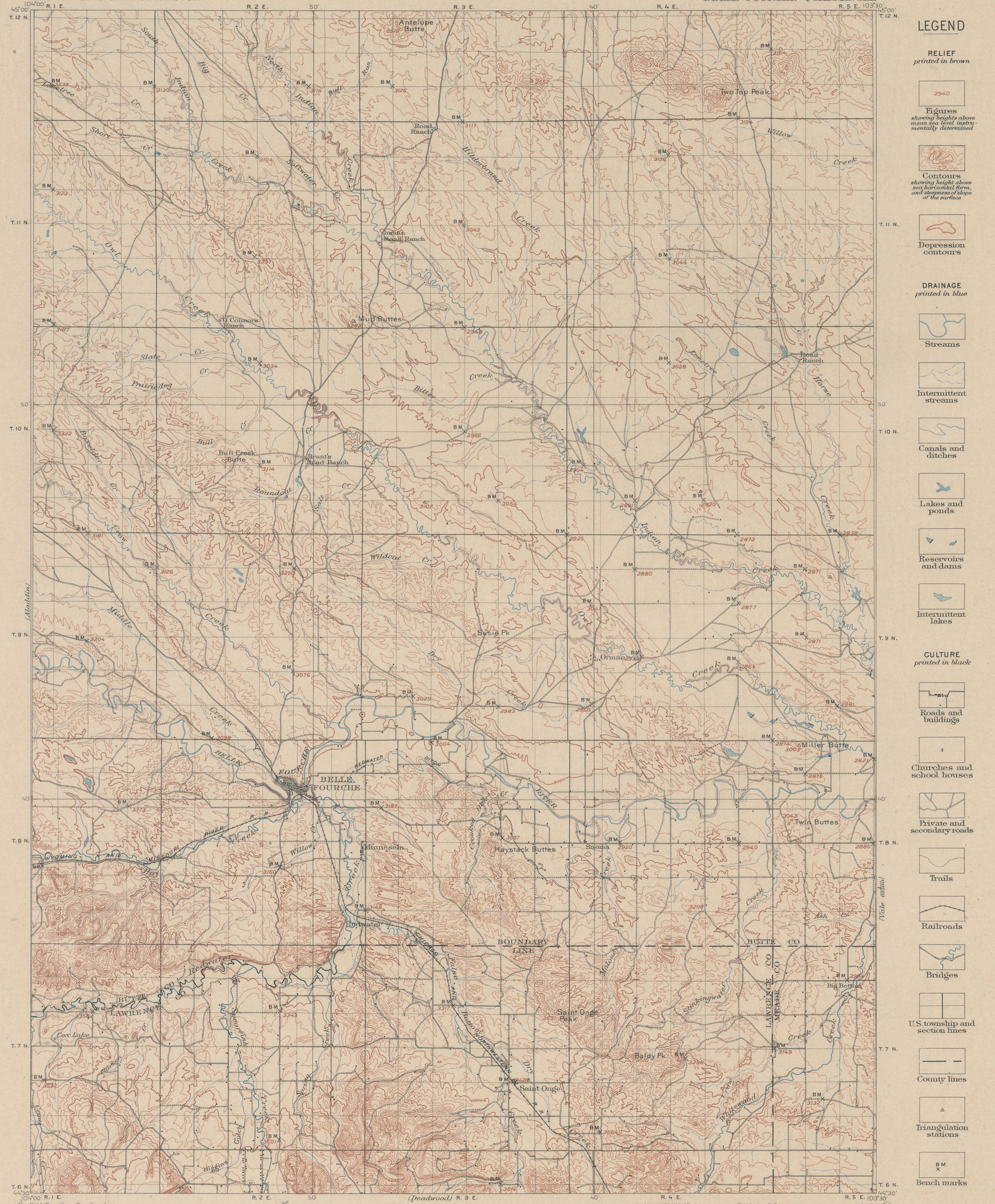
GEORGE OTIS SMITH, DIRECTOR

TOPOGRAPHY

SOUTH DAKOTA
BELLE FOURCHE QUADRANGLE



E. M. Douglas, Geographer.
W. H. Herron, in charge of section.
Topography by W. H. Herron, Chester Irvine,
J. E. Blackburn, S. P. Floore, and R. M. La Follette.
Triangulation by A. E. Dunnington and R. B. Robertson.
Surveyed in 1903-1906.

