DEPARTMENT OF THE INTERIOR

UNITED STATES GEOLOGICAL SURVEY

CHARLES D. WALCOTT, DIRECTOR

GEOLOGIC ATLAS

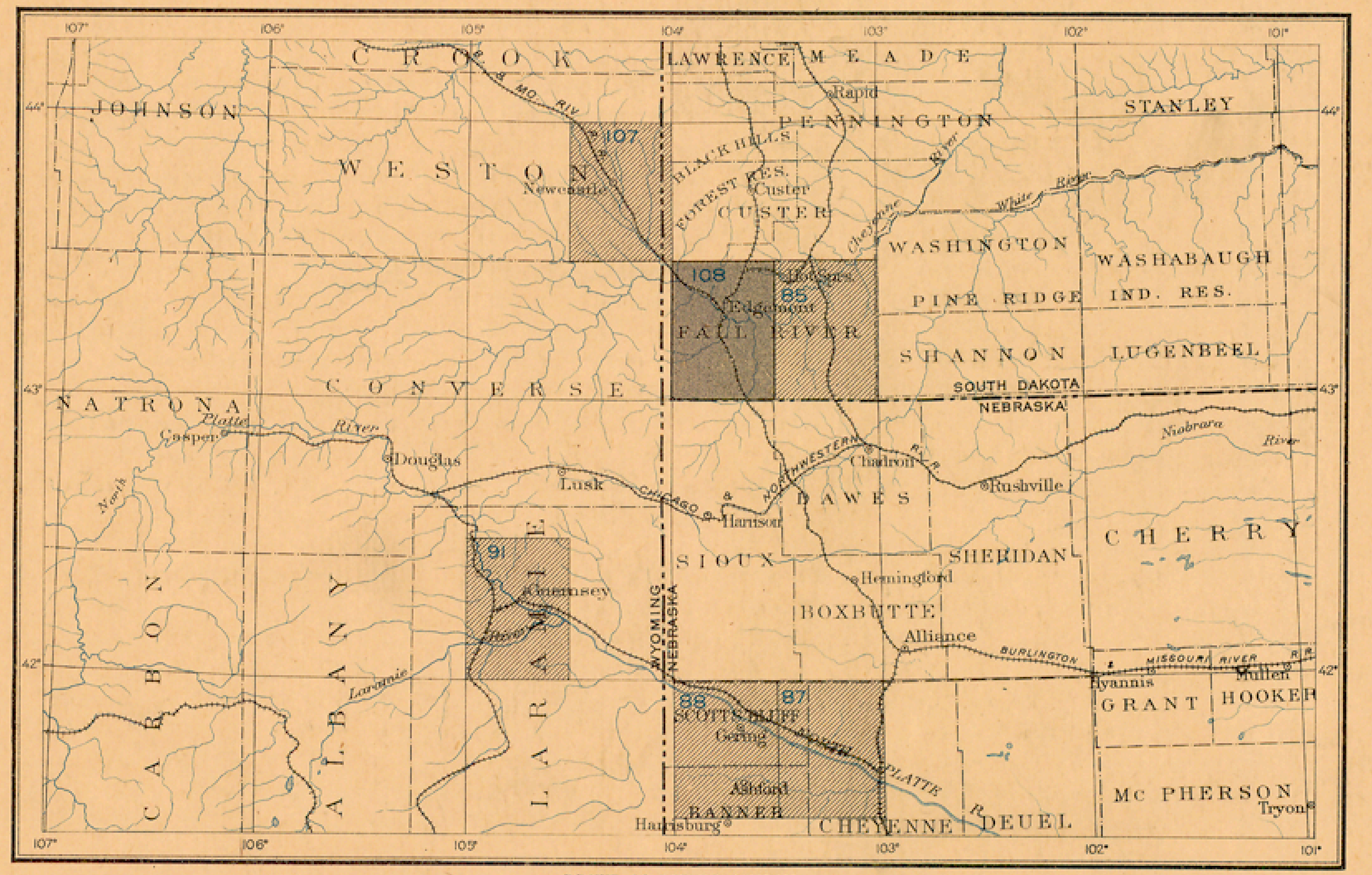
OF THE

UNITED STATES

EDGEMONT FOLIO

SOUTH DAKOTA - NEBRASKA

INDEX MAP



SCALE: 40 MILES=1 INCH

AREA OF THE EDGEMONT FOLIO

AREA OF OTHER PUBLISHED FOLIOS

CONTENTS

FIELD EDITION

EDGEMONT FOLIO
NO. 108

WASHINGTON, D. C.

ENGRAVED AND PRINTED BY THE U. S. GEOLOGICAL SURVEY

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

1904

GEOLOGIC AND TOPOGRAPHIC ATLAS OF UNITED STATES.

The Geological Survey is making a geologic map of the United States, which is being issued in parts, called folios. Each folio includes a topographic map and geologic maps of a small area of country, together with explanatory and descriptive texts.

THE TOPOGRAPHIC MAP.

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

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

The manner in which contours express elevation, form, and grade is shown in the following sketch and corresponding contour map (fig. 1).

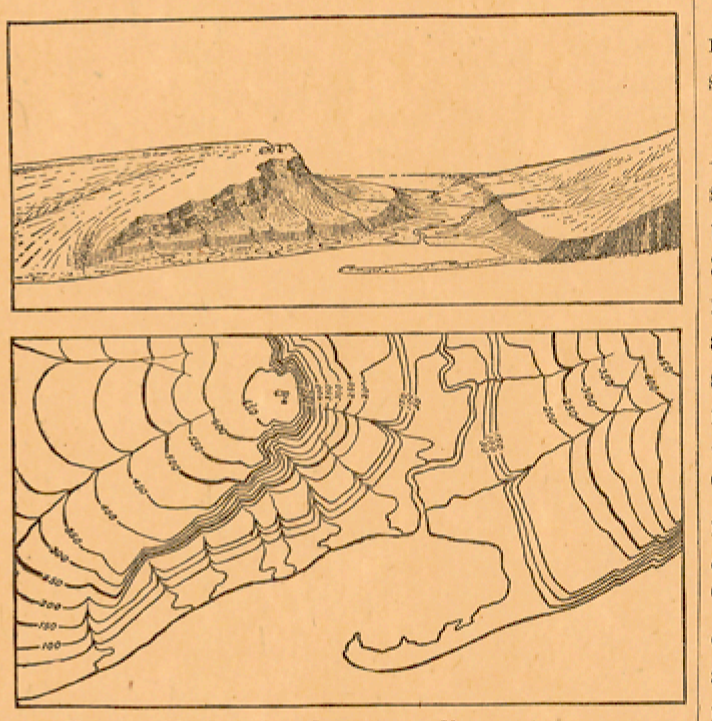


FIG. 1.—Ideal view and corresponding contour map.

The sketch represents a river valley between two hills. In the foreground is the sea, with a bay which is partly closed by a hooked sand bar. On each side of the valley is a terrace. From the terrace on the right a hill rises gradually, while from that on the left the ground ascends steeply, forming a precipice. Contrasted with this precipice is the gentle slope from its top toward the left. In the map each of these features is indicated, directly beneath its position in the sketch, by contours. The following explanation may make clearer the manner in which contours delineate elevation, form, and grade:

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

2. Contours define the forms of slopes. Since contours are continuous horizontal lines, they wind smoothly about smooth surfaces, recede into all reentrant angles of ravines, and project in passing about prominences. These relations of contour curves and angles to forms of the landscape can be traced in the map and sketch.

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

For a flat or gently undulating country a small contour interval is used; for a steep or mountainous country a large interval is necessary. The smallest interval used on the atlas sheets of the Geological Survey is 5 feet. This is serviceable for regions like the Mississippi delta and the Dismal Swamp. In mapping great mountain masses, like those in Colorado, the interval may be 250 feet. For intermediate relief contour intervals of 10, 20, 25, 50, and 100 feet are used.

