DEPARTMENT OF THE INTERIOR
FRANKLIN K. LANE, SECRETARY
UNITED STATES GEOLOGICAL SURVEY
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GEOLOGIC ATLAS
OF THE
UNITED STATES

NEWELL FOLIO
SOUTH DAKOTA

BY

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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
1919

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.

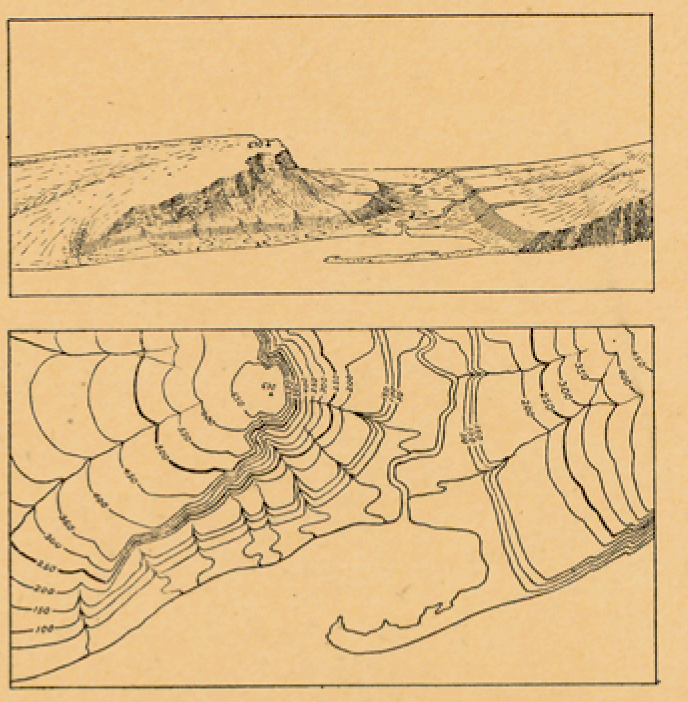


FIGURE 1.—Ideal view and corresponding contour map.

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*,

DESCRIPTION OF THE NEWELL QUADRANGLE.

By N. H. Darton.

GEOGRAPHY.

POSITION AND EXTENT OF THE QUADRANGLE.

The Newell quadrangle embraces the quarter of a "square degree" that lies between parallels 44° 30′ and 45° N. and meridians 103° and 103° 30′ W. It measures about 34½ miles from north to south and about 25 miles from east to west and includes 849.46 square miles. It comprises most of the eastern half of Butte County and a small part of Meade County, S. Dak. (See fig. 1.) Most of the quadrangle is drained by

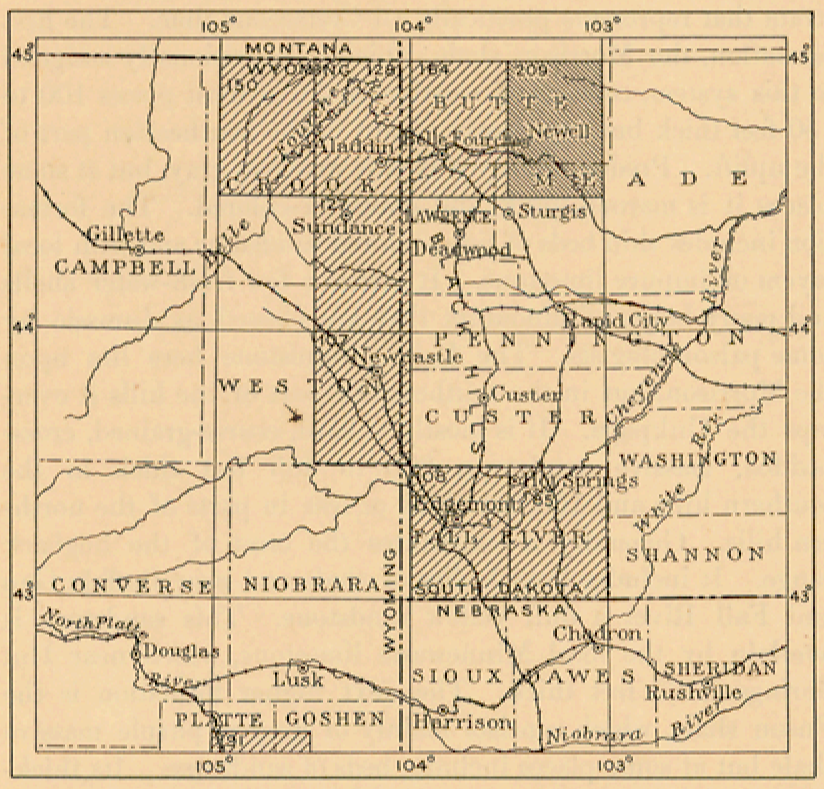


FIGURE 1.—Index map of southwestern South Dakota and northeastern Wyoming.

The location of the Newell quadrangle is shown by the darker ruling (No. 209). Published folios describing other quadrangles, indicated by lighter ruling, are as follows: Nos. 85, Oelrichs; 91, Hartville; 107, Newcastle; 108, Edgemont; 127, Sundance; 128, Aladdin; 150, Devils Tower; 164, Belle Fourche.

Belle Fourche River, but its northern part lies across the divide, at the head of Frog Creek and some other small branches of Moreau River, and much of its northeast corner is drained by Sulphur Creek, a branch of Cheyenne River. The quadrangle lies entirely in the Great Plains province, although the rocks underlying it rise on the northeastern slope of the Black Hills uplift not far south of the quadrangle. As the area exhibits typical features of the Great Plains, a general account of that province will be given as an introduction to the detailed description of the quadrangle.

THE GREAT PLAINS PROVINCE.

General features.—The Great Plains province 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 include wide areas of tabular surface traversed by broad, shallow valleys of large rivers that rise mainly in the Rocky Mountains and are more or less deeply cut by narrower lateral valleys. Smooth surfaces and eastward-sloping plains are their characteristic features, but in parts of the province there are buttes, extended escarpments, and local areas of badlands. Wide areas of sand hills occur in some localities, notably in northwestern Nebraska, where they occupy several thousand square miles.

The province is underlain by 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 beds lie upon relatively smooth surfaces of older rocks. The materials of the beds 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. Except for a few local flexures the beds have not been folded but the region has been broadly uplifted and depressed successively. Though now generally smooth the region was still smoother during earlier epochs. Owing to the great breadth of the plains and their relatively gentle slope, general erosion has progressed slowly notwithstanding the softness of the formations, and as at times of freshet 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 slopes toward the east at the rate of about 10 feet to the mile, descending from about 6,000 feet at the foot of the Rocky Mountains to about 1,000 feet near Mississippi River. The altitudes and rates of slope vary considerably in different districts, particularly those 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 6,200 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 that 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 that descend a thousand feet into the drainage basin of Cheyenne River, one of the largest branches of the Missouri. From this basin northward there is a succession of other basins and relatively low intervening divides, which do not attain the high level of the Great Plains to the south.

Drainage.—The northern part 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, Moreau, Cheyenne, Bad, and White rivers. On Pine Ridge not far south of the escarpment is Niobrara River, which rises in 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 that head in the western part of the plains. Between Arkansas and Platte rivers is Republican River, which rises near the one hundred and fifth meridian, and an extended system of local drainage in eastern Kansas and Nebraska.

CLIMATE.

The climate of the Newell quadrangle is that of the north-central portion of the semiarid zone of the Great Plains. The mean annual precipitation is about 20 inches, but the amount varies greatly from year to year, ranging generally from 15 to 23 inches and occasionally exceeding 25 inches. There are frequent droughts which reduce the precipitation for the year or for the summer below the normal rate. The mean annual

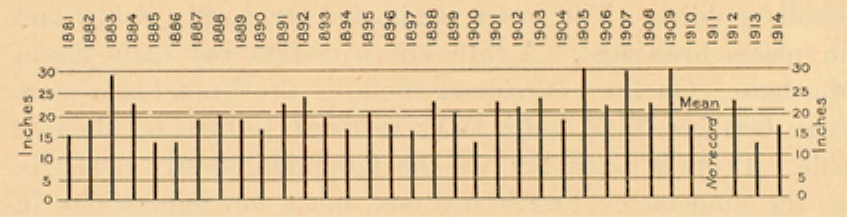


FIGURE 2.—Chart showing annual precipitation in inches at Fort Meade, S. Dak., 1881–1914.

Computed from records of the United States Weather Bureau.

temperature is about 45°. There is very cold weather at intervals from October to March and very high temperature, sometimes exceeding 100° F., from June to September. The summer nights are usually cool and, owing to the dryness of the air, the midsummer heat is seldom oppressive. There is a moderate snowfall in most years, but the snow is rarely deep nor does it lie long on the ground. Weather observations made since 1879 at Fort Meade indicate most of the features of the climate. Summaries of the records of precipitation at that place are given in figures 2 and 3.

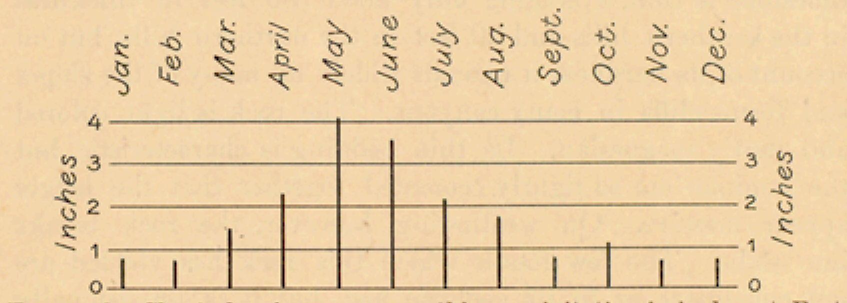


FIGURE 3.—Chart showing mean monthly precipitation in inches at Fort Meade, S. Dak., 1879–1914.

Computed from records of the United States Weather Bureau.

The average number of days in each year for 28 years in which there was one one-hundredth of an inch or more of precipitation was 60, but the number varies greatly from year to year. The average annual depth of the total snowfall during the same period was 4.5 inches.

Annual average precipitation at Fort Meade, S. Dak., 1881–1914.

	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
Rain (0.01 inch or more) ....days..	4	4	6	6	8	8	6	5	3	3	3	4
Snow..........inches..	6	7	12	6	1½	......	......	......	Tr.	2	4½	5½

The principal features of temperature during the same period are shown below:

Average and extreme temperatures (°F.) at Fort Meade, S. Dak., 1881–1908.

	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
Mean.........	13.4	14.5	29.4	45.1	55.1	64.3	71.7	70.6	60.5	48.2	34.4	27.7
Highest......	79	71	78	90	94	105	108	109	104	96	77	73
Lowest.......	—34	—37	—22	1	20	33	34	32	20	—11	—25	—32

The average date of the first killing frost in autumn during the same period was September 6 and of the last frost in spring May 28.

SETTLEMENT.

Until recently the entire plains country around the Black Hills was an open cattle range. The ranches were widely scattered. The only cultivated land was in some of the valleys, where hay was raised for winter feed. A few years ago many persons took up lands in the region for homesteads and fenced large areas. At the same time the Reclamation Service extended ditches from Belle Fourche reservoir to Newell and along the sides of Belle Fourche Valley and in 1908 the town of Newell was established. Soon after this a railroad was built from Belle Fourche to Newell. A large amount of land was cultivated, some of it by irrigation but much of it by dry farming on the rolling plains of shale. In areas where rainfall has to be depended on for crops, the results have been unsatisfactory and most of the homesteads have been abandoned. Although the rainfall in some seasons is sufficient to yield crops, there are long periods of drought, and no permanent agriculture can be established in a region having an average rainfall of only 20 inches. The weather records for many years show that there is no likelihood of change of climate, and extensive tilling of the soil does not increase the rainfall. Moreover, the Pierre shale, which underlies most of the Newell quadrangle, does not make good soil, especially in a semiarid climate.

TOPOGRAPHIC FEATURES OF THE QUADRANGLE.

The Newell quadrangle lies near the western margin of the Great Plains, the front ridges of the Black Hills rising a short distance from its southwest corner. A prominent isolated peak known as Bear Butte, a large igneous mass, lies 2 miles south of its southern edge. The rolling plains here and there rise to form low ridges between which lie wide, shallow valleys. (See Pl. I.) Most of these valleys are flat-bottomed, notably the valley of the Belle Fourche, which is bordered by a wide, alluvial plain and several terraces. Another wide valley is occupied by Cottonwood Creek. Some of the divides south of Belle Fourche Valley are remnants of old valley bottoms and present extensive areas of smooth surfaces. Several notable buttes that rise above the general slope represent remnants of former higher surfaces of the plain.