APPROXIMATE MEAN DECLINATION 1903.

Scale 1/125000

Contour interval 50 feet.
Datum is mean sea level.

DIAGRAM OF TOWNSHIP

Edition of Oct. 1907, reprinted Oct. 1908.

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AREAL GEOLOGY

SOUTH DAKOTA
BELLE FOURCHE QUADRANGLE

LEGEND

SEDIMENTARY ROCKS

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

QUATERNARY

Recent
Qal — Alluvium *(sand and loam; only the larger deposits represented)*

Pleistocene
Qt — Older terrace deposits *(gravel and loam)*

CRETACEOUS

Upper Cretaceous
Kfh — Fox Hills? sandstone *(buff, massive to slabby sandstone)*
Kp — Pierre shale *(dark-gray shale with concretions and limestone lentils that form "Tepee buttes")*
Kn — Niobrara formation *(limy shale and impure chalk)*

Benton group
Kcr — Carlile shale *(gray shale with concretions and thin sandstones)*
Kg — Greenhorn limestone *(impure slabby limestone)*
Kgs, Kmr — Graneros shale *(gray fissile shale with Mowry member, Kmr, composed of hard gray shale)*

Kd — Dakota sandstone *(brownish sandstone, mostly massive)*

Lower Cretaceous
Kf — Fuson formation *(shale and sandstone)*
Klk — Lakota sandstone *(massive buff sandstone)*

CRETACEOUS OR JURASSIC

Km — Morrison shale *(massive sandy shale, gray, greenish, and maroon)*

UNCONFORMITY?

JURASSIC

Jsd — Sundance formation *(buff sandstone, greenish-gray shale, and reddish sandy shale; buff and white sandstone, probably Unkpapa, at top)*

UNCONFORMITY

TRIASSIC?

Trs — Spearfish formation *(red sandy shale with beds of gypsum; the "Red Beds")*

CARBONIFEROUS

Permian?
Cmk — Minnekahta limestone *(thin-bedded gray limestone)*
Co — Opeche formation *(red sandy shale and red sandstone)*

Pennsylvanian
Cml — Minnelusa sandstone *(gray to buff sandstone)*

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Surveyed in 1903-1906.

APPROXIMATE MEAN DECLINATION 1903.

Scale $\frac{1}{125000}$

Contour interval 50 feet.
Datum is mean sea level.
Edition of Jan. 1909.

DIAGRAM OF TOWNSHIP

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

Geology by C. C. O'Harra, under the supervision of N. H. Darton.
Surveyed in 1906.