Drainage.—Watercourses are indicated by blue lines. If a stream flows the entire year the line is drawn unbroken, but if the channel is dry a part of the year the line is broken or dotted. Where a stream sinks and reappears at the surface, the supposed underground course is shown by a broken blue line. Lakes, marshes, and other bodies of water are also shown in blue, by appropriate conventional signs.

Culture.—The works of man, such as roads, railroads, and towns, together with boundaries of townships, counties, and States, are printed in black.

Scales.—The area of the United States (excluding Alaska and island possessions) is about 3,025,000 square miles. A map representing this area, drawn to the scale of 1 mile to the inch, would cover 3,025,000 square inches of paper, and to accommodate the map the paper would need to measure about 240 by 180 feet. Each square mile of ground surface would be represented by a square inch of map surface, and one linear mile on the ground would be represented by a linear inch on the map. This relation between distance in nature and corresponding distance on the map is called the *scale* of the map. In this case it is "1 mile to an inch." The scale may be expressed also by a fraction, of which the numerator is a length on the map and the denominator the corresponding length in nature expressed in the same unit. Thus, as there are 63,360 inches in a mile, the scale "1 mile to an inch" is expressed by $\frac{1}{63,360}$.

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

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

The atlas sheets, being only parts of one map of the United States, disregard political boundary lines, such as those of States, counties, and townships. To each sheet, and to the quadrangle it represents, is given the name of some well-known town or natural feature within its limits, and at the sides and corners of each sheet the names of adjacent sheets, if published, are printed.

Uses of the topographic map.—On the topographic map are delineated the relief, drainage, and culture of the quadrangle represented. It should portray to the observer every characteristic feature of the landscape. It should guide the traveler; serve the investor or owner who desires to ascertain the position and surroundings of property; save the engineer preliminary surveys in locating roads, railways, and irrigation reservoirs and ditches; provide educational material for schools and homes; and be useful as a map for local reference.

THE GEOLOGIC MAPS.

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

KINDS OF ROCKS.

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

Igneous rocks.—These are rocks which have cooled and consolidated from a state of fusion. Through rocks of all ages molten material has from time to time been forced upward in fissures or channels of various shapes and sizes, to or nearly to the surface. Rocks formed by the consolidation of the molten mass within these channels—that is, below the surface—are called *intrusive*. When the rock occupies a fissure with approximately parallel walls the mass is called a *dike*; when it fills a large and irregular conduit the mass is termed a *stock*. When the conduits for molten magmas traverse stratified rocks they often send off branches parallel to the bedding planes; the rock masses filling such fissures are called *sills* or *sheets* when comparatively thin, and *laccoliths* when occupying larger chambers produced by the force propelling the magmas upward. Within rock inclosures molten material cools slowly, with the result that intrusive rocks are generally of crystalline texture. When the channels reach the surface the molten material poured out through them is called *lava*, and lavas often build up volcanic mountains. Igneous rocks thus formed upon the surface are called *extrusive*. Lavas cool rapidly in the air, and acquire a glassy or, more often, a partially crystalline condition in their outer parts, but are more fully crystalline in their inner portions. The outer parts of lava flows are usually more or less porous. Explosive action often accompanies volcanic eruptions, causing ejections of dust, ash, and larger fragments. These materials, when consolidated, constitute breccias, agglomerates, and tuffs. Volcanic ejecta may fall in bodies of water or may be carried into lakes or seas and form sedimentary rocks.

Sedimentary rocks.—These rocks are composed of the materials of older rocks which have been broken up and the fragments of which have been carried to a different place and deposited.

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

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

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

The surface of the earth is not fixed, as it seems to be; it very slowly rises or sinks, with reference to the sea, over wide expanses; and as it rises or subsides the shore lines of the ocean are changed. As a result of the rising of the surface, marine sedimentary rocks may become part of the land, and extensive land areas are in fact occupied by such rocks.

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

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

From time to time in geologic history igneous and sedimentary rocks have been deeply buried and later have been raised to the surface. In this process, through the agencies of pressure, movement, and chemical action, their original structure may be entirely lost and new structures appear. Often there is developed a system of division planes along which the rocks split easily, and these planes may cross the strata at any angle. This structure is called *cleavage*. Sometimes crystals of mica or other foliaceous minerals are developed with their laminæ approximately parallel; in such cases the structure is said to be schistose, or characterized by *schistosity*.

As a rule, the oldest rocks are most altered and the younger formations have escaped metamorphism, but to this rule there are important exceptions.

FORMATIONS.

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

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

AGES OF ROCKS.

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

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

(Continued on third page of cover.)

DESCRIPTION OF THE EDGEMONT QUADRANGLE.

By N. H. Darton and W. S. Tangier Smith.

GEOGRAPHY.

Position and extent.—The Edgemont quadrangle embraces the quarter of a square degree which lies between parallels 43° and 43° 30′ north latitude and meridians 103° 30′ and 104° west longitude. It measures approximately 34½ miles from north to south and 25¼ miles from east to west, and its area is about 871 square miles. It comprises the western half of Fall River County, S. Dak., with a strip of Custer County on the north and a little of Sioux County, Nebr., on the south. The northeastern portion of the quadrangle lies on the slopes of the Black Hills, but the larger part of it belongs to the Great Plains, although these plains are lower here than in the greater part of adjoining portions of Nebraska and Wyoming. The district is crossed by South Branch of Cheyenne River and it all lies within the drainage basin of that stream.

Being part of the Black Hills and the Great Plains, this quadrangle illustrates many features of both, and a general account of these provinces will be given before the detailed description is presented.

GREAT PLAINS PROVINCE.

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

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

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

THE BLACK HILLS.

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

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

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

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

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

EDGEMONT QUADRANGLE.

The Edgemont quadrangle in its northeastern part presents some of the characteristic features of the Black Hills, while in its southern portion the topography is typical of the Great Plains. Cheyenne River is near the line of division between the two portions. North of the river lies the hogback which marks the limit of the Black Hills and which is succeeded on the north by the Red Valley. Still farther north, not far from the northern margin of the quadrangle, is the Minnekahta limestone slope, with its low north-facing escarpment, and finally, near the northeast corner of the quadrangle, is the beginning of the long inner plateau of the Black Hills dome. South of the river the country is mainly rolling prairie, broken by two lines of low cliffs.

The rocks are horizontal for very short distances only. The general dip is southerly, so that the higher and younger formations outcrop successively to the south, and the greatest elevations are found in the northern part of the quadrangle, where the older and harder rocks outcrop. The normal slopes, however, have been so modified by erosion that the lowest points are not toward the south but in the central and eastern parts, along Cheyenne River, to which all the other streams of the quadrangle are tributary.

The lower slopes of the Black Hills are characterized by bare rocks and generally thin soils. The rocks of the quadrangle have, therefore, a marked influence on its topography, the three chief factors governing the physiographic development of the region being the hardness, the attitude, and the thickness of the formations.

The quadrangle includes a considerable part of the southern portion of the Black Hills dome, the axis of the uplift passing a little east of and nearly parallel to a north-south line through the center of the quadrangle. Normally the rocks west of the axial line have a comparatively low dip, while those east of it are inclined at a somewhat greater angle. This simple structure is modified by minor folding which has caused local variations in the dip. Most of these minor folds have steep westerly and low easterly dips, and are roughly parallel to the main Black Hills axis. The most important fold occurs in a low dome more than 20 miles in length, near the eastern margin of the quadrangle.

While the main Black Hills dome and the minor folds have had a marked effect on the development of the physiographic features, they did not have so great an influence as the character of the rocks. There is no structural break corresponding to the marked contrast in the topography north and south of Cheyenne River, and since the Black Hills structure does not cease with the hogback or the Cheyenne, but continues unbroken over the entire quadrangle, the changes in topography must be ascribed to differences in the character of the rocks.