Relief.—The greater part of the plains in the Newell quadrangle stands at altitudes between 3,000 and 2,700 feet above sea level, the elevation decreasing gradually from west to east. In both the northwest and the southwest corners of the quadrangle the general plain attains an altitude of about 3,250 feet. The altitude along the valley of the Belle Fourche at the western margin of the quadrangle is 2,970 feet and slightly less than 2,550 feet at the southern margin, which is the lowest point in the quadrangle. The highest point is the east summit of the Deer Ears buttes, at the northern margin of the quadrangle, the altitude of which is 3,450 feet. Owl Butte (3,200 feet) and Wolf Butte (3,000 feet) are other notably high points.

The main divide separating the drainage basins of the Belle Fourche and the Cheyenne from that of Moreau River is not a conspicuous topographic feature except where it is marked by Castle Rock and Deer Ears. (See Pls. III and IV.) At Castle Rock post office it is a broad rolling plain extending northwestward and eastward. Its lowest point, on the east side of R. 6 E., stands about 2,980 feet above sea level. Northeast of this point the divide rises and, passing through Deer Ears, crosses the northeast corner of the quadrangle at altitudes of 2,850 to 3,000 feet. The basin about the headwaters of Sulphur Creek is bordered by plains that range in altitude from 2,850 feet on the east to about 3,000 feet on the west.

Causes of some topographic features.—In the description given above it is shown that the Belle Fourche Valley was a broad trench eroded by the river 100 to 200 feet below the general level of the adjoining plains. It is cut in the soft shale of the lower and medial members of the Pierre shale, the outcrops of which it crosses diagonally from west to east. The broad alluvial flats adjoining the stream are covered by river deposits (see Pl. VII), and similar materials cap the terraces that extend at different heights along the valley slopes. These terraces were cut and covered when the valley was at various earlier stages of its excavation. The characteristic flat surfaces of the river deposits give place laterally to slopes of shale where streams cut into the sides of the valleys, and cut banks or steep slopes of shale appear. Portions of the various terraces, especially the higher ones, have been removed by changes in the courses of the streams. The former presence of old streams flowing from west to east across the country is shown by deposits of gravel and sand that cover a large part of the divide between Ninemile and Bear Butte creeks and that cap the ridges south of Vale. Doubtless these streams were predecessors of Ninemile and Bear Butte creeks, which have since shifted their courses and cut their valleys to grades deeper by 150 to 200 feet.

Some very striking topographic features in the Newell quadrangle are the relatively steep fronts or escarpments of the cuestas or sloping plains that mark the tops of certain members of the upper part of the Pierre shale. One of these cuestas is well marked in the divide between Fourmile Creek and the Belle Fourche. Here the divide presents a steep westerly slope to the river and a gentle slope to the southeast down the dip of the beds. To the north it merges into the broad plain at the head of the Elm Creek basin but continues to and beyond Willow Creek and passes westward out of the quadrangle near the south line of T. 11 N. On its western slope there are many tepee buttes. Another similar escarpment, which stands at a higher horizon in the Pierre, passes 2 miles north of Station Elm and 1½ miles north of Owl Butte, where it is about 125 feet high. It is a strongly marked feature in the basin of Willow Creek and is deeply trenched by the head branches of that creek. It is well defined south and southwest of Castle Rock post office. These cuestas are developed entirely in soft shale, but the increased resistance to erosion is probably given by scattered concretions, which occur at certain horizons in the formation.

The buttes that rise from the plains are remnants of beds of harder rocks. Deer Ears, capped by a hard conglomerate, is the most notable of these buttes, and Castle Rock, with a similar cap, half a mile north of the quadrangle, is even more conspicuous. Wolf Butte is capped by hard sandstone at the same horizon as that capping the many smaller similar buttes north and northwest of Castle Rock post office.

The tepee buttes (see Pl. II), which occur in large numbers in a zone passing from northwest to southeast across the center of the quadrangle, are formed of masses of hard limestone in the Pierre shale. Some of these steep-sided conical buttes are 100 feet high and look like tepees; others are very small. Their size depends mainly on the volume of the limestone masses and the extent of erosion of the shale in which they were originally buried. Concretions in the Carlile shale give rise to rather steep slopes and to low but rugged ridges near the southwest corner of the quadrangle.

DESCRIPTIVE GEOLOGY.

ROCKS OF THE BLACK HILLS REGION.[1]

The Black Hills uplift, on whose northeastern flank the Newell quadrangle lies, is an irregular, dome-shaped anticline embracing an oval area 125 miles long and 60 miles wide, whose longer dimension trends nearly northwestward. It is situated in a wide area of almost horizontal beds, which underlie the adjoining country. In its center are metamorphic schists and granites of Algonkian age, which have been lifted high above the general level of the plains and about which is upturned a nearly complete sequence of sedimentary formations ranging in age from Upper Cambrian to latest Cretaceous, all dipping away from the central nucleus. Extensive overlaps of the Tertiary deposits 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 that flow out of the central mountain area have cut canyons and gorges, in the walls of which the formations are extensively displayed. The structure along the sides of the uplift is that of a monocline dipping toward the plains. The oldest Paleozoic sedimentary rocks constitute the escarpment facing the area of crystalline rocks, and each stratum passes beneath a younger one in regular succession outward toward the margin of the uplift. The Paleozoic and Mesozoic sedimentary formations consist of thick sheets of sandstone, limestone, and shale, all essentially conformable in attitude, except the overlapping Tertiary deposits, which extend across the edges of the older rocks. The stratigraphy is in many respects similar to that of the Rocky Mountains in Colorado and Wyoming but possesses numerous distinctive local features.

[1] For a detailed account of the geology of the Black Hills, see Darton, N. H., Preliminary report on the geology and underground-water resources of the central Great Plains: U. S. Geol. Survey Prof. Paper 32, 433 pp., 1905; Preliminary description of the geology and water resources of the southern half of the Black Hills and adjoining regions in South Dakota and Wyoming: U. S. Geol. Survey Twenty-first Ann. Rept., pt. 4, pp. 489–599, 1901; Geology and water resources of the northern portion of the Black Hills and adjoining regions in South Dakota and Wyoming: U. S. Geol. Survey Prof. Paper 65, 105 pp., 1909. Jaggar, T. A., jr., Laccoliths of the Black Hills: U. S. Geol. Survey Twenty-first Ann. Rept., pt. 3, pp. 163–303, 1901. Darton, N. H., and others, U. S. Geol. Survey Geol. Atlas, Oelrichs, Newcastle, Edgemont, Sundance, Aladdin, Devils Tower, and Belle Fourche folios (Nos. 85, 107, 108, 127, 128, 150, 164), 1902–1907.

The Cambrian system is represented by the Deadwood formation, which reaches a thickness of nearly 500 feet in the northern hills but decreases to 50 feet or possibly less in the southern part of the uplift and locally to 4 feet at places southwest of Hermosa. The formation, where thin, consists only of a basal sandstone, generally conglomeratic, which lies on a nearly smooth eroded surface of Algonkian schists and granites. As the formation thickens to the north, however, it takes in also overlying gray shale and slabby sandstone, partly glauconitic, which grade upward locally into slabby limestone, mostly of a flat-pebble intraformational conglomerate. Next above is a persistent and prominent member consisting of 5 to 30 feet of gray to reddish-buff massive sandstone, which is overlain by 20 to 40 feet of green fissile shale, regarded as the top of the formation. The Deadwood carries an Upper Cambrian fauna.

The Ordovician system is represented by the Whitewood limestone, a massive tough limestone of pale-buff color, with brownish spots or mottlings, which occupies small areas near Deadwood and in the Bearlodge uplift. On Spearfish Creek its thickness is 80 feet, but it thins rather abruptly to the south. Later Ordovician, Silurian, and Devonian beds are absent.

In the Black Hills region the Carboniferous system comprises several formations that apparently represent long-continued deposition during the earlier and later parts of the period, except that late Mississippian time is unrepresented. Limestone predominates, but a large amount of sandstone occurs in the higher formations.

Everywhere at the base of the Carboniferous is the Englewood limestone, 30 to 60 feet thick, which consists of slabby beds of pinkish or buff color, containing Kinderhook fossils.

The Englewood grades up into the Pahasapa limestone, so named from the Indian term for the Black Hills, a massive light-colored limestone 300 feet thick in the southern and central hills, 400 to 500 feet thick about Deadwood, and 630 feet thick on Spearfish Creek. The Pahasapa gives rise to prominent cliffs in the great limestone escarpment and in many canyons. It carries lower Mississippian fossils and is equivalent to the Madison limestone (lower Mississippian) of Wyoming and Montana. Later Mississippian rocks are absent in the Black Hills.

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. It consists mainly of white, buff, and reddish sandstones, interbedded locally with limestones, and invariably carries at its top a thick, massive cross-bedded coarse granular, moderately hard sandstone, as a rule white to buff but locally reddish. The lower sandstones are mostly slabby and in places brecciated. A thin but persistent red shale lies at the base. On the west side of the hills the formation is more than 600 feet thick, but it thins 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 Big Horn and other uplifts in Wyoming.

Upon the Minnelusa sandstone lie the red slabby sandstones and sandy shales of the Opeche formation, which is 100 feet thick in the southern hills and 75 to 85 feet thick in the northern hills. The formation yields no fossils but is provisionally referred to the Permian, on the basis of its lithology and stratigraphic position. 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 only about 50 feet in thickness in the southern hills and 30 feet in the northern hills, but on account of its hardness it extends widely up many of the slopes and forms cliffs in many canyons. The rock is light colored and partly magnesian. Its thin bedding is characteristic, but the laminae are so tightly cemented together that the ledges appear massive. On weathering, however, the rock breaks into slabs. The few fossils which this rock has yielded are not conclusive as to its geologic age, but it is provisionally referred to the Permian.

The thick mass of red shales with gypsum deposits lying on the Minnekahta limestone and underlying the Red Valley has been designated the Spearfish formation. It has been supposed to be Triassic, but it presents no direct evidence as a basis for classification and may prove to be Permian in whole or part. Its thickness ranges from 550 to 695 feet, as indicated by a boring at Fort Meade. The gypsum deposits are in places more than 30 feet thick. The most persistent bed occurs about 100 feet above the base of the formation but is not continuous. Local deposits occur at other horizons, notably at the top of the formation near Cambria and in the Spearfish-Rapid City area.

The Spearfish red beds are overlain unconformably, but with no discordance of dip, by the Sundance formation, which represents part of the later Jurassic. The formation crops out along the lower inner slopes of the hogback range. It ranges in thickness from 70 to 350 feet and consists mainly of gray shales but includes a persistent bed of buff sandstone, 40 feet thick, about 50 feet above the bottom. In most regions the sandy shales a short distance above this sandstone are reddish. 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 part of the uplift the Sundance formation is overlain by 100 to 225 feet of massive fine-grained Unkpapa sandstone, in greater part pure white or bright pink. This sandstone thins out and is absent on the western side of the hills, but it extends far to the north on the eastern side, although thin and showing few exposures. It has yielded no fossils, and its inclusion in the Jurassic is purely arbitrary, being based on its close association with the Sundance formation.

In the Black Hills uplift the Cretaceous system comprises an apparently continuous succession of about 4,000 feet of strata that represents practically all Cretaceous time. The first formation, the Morrison shale, which is provisionally assigned to this system, consists of massive shale, in most places 100 to 150 feet thick but apparently absent in the southeasten part of the uplift. Predominantly it is pale greenish gray, but at some places it is maroon, pink, and chocolate-colored. The formation includes thin beds of light-colored sandstone and thin local layers of impure limestone. It carries a few fresh-water shells and many bones of dinosaurs that are classed as Jurassic by some paleontologists. The Lakota sandstone here lies upon the Morrison, but in the southeastern part of the hills it overlaps the Unkpapa. It is mostly a hard, coarse-grained, cross-bedded, massive sandstone, 200 to 485 feet thick in the southern hills and 100 feet thick or less in parts of the northern hills. Generally it constitutes the crest of the hogback range. It includes local bodies of shale and near Buffalo Gap and Fall River a dull yellow sandstone. This sandstone is overlain by the local Minnewaste limestone, which near Hot Springs is 25 feet thick. The next higher formation is the Fuson shale, which consists mainly of gray to purple massive shale but at some places includes beds of sandstone. Its thickness ranges from 30 to 188 feet and averages 65 feet. The Fuson and Lakota beds contain an extensive Lower Cretaceous flora.

The Dakota sandstone, which lies on the Fuson shale throughout the uplift, is mostly a hard massive buff sandstone, slabby at the top. Its thickness exceeds 100 feet in most localities but it thins to less than half as much in the northeastern part of the hills. Locally the Dakota sandstone extends to the crest of the hogback ridge, but ordinarily it outcrops on the outer slope. It contains an Upper Cretaceous flora.

The Dakota is followed by the thick series of dark shales—Graneros, Carlile, and Pierre—which underlie the plains at the foot of the hogback range. The Graneros shale, 900 to 1,150 feet thick, includes the hard Mowry shale member, which weathers light gray and is full of fish scales, and some local sandstones, one of which lies just under the Mowry shale and is the "oil sand" in the Newcastle region. The Greenhorn limestone, averaging 65 feet in thickness, caps the Graneros shale all around the Black Hills and forms a low but distinct ridge. It is filled with characteristic *Inoceramus labiatus* (see Pl. IX) and weathers out in thin slabs. The Carlile shale, 500 to 750 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, which averages 200 feet in thickness and weathers to a bright straw color. This formation contains aggregations of distinctive *Ostrea congesta*. (See Pl. VIII.)