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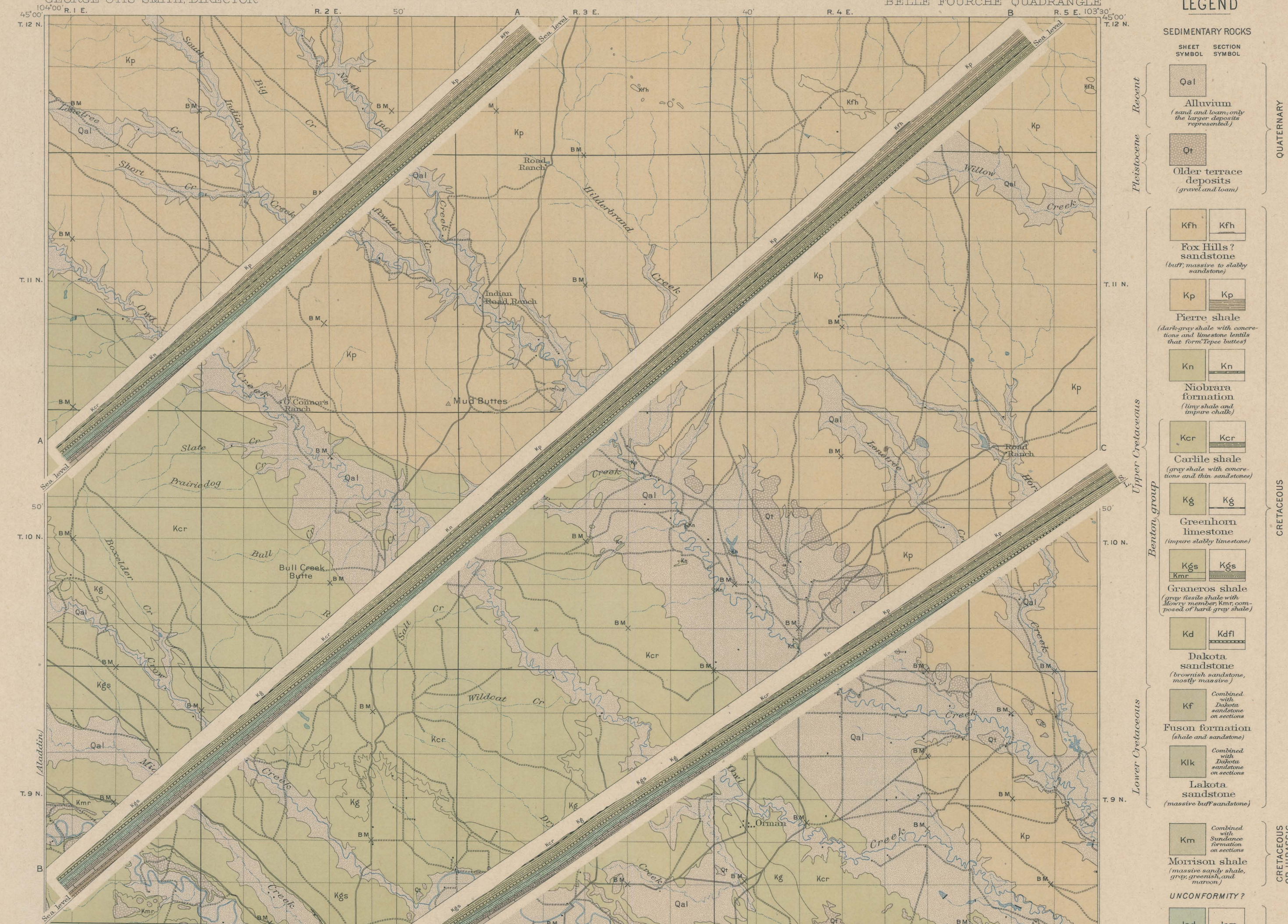
STRUCTURE SECTIONS