Relief.—The rocks of the quadrangle vary greatly in hardness, ranging from extremely soft shale and chalk to resistant quartzite, and the topographic forms are due largely to alternation of harder and softer layers. The softer rocks, especially where they occur between the more resistant formations, are characterized by valleys, while the harder strata tend to form uplands or ridges. If the hard rocks are underlain by a softer formation, mesas bordered by abrupt cliffs are formed when the strata are horizontal or nearly so, and "hogback" ridges result when the beds are inclined.

Here, as in general elsewhere, the softer the rocks the slighter the topographic contrasts; so in areas of clay and shale the divides are low and the valleys open and shallow. On account of the slight relief the thickness of the formation does not have much effect upon the topographic features. Where a soft formation is unusually thin, as in the case of the Fuson, which occurs between the hard and thick Dakota and Lakota formations, the resulting valley is insignificant. Where the dips are low, as in the main Dakota hogback, erosion at the horizon of the Fuson formation has resulted in the development of a bench at or near the top of the Lakota formation, which is separated from the plateau surface by a cliff of the Dakota sandstone with the Fuson formation in its lower slope. Where the dips are steep, as in the sharp hogback just south of Cascade Springs, the erosion of the Fuson rocks has developed a notch in the ridge near and parallel to its summit.

On the other hand, the harder the rocks and the thicker the formation the greater the topographic contrasts. The valleys are deeper and narrower, and the slopes are more abrupt. The Dakota and Lakota formations, which are the hardest rocks of the quadrangle and the thickest of the hard formations, give rise to by far the most prominent feature, the hogback ridge which limits the Black Hills and which contains the highest points within the quadrangle. The other comparatively resistant formations are not thick, and their erosion has resulted in features which lack the prominence of those in Dakota and Lakota areas.

The Dakota rocks are the most resistant in the quadrangle and give rise to the most prominent and the most rugged topographic forms. They are characterized by a prominent hogback ridge extending in a broken line diagonally across the quadrangle. The direction of the ridge and the steepness of its slopes toward the Graneros shale vary with the dip and strike. The slope of that side of the hogback facing the Graneros shale conforms very closely to the dip. It is long and gentle where the dip is low, as in the northwest and northeast limbs of the Chilson anticline, but short and steep where the dip is high, as in the narrow ridge west of Cascade Springs. This surface of the hogback has been more or less eroded, so that in general lower beds in the series are exposed with the ascent of the slope. The transition from one bed to the next below is marked in some cases by a more or less abrupt cliff, facing away from the Graneros trough. As has already been indicated, such cliffs are generally due to the occurrence of a soft rock beneath a harder one, and here they are most characteristic of the basal beds of the Dakota formation, which are separated from the Lakota rocks by the soft Fuson formation.

On the side toward the Red Valley the hogback is bordered by an abrupt cliff ranging from about 250 to about 800 feet in height, the upper and steeper portions composed of Dakota or Lakota sandstone, the lower slopes being cut from the softer rocks of the Morrison, Unkpapa, and Sundance formations. This slope of the hogback is more or less notched by drainage lines, being most irregular northwest of Chilson Canyon, where it has been deeply cut into by the streams of Chilson, Red, and Craven canyons and their tributaries. Except where the dips are steep, the valleys of the southern slope of the Dakota hogback are long, deep, narrow, and steep walled. In the case of those which head in the hogback the steep walls continue around their upper ends, forming box canyons. The maximum height of the canyon cliffs is over 900 feet, this height being noted just west of Matias Peak; many of the valleys are from 300 to 600 feet in depth. The more important streams head far up the slope, near the cliff facing the Red Valley, and in only four places in the quadrangle have streams cut entirely through the ridge—in Red and Chilson canyons and at two points south of Cascade Springs. Where soft underlying formations have been cut into by the streams, the canyons, though still narrow, are widened considerably. This is well shown in Falls, Hell, Red, and Craven canyons.

Between Chilson and Alabaugh canyons the important drainage lines have a constant southeasterly course, giving rise to a series of long, finger-like ridges. West of Chilson Canyon the drainage is less regular. Just west of the lower part of Red and Craven canyons is a slightly dissected area with nearly parallel drainage down the Dakota slope. Aside from this there appears to be no regular direction of the stream courses, some of them flowing with the dip and others following in a general way the strike.

Drainage.—From the valley of Cheyenne River, which is the main stream of this quadrangle, the general surface rises both to the north and to the south. These general slopes, as well as the depression between them, have been developed through erosion by the Cheyenne and its tributaries. While the course of Cheyenne River is on the whole independent of the structure and hardness of the rocks, there are local adjustments of the stream to these. Thus across the Edgemont quadrangle the greater part of its valley is developed in the soft Graneros shale, and the evidence seems to show that the stream has followed this formation for a long time, gradually working southward down the Dakota slope as the shale was removed. In parts of its course the Cheyenne has developed meanders, especially in the eastern half of the quadrangle. Some of them have been entrenched in the hard Dakota and Lakota sandstones, and southeast of Edgemont and near the eastern margin of the quadrangle gorges several hundred feet in depth have been formed. Cutting along the outer margin of the meanders has tended to widen the gorge to a greater or less extent.

The main tributaries of the Cheyenne, both north and south, are on the whole independent of structure, flowing with the general slope of the surface, and for the most part across the strike of the rocks. Occasionally, however, they show local modifications due to structure or to variation in the hardness of the rocks.

In contrast to the more important streams the minor drainage lines of the quadrangle are dependent for their general direction mainly on the structure and hardness of the rocks. In the areas of harder rocks—e. g., the Dakota hogback and the Minnekahta limestone—the streams tend to follow the surface slopes, or the direction of the dip; in the areas of softer rocks, on the other hand—e. g., the Pierre shale and the Graneros shale—they tend to follow the strike. This latter tendency is due to variation in the resistance of the beds to erosion, and consequently is least pronounced in the more nearly homogeneous of the soft or moderately resistant rocks, such as the Spearfish shale.

The general tendency of streams is to follow the contact between soft rocks and underlying harder rocks. In the area northwest of Edgemont, where this tendency is illustrated, the drainage down the Dakota slope is tributary to the northwest-southeast valleys thus formed. Where erosion along this contact has been sufficiently vigorous, a well-defined channel is found in the Dakota sandstone at the edge of the shale. A good example of this is seen in the canyon just west of Bennett Canyon. This cutting has occasionally followed the same line even after erosion had removed the shale, and the contact is found farther southwest, down the Dakota slope. This interpretation largely accounts for the irregularity in the direction of the drainage in the Dakota hogback northwest of Edgemont, many of the lines parallel to the Dakota-Graneros contact representing stream courses along earlier lines of contact when the shale extended higher on the Dakota slope. Small gravel-covered shale areas on the Dakota surface—up to 700 feet above Cheyenne River—and bordering some of the canyons parallel to the present Dakota-Graneros contact, tend to confirm this view.

It seems probable that the streams in Red and Craven canyons at one time flowed southeastward, through the valley northwest of Sheep Canyon, into what is now Chilson Canyon, and for most of their course originally followed the Dakota-Graneros contact. This conclusion is based partly on the relations of certain stream gravels on the uplands between Chilson and Red canyons, and partly also on the character of the open valley connecting Sheep Canyon with the next valley to the northwest. This connecting valley, which drains both ways—into Sheep Canyon and into the valley to the northwest—has a depth at the divide of more than 150 feet, and is far too large to have been formed by its present stream. The present drainage relations were brought about by the diversion of parts of the stream between Chilson and the mouth of Craven Canyon to courses steeper and more direct to Cheyenne River.

It is probable that in the same way a further diversion will occur at some future time and that the stream north of Chilson will reach Cheyenne River through Sheep Canyon instead of through Chilson Canyon as at present. The reasons for this belief are as follows: The pass west of Chilson is only a little above the valley floor at Chilson; the average grade from the bench mark in this pass to Cheyenne River at the mouth of Chilson Canyon is about 60 feet to the mile, while from the same point to Cheyenne River at the mouth of Sheep Canyon it is nearly 140 feet to the mile; finally, the ridge forming the divide between Chilson and Sheep canyons has already been cut nearly through by the short eastern tributary of Sheep Canyon.