The Pierre shale, overlying the Niobrara, attains a thickness of 1,400 feet in the southwestern part of the State. Toward the top it contains scattered limestone masses filled with *Lucina occidentalis*, which weather out as tepee buttes. These fossils also occur locally at a lower horizon. Many smaller oval concretions filled with molluscan remains occur in the shale. The sandstone of Fox Ridge extends west to the margin of the Black Hills uplift, capping low ridges of Pierre shale. To the north the sandstone is overlain by the Lance and later formations, which occupy a wide area in northwestern South Dakota.

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

ROCKS EXPOSED IN THE NEWELL QUADRANGLE.

The strata exposed in the Newell quadrangle have a thickness of about 2,000 feet. Their sequence and general character are shown in the columnar section at the end of the text. They are all sedimentary and range in age from early Upper Cretaceous to Quaternary. Cretaceous rocks occupy more than 90 per cent of the surface. Beneath the surface, as shown in part in the structure section (see fig. 5), there are 3,000 feet of sedimentary rocks, comprising Lower Cretaceous, Jurassic, Triassic(?), Carboniferous, and Cambrian strata lying on Algonkian crystalline rocks. These rocks rise to the surface in the Black Hills beyond the southern margin of the quadrangle—all of them within a short distance to the southwest and some of them on the slopes of Bear Butte a mile to the south.

CRETACEOUS SYSTEM.

Rocks of Upper Cretaceous age lie at the surface or under the thin alluvial and terrace deposits throughout the Newell quadrangle. They comprise the Graneros shale, Greenhorn limestone, Carlile shale, and Niobrara formation of the Colorado group and the Pierre shale and Fox Hills (?) sandstone of the Montana group. The Graneros, Greenhorn, and Carlile together form the equivalent of the Benton shale of other areas.

UPPER CRETACEOUS SERIES.

COLORADO GROUP.

GRANEROS SHALE.

The Graneros shale is at or near the surface in an area of about 3 square miles in the southwest corner of the Newell quadrangle. It is largely covered by terrace sand and gravel but outcrops in hollows and slopes. The outcropping beds including part of the Mowry shale member are about 600 feet thick—about half the formation. They consist of dark-gray shale, mostly soft but showing thin lamination where not reduced to clay by long weathering. This shale contains a few concretions of carbonate of lime, with more or less iron, which on weathering give a decided yellowish-brown color to the outcrop. A thin bed of limestone is included in the formation near the southwest corner of the quadrangle, but whether or not it extends into the area could not be determined owing to the cover of sand.

The Mowry shale member, which lies about 300 feet above the base of the Graneros, consists of about 250 feet of harder shale and thin-bedded, very fine grained sandstone. It weathers grayish white and contains large numbers of fish scales, both of which are characteristic. The Mowry is well exposed in a draw along the southern margin of the quadrangle near the center of sec. 12, T. 6 N., R. 5 E., but elsewhere is covered by later formations.

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. Its zone of outcrop extends across the southwest corner of the quadrangle, where it constitutes part of the northern slope of a low ridge capped by terrace deposits. This zone is less than a quarter of a mile wide and is interrupted in many places by sand and talus. The most extensive outcrop is in the northwest corner of sec. 2, T. 6 N., R. 5 E., and smaller exposures occur in the southwestern portion of sec. 6 and the northwestern portion of the adjoining sec. 7, T. 6 N., R. 6 E.

The formation is 25 to 30 feet thick. It includes clay and sand in varying quantities, and in its unweathered condition is gray and only moderately compact. It becomes harder on weathering and in outcrop appears mostly as thin pale-buff slabs. The limestone beds are separated by shale layers half an inch to 3 inches thick in greater part. The limestone is characterized by impressions of *Inoceramus labiatus* (see Pl. IX), a fossil which has not been observed in the adjoining formation. At its base the limestone is in most places clearly distinct from the dark shale of the Graneros formation, but the contact suggests no unconformity. Its upper part appears to grade into the Carlile shale through 6 to 8 feet of passage beds. The formation has been penetrated by some of the deep artesian wells and is ordinarily reported as "rock," so that it is evidently hard enough to be noticeable as a definite stratum in the inclosing softer shales.

CARLILE SHALE.

The Carlile formation consists mainly of dark-gray shale containing numerous concretions. It outcrops extensively in the southwestern portion of the quadrangle south of Whitewood Creek, its greatest width being about 3 miles, in the area south of Cottonwood Creek. It gives rise to irregular hills and ridges of considerable prominence, most of which are bare of Quaternary deposits. Its thickness is 550 feet, as nearly as could be determined from the low and indefinite dips. The shale merges into adjoining formations through a few feet of passage beds.

Most of the shales are dark gray, but some are black. The beds generally separate readily into thin layers where they are not changed to clay by weathering. Thin beds of sandstone are included in the formation, mostly near its base.

The formation contains numerous biscuit-shaped concretions of calcium carbonate, most of them 3 to 5 feet thick but some larger. Many exhibit cone-in-cone structure in part. They are scattered through certain layers, and, being hard, they accumulate on the surface as the soft shale is removed by erosion. Many of the concretions are traversed by cracks filled with calcite, and their surfaces are yellow to yellowish red from oxidation of the iron. Some of them are highly fossiliferous, containing impressions of a large flat *Inoceramus*, of *Prionocyclus*, and of other fossils typical of the upper Benton fauna.

NIOBRARA FORMATION.

The zone of outcrop of the limy shales of the Niobrara formation extends across the southwest corner of the Newell quadrangle just east of the outcrop of Carlile shale. It crosses Belle Fourche River at the western margin of the quadrangle and extends southeast in a belt about a mile wide into the northwest corner of T. 6 N., R. 6 E., where it disappears under terrace deposits and alluvium. The formation is soft and is largely covered by alluvium, wash, and sod, so that outcrops are rare. It appears in the banks of the Belle Fourche, in the ridges on both sides of Whitewood Creek, at intervals up the broad valley of Cottonwood Creek and its south branch, and extensively in the slopes in the southwest corner of T. 7 N., R. 6 E. Its relations to the Pierre shale are well exposed in the bank of the Belle Fourche a mile northwest of Butte Hall in the southeast corner of sec. 31, T. 7 N., R. 6 E., and in the southwest corner of sec. 26, T. 8 N., R. 5 E.

The Niobrara formation consists of mixtures of clay and carbonate of lime in different proportions, in greater part constituting an impure chalk, which grades into and is interbedded with calcareous shale. Its thickness is between 150 and 200 feet. The fresh material is light gray to pale buff, changing on weathering to a pale chrome-yellow, which is a characteristic feature of the outcrops. It includes here and there thin masses of irregular aggregates of *Ostrea congesta* (see Pl. VIII), a species distinctive of the formation, which also occurs scattered through the shale. Some hard layers in the upper beds of the formation exposed on the east bank of the Belle Fourche a mile north of Butte Hall contain many fossil shells of undescribed species. The type locality of the formation is on Missouri River at the mouth of the Niobrara.

MONTANA GROUP.

PIERRE SHALE.

Distribution and character.—About 820 square miles of the Newell quadrangle is occupied by the soft dark Pierre shale, which overlies the limy beds of the Niobrara formation. The line of separation is arbitrarily placed at the top of these limy shales, but it is possible and even probable that a considerable thickness of the shales here classed as Pierre are equivalent to the upper portion of the Niobrara formation of other regions. The outcrop of the Pierre extends along the wide valley of the Belle Fourche and north across the divides to Elm, Sulphur, and Frog creeks, and its surface is a smooth rolling plain. (See Pl. I.) Along the river and in the high terrace remnants south of Vale it is thinly covered by Quaternary deposits, but these are cut through at many places, revealing the dark shale below. North of the river the zone of outcrop is about 20 miles wide and extends to the edge of the supposed Fox Hills sandstone, which overlies it without unconformity and apparently at a uniform horizon throughout, a few feet of sandy shale constituting a bed of transition between the two.

The low and indefinite dips and the great width of outcrop make it difficult to measure the thickness of the Pierre shale, but it is believed to be about 1,400 feet.

The formation consists of a monotonous succession of dark-gray to black shales, containing numerous concretions of different kinds. Most of these concretions are oval and smooth surfaced and measure from a few inches to 2 feet or more. Some are gray limestone; but most of them contain considerable iron and weather to a bright brown-red. A sample collected 6 miles north of Newell was found to contain 54.5 per cent of oxide of iron and a little calcium and magnesium carbonate. The concretions break up on exposure and accumulate on the surface in small irregular fragments that are characteristic of the Pierre outcrop.

About 200 feet or more of the lowest beds of the Pierre shale weathers to a lighter tint than the beds above, evidently owing to the presence of calcium carbonate. This lowest member contains thin brown lenses and flat concretions of oxide of iron, especially near its contact with the underlying Niobrara.

Tepee butte zone.—Most of the concretions that give rise to tepee buttes occur in a zone beginning about 1,000 feet above the base of the Pierre shale and reaching the surface along a belt extending diagonally across the quadrangle from T. 6 N., R. 9 E., to the north-central part of T. 10 N., R. 5 E. They consist of limestone and aggregates of shells in masses that range from a few cubic inches to several thousand cubic feet and are scattered irregularly through a thickness of 100 feet or more of the shale. When weathered out, they appear as rocky masses (see Pls. V and VI), many of them capping conical hills of the soft shale. (See Pl. II.) Tepee buttes are conspicuous along the east slope of the Belle Fourche Valley in T. 7 N., R. 8 E., T. 8 N., R. 8 E., and T. 8 N., R. 7 E.; along Willow Creek valley; in the ridge next west of that valley; and in the region east and north of Newell. In places the limestone masses are large and abundant; in others they are small and far apart. These limestone masses occur also, though much less abundantly, at both lower and higher horizons in the Pierre shale. The lowest horizon, which is about 550 feet above the base of the formation, is indicated by exposures in sec. 12, T. 8 N., R. 6 E., and in the SW. ¼ sec. 36, T. 8 N., R. 6 E. The highest horizon is about 250 feet above the main tepee zone. Its numerous but widely scattered limestone masses appear about Rothford, Owl Butte, and Station Elm and at intervals from Station Elm to the northwest part of T. 7 N., R. 9 E.

Fossils.—Many fossils occur in the concretions in the Pierre shale. They comprise several forms of a characteristic marine fauna, which appears throughout the zone of outcrop in the Great Plains region and elsewhere. Probably the largest numbers of individuals occur in the rock of the tepee buttes, many masses of which consist of shells of the characteristic *Lucina occidentalis*. *Limopsis striatopunctata* was also collected from both the lower and the main tepee butte horizons near Newell. The lower beds, 200 feet or more in thickness, have yielded no fossils, but the upper beds, a few feet below the base of the Fox Hills (?) sandstone, contain many. *Inoceramus sagensis* Owen? and *Leda* (*Yoldia*) *evansi* Meek and Hayden were collected at Wolf Butte, and *Inoceramus barabini* Morton was collected not far above the horizon of the uppermost tepee butte, northeast of Owl Butte. The fossils were all determined by T. W. Stanton.

Fossils from the upper part of the Pierre beds 2 miles north of Castle Rock post office were determined as follows by Mr. Stanton: *Ostrea pellucida*, *Avicula linguiformis*, *Inoceramus barabini*, *Leda scitula*, *Lucina* sp., *Dentalium* sp., *Margarita nebrascensis*, *Lunatia occidentalis*, and *Scaphites nodosus*.

FOX HILLS (?) SANDSTONE.

The higher parts of the Sulphur-Moreau divide, in the northern part of the Newell quadrangle, are underlain by a thin body of sandstone which may represent the Fox Hills sandstone. Outliers of this sandstone also underlie Wolf Butte, the ridge south of Ball post office, and the Castle Rock ridge in the northwest corner of the quadrangle. No fossils have been found in it. The formation lies on Pierre shale and appears to grade into it through beds a few feet thick. The first well-defined sandstone layer, which is regarded as the base of the formation, begins about 10 feet above the top of a peculiar light-gray shale containing gray concretions carrying abundant Pierre fossils. As this succession persists throughout the area it is believed to indicate conformable succession.

The supposed Fox Hills sandstone varies considerably in character from place to place but is predominantly of light-buff to gray slabby sandstone. A characteristic phase consists of thin, moderately hard beds, with smooth surfaces. Some beds, especially the upper ones, are soft and massive. Outcrops are not common, for the sandstone generally weathers into a slope, at most places covered by soil. The average thickness is about 25 feet. In Wolf Butte it consists of about 30 feet of soft gray sandstone with some clay admixture, especially near the base. In the Castle Rock ridge the basal part of the supposed Fox Hills sandstone consists of a light-gray rock in thin smooth surfaced layers. This member is overlain by varying amounts of soft pale-buff massive sandstone that is not well exposed, for the surface is mostly covered by soil.