SOUTH DAKOTA
BELLE FOURCHE QUADRANGLE



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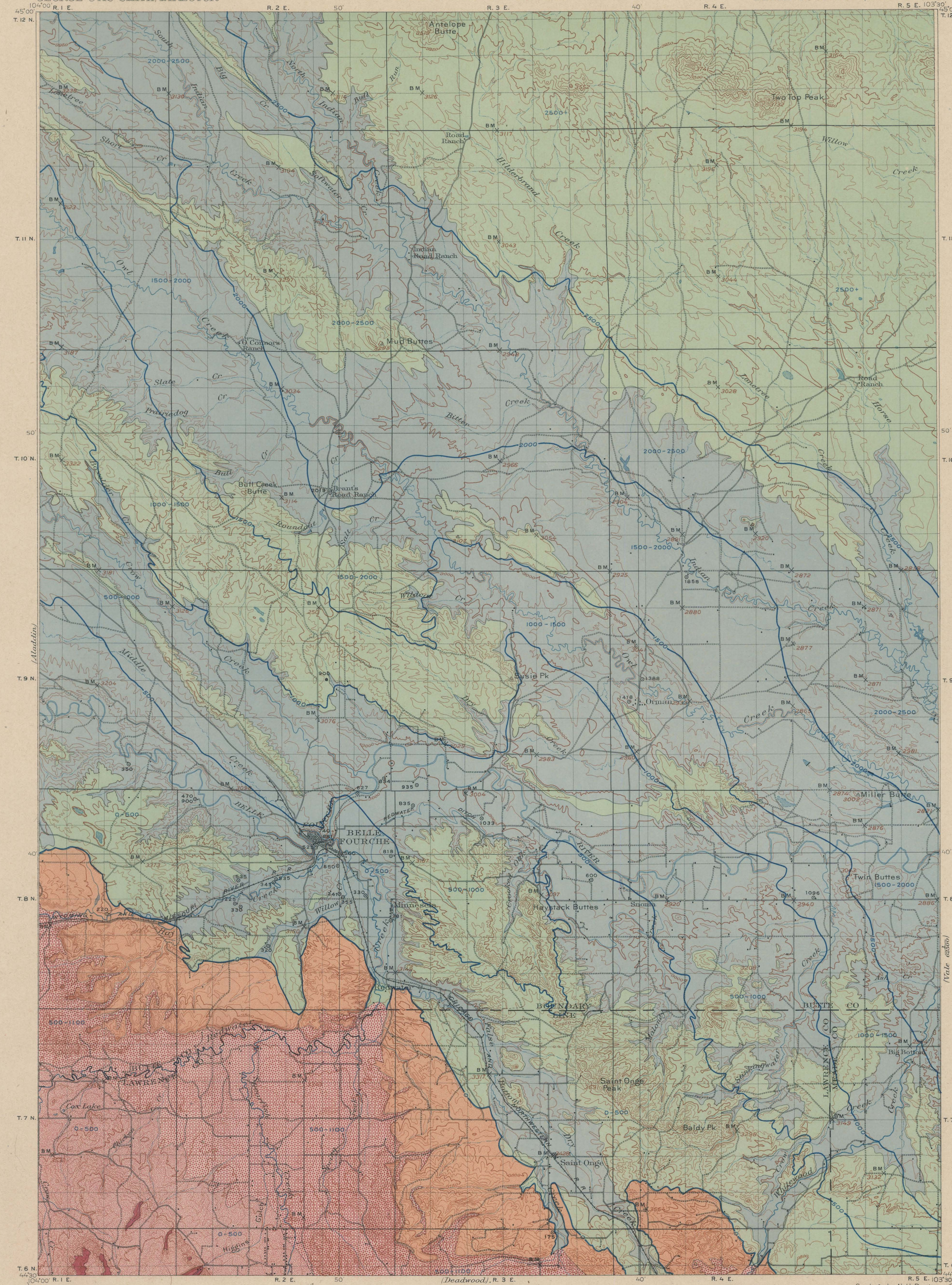
ARTESIAN WATER

SOUTH DAKOTA
BELLE FOURCHE QUADRANGLE



LEGEND

Area in which Dakota sandstone will probably yield flowing wells

Area in which Dakota sandstone will probably yield pumping wells

Depth to Dakota sandstone (artesian water may be expected from 5 to 200 feet below the top of the formation)

Outcrop of Dakota and associated underlying sandstones (area in which surface waters enter water-bearing strata)

0-500
500-1100
Depth to Minnelusa sandstone (from which flowing water can probably be obtained in low valleys; water can probably also be had from underlying Pahasapa limestone, 500 to 1000 feet deeper)

Outcrop of Minnelusa sandstone

935 Flowing wells
Depth in feet

627 Deep borings that failed to reach Dakota water-bearing sandstone.

E. M. Douglas, Geographer.
W. H. Herron, in charge of section.
Topography by W. H. Herron, Chester Irvine, J. E. Blackburn, S. P. Floore, and R. M. La Follette.
Triangulation by A. E. Dunnington and R. B. Robertson.
Surveyed in 1903-1906.

APPROXIMATE MEAN DECLINATION 1903.

Scale $\frac{1}{125000}$

Contour interval 50 feet.
Datum is mean sea level.

Edition of Jan. 1909.