Timber.—The forests of the Black Hills do not extend as far south as the Edgemont quadrangle, but there is a scattered growth of pine on portions of the Dakota hogback, the Minnekahta limestone slopes, and the Minnelusa sandstone hills. The prevalent species is the Rocky Mountain pine (*Pinus ponderosa*), which often attains a diameter of a foot or more. A few scattered pines also occur in the Graneros shale area north of Argentine, east of Edgemont, between Plum and Pine creeks, and north and east of Maitland. Cottonwoods and some other deciduous trees grow along the low flats bordering Cheyenne River, and Pass, Hat, Red Canyon, Moss Agate, and Indian creeks.

Settlement.—The Edgemont quadrangle is very thinly settled. The land is mostly public and devoted to grazing. Edgemont is the principal town. Cascade Springs is a small settlement. Ardmore is a small railroad town. Rumford, Provo, Marietta, Argentine, and Minnekahta are railroad sidings with station houses. Maitland, Jones, and Eckard are ranch houses with post-offices. Ranches are scattered over the country at varying intervals and are mostly located in the larger valleys where water is available. There are several along Cheyenne River below the mouth of Plum Creek, on Hat and Ash creeks, and in the Red Valley about Minnekahta and eastward.

GEOLOGY.

GEOLOGIC HISTORY.

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

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

Cambrian submergence.—One of the great 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 Cambrian time, and for a while the central portion of the Black Hills remained as one of the islands rising above the waters. From the ancient crystalline rocks streams and waves gathered and concentrated sands and pebbles, which were deposited as a widespread sheet of sandstone and conglomerate on sea beaches, partly in shallow waters offshore and partly in estuaries. Abutting against the irregular surface of the crystalline rocks which formed the shore are sediments containing much local material. Subsequently, the altitude being reduced by erosion and the area possibly lessened by submergence, the islands yielded the finer grained muds now represented by the shales that occur in the upper portion of the Cambrian in some areas. In many regions the land surface of crystalline rocks was buried beneath the sediments.

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

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

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

Jurassic sea.—In the Black Hills region the Jurassic was a period of varying conditions, shallow and deep marine waters alternating. The materials are nearly all fine grained and indicate waters without strong currents. In the southeastern Black Hills region some of the earliest deposits are thin masses of coarse sandstone, indicating shore conditions, but generally there is shale lying directly on the Spearfish red shales, which was deposited in moderately deep water. Upon this shale is ripple-marked sandstone, evidently laid down in shallow water and probably the product of a time when sedimentation was in excess of subsergence, if not during an arrest of submergence. The red color of the upper part of the medial sandy series in some portions of the Black Hills appears to show a transient return to arid conditions similar to those under which the Spearfish formation was laid down. An extensive marine fauna and limestone layers in the upper shales of the Sundance formation indicate that deeper water followed. After this stage changed conditions gave rise to fresh-water bodies, probably through widespread uplift. The first product was the thick body of fine sand of the Unkpapa sandstone, now a prominent feature along the eastern side of the Black Hills, but thinner or absent elsewhere.

Cretaceous seas.—During the Cretaceous period deposits of various kinds, but generally uniform over wide areas, gathered in a great series, beginning with such as are characteristic of shallow seas and estuaries along a coastal plain, passing into sediments from deep marine waters, and changing toward the end to fresh-water sands and clays with marsh vegetation. The earliest deposits constitute the Morrison formation, a widespread mantle of sandy shales, which is absent to the southeast, although probably originally deposited there to a greater or less thickness and then removed by erosion in consequence of the uplift which initiated the next epoch. The extent of this degradation is not known, but it has given rise to a general erosional unconformity at the base of the Lakota sandstone, the next succeeding deposit. The materials of this formation consist mainly of coarse sands spread by strong currents in beds 30 to 40 feet thick, but includes several thin partings of clay and local accumulations of vegetal material. Next there was deposited a thin calcareous series, represented by the Minnewaste limestone, but apparently it was laid down only in a local basin in the southern portion of the Black Hills. Over this was spread a thin but widely extended sheet of clays of the Fuson formation. After the deposition of these clays there was a return to shallow waters and strong currents, as in Lakota times, and coarse sands of the Dakota formation were accumulated. At the beginning of the Benton there was everywhere in the region a rapid change of sediment from sand to clay.

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

Early Tertiary mountain growth.—The Black Hills dome developed early in Tertiary time—or possibly in latest Cretaceous time—to a moderate height, and the larger topographic outlines of the region were established before the Oligocene epoch, the dome being truncated and its larger old valleys excavated in part to their present depths. This is indicated by the occurrence in them of White River (Oligocene) deposits, even in some of the deeper portions. Where the great mass of eroded material was carried is not known, for in the lower lands to the east and southeast there are no early Eocene deposits nearer than those of the Gulf coast and Mississippi embayment and those of the Denver basin.

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

Later Tertiary mountain growth.—Following the Oligocene epoch the dome was raised several hundred feet higher and was more extensively eroded. No representatives of the succeeding Loup Fork group—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 northwestern corner of South Dakota. There was probably slow but continuous uplift during the Loup Fork epoch, and materials were contributed by the higher slopes of the Black Hills at that time, but whether the formations ever were deposited in the immediate vicinity of the hills has not been ascertained.

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

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

DESCRIPTION OF THE ROCKS.

The strata coming to the surface in the Edgemont quadrangle have a thickness of about 5000 feet, and comprise limestones, sandstones, and shales, of which the general characters are given in the columnar section sheet.

CARBONIFEROUS SYSTEM.

Minnelusa sandstone.—The lowest formation exposed in the Edgemont quadrangle, the Minnelusa sandstone, appears in its northeast corner and at intervals in the anticline that extends north of Cascade Springs. Near the northern margin of the quadrangle the formation outcrops in a broad region of rolling hills and ridges, but to the south it passes beneath the Opeche formation and Minnekahta limestone and is exposed for some distance in the narrow canyons of Hot Brook and its numerous branches, as far west as the Deadwood branch of the Burlington and Missouri River Railroad. There is also a small exposure in a branch of Red Canyon at the northern margin of the quadrangle, west of the railroad. The exposures north of Cascade Springs are in small canyons cut into the steep western flank of the anticline. In the high cliff rising above the railroad track in the center of the anticline crossed by Hot Brook there is one of the finest exposures of the formation in the Black Hills, comprising somewhat more than two-thirds of it. The outcrop shows in its upper part brilliant-colored, massive sandstones and in its lower part buff and gray sandstones, with several beds of limestone and bright-purple clays. The upper sandstones are brilliant red, brown, orange, and, in certain layers, bright yellow, and are surmounted by the dark-red Opeche sandstone, which is capped by purplish-gray Minnekahta limestone. Some of the beds are tinted partly by staining from the overlying strata, but several of the sandstones are colored throughout. The thickness exposed is 376 feet, comprising the following strata:

Section of Minnelusa sandstone on Hot Brook, South Dakota.

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

The section comprises about two-thirds of the formation, which is about as much as is exposed in this quadrangle in the wide area of outcrop to the north. The uppermost layer is a nearly pure limestone, in which, in an adjoining canyon, the fossils *Productus semireticulatus* and *Chonetes* (?) were discovered. The formation has not elsewhere yielded fossils, but these suggest that the age, of its upper beds at least, is Pennsylvanian. In its unweathered condition many of the Minnelusa beds contain much carbonate of lime, as may be seen in borings from deep wells in various portions of the Black Hills. The lime weathers out near the surface and porous sandstone remains.