The two small outliers on the north side of Frog Creek consist of low knobs of hard, slabby gray sandstones only a few feet thick, lying 3,100 feet above sea level. The eastern one is the smaller. Some fragments of thin sandstone on Owl Butte may represent this formation.

TERTIARY SYSTEM.

Doubtless the entire Newell quadrangle was originally covered by deposits of Tertiary age, but they have all been removed, except on the divides near the northern margin of the quadrangle, where the Lance formation, provisionally regarded as earliest Tertiary, overlies the supposed Fox Hills sandstone and where the Chadron formation of the Oligocene White River group caps a small area in Deer Ears.

EOCENE (?) SERIES.

LANCE FORMATION.

Distribution and character.—In the area north of Sulphur Creek, in the higher slopes of the Castle Rock ridge northwest of Castle Rock post office, in the ridge south of Ball, and in Wolf Butte the supposed Fox Hills sandstone is overlain by clay of the Lance formation. So far as observed in this region there is no noticeable unconformity between the two formations. The greatest thickness of the Lance is at Deer Ears and in the slopes farther south, where about 375 feet of beds are exposed.

The predominating material of the Lance formation is dark-gray clay, close to fuller's earth in composition, and mixtures of fine sand and clay, locally developing into light-colored sandstones, some of which outcrop in hard ledges. (See fig. 4.) The basal member is dark-gray clay, 60 to 90 feet thick, which at many places weathers into miniature badlands, such as those that are especially conspicuous in the ridges south of Ball and that appear from place to place in the ridge north of Sulphur Creek. When wet the clay is very plastic, and when dry its surface looks chalky and blistered. It contains light-colored lens-shaped concretions of calcium carbonate, which break into acicular fragments. Northwest of Ball the clay is overlain by a thin bed of soft and massive sandstone, on which lies a widespread deposit of impure brown lignite containing in places so much carbonaceous material that it has been worked for fuel. (See fig. 4.) It contains much clay and grades both

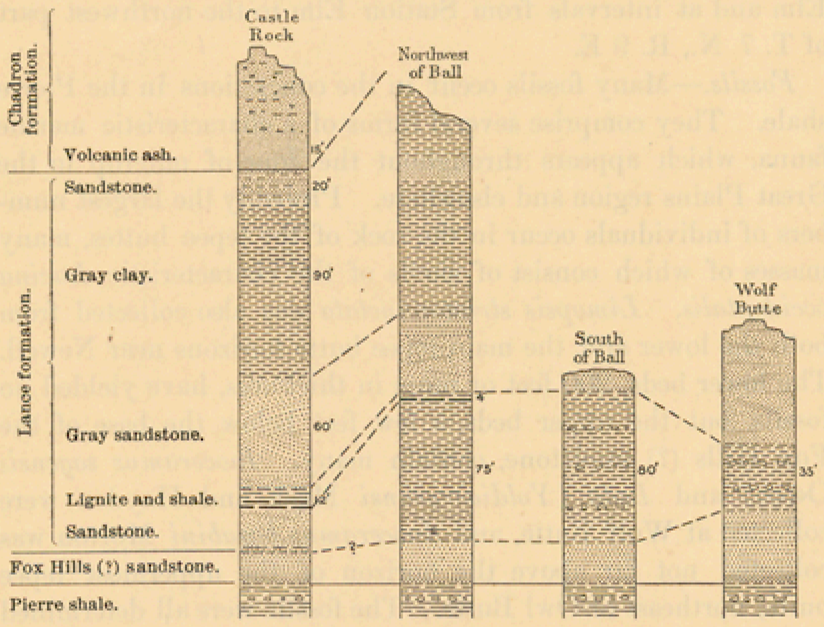


FIGURE 4.—Sections of Lance and associated formations in the Newell quadrangle.
Scale: 1 inch=100 feet.

laterally and upward into dark shale. It averages 3 feet in thickness in the region northwest of Ball and 12 feet near Castle Rock but is absent on Wolf Butte. The underlying sandstone is 10 feet thick in slopes 4½ miles northwest of Ball but thickens considerably in the Castle Rock region, where it apparently takes the place of the lower clay member. One of the most extensive exposures of this lignitic layer is in many pits on the slopes of a round hill in the south-central part of sec. 31, T. 12 N., R. 8 E. It is well exposed in hills and ravines southwest of Castle Rock, where it consists of a succession of beds of dark shale and impure brown lignite 12 feet thick lying on 15 feet or more of soft light-buff massive sandstone.

The lignitic layer is overlain by a succession of sandstones of different thicknesses and degrees of hardness. In most localities part of this sandstone is hard, and it caps prominent knobs and ridges north of Sulphur Valley, southeast of Ball, and southwest of Castle Rock. In Wolf Butte the basal dark clay of the formation is overlain by 60 feet of soft gray sandstone, cross-bedded in part and containing a few hard layers, and capped by 20 feet of very hard gray sandstone that constitutes the summit of the butte. Many prominent knobs of this sandstone member appear on the many ridges leading up to Deer Ears. In one nearly complete exposure in a draw in the northwest corner of sec. 24, T. 12 N., R. 5 E., a mile

have yielded numerous bones of *Triceratops* and *Trachodon*. Extensive field work in these regions, however, has definitely correlated the formation, Calvert, Beekly, Barnett, and Pishel[1] having applied the term Lance to the fresh-water beds immediately succeeding the Fox Hills sandstone. Unconformity between the Fox Hills and the Lance occurs in places, but it is not known whether or not it is widespread or represents much time interval. Stanton[2] examined part of the region not far northeast of the Newell quadrangle and in some other typical areas and concluded that there was transition from Fox Hills to Lance deposits. In the quadrangle there is no evidence of unconformity, for the absence of a lower clay member about Castle Rock is probably due to lateral gradation into sandstone. It is possible that the supposed Fox Hills sandstone of the Newell quadrangle is basal Lance. It appears, however, to lie conformably on the Pierre shale.

Sandstone dike.—In the NW. ¼ sec. 24, T. 12 N., R. 5 E., 3 miles northwest of Castle Rock post office, the Lance formation is traversed by a small, nearly vertical sandstone dike, which trends N. 30° W. and is about 14 inches thick, consisting of two layers of hard sandstone separated by a 2 to 3 inch layer of soft sand. At the exposure it cuts soft sandstone. This dike consists of material from some adjoining formation forced up or down in a plastic condition through a crack.

OLIGOCENE SERIES.

CHADRON FORMATION.

The Chadron or lower formation of the White River group caps both tips of the butte known as Deer Ears (see Pl. III), only the southernmost of which lies in the Newell quadrangle. The beds, which are 50 feet thick, consist of 40 feet of fine buff loam, developing into a soft sandstone in its lower part and capped abruptly by a 10-foot member of rather hard, coarse cross-bedded white sandstone, which forms the summit of the butte. The lower portion of the sandstone is coarsely conglomeratic and contains several kinds of pebbles, all apparently derived from rocks that appear in the Black Hills. Fragments of bone occur in this material; a lower jaw was determined by Mr. Gidley, of the United States National Museum, to be that of a *Titanotherium*, a genus highly characteristic of the Chadron formation in the Big Badlands and along the slopes of the Black Hills. The formation also caps Castle Rock, which lies just north of the north edge of the quadrangle. (See Pl. IV.) It here consists of 50 to 60 feet of light sandstone underlain by 15 feet of volcanic ash.

QUATERNARY SYSTEM.

Quaternary deposits occur in all the larger valleys of the quadrangle and on terraces adjoining the Belle Fourche Valley. They are classified as high terrace deposits and alluvium.

PLEISTOCENE SERIES.

HIGH TERRACE DEPOSITS.

Remnants of old terrace deposits occur at several heights above the Belle Fourche Valley, especially on the south side, where the slopes rise to the Black Hills. They mark the courses of streams which have since excavated their valleys to lower levels, and undoubtedly they were originally more exten-

this same terrace deposit also occupy the ridge west of Butte Hall and the north side of the Belle Fourche east of Butte Hall and north of Vale. Thin deposits cap the part of the divide between Dry and Willow creeks southwest, south, and east of Newell and also the divide between Deer and Willow creeks east of Newell. Owl Butte is capped by some sandstone fragments which may represent an old terrace deposit but which can not be classified. In places along the valleys north of the Belle Fourche there are suggestions of terrace flats, but if they bear a deposit the material is of such local nature that it can not be distinguished from the underlying Pierre shale.

On Owl Butte and in places on the rolling prairies of Pierre shale there are found masses of limestone made up of thin layers irregularly bent and twisted, which are probably remnants of some former capping, possibly of Tertiary age. A specimen was polished and a thin slice was examined microscopically, but no evidence of organic character was found. The structure is more like that of travertine.

RECENT SERIES.

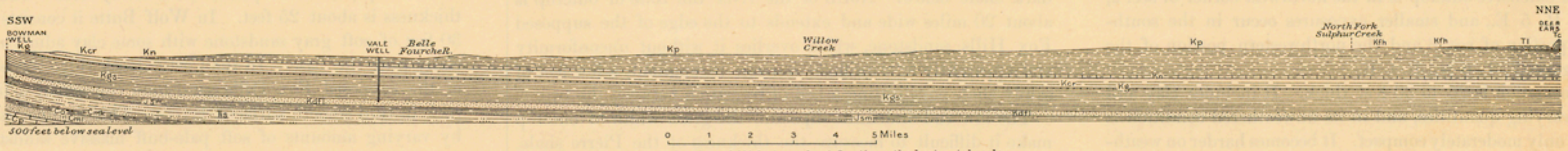
ALLUVIUM.

Alluvial deposits border the Belle Fourche and portions of the valleys of Horse, Cottonwood, Ninemile, Willow, and Sulphur creeks and some of the smaller streams on which erosion is not greater than deposition. The broadest deposits are in the river flats along the Belle Fourche. In places these are 1 to 3 miles wide, their greatest width being where other valleys are confluent and especially west of Vale, where the bottom lands spread out widely along the river, and in the lower portions of the Cottonwood and Whitewood valleys. This wide deposit extends up the Cottonwood Valley for some distance, but in places it is very thin. The alluvium along the Belle Fourche ranges in elevation from water level to 30 feet above the stream (see Pl. VII), and in many localities the river cuts through to the underlying Pierre shale. The deposit occupies the freshet plain, the first bench, and the second bench, features which are separated locally by terrace scarps but which merge irregularly in most parts of the valley. The alluvium near the river averages 25 feet in thickness, but it is much thinner in the smaller valleys and it varies irregularly from place to place.

The alluvium consists of sand, gravel, loam, and clay. It changes in character from place to place, and it generally merges irregularly into the hillside wash on the slopes adjoining the valleys, making it difficult to define its boundary. Along Whitewood Creek there is much material from the Black Hills and some extensive deposits of tailings brought down from the gold mines and mills of Lead and vicinity.

GEOLOGIC STRUCTURE.

The Newell quadrangle includes a portion of the outer slope of the Black Hills uplift. The strata all dip to the northeast at angles which are perceptible in the southwest corner of the area but which northeast of the Belle Fourche are so low that the beds appear to be horizontal. A section (fig. 5) from south-southwest to north-northeast across the Newell quadrangle shows the steeper dip near the Black Hills in the



Vertical scale: 1 inch=about 3,000 feet, or about five times the horizontal scale.

FIGURE 5.—Structure section across the Newell quadrangle along line A–A on the areal-geology map.

Tc, Chadron formation; Tl, Lance formation; Kfh, Fox Hills (?) sandstone; Kp, Pierre shale; Kn, Niobrara formation; Kcr, Carlile shale; Kg, Greenhorn limestone; Kgs, Graneros shale; Kdfl, Dakota sandstone, Fuson formation, and Lakota sandstone; Jsm, Sundance formation and Morrison shale; Tes, Spearfish formation; Cmk, Minnekahta limestone; Co, Opeche formation; Cml, Minnelua sandstone; Cp, Pahasapa limestone.

southwest of Castle Rock, the sandstone is 60 feet thick and, except for a few hard concretions, is soft and massive. Its color is light buff and its appearance strongly suggests dune sand. It lies on 12 feet of impure lignite. In the higher slopes on the east and northeast and also in the higher slopes at the foot of Deer Ears it is overlain by about 100 feet of dark-gray clays, which are very sticky when moist and which in greater part erode in badlands slopes. The dried surface of the clay is blistered and crumbly. The material, which is somewhat of the nature of fuller's earth, is closely similar to the basal clay member exposed north, northwest, and south of Ball. About Castle Rock it grades upward into alternate deposits of gray and buff sand separated by thin, hard layers of clay, in all about 35 feet thick, that extend to the base of the volcanic ash of the supposed Chadron formation. In the slopes of Deer Ears it grades up into a soft sandstone, mostly white with red concretions, which is capped by 40 feet of buff, very fine loam, with sandstone layers extending to the base of the 10-foot bed of sandstone that caps the buttes. This 40-foot member is believed to be of Chadron age, for at its base is a very marked plane of separation.