DIAGRAM OF TOWNSHIP

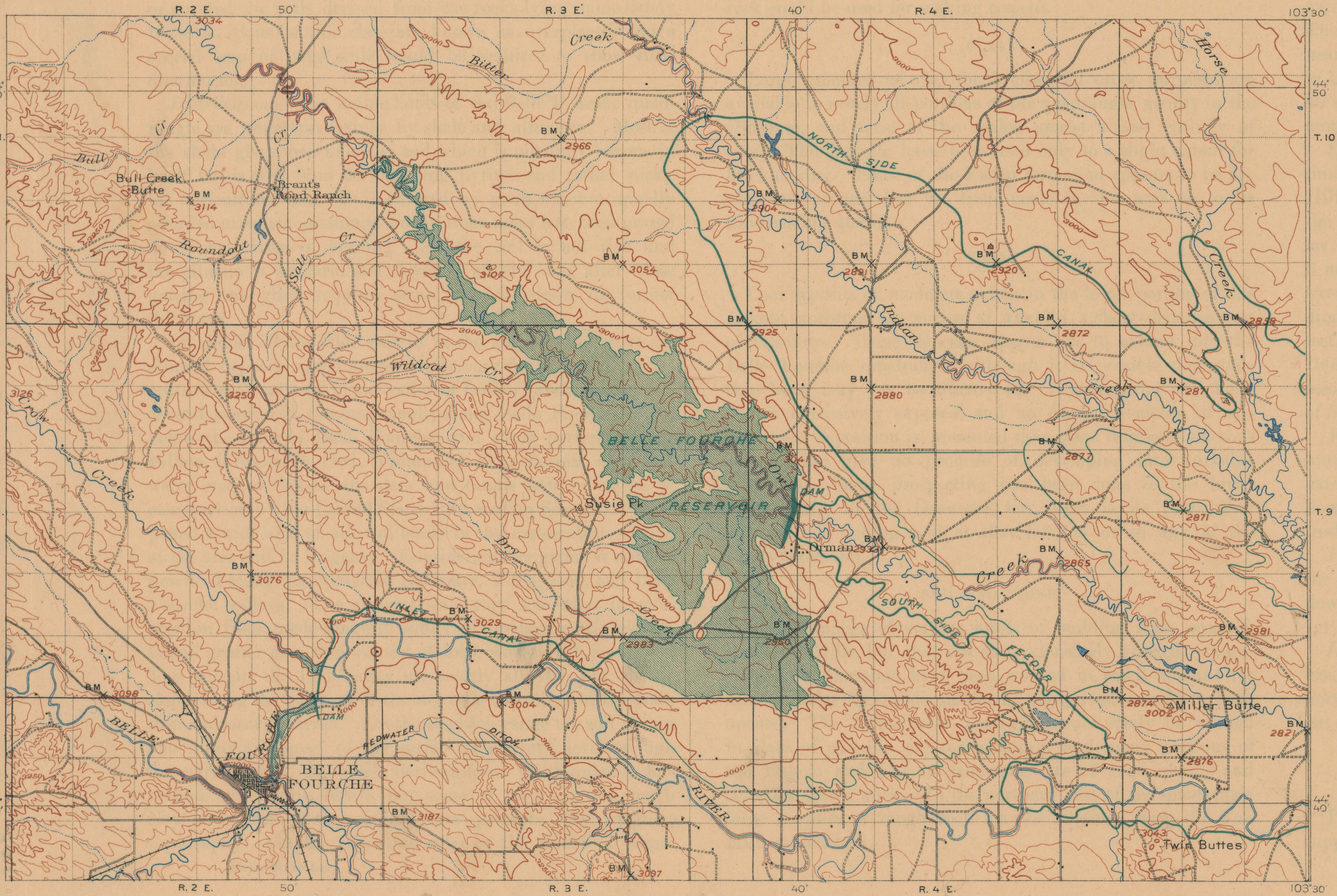
6	5	4	3	2	1
7	8	9	10	11	12
18	17	16	15	14	13
19	20	21	22	23	24
30	29	28	27	26	25
31	32	33	34	35	36

Geology by N. H. Darton and C. C. O'Harra.
Surveyed in 1905-1906.

BELLE FOURCHE IRRIGATION PROJECT

IN COURSE OF CONSTRUCTION BY U. S. RECLAMATION SERVICE

1909



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52	Absaroka	Wyoming	25
53	Standingstone	Tennessee	25
54	Tacoma	Washington	25
55	Fort Benton	Montana	25
56	Little Belt Mountains	Montana	25
57	Telluride	Colorado	25
58	Elmoro	Colorado	25
59	Bristol	Virginia-Tennessee	25
60	La Plata	Colorado	25
61	Monterey	Virginia-West Virginia	25
62	Menominee Special	Michigan	25
63	Mother Lode District	California	50
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