Opeche formation.—The Opeche formation is a series of soft red sandstones, mainly thin bedded and containing variable amounts of clay, which lies between the Minnelusa sandstone and the Minnekahta limestone. Owing to its softness, its outcrop is usually marked by a shaly slope below the steep cliff of the limestone. It is extensively exposed along the canyons of Hot and Cold brooks, rising on the high anticline in the gorge of Hot Brook, and it outcrops in numerous canyons cut in the slopes of the Minnekahta limestone westward to beyond the railroad to Deadwood and southward along the west flank of the anticline at intervals nearly to Cascade Springs. The top of the formation, for the first few feet below the Minnekahta limestone, consists of shales, which invariably have a deep-purple color, and the basal layers are red sandstones, varying in thickness from 4 to 15 inches. Along the northeastern margin of the quadrangle the thickness averages 115 feet, with purple shale at the top, 50 feet of red sandy clay beneath, and at the bottom 60 feet of deep-red sandstone in beds 1 to 4 feet thick, with red shale partings. The age of the Opeche formation has not been definitely determined, as it has yielded no fossils, but it is provisionally assigned to the Permian for the reason that it is so closely associated with the overlying Minnekahta limestone, which was probably deposited in that epoch.

Minnekahta limestone.—The Minnekahta limestone, formerly known as the "Purple limestone," is prominently exposed in the Black Hills, but in this quadrangle it occupies only a limited area in the northeast corner, extending from Cascade Springs to Red Canyon Creek. It averages only 50 feet in thickness, but through its hardness gives rise to prominent topographic features, being usually exposed on wide dip slopes and in transverse escarpments. It contains numerous sink holes and caves. Owing to its thinness it is cut through by all but the smallest streams, producing many canyons, which are noticeable features in the ridge south and southeast of Jones station. In these canyons and along its inner margin the limestone generally presents nearly its entire thickness in a characteristic vertical cliff. Ordinarily it is massive in appearance in cliff faces, but on close examination is found to consist of thin layers, differing slightly in color. On weathering it breaks into slabs, usually 2 to 3 inches in thickness. The color as a whole is light gray, but there is always a slight pinkish or purplish tinge, from which the name "Purple limestone" originated. When broken the limestone gives a characteristic bituminous odor. Its composition varies somewhat, mainly in the percentage of magnesia, which is usually present in considerable proportion, and of clay, which is a constant ingredient. An analysis of a typical sample from Cascade Springs, made by Mr. George Steiger in the laboratory of the United States Geological Survey, is as follows:

Analysis of Minnekahta limestone from Cascade Springs, S. Dak.

	Per cent.
Lime (CaO)	31.51
Magnesia (MgO)	19.85
Alumina, iron, etc. (Al_2O_3, Fe_2O_3)	.36
Water (H_2O)	1.25
Carbon dioxide (CO_2)	44.66
Sulphur trioxide (SO_3)	.07
Silica (SiO_2)	1.12
Manganese, soda, and potash	none
Total	98.82

In the region north and northeast of Minnekahta station this formation dips generally to the south-southwest at a very moderate angle, and from Cascade Springs northward it rises over a prominent anticline with steep dips on its western flank. Through its course there are frequent local variations in the amount and direction of dip, as the limestone is a thin, relatively hard bed of homogeneous rock lying between masses of softer red beds, and consequently was much affected by local conditions of pressure. The thinnest layers are often minutely crumpled and faulted, but considering the large amount of deformation to which the formation has been subjected, the strata are but little broken.

Sink holes occur frequently on the limestone slopes, and several large, deep, steep-sided ones occur on the west side of the road 4 miles northeast of Cascade Springs. In its contacts with adjoining formations the Minnekahta limestone presents an abrupt change in material, but no evidence of unconformity. The formation is classified as probably Permian from fossils that were found in it in the railroad cut at the road crossing just 4 miles north of Minnekahta station. These are inconspicuous little shells, occurring abundantly in one of the layers and comprising *Bakewellia*, *Edmondia*, and *Nuculana*. The name "Minnekahta" is derived from the Indian name for the hot springs that issue in Hot Brook Canyon a short distance east of this quadrangle, just west of the town of Hot Springs. The water rises in large volume through crevices in the limestone, with a temperature of 92°. Similar springs have their source in the limestone at Cascade.

The northern margin of the Minnekahta limestone, as shown on the map, is extremely irregular, and erosion has left outliers of this resistant rock capping a number of small, flat-topped hills north of its main area. East of Alabaugh Canyon the Minnekahta limestone forms a low, elongated dome with steep westerly and low easterly slopes. The eastern slope is cut by long box canyons with some tendency to the development of fan-shaped forms, a tendency noted also to a very limited extent on the western slope. This slope is characterized by short, steep-walled canyons, which are narrow where cut in the Minnekahta alone, but broader where the Opeche and Minnelusa formations have been reached. This broadening of the valley is always in the upper part, which is connected with Alabaugh Canyon by a narrow notch or gate, sometimes only a few feet in width, cut in the Minnekahta rocks. In some cases the divide between adjacent valleys has been completely cut through, and the headwaters of one valley have been captured by the stream of the other. An example of several interior valleys connected in this way occurs about 2 miles north of Cascade Springs, the resulting valley still draining into Alabaugh Canyon through one of the narrow notches already described. There is thus a tendency to develop a drainage parallel to the strike of the rocks, and, at the same time, to divide the Minnekahta dome into two parts, the remnant of the western slope forming a line of low, but steep, hogback hills separated by narrow notches, and the low eastern slope changing into a hogback ridge by the development of an abrupt scarp on the west, along the summit of the dome. Further erosion on this steeper slope leaves only occasional outliers of Minnekahta rocks, capping low hills, formed for the most part in the Minnelusa formation. All these features are best seen between the head of Alabaugh Canyon and Hot Brook.

TRIASSIC (?) SYSTEM.

Spearfish shale.—The Spearfish shale, formerly called "Red Beds," consists of red sandy shale with intercalated beds of gypsum, having in all a thickness of about 400 feet. It outcrops across the northern part of the Edgemont quadrangle in the broad, treeless Red Valley, in which Minnekahta station is situated, usually presenting wide, bare slopes and high buttes of bright-red clay with snowy white gypsum in striking contrast.

The Red Valley is bordered on one side by a cliff—here the northern slope of the Dakota hogback—and on the other by the gently sloping surface of the harder underlying formation. West of Minnekahta it is drained by Red Canyon and its tributaries; east of that place, by Hot Brook and its tributaries. Near the eastern margin of the quadrangle it turns to the south and forms the floor of the long, narrow Alabaugh Canyon, the beds dipping so steeply that their outcrop is narrow. South of Cascade Springs, at the southern point of the Cascade anticline, it widens into an open valley, draining to the west through a gap in the Dakota hogback. Here the Red Valley turns to the northeast over a low saddle, and forms the lower part of the valley drained by Sheps Canyon and its tributaries on the south and by a tributary of Fall River on the north. Except in Alabaugh Canyon, the Spearfish formation is intricately dissected for the most part by numerous small stream courses. Here and there small buttes rise above the general level, and occasional outlying hills occur on the Minnekahta slope to the north. One of this character is seen at the northern margin of the quadrangle.

A series of gravel-strewn terraces occurs on the slope of the Spearfish formation about Bradley Flat, and also bordering Red Canyon. The gravels covering these terraces have, as usual, protected the underlying rocks from erosion to a greater or less extent.

The Spearfish formation is composed almost entirely of sandy red shale, generally thin bedded and without special features except the gypsum, which occurs in beds at various horizons, sometimes extending continuously over wide areas. Throughout the formation there are small veins of gypsum due to secondary deposition. The principal bed of gypsum, which is continuous over a large area, lies about 80 feet above the base of the formation, and has a thickness varying from 10 to 20 feet.

The formation has not yielded fossils in this vicinity, except a few fragments of fish scales of indeterminate genus, but it has been regarded as Triassic because it lies unconformably beneath marine Jurassic deposits and is underlain by the Minnekahta limestone, which is probably Permian.

JURASSIC SYSTEM.