Correlation.—No determinable fossils were obtained from the Lance formation in the Newell quadrangle, but closely similar beds in adjoining regions north and northeast

sive, for with the erosion of the country a large amount of such material has been removed or widely scattered, especially in districts where it was thin. In the wide area north of the Belle Fourche the shale surface is practically bare or shows only a few scattered pebbles and a thin sprinkling of fragments of concretions.

The high terrace deposits are mainly sands, loams, gravels, and boulders. The coarse materials are largely of quartz or quartzite, derived mostly from the Black Hills not far south. The most extensive deposit, which covers the wide tabular divide between Belle Fourche River and Bear Butte Creek in a sheet 30 feet thick in places, rising to an altitude of 3,250 feet in the southwest corner of the quadrangle, is cut through by various draws emptying southward and by the basins of Ninemile and Cottonwood creeks. Outliers remain in the northern part of T. 7 N., R. 6 E., and south of Vale and Empire. This sheet slopes eastward and northeastward toward the Belle Fourche but ends in a terrace scarp above the second alluvial terrace of the immediate valley bottom. The lower stages of

[1] Calvert, W. R., Beekly, A. L., Barnett, V. H., and Pishel, M. A., Geology of the Standing Rock and Cheyenne River Indian reservations, North and South Dakota: U. S. Geol. Survey Bull. 575, 1914.

[2] Stanton, T. W., Fox Hills sandstone and Lance formation ("*Ceratops* beds") in South Dakota, North Dakota, and eastern Wyoming: Am. Jour. Sci., 4th ser., vol. 30, pp. 172–188, 1910.

southwest corner of the area and the very low dips in the region to the north. Near the southern margin of the quadrangle the dip is 10° to 15° to the mile, but this rate diminishes greatly to the north, and through Vale it is only 80 feet to the mile, or less than 1°. Farther north it is still less. In the area of the Fox Hills (?) sandstone the direction of maximum dip is more to the east-northeast, but it varies in direction and rate. In the Castle Rock ridge and from Wolf Butte northward the rate is 45 to 50 feet to the mile. In places near the Deer Ears it appears to be slightly greater locally. The main tepee butte zone is of great assistance in indicating the structure in the central part of the quadrangle, for the altitude of its outcrop indicates the position of the underlying strata.

The steep dips in the southwest corner of the quadrangle, especially in the northwestern part of T. 6 N., R. 6 E., are due to the rise of beds on the western extension of the Bear Butte uplift a short distance south. It is manifested in Mowry, Greenhorn, and Carlile beds, greatly narrowing the outcrop zones of all of them in secs. 5, 6, and 8, T. 6 N., R. 6 E., near the southern margin of the quadrangle.

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

GEOLOGIC HISTORY.

General sedimentary record.—The rocks at the surface in the Newell quadrangle are mainly of sedimentary origin. They consist of sandstone, shale, limestone, sand, loam, and gravels, all more or less varied in composition and appearance. They were formed principally of gravel, sand, and mud derived from the waste of older rocks or of chemical precipitates from salt waters.

These rocks afford a record of the geologic history from early Upper Cretaceous time to the present, and a thick series of strata buried beneath the surface extend the record back to Cambrian time. 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 show deposition in shallow water; pure limestones indicate clear, open seas and scarcity of land-derived sediment. The species of the fossils found in the strata show whether the waters in which they lived were 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 it. The quartz sand and pebbles in coarse sandstones and conglomerates, like those in the Lakota sandstone, were derived from crystalline rocks but have been repeatedly redistributed by streams and concentrated on beaches by waves. Red shale and sandstone, such as make up the Spearfish formation, are a result of the revival of erosion on a land surface that has long been exposed to decay and oxidation and hence covered by deep residual soil. Limestone, on the other hand, if deposited near the shore, indicates 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 part 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 shore lines are not even approximately determined for any one epoch, and the relations of land and sea changed 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 part of the Black Hills remained an island rising above the waters. From the ancient crystalline rocks streams and waves gathered and concentrated sands and pebbles and deposited them as a widespread sheet of sandstone and conglomerate on sea beaches, in shallow offshore waters, and in estuaries. Abutting against the irregular surface of the crystalline rocks that 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 part of the Cambrian in some areas. In many regions the surface of the crystalline rocks was buried beneath the sediments.

Ordovician-Devonian conditions.—The Black Hills area presents a scanty geologic record of the vast time that elapsed between the close of Cambrian and the beginning of Carboniferous time. Ordovician, Silurian, and Devonian rocks are absent in the southern part of the area, and only a portion of the Ordovician is present in the northern part. The meagerness of this record is probably due to the fact that during these periods this region was occupied by a broad but very shallow sea or by land so low as to leave no noticeable evidence of erosion. Whether it was land or sea, or alternated from one to the other, the region shows no evidence of having undergone any considerable uplift or depression until early Carboniferous time. Then there was a decided subsidence, which led to the formation of a deep sea not only over the Black Hills area but generally throughout the Rocky Mountain province.

Carboniferous sea.—In the sea of early Carboniferous (Mississippian) 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 there are no coarse deposits of this age it is probable that no crystalline rocks were then exposed above water in this region, though they were probably not deeply submerged, for elsewhere the limestone, or its stratigraphic equivalent, was deposited immediately upon them. In later Carboniferous (Pennsylvanian) time fine sand was brought into the region in large amount and deposited in thick but regular beds, apparently with much calcareous 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 ponded saline water in lakes, in which accumulated the bright-red sands and sandy muds of the Opeche formation, probably of Permian (latest Carboniferous) age. The Minnekahta limestone, the next formation in the sequence, was deposited from sea water. Its fossils do not show with certainty whether it is a representative of Permian or Triassic time. It was laid down in thin layers to a thickness now represented by only 40 feet of limestone. The nearly uniform distribution of this formation over the Black Hills area probably indicates widespread submergence.

Red gypsiferous sedimentation (Triassic?).—At the close of Minnekahta time red bed deposition was resumed, and the great mass of red sandy clay constituting the Spearfish formation was accumulated, probably in vast salt lakes that had resulted from extensive uplift and aridity. In these lakes mud accumulated in thin layers to a depth of about 700 feet, the maximum thickness of the formation. The Spearfish beds are uniformly deep red, and this was undoubtedly their original color, for it is conspicuous 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. At many times the accumulation of red clay was interrupted by the chemical precipitation of comparatively pure gypsum, free from mechanical sediment, in beds ranging in thickness from a few inches to 30 feet. From their very general purity these beds are believed to be the products of evaporation during an epoch of little or no rainfall and consequently of little or no erosion. The Spearfish red beds are supposed to be Triassic, but they may be Permian. Their deposition appears to have been followed, during a portion of Triassic and Jurassic time of unknown duration, by extensive uplift, without local structural deformation but with some planation and occasional channeling. This uplift was succeeded by the deposition of later Jurassic sediments.

Jurassic sea.—In the Jurassic period the Black Hills region was occupied alternately by shallow and deeper marine waters. The materials then laid down are nearly all fine grained and indicate no strong currents. Some of the earliest deposits are thin masses of coarse sandstone, evidently laid down near the shore, but most of them are shales laid down directly upon the Spearfish red beds. Upon these shales a widespread body of ripple-marked sandstone was deposited in shallow water, probably at a time when sedimentation exceeded submergence, if not at a time during which the land was stationary. The red color of the upper part of the medial sandy series in some parts of the Black Hills appears to show a transient aridity similar to that which attended the deposition of the Spearfish formation. An extensive marine fauna and layers of limestone 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 sediment to be laid down being the thick deposit of fine sand of the Unkpapa sandstone, now prominent along the east side of the Black Hills but thinner or absent elsewhere.

Cretaceous seas.—During the Cretaceous period deposits of several kinds, but generally uniform over wide areas, gathered in a great series, beginning with sediments characteristic of shallow seas and estuaries along a coastal plain, passing into sediments derived from marine waters, and changing toward the end to fresh-water sands and clays and 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 uplifted region was due either to a local land area of Unkpapa sand or to a local renewal of uplift, which caused increased erosion and initiated the deposition of the Lakota sandstone. The duration of this erosion is not known, but although it produced a general erosional unconformity at the base of the Lakota it is believed to have been brief.

The materials of the Lakota consist mainly of coarse sands spread by strong currents in beds 20 to 60 feet thick, separated by deposits of clay and local accumulations of vegetal material. Next deposited was the thin calcareous Minnewaste limestone, which apparently was laid down only in a local basin in the southern part of the Black Hills region. Upon this limestone was spread the thin but widely extended clay of the Fuson formation. After this clay was laid down there was a return to shallow waters and strong currents, as in Lakota time, and the coarse sands of the Dakota formation were accumulated. The beginning of the Benton epoch marked a rapid change of sedimentation from sand to clay.

During the great Upper Cretaceous submergence, throughout the Benton, Niobrara, and Pierre epochs, the sea occupied the region and several thousand feet of clay were deposited. In Benton time there were several deposits of sand—an earlier, which produced the lenses of sandstone that now underlie the Mowry at several localities, and two thin later ones. The earlier sandstone probably indicates uplift which is connected with the peculiar character of the Mowry sediments. Another marked episode was the general deposition of the thin Greenhorn limestone somewhat above the middle of the Benton sediments. The deposition of clay in Benton time was followed by that of several hundred feet of impure chalk, now constituting the Niobrara formation, and this in turn by the deposition of more than 1,400 feet of Pierre shale, which was laid down under very uniform conditions. The Cretaceous sea retreated in the Fox Hills epoch, when sands were spread in an extensive sheet over the beds of clay, and large bodies of brackish or fresh water were formed, in which were laid down the sands, clays, and marsh deposits of the next epoch. Whether the Fox Hills and overlying sediments were deposited in any part of the Black Hills region is not definitely known, but possibly they were, as they are upturned around two sides of the uplift.

Early Tertiary mountain growth.—The uplift that formed the Black Hills dome began early in Tertiary time—or possibly in latest Cretaceous time—and the major topographic outlines of the region were then established. The products of erosion were carried into regions adjoining the uplift and some of them now constitute the Lance and later formations of the area north of the Black Hills. These materials were deposited in fresh-water streams, with wide overflows and shifting channels and in brackish waters. At times during this epoch the sea encroached on parts of the plains area, as shown by the marine fossils of the Cannonball member of the Lance. During these times and in the remainder of the Eocene epoch the domed strata were deeply truncated and some of the larger old valleys were excavated nearly to their present depth, as is indicated by the occurrence in them of White River (Oligocene) deposits, even in some of their deeper parts. Where most of the great mass of eroded material was carried is not known, for in the lower lands to the east and south there are no 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, especially on the western side of the Black Hills; but in the vicinity of Lead small outliers remain to an altitude of over 5,200 feet, and on the north end of the Bearlodge Mountains to a thousand feet higher. In many places on the slopes of the uplift there is clear evidence of superimposition of drainage, caused by a former capping of Oligocene formations.

Later 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 part of the Quaternary period there was widespread denudation, which revived many of the old valleys and rearranged the drainage. On the east side of the Black Hills this rearrangement was caused mainly by increased tilting to the northeast and several streams which were superposed upon Oligocene deposits have been enabled to cut across old divides and in some places to connect 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 that 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.

Further uplift apparently took place 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 was necessary to grade their profiles to the level of Missouri and Cheyenne rivers. Wide, shallow valleys have been formed in the soft deposits, and canyons of moderate extent and depth in the harder rocks. Later erosion has been attended by little local deposition, but the shifting of some channels has been accompanied by the accumulations of local deposits on small terraces at various levels.

ECONOMIC RESOURCES.

With the exception of the underground water and the soils the economic resources of the Newell quadrangle are of no great value. They are soils, clay, limestone, building stone, surface water, and underground water.

SOILS.

Derivation.—The soils in this region are closely related to the underlying rocks, being residual products of decay and disintegration except where formed as alluvial deposits in the larger valleys. In the process of disintegration residual soil develops more or less rapidly 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 scanty soil. Calcareous cement is more readily dissolved by water containing carbonic acid; 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, and the rock may retain its form though becoming soft and porous. If the calcareous material forms a greater part of the rock, as on the outcrop of the Niobrara limestone, the insoluble portions collect on the surface as a mantle whose thickness depends on the character of the limestone, being thinner where the rock is pure and thicker where it contains much insoluble matter. The amount of soil remaining on the rocks depends on the vigor of the 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 by changes of temperature, by frost, and by water, and thus by softening and washing give rise to soils—sandy or clayey, according to the composition of the shale. The character of the soils thus derived from the several 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, however, that some of the geologic formations present alternations of beds of various materials—shales and sandstones, for instance, 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.

Arable lands.—The arable lands of the Newell quadrangle are underlain mainly by shale, sandstone, and terrace deposits of alluvium.