Sundance formation.—The Sundance formation lies unconformably on the Spearfish red beds and its outcrop occupies the greater portion of the slope which rises from the Red Valley to the crest of the Dakota hogback. It has a broad outcrop along the south side of the valley extending east and west of Minnekahta station. It narrows in the monoclinal ridge west of Cascade Spring, but spreads out again in the anticline and syncline southeast of Cascade Spring. A portion of the formation outcrops in Hell and Falls canyons, and its upper part is exposed in the canyon south of Parker Knob, in the canyon of Cheyenne River 5 miles east of Edgemont, and again at a point where the river cuts across the anticline southeast of Cascade Springs.

The formation comprises a series of shales and sandstones, the order and character of which vary but little from place to place. At the top are 100 feet or more of dark greenish-gray shales, usually including thin layers of limestone which are highly fossiliferous. Next below are soft sandstones and sandy shales of reddish color, usually having a thickness of from 30 to 50 feet. These are underlain by about 40 feet of buff sandstone, including a prominent layer, about 25 feet thick, at its base. The latter is underlain by dark shales which have an average thickness of about 60 feet and which are separated from the Spearfish red beds by massive, buff to bright-red sandstone. The thickness of the formation averages about 300 feet throughout.

A typical section of the Sundance beds at the high red bluff 2 miles northwest of Minnekahta station is as follows:

Section of Sundance formation near Minnekahta station, South Dakota.

	Feet.
Morrison shale at top.	
Limestone with many fossils	3
Buff to gray sandstone	5
Dark-grayish-green shales, with thin fossiliferous layers, and a 4-foot bed of buff sandstone near its base	100
Red sandstones, mostly soft, partly massive, with a thin mass of gray shales in middle	75
Pale-greenish-buff, thin-bedded sandstone, ripple-marked	10
Pale-grayish-green shales	10
Buff sandstone, flaggy and ripple-marked above, massive below	35
Fissile gray shale	45
Red sandstone, coarse, massive, fossiliferous	20
Buff, brown, and red sandstones, thin-bedded above, lying unconformably on Spearfish red beds	5
Total	308

The dark shales of the upper portion of the formation are soft, but are usually distinctly laminated and their limestone layers are highly fossiliferous. Many impressions of distinctive shells are found, and some layers contain large numbers of a very characteristic cigar-shaped fossil, *Belemnites densus*. The fossils vary in size from an inch, or less, to 4 inches, have a dark color, are hard and heavy, and exhibit a radiated structure when seen in transverse section. They often weather out in considerable numbers on the hill slopes, or occur scattered in slabs of limestone. The reddish sandstones of the middle of the formation are usually soft and of a dull-red color, merging into soft, impure, buff sandstones below. The sandstone in the lower part of the formation is the most prominent feature in the outcrops along the south side of the Red Valley east and west of Minnekahta, its presence usually being marked by a distinct bench and a precipitous ledge in the general shaly slope. There are also frequent outliers of it in low buttes. Part of the rock is massive, but some is slabby and presents finely developed ripple marks, indicating that it was deposited in shallow waters. It varies from fine to coarse grain. Fossils occur in it sparingly, the most common being a distinctive crinoid known as *Pentacrinoides aristicus*. The lower shales are similar to the upper ones, but are ordinarily of slightly harder texture and of much less thickness, being 60 feet thick near Craven ranch, 45 feet near Minnekahta, 60 feet near Cascade Springs, and 55 feet in Sheps Canyon.

The basal red sandstone is found throughout the exposures in the Edgemont quadrangle, but it varies considerably in thickness. It is often bright red and is very massive, so that it gives rise to prominent cliffs that rise above slopes on the red Spearfish shales. Some notable exposures of this sandstone occur in the section given above, about 2 miles northwest of Minnekahta station, and again on the west side of Red Canyon, a mile northeast of Craven ranch. In both of these exposures the bright-red color is conspicuous. The sandstone contains a few fossil shells of distinctive Jurassic species, and there is a marked erosional unconformity between it and the underlying Spearfish shale. East of Minnekahta for some distance the basal red sandstone seems to thin out almost entirely, but it reappears in considerable prominence north of Cascade Springs and on the east side of the Red Valley northeast of Cascade Springs, where its color is mostly light buff. Near Sheps Canyon its thickness is 45 feet.

In Falls Canyon and Hell Canyon the greater portion of the formation is exhibited, including the red rocks in the lower half. In Hell Canyon the upper shales, a hundred feet or more thick, are overlain by 10 feet of soft sandstone and 10 feet of shales, red at the top, which give place abruptly to the Unkpapa sandstone. In the deep boring at Edgemont the upper shales of the Sundance formation appear to extend from a depth of 802 to 957 feet, showing a thickness of 155 feet. The underlying red sandy shales are 20 feet thick, the massive buff sandstone is 35 feet thick, with its base at a depth of 1012 feet, and thence to the bottom of the well, at 1125 feet, are dark shales of the basal member of the formation, indicating that the lower shales increase considerably in thickness toward the south.

Unkpapa sandstone.—The Unkpapa sandstone is a massive, fine-grained deposit of remarkably uniform texture, varying in color from white to purple and buff, and always clearly separable both from the Sundance shales below and from the Lakota sandstone which usually overlies it. It appears to be less distinctly separated from the Morrison shales which overlap it from the west. Its greatest development in the Black Hills region is in the hogback east of Hot Springs and Cascade Springs, where the brilliant pink, purple, and pure white exposures are very striking. The greatest thickness, 225 feet, is in Sheps Canyon east of Cascade Springs.

The Unkpapa sandstone outcrops along the east side of the monoclinal ridge just west of Cascade Springs and underlies the plateau to the west. Near Cascade Springs it is about 100 feet thick, and it gradually decreases in thickness westward. It outcrops along the northern edge of the plateau, giving rise to a small shelf at some points. It is exposed along the slopes of Falls and Hell canyons, and its westernmost exposure is in the canyon south of Parker Peak. It has a thickness of over 80 feet in Falls Canyon, and of 30 feet in Hell Canyon, comprising the usual white sandstone at the top and 10 feet of pale-pink, massive, fine-grained sandstone below, sharply separated from the underlying Sundance beds. One of the finest exposures of the formation is in a small canyon 2¼ miles south by west of Jones station, where over 100 feet are exhibited, of which the upper half is white and the lower half a deep pink. The rock is fine, even grained, and massively bedded. In this ridge and eastward the Lakota sandstone lies directly on the Unkpapa sandstone, the Morrison formation disappearing east of Falls Canyon. Between the two sandstones there is a strongly marked unconformity representing an erosion interval in which there was a land surface during deposition elsewhere of the Morrison. The plane of unconformity is irregular in contour, with local channels, and is plainly exhibited by the contact between the coarse, cross-bedded, buff sandstone above and the fine-grained, massive, pure white sandstone of the upper Unkpapa beds below. This contact is exposed in the ridges east and southeast of Cascade Springs, particularly at the one point in a high cliff that can be seen for many miles to the west. It is also exhibited at intervals northwest of Cascade. Possibly the Unkpapa sandstone originally extended farther westward and its western extension has been removed by erosion, but more likely it is a local beach deposit of latest Jurassic or earliest Cretaceous times. No fossils have been found in it, but from its association with the Sundance beds and the apparent conformity between them, it is provisionally classed with the Jurassic.

CRETACEOUS SYSTEM.