Most of the shale gives rise to a barren clay soil which is somewhat acid from decomposing pyrites and is also rather sticky for agricultural use. It is covered by grass, which originally afforded excellent pasturage but which in parts of the area has been overgrazed; in some seasons much of it is killed by drought and excessive cold. As the soil is not rich and the climate is semiarid, sod develops slowly, and when the grass is damaged it does not readily regain its former thickness.

The alluvial deposits are generally fertile, and accordingly most of the farming is along the valley bottoms. The widest areas of alluvial soils are along Belle Fourche River and in portions of the valleys of Horse, Whitewood, Cottonwood, Bear Butte, Dry, Willow, Ninemile, and Sulphur creeks. The extensive series of canals completed and in course of construction by the United States Reclamation Service supplies a wide area of alluvial and Pierre clay lands along the Belle Fourche and on Cottonwood, Horse, Dry, Willow, and Ninemile creeks. Considerable irrigation is already being done along the canals now in operation, and there is extensive dry farming of hay and other crops along the wide alluvial bottom lands adjoining Belle Fourche River and Cottonwood, Horse, Willow, and Sulphur creeks.

The alluvial soils vary in composition from predominantly sandy to predominantly clayey, but in greater part they consist of loam well suited for tillage. Most soils on shale areas are too nearly a pure clay to be well suited to agriculture, but after tilling they become more tractable. Most soils on high terrace remnants are sandy loams of high fertility. They withstand drought remarkably well, for in most places they contain in their lower parts a considerable volume of water sustained by the impervious shale which underlies the sand and gravel. Many excellent farms are established in areas of this sort in the south-central part of the quadrangle. They yield fair crops of grain even in seasons of moderate drought.

CLAY.

The Pierre, Carlile, and Graneros shales and the Lance formation consist largely of clay, which could be used to make terra cotta and other similar materials if there were a suitable market for such products. Much sandy loam is available for brickmaking.

LIMESTONE.

The tepee buttes in the Pierre shale consist of impure limestone, some of which could probably be used for making lime. A representative sample from one of the buttes on Willow Creek was analyzed in the laboratory of the United States Geological Survey and found to contain about 82 per cent of calcium carbonate and 4 per cent of magnesium carbonate and about 16 per cent of sand and other impurities. Some of the material may be purer than this, but much of it is poorer in calcium carbonate. A large amount of this rock is available in many buttes which occur in the tepee butte zone of the Pierre shale area, especially in the vicinity of Willow Creek.

The chalky deposits of the Niobrara are locally of sufficient purity for the manufacture of Portland cement, but the region is too remote from market to be favorable for that industry.

The reddish-brown oval concretions which are so abundant in the Pierre shale consist largely of impure limestone, but some of them—especially in the middle of the formation—are largely of impure iron ore. Samples collected 6 miles northwest of Newell and analyzed in the laboratory of the United States Geological Survey were found to contain 54.56 per cent of sesquioxide of iron or 38 per cent of metallic iron; small amounts of lime and magnesia were included.

The Greenhorn limestone is too impure for use for lime, as it consists of an admixture of clay, sand, and calcium carbonate.

BUILDING STONE.

As there are very few ledges of hard rock in the Newell quadrangle building stone is rare, and concrete is generally used instead. A large amount of the limestone of the tepee buttes is available in many parts of the Pierre shale area and has been used to some extent for foundations and other structural purposes. Much of the Fox Hills (?) sandstone is suitable for building, and some of it, which breaks out in square blocks or slabs, is very serviceable. The Niobrara limestone is too soft for building, and the Greenhorn limestone breaks up into small flakes.

WATER SUPPLY.

SURFACE WATER.

Irrigation.—The average annual rainfall in the Newell region is probably somewhat less than 20 inches. 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 in the summer. As most of the soils are thin and few of the surficial rocks are porous, the water from rains and melting snows runs off rapidly, usually in freshets that follow storms or the melting of snow in the spring. Snow seldom continues for any considerable length of time. In consequence of these conditions the minor valleys contain little running water during the greater portion of the year and springs are few and small in the lower lands. A large amount of the run-off could be saved by dams and made available for stock and local irrigation. Suitable dam sites are numerous, and at several places considerable water has been impounded by small earth dams across draws, but as the evaporation of standing water in this region is about 6 feet a year a large amount of water has to be collected.

Belle Fourche River.—The Belle Fourche, above the mouth of Redwater Creek, drains a basin of about 3,250 square miles. Its flow has been gaged at Belle Fourche, above the mouth of Redwater Creek, since 1903 and found to range from practically nothing in June, 1903, to nearly 6,000 second-feet in June, 1904. Ordinarily it ranges from 50 to 200 second-feet, but the mean for 27 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, where, in August, after the usual flood in May and June, the flow varied from 72 to 775 second-feet. The mean flows for August, September, October, and November ranged from 221 to 266 second-feet.

Whitewood Creek.—Whitewood Creek, which empties into the Belle Fourche below Butte Hall, has a large, constant flow, brought from the mining district about Lead and Deadwood, in the Black Hills, which carries considerable suspended and dissolved mineral matter. No measurements of its volume are available.

Horse Creek.—Horse Creek is a small meandering stream which usually runs in small volume but occasionally ceases in very dry weather. Many large holes along its course always contain considerable water available for stock.

Owl Creek.—Owl Creek is small, but its flow rarely ceases and there are always many large water holes along its course.

Willow Creek.—Willow Creek, which drains a large area of plains in the central and northwestern parts of the quadrangle, flows only in times of rainfall. Many water holes along its bed supply abundant water for stock.

Sulphur Creek.—Sulphur Creek flows in small volume for part of the year but ceases in the dry season, when its course is marked by closely scattered water holes.

Bear Butte Creek.—The water brought from the Black Hills by Bear Butte Creek usually flows continuously through the year, but its volume is small. No measurements of flow are available.

UNDERGROUND WATERS.

GENERAL FEATURES.

The formations in the Newell quadrangle, as shown in the columnar section at the end of the text, include several beds of water-bearing sandstone, which absorb surface waters in their outcrop zones in the higher ridges and slopes of the Black Hills. These sandstones pass underground on the sides of the uplift and, owing to the relative steepness of their dip, attain considerable depth within short distances. In the southern portion of the Newell quadrangle, however, one or more of them is everywhere within reach of the well borer. As the region is semiarid and most of its surface waters are inadequate or of bad quality, the need for underground water is considerable.

The principal water-bearing strata, which rise above the surface in regular succession in wide zones encircling the Black Hills uplift, receive a large amount of water, not only from the rainfall on their surface but from streams which sink into them, wholly or partly, in crossing their outcrops. This sinking is observable in almost every valley leading out of the central area, few of the streams carrying to the Belle Fourche or the Cheyenne more than a small part of the original run-off of their drainage basins. The greatest amount of water sinks in crossing the sandstones of the Minnelusa,

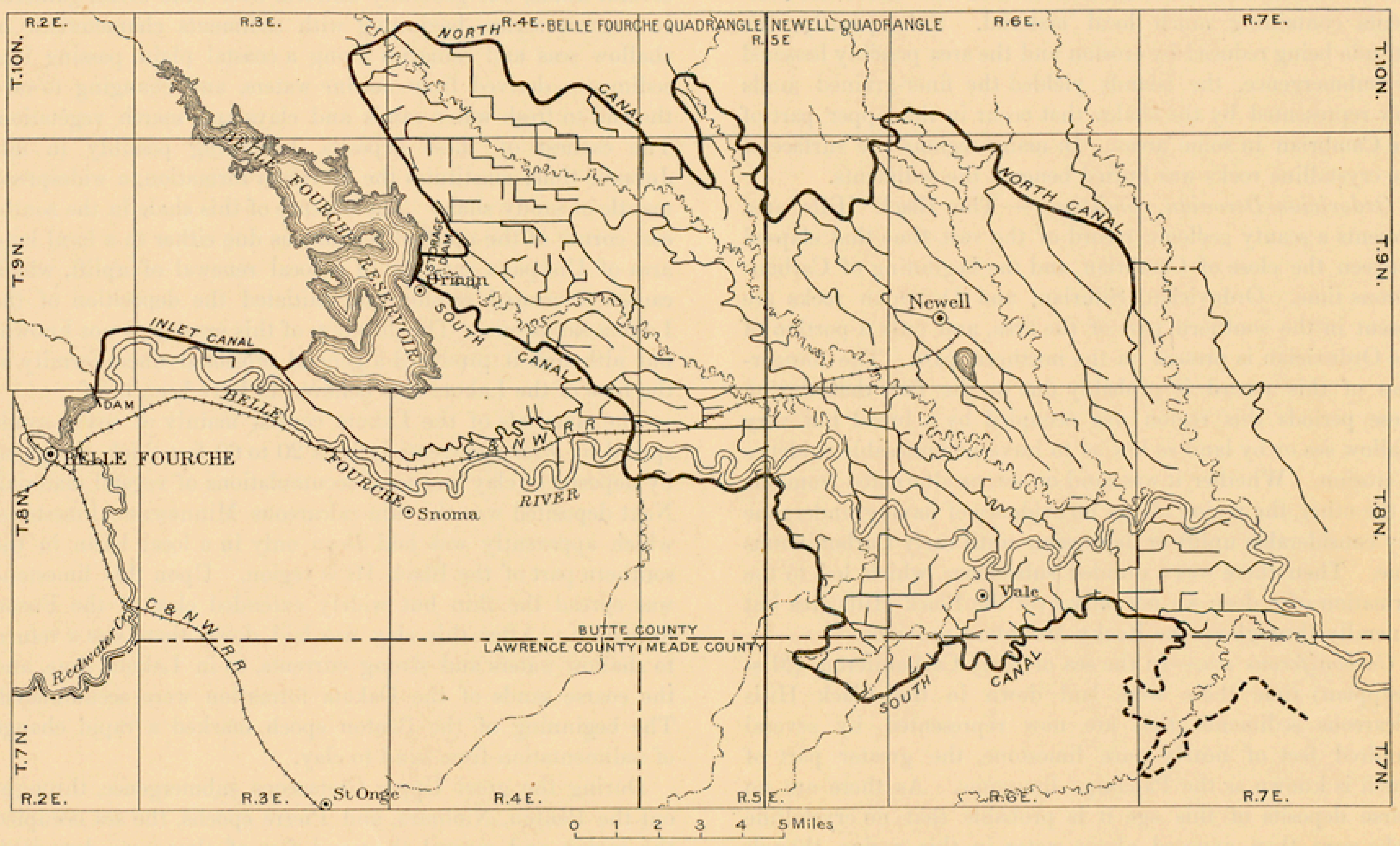


FIGURE 6.—Map of the Belle Fourche reclamation project, S. Dak.
Main canals are shown by heavy lines; branch distributaries by fine lines. From map by United States Reclamation Service, 1914.

Below Belle Fourche the United States Reclamation Service has constructed a large storage reservoir and a canal which deflects to it the flood water of Belle Fourche River. (See fig. 6.) From the reservoir an extended system of canals runs along both sides of the Belle Fourche Valley past Newell, Vale, and Empire and far across the western half of the Newell quadrangle.

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. The Fox Hills (?) sandstone also receives considerable water, which is stored in some of its beds.

WATER-BEARING FORMATIONS.

The Dakota and Lakota sandstones are the principal formations in which water supplies are to be expected in the southern and southwestern third of the Newell quadrangle. They lie beneath the Graneros shale and dip northeastward at angles which vary considerably, but which carry them to a depth of about 3,700 feet in the northeast corner of the quadrangle. (See fig. 5, p. 4.) The depth to the top of the Dakota sandstone is indicated approximately on the artesian-water map. In different parts of the country surrounding the Black Hills the Dakota and the Lakota have been reached by wells and have generally yielded flows of greater or less volume and, as a rule, of satisfactory quality.

The shales of the Morrison and Sundance formations, underlying the Lakota sandstone, offer no prospects for water; although the sandstone layer in the lower portion of the Sundance formation contains a small amount, as shown by the flow in the Bowman well. The great mass of gypsiferous red shale of the Spearfish and Opeche formations, still deeper, is not water bearing. The Minnekahta limestone is too dense to carry water, although in some places it is cavernous.

In its outcrops the Minnelusa formation appears to be a very porous sandstone, likely to imbibe much surface water and to constitute a water-bearing formation available for deep wells. Numerous springs emerge locally from its upper sandstone bed. In some borings in the Black Hills region this sandstone has been found to be very fine textured and so closely cemented by lime as to leave little room for water. In the Newell quadrangle, however, it appears to be much coarser grained and less calcareous, especially in its upper bed of white sandstone, which is conspicuous in the outcrops in the Bear Butte uplift and in the slopes south of Sturgis. It is therefore probable that the sandstone contains water, which, as its zone of intake is high on the slopes of the Black Hills, should be under sufficient pressure or head to afford flows throughout the southern and western portions of the quadrangle. However, as its top is about 1,500 feet below the Dakota sandstone, it probably lies too deep to be of service. The Deadwood sandstone, which is several hundred feet deeper, also contains artesian water, but it lies too deep to be reached by ordinary well boring.