Morrison formation.—The Morrison formation consists of massive shales, or hard clays, mainly of light-gray or pale-greenish-gray color, but generally in part also red or maroon, with occasional layers of fine-grained, white sandstone. This formation usually is prominent in the Black Hills uplift, but is absent in the southeastern portion of the region. West of Minnekahta it has a thickness of 100 feet or more, but eastward, in the eastern portion of the plateau northwest of Cascade Springs, it thins out and disappears, the Lakota sandstone lying directly on the Unkpapa sandstone in the ridge just west of Cascade Springs and in the region farther south and east. The Morrison shale is exposed in the upper part of the slope at the base of the cliffs of Lakota sandstone in the northern face of the hogback westward. As the dip is low and the formations are relatively thin, the outcrop is somewhat irregular, extending far northward up the points of the ridges, and southward down the canyons which cross the ridge, notably in the plateau southeast of Minnekahta. The formation is exposed in Hell and Falls canyons and in the canyon south of Parker Peak, lying on the Unkpapa sandstone. In Hell Canyon the formation extends to within about a mile of Cheyenne River, and, although varying in thickness and character, consists mainly of gray and red sandy clay. On the west side of Falls Canyon the Unkpapa sandstone is overlain by 60 feet of shale, greenish at base, darker above, and light green and maroon in its upper portion, but on the east side it thins rapidly to about 20 feet. There are also small exposures in Chilson Canyon a mile southeast of Chilson, and in the heads of branches of Bennett Canyon, where it is pale-greenish, massive clay, with thin, white, fine sandstone layers 3 to 10 inches thick. It is also cut through by Cheyenne River east of Edgemont. In an exposure in Red Canyon just west of Craven's ranch, where the formation is 80 feet thick, there is, at its base, a thin layer of limestone filled with remains of fresh-water algæ. In the well at Edgemont the formation appears to extend from 652 to 802 feet, a distance of 150 feet, including a thin limestone bed at 705 feet and some "soft white beds" at its base.

In the western part of the quadrangle the Morrison shale is distinctly separated from the Sundance formation, and in the eastern part from the Unkpapa sandstone, by an abrupt change in character and material, but there is no evidence of erosional unconformity. The character of the material and the occurrence of bones and of fresh-water mollusks in it in various portions of the Black Hills indicate that the shales are of fresh-water origin. In the northern Black Hills the shales have been designated the Atlantosaurus formation and the Beulah shales, and in central Wyoming they have been called the Como beds, and there is good evidence that these are precisely equivalent to the Morrison formation of the Denver, Colo., region. As this formation appears to be equivalent to a portion of the Comanche series in northwestern Oklahoma and southeastern Colorado, it is classed in the Cretaceous.

Lakota formation.—The Lakota sandstone, consisting of a series of hard beds, usually from 200 to 350 feet thick, is prominent in the hogback and the plateau bordering the Red Valley. Its outcrop crosses the northeastern third of the quadrangle in a belt passing south of Minnekahta, where, owing to low dips and the removal of the overlying Dakota sandstone, the Lakota is broadly exposed in high, smooth-topped ridges sloping southward. On approaching Cascade Springs, where the dips steepen, it gives rise to a narrow hogback and passes, in a hook-shaped course, around the point of the anticline. A few miles below Edgemont, and again south of Cascade Springs, Cheyenne River has cut high-walled gorges in it. Chilson, Hell, and Falls canyons also cut through it and trench more or less deeply into underlying formations.

The Lakota formation is composed of hard, coarse-grained, mostly cross-bedded and massive sandstone, with occasional thin partings of shale. Streaks of conglomerate often appear, especially in its lower portion. Small basins of coal occur in it east and north of Edgemont. In the eastern portion of the quadrangle the formation lies unconformably on the Unkpapa sandstone; to the west it abruptly overlies the Morrison shales without transition beds, but does not present other evidence of unconformity. There are frequent local variations in character, but the general features are constant. The thickness varies considerably, but within moderate limits. In the gorge at Cascade Springs 275 feet of nearly vertical sandstone beds were measured, but the precise upper limit is not clear. In Falls Canyon the lower beds include massive buff sandstone with few shale partings and a mass of gray fire clay overlain by heavy beds of light-buff, coarse-grained, cross-bedded sandstone. The lower portion of the formation often includes considerable dark shale, as in Hell Canyon and especially in the region a few miles southwest of Minnekahta. On the north side of Red Canyon the basal series comprises massive, cross-bedded sandstones lying on a few feet of carbonaceous shales with some coal, and overlain at one place by a 30-foot deposit of massive greenish shale, which resembles the Morrison formation in appearance, but which grades laterally into soft buff sandstone. The overlying beds are of the usual character. West of Red Canyon the uppermost member is a massive sandstone of light color, which weathers into rounded forms and gives rise to a shelf of considerable width west of Craven's ranch. In this region the thickness of the formation diminishes in places, and at one point in the East Fork of Bennett Canyon is only 180 feet. In Pass Creek Canyon also the formation thins considerably and presents in its lower portion a 50-foot ledge of massive, cross-bedded, buff sandstone lying on 50 feet of carbonaceous shale which grades down into gray shales with sandstone intercalations that extend to the Morrison contact.

In the gorge cut by Cheyenne River across the anticline east of Edgemont the Lakota formation, lying on Morrison shales, is exposed in its entire thickness. The beds rise on the west side of the arch and, with a dip of 5°, comprise at the top 100 feet or more of massive, white to pale-buff, fine-grained sandstone, 40 feet of slabby sandstone and shale, 40 feet of massive, light-gray, fine-grained sandstone, 10 feet of shaly and thin-bedded sandstone, and 30 feet or more of massive, white to dirty gray sandstone. In Chilson Canyon the formation appears to be of greatly increased thickness, measuring over 500 feet, but this may be partly due to landslides in the deeper portion of the canyon, by which the basal beds have slipped down over the Morrison shale.

At a coal prospect 4½ miles east of Edgemont, on Cheyenne River, on the north side of the first large bend, the coal occurs 250 feet above the river, or about 200 feet above the base of the formation, between layers of massive white sandstone. One and one-half miles farther down the river, also on the north side, there is a 3-foot bed of poor coal 90 feet above the river and 65 feet above the base of the formation. At the mine around the next bend, in sec. 24, there is a coal bed which has a thickness of 5 feet for some distance, but thins out eastward. It is about 30 feet above the river and lies between two heavy beds of massive white sandstone, of which the upper is 25 feet thick and is overlain by 50 feet of thinner bedded, light-colored sandstones capped by terrace materials.

The Lakota sandstone was pierced by the borings at Edgemont and appears to extend from 430 to 652 feet, a thickness of 222 feet. A characteristic feature of the Lakota sandstone is the occurrence of numerous fossil vegetal remains. Large numbers of cycads have been found in its middle beds west of Payne and Arnold's ranch (see fig. 8, illustration sheet); petrified tree trunks are also of frequent occurrence. One of these, near the cycad locality above referred to, is shown in fig. 7 of the illustration sheet. They are abundant in the wide plateau of Lakota sandstone extending east of Parker Peak. On the evidence of its fossil plants the Lakota formation is classed in the lower Cretaceous.

Minnewaste limestone.—The Minnewaste limestone is a formation of limited occurrence in the Black Hills, its principal outcrops extending from the vicinity of Cascade Springs to Buffalo Gap. A small outlying area is also found at the head of Bennett Canyon.

In the high ridges east of Cascade Springs the formation is 25 feet thick and caps some plateau areas of moderate extent, but it thins rapidly south and west and appears not to extend north of Cascade Springs or west of Falls Canyon. It is exposed at intervals on the slopes above Tepee Creek with a thickness of 15 to 20 feet, is well exhibited on the north side of Cheyenne River east of Coffee Flat with a thickness of 18 feet, and is exposed in a gorge a mile south of Cascade Springs, where its thickness is 10 feet. At the head of Bennett Canyon there are several small areas in which it has a thickness of from 3 to 12 feet, and it caps some narrow ridges and slopes near the county line, passing beneath typical Fuson clays on the slopes of knobs capped by the massive reddish sandstone of the Dakota. Small traces of calcareous deposits are seen at the base of the Fuson formation at various points north of Edgemont, which doubtless represent Minnewaste limestone.

The typical rock is a nearly pure, light-gray limestone presenting a uniform character throughout. An extended search has failed to detect any fossils in it, but it is known to be of lower Cretaceous age because it lies below the Fuson formation.