The supposed Fox Hills sandstone, which occupies part of the divide north of Sulphur Creek and the Castle Rock ridge, contains considerable water, but as it lies above the larger adjoining valleys, it offers no prospect for artesian flow, unless possibly in small amount in some of the draws south and east of Deer Ears.

The thick sheet of gravel and sand that caps the high terraces in the south-central part of the quadrangle contains considerable water at many places, mostly in basal beds on or near the shale surface. Part of this water flows out in small springs and seeps, but in some of the deeper draws wells 15 to 30 feet deep find excellent supplies. Most of the lower terrace deposits near the Belle Fourche contain water under similar conditions and supply sundry wells.

Nearly all the alluvial deposits, especially those along the Belle Fourche, contain considerable water. Many wells 10 to 30 feet deep draw from this source and, although in places the water contains noticeable amounts of mineral matter, the supply is satisfactory for domestic and ranch use.

DEEP WELLS.

At Vale an artesian well, which was sunk in 1909, flows somewhat less than 1 gallon a minute of excellent water. Its depth is 2,215 feet, comprising, according to one statement, 2,100 feet of shale, some sandstone, a thin coaly layer, 25 feet of hard gray shale, about 15 feet of white chalky clay alternating with blue and red chalky material, and again sandstone which extended from 2,200 feet to a fine black sand that bottoms the well and yields the flow. The identity of the first sandstone is not clear, but presumably the bed that was reached at 2,200 feet was the top of the Dakota. The good quality of the water and the light flow also indicate a source near the top of this formation. Doubtless if the boring had been continued into the Lakota sandstone, 150 feet or more below, a large volume of water would have been obtained under greater head. It might, however, have contained more mineral matter, as do most wells in the Belle Fourche region and at Fruitdale. It is reported that the well has 4½-inch casing at the top, 3-inch casing for 900 feet, and 1¼-inch casing to the bottom. The pressure is stated to be sufficient to lift the water about 50 feet above the surface in a pipe—equivalent to about 22 pounds to the square inch.

The Bowman well, in the southwest corner of sec. 2, T. 6 N., R. 5 E., near the southwest corner of the quadrangle, was sunk in 1907 to a depth of 1,560 feet and flows 4 gallons a minute, with low pressure. Very little information is available as to the record. Samples from 1,000 to 1,200 feet were all light-gray clay, apparently Sundance. The Dakota sandstone was probably entered at about 700 feet and the Lakota sandstone at 850 feet, but presumably their water did not have sufficient head to rise to 3,200 feet, the elevation of the high table-land on which the well is situated. Probably the flow is from the basal sandstone of the Sundance formation. Flowing wells from the Dakota sandstone, however, may be expected throughout lower lands to the north.

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 wells in regions to the west and far to the east and on a calculated slope of the head that should be expected from the altitude of the outcrops of the water-bearing sandstone in the hogback ridge from Sturgis to Whitewood. Owing to lack of sufficient evidence the boundaries of the flow area can be only approximately delineated, 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 and will flow at higher altitudes than the water from the Dakota sandstone, or "first flow." The pressure of the well at Vale is stated to be about 22 pounds, but as the water probably is from the first flow the maximum pressure there is not known; possibly it is equivalent to a head of 2,900 feet, as shown on the map. The head diminishes toward the east and at the mouths of Willow and Horse creeks is less than 2,850 feet, but this is sufficient to afford a flow in all the lower lands.

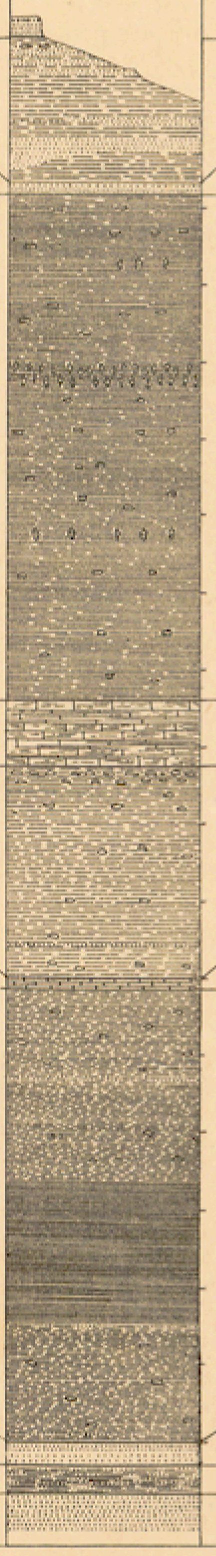
Flowing wells are to be expected from the second flow far up the slopes about Newell and in all of the area southwest of Vale, except on the higher divide summits, as indicated on the artesian-water map. It is likely that a flow may be obtained at Newell, altitude 2,850 feet, for the head of the second flow at that place probably will be found to be sufficient to raise the water to 2,875 feet. Possibly, however, the head will be slightly less, 2,850 feet, in which event the water would come near enough to the surface to be pumped. The depth to the Dakota sandstone or first flow at Newell is about 2,450 feet, and the Lakota sandstone carrying the second flow is 150 to 200 feet deeper. Apparently the prospects also are fairly good in the Elk Creek and Fourmile Creek areas in the southeast corner of the quadrangle.

The Minnelusa sandstone doubtless underlies the Vale-Newell region but at depths of 3,500 to 4,000 feet—too deep for ordinary drilling.

September, 1917.

GENERALIZED SECTION FOR THE NEWELL QUADRANGLE.

SCALE: 1 INCH=500 FEET.



System.	Series and Group.	Formation.	Symbol.	Thickness in Feet.	Columnar Section.	Depth in Feet to Top of Dakota Sandstone.	Character of Rocks.	Character of Topography and Soils.
TERTIARY	OLIGOCENE (WHITE RIVER)	Chadron formation.	Tc	50			Coarse white sandstone capping buff loam and soft fine sandstone.	Caps Deer Ears Butte and Castle Rock.
TERTIARY?	EOCENE?	Lance formation.	Tl	375			Gray clay containing soft and hard sandstone layers at intervals.	Badland slopes, rocky buttes, and grassed slopes.
CRETACEOUS	UPPER CRETACEOUS; Montana group	Fox Hills? sandstone.	Kfh	30			Light-gray to buff sandstone, mostly slabby at base, massive and soft above.	Slopes, mostly covered by soil.
		Pierre shale.	Kp	1,300±		3,200 3,000 2,800 2,600 2,400 2,200 2,000	Upper horizon of concretions that form "tepee buttes" on surface. Main horizon of limestone concretions that form "tepee buttes" on surface. Dark-gray shale with numerous calcareous concretions. Lowest horizon of concretions that form "tepee buttes" on surface.	Wide rolling plains with scattered small conical hills. Clay soil, mostly well grassed.
	Colorado group	Niobrara formation.	Kn	150-200		1,800	Soft impure limestone or chalk and limy shale containing thin masses of limestone composed of fossil shells (*Ostrea congesta*).	Valleys, mostly covered by alluvium. Fertile soil.
		Carlile shale.	Kcr	550		1,600 1,400	Gray fissile shale with numerous concretions near top. Thin sandstone bed near base.	Irregular ridges of moderate height. Clay soil.
		Greenhorn limestone.	Kg	25-35		1,200	Impure gray slabby limestone with intercalated shales.	Slopes, mostly covered by sand. Thin soil.
		Graneros shale. (Mowry shale member.)	Kgs	1,100-1,200		1,000 800 600 400 200	Dark-gray fissile shale containing scattered concretions. Hard gray shale and fine-grained sandstone which weathers light gray and contains numerous fish scales. Dark fissile shale containing concretions and thin layers of sandstone near base.	Mostly overlain by terrace deposits. Not exposed at surface; encountered only in artesian wells.
		Dakota sandstone.	Kd	40-80		0	Gray to brown sandstone, mostly massive below, slabby above.	
	LOWER CRETACEOUS	Fuson shale.	Kf	60-80			Gray to purple sandy shale and thin beds of sandstone.	
		Lakota sandstone.	Klk	60-150			Gray to buff sandstone, massive to flaggy; mostly hard.	

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FRANKLIN K. LANE, SECRETARY
U. S. GEOLOGICAL SURVEY
GEORGE OTIS SMITH, DIRECTOR

TOPOGRAPHY

SOUTH DAKOTA
NEWELL QUADRANGLE

LEGEND

RELIEF
printed in brown

Altitude
above mean sea level instrumentally determined

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

DRAINAGE
printed in blue

Streams

Intermittent streams

Ditches

Lake or pond

CULTURE
printed in black

Roads and buildings

Church

Public school

Private or secondary roads

Railroad

Bridge

U.S. township and section lines and located corner

County line

Triangulation station

Bench mark giving precise altitude

R.B.Marshall, Chief Geographer.
Sledge Tatum, Geographer in charge.
Topography by Glenn S.Smith, C.P.Gross, and H.L.Caldwell, and from Vale sheet.
Irrigation ditches by U.S.Reclamation Service, 1913.
Control by A.F.Dunnington, R.B.Robertson, and H.M.Hadley.
Surveyed in 1904 and 1910.

APPROXIMATE MEAN DECLINATION 1910.

Scale $\frac{1}{125000}$

Contour interval 50 feet.
Datum is mean sea level.

DIAGRAM OF TOWNSHIP

Edition of Jan. 1913, reprinted Dec. 1916.

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AREAL GEOLOGY

SOUTH DAKOTA
NEWELL 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 shown, boundaries mostly indefinite)

Pleistocene

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

TERTIARY

Oligocene — *White River group*

Tc — **Chadron formation**
(coarse white sandstone and conglomerate and fine buff sandstone, caps buttes on north edge of quadrangle)

TERTIARY ?

Eocene ?

Tl — **Lance formation**
(gray clay, in part sandy, sandstone, and impure lignite)

CRETACEOUS

Upper Cretaceous

Montana group

Kfh — **Fox Hills ? sandstone**
(gray sandstone, in part indurated)

Kp, Kpt — **Pierre shale**
(dark shale with gray and red calcareous concretions and limestone lentils that form tepee buttes at the surface, Kpt)

Colorado group

Kn — **Niobrara formation**
(limy shale and impure chalk; weathers light yellow)

Kcr — **Carlile shale**
(gray shale with many oval limestone concretions near top)

Kg — **Greenhorn limestone**
(impure, slabby, buff limestone)

Kgs — **Graneros shale**
(dark-gray, fissile shale)

Economic data: *Underground water is obtainable from the Dakota and other sandstones, as shown on the Artesian-water map. Limestone concretions in the Pierre shale may be used for lime or building stone. Much of the chalk of the Niobrara formation is suitable for manufacture of cement. Shales are available as clay for brick manufacture. Gravel of terrace deposits is suitable for road surfacing.*

Note: *Section along line A A is shown in the text.*

R.B. Marshall, Chief Geographer.
Sledge Tatum, Geographer in charge.
Topography by Glenn S. Smith, C.P. Gross, and H.L. Caldwell, and from Vale sheet.
Irrigation ditches by U.S. Reclamation Service, 1913.
Control by A.F. Dunnington, R.B. Robertson, and H.M. Hadley.
Surveyed in 1904 and 1910.

TRUE NORTH
MAGNETIC NORTH
APPROXIMATE MEAN DECLINATION 1910.

Scale $\frac{1}{125000}$

1 ½ 0 1 2 3 4 5 Miles

1 ½ 0 1 2 3 4 5 Kilometers

Contour interval 50 feet.
Datum is mean sea level.

Edition of Jan. 1917.

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.
Surveyed in 1912.

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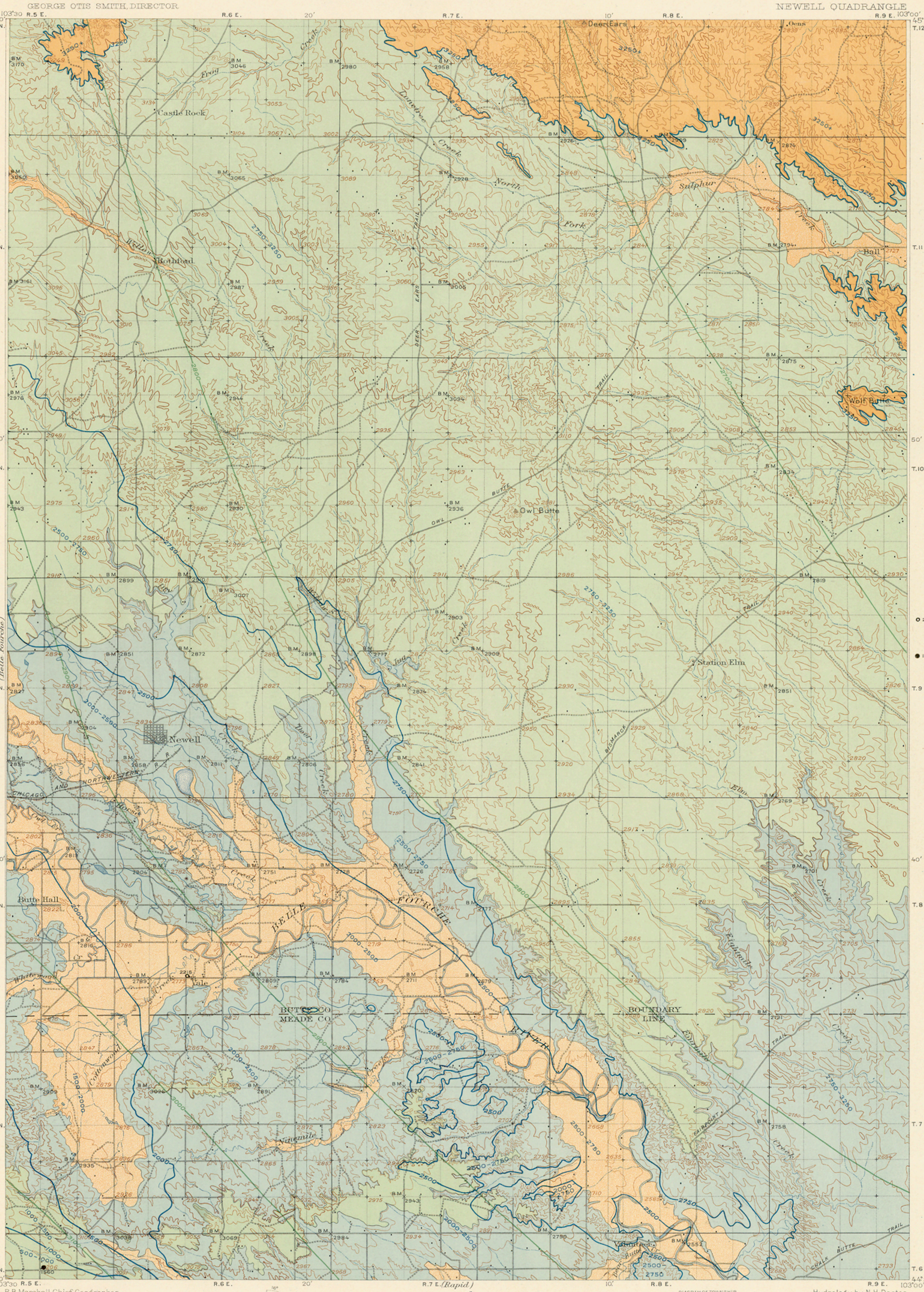
ARTESIAN WATER

SOUTH DAKOTA
NEWELL QUADRANGLE



LEGEND

Area in which Dakota and Lakota sandstones will probably yield flowing wells

Area in which Dakota and Lakota sandstones will probably yield pump wells

2750 / 2500–2750 / 2500

Depth to Dakota sandstone (artesian water may be expected in the Dakota and underlying sandstones, volume will be greater and pressure higher in the Lakota sandstone, 150 to 300 feet below the top of Dakota sandstone. The 2750-foot depth line is at base of principal "tepee butte" concretion zone; 3250-foot depth line at base of Fox Hills? sandstone)

Area underlain by Fox Hills? sandstone which in most areas contains water obtainable by pump wells of moderate depth

Area of alluvium which contains water obtainable at most places by wells 5 to 40 feet deep

2800

Artesian head of water in Lakota sandstone (lines indicate altitude to which the water from Lakota sandstone will rise in wells; water from Dakota sandstone will not rise so high; datum is sea level; interval, 100 feet)

o 2215 Flowing well in Dakota sandstone
Depth in feet

● 1560 Flowing well in sandstone of the Sundance formation
Depth in feet

Note: In areas of flowing wells the artesian head is higher than the surface, in areas of pump wells it is lower than the surface, and the difference in elevation represents the depth to the surface of water in wells that penetrate the Lakota sandstone water horizon. Some artesian water may also be had from sandstone in the Sundance formation about 450 feet below the Lakota sandstone. Water in shallow wells that does not come from alluvial sand or Fox Hills? sandstone is mostly unsatisfactory in amount and quality.

R.B. Marshall, Chief Geographer.
Sledge Tatum, Geographer in charge.
Topography by Glenn S. Smith, C.P. Gross, and H.L. Caldwell, and from Vale sheet.
Irrigation ditches by U.S. Reclamation Service, 1913.
Control by A.F. Dunnington, R.B. Robertson, and H.M. Hadley.
Surveyed in 1904 and 1910.

APPROXIMATE MEAN DECLINATION 1910.

Scale $\frac{1}{125000}$

Contour interval 50 feet.
Datum is mean sea level.
Edition of June 1917.

DIAGRAM OF TOWNSHIP

Hydrology by N.H. Darton.
Surveyed in 1912.

PLATE I.—ROLLING PRAIRIE OF THE PIERRE SHALE, WHICH CONSTITUTES A LARGE PART OF THE REGION NORTHEAST OF THE BLACK HILLS, INCLUDING THE NEWELL QUADRANGLE.

PLATE II.—A "TEPEE BUTTE" FORMED BY A MASS OF LIMESTONE IN THE PIERRE SHALE NEAR WILLOW CREEK, NORTHEAST OF NEWELL, S. DAK.

PLATE III.—DEER EARS, A HIGH BUTTE OF THE LANCE FORMATION CAPPED BY SANDSTONE AND CONGLOMERATE OF THE CHADRON FORMATION, AT THE NORTH EDGE OF THE NEWELL QUADRANGLE.

View from the south.

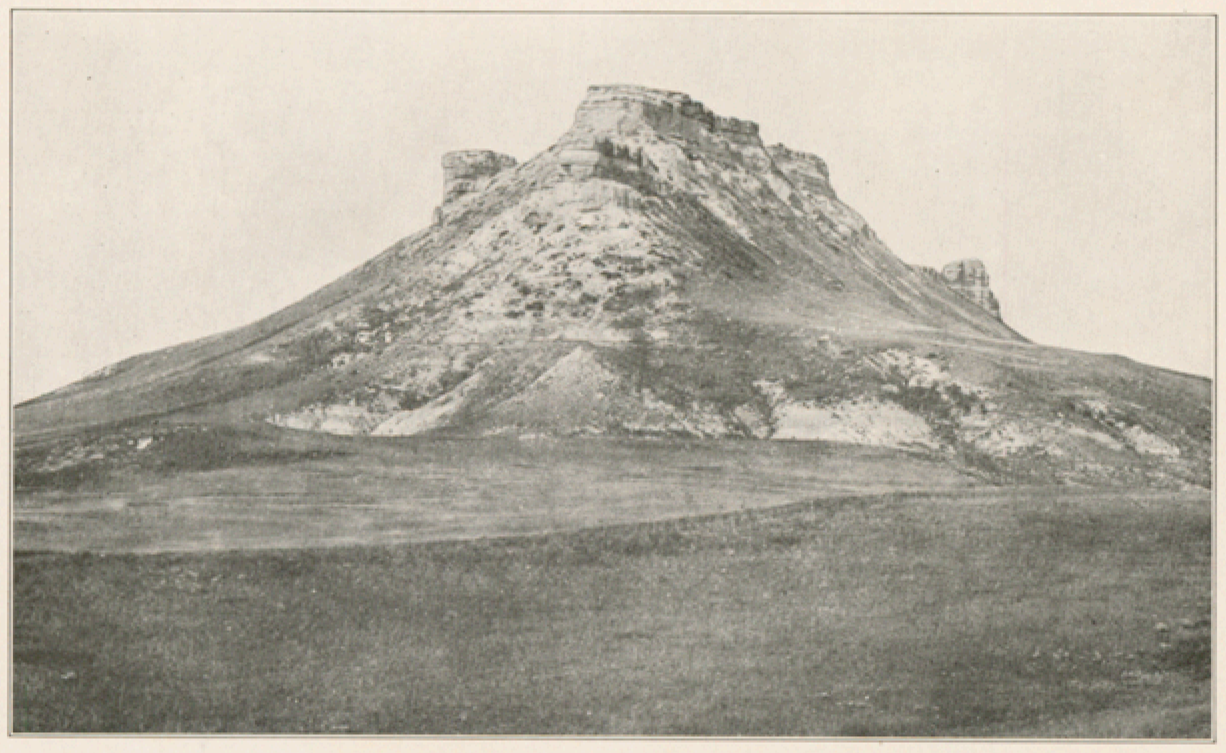


PLATE IV.—CASTLE ROCK, A PROMINENT BUTTE JUST OUTSIDE THE NORTHERN MARGIN OF THE NEWELL QUADRANGLE, CAPPED BY A HARD BED IN THE CHADRON FORMATION WHICH OVERLIES THE LANCE FORMATION.

View looking north from platform of Fox Hills (?) sandstone.

PLATE V.—MASS OF LIMESTONE AT THE "TEPEE BUTTE" HORIZON OF THE PIERRE SHALE EXPOSED BY EROSION IN THE SLOPE OF A SMALL VALLEY IN THE NEWELL QUADRANGLE.

PLATE VI.—MASS OF LIMESTONE AT THE "TEPEE BUTTE" HORIZON OF THE PIERRE SHALE EXPOSED ON A HILLTOP BY WEATHERING, EAST OF WILLOW CREEK, SOUTHEAST OF NEWELL, S. DAK.

PLATE VII.—THICK ALLUVIAL DEPOSIT THAT FORMS THE BANK OF BELLE FOURCHE RIVER NEAR THE WEST MARGIN OF THE NEWELL QUADRANGLE.

PLATE VIII.—CHARACTERISTIC FOSSIL SHELLS OF THE NIOBRARA FORMATION (OSTREA CONGESTA).

Natural size.

PLATE IX.—CHARACTERISTIC FOSSIL SHELL OF THE GREENHORN LIMESTONE (INOCERAMUS LABIATUS.)

Natural size.

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 in 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		Ћ	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.

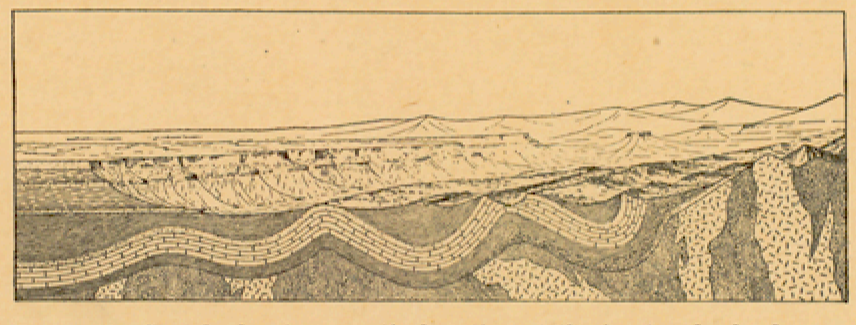


FIGURE 2.—Sketch showing a vertical section at the front and a landscape beyond.

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.

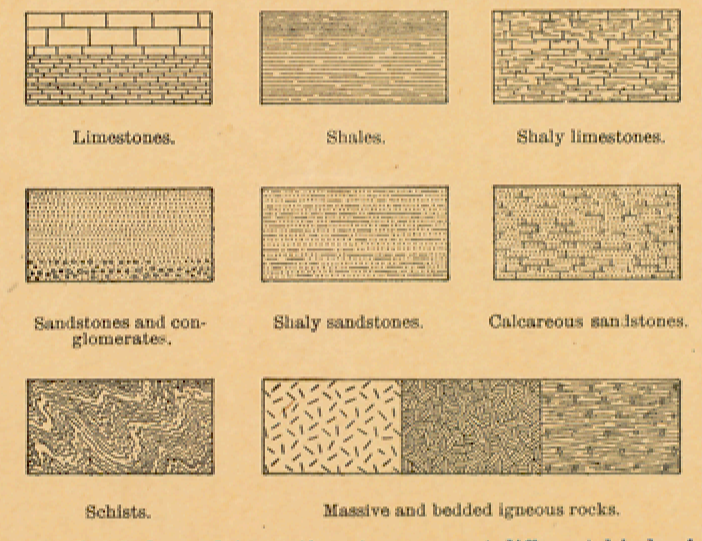


FIGURE 3.—Symbols used in sections to represent different kinds of rocks.

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.

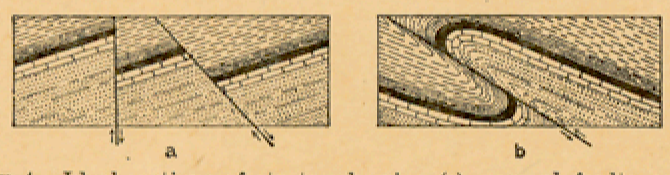


FIGURE 4.—Ideal sections of strata, showing (a) *normal* faults and (b) a *thrust* or *reverse* fault.

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,

May, 1909. *Director.*

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