Fuson formation.—The Fuson formation consists of a thin sheet of clays and impure sandstone lying between the Dakota sandstone and the Minnewaste limestone or the Lakota sandstone. It has a thickness of nearly 100 feet southeast of Cascade Springs, but westward it thins rapidly, varying from 30 to 60 feet. The predominant material is clay and sandy clay of gray color, with conspicuous maroon and purple portions. Thin beds of buff sandstone and one or two layers of a characteristic dark-green sandstone are usually included. Locally the clay appears to give place in greater part to sandy shale with gray to purple clay partings. To the east, overlying the Minnewaste limestone, is a 20-foot basal bed of coarse sandstone, much honeycombed by weathering.

In places, as at Pass Creek, the formation consists largely of dark shale and gray sandy shale. Ten miles north of Edgemont there are 40 feet of dark, sandy shale in the upper part of the formation, lighter colored sandy shale in the middle, and dark shales lying on massive Lakota sandstone at the base. Two miles west of Craven's ranch the Dakota sandstone is underlain by 7 feet of dark-gray to black massive shale, 3 feet of light-gray clay, 6 feet of dark clay, 3 feet of green sandstone, 16 feet of dark-brown, very soft sandstone or sandy clay, 6 feet of purplish clay, and 16 feet of light-colored, very sandy clay lying on typical Lakota sandstone. As the formation is soft as compared with adjoining sandstones and limestones, it usually lies along the base of Dakota sandstone cliffs and is more or less hidden by talus.

In the well at Edgemont the Fuson formation appears to extend from 250 to 430 feet, a thickness of 80 feet, being reported as "shale." No fossils have been found in the formation in the Edgemont area excepting a few indeterminable plant fragments, but in the Hay Creek region in the northern hills it has yielded large numbers of plants of lower Cretaceous age.

Dakota sandstone.—The Dakota sandstone constitutes the outer slopes of the hogback and plateau, being prominent in the steep rise from the valley underlain by the Graneros shale. In the region north and east of Edgemont it presents a regular slope to the southwest and is deeply notched by canyons, some of which have cut away portions of the formation, leaving scattered outliers. Southeast of Minnekahta, where the dip is southeastward and is very gentle, the formation extends far up the sloping plateau, mostly in outliers capping the narrow ridges between the deep canyons. One of the most conspicuous of these outlying masses is Parker Peak, in which the formation attains an altitude of 4848 feet.

The formation rarely exceeds 125 feet in thickness, being about half as thick as the Lakota sandstone. It generally consists of hard, coarse sandstone from 60 to 80 feet thick, overlain by a thin series of purplish and thinner bedded buff sandstones, with a variable series of sandstones 30 to 40 feet thick at the top. The basal member usually is very massive, giving rise to cliffs in which the jointing gives a rude palisadal effect, and its color on weathering is a characteristic dull reddish brown. Prominent exposures of this member occur along Red and Hell canyons, and it rises in a sharp, rocky hogback ridge on the west flank of the anticline south of Cascade Springs. In places it changes into thinner bedded sandstone, especially in its lower part, as east of the grindstone quarry. In the high ridge on the east side of Red Canyon, a short distance above the mouth of Craven Canyon, there are prominent reddish cliffs of the characteristic massive sandstone, 30 feet thick, lying on 8 feet of softer, thinner bedded sandstones, underlain by 20 feet of very light-colored sandstone, reddish at top, which lies on typical Fuson purple shales. In the ridges on either side of Chilson Canyon the formation is largely represented by a hard, gray to purplish-gray quartzite, a rock which is extensively developed in Parker Peak and at Flint Hill, where there are extensive excavations made by the Indians for materials for arrow heads and other implements.

South of Cascade Springs the upper bed is a hard sandstone 15 feet thick, underlain by 85 feet of thin sandstone and alternating shale and sandstone, at one place containing a 4-inch bed of coal.

The upper beds of the Dakota formation exposed under the Graneros shales in the bank of Cheyenne River a short distance above the mouth of Plum Creek are as follows: 10 feet of slabby brown sandstone; 10 feet of yellow to drab mottled clay; 10 feet of thin-bedded, light-brown sandstone; 5 feet of drab shale, and 5 feet of yellow and drab shales lying on the massive lower member. At the coal prospect on the river bank 3 miles east of Edgemont there are, below the Graneros shales, 15 feet of slabby, light-colored, fine-grained sandstone, 20 feet of dark shaly sandstone, 20 feet of massive, fine-grained, light-buff sandstone, and 30 feet or more of dark shales containing a body of very coaly shale near the top.

The Dakota beds at the grindstone quarry north of Edgemont belong in the upper member, which is about 45 feet thick and is overlain by Graneros shale and separated from the lower massive sandstones exposed in the adjoining canyons by 25 to 30 feet of maroon and gray clay, with thin buff sandstone intercalations. The beds at the quarry are as follows: At the top 3 feet of buff sandstone with a thin parting of drab shale, 1 foot of drab shaly sandstone, 10 feet of massive, fine-grained, light-colored quarry stone, 5 feet of thin-bedded buff sandstones, 7 feet of massive buff sandstone, 3 feet of thin-bedded to shaly sandstone, and 5 feet of slabby light-buff sandstones lying on maroon and gray clays. These clays somewhat resemble those of the Fuson beds, but they are underlain by typical massive sandstone of the lower Dakota, which rises in cliffs farther up Red Canyon.

In the region north and east of Marietta the upper members of the Dakota comprise thin-bedded sandstones underlain by drab, gray, and red to maroon clays, and the lower Dakota beds are in part thin bedded.

In the wells at Edgemont the Dakota sandstone appears to have been entered at a depth of 295 feet and to have a thickness of 55 feet.

The upper sandstone of the Dakota sandstone near Hot Springs has yielded fossil plants of the Dakota flora, of upper Cretaceous age.

Graneros shale.—This shale is the lowest formation of the Benton group and is believed to be the precise equivalent of the Graneros shale of southeastern Colorado, as it lies between the Dakota sandstone and the Greenhorn limestone, which in both regions is characterized by numerous remains of the same species of *Inoceramus*. The shale is dark and in greater part breaks up into thin flakes. It contains numerous concretions, usually lens shaped, ranging in diameter from a few inches to several feet. Its thickness averages about 850 feet, so far as could be ascertained from several cross-section measurements made with rather uncertain dip determinations. Usually its limits above and below are sharply defined, but locally, as near Cascade Springs, there are some basal sandy beds. A contact with the overlying Greenhorn limestone is shown in fig. 12 of the illustration sheet.

To the northwest the shale underlies the valley occupied by Cheyenne River and to the southeast some of the lower western branches of Hat Creek. This valley narrows as the dips steepen east of Edgemont, and still more on the east flank of the syncline east of Maitland. It is extended southward beyond Rumford by the anticline west of Hat Creek, and its extension to the southwest up Cottonwood Valley is also due mainly to an anticline. Small outlying areas are found on the Dakota sandstone plateaus, notably in the high ridges 6 miles north of Edgemont and at other points northeast of that town, where it has been protected by Oligocene deposits. The formation is extensively exposed and its surface is generally bare of vegetation. Along Cheyenne River and Hat Creek it is extensively covered by alluvium, and west of Marietta and near Maitland its upper portion is covered by dune sand. In an area of considerable size north of Maitland the Graneros shale is traversed by dikes or masses of sandstone occupying fissures. The most extensive of these are near the road to Maitland as it enters the draw just south of Coffee Flat; others are exposed a mile farther west, in the east bank of the river and on the slopes above. Two small dikes were observed 3 miles southeast of Edgemont, and there is another 2 miles south of Cascade Springs. These dikes consist of sand derived from the underlying Dakota sandstone, which has been forced up along joint planes or in fissures for some distance through the lower beds of the shale. They vary in width from a fraction of an inch to more than 20 feet; and while most of them are short, some of the largest of the dikes extend several hundred yards. One of the largest, which is at least 20 feet wide, is shown in fig. 6 of the illustration sheet. The trend varies considerably, but the general direction is northeast-southwest, and some are curved. Most of them dip steeply, but in places the inclination is low. In the cliff east of Cheyenne River there are two dikes that cross each other, showing that one was intruded after the other. At some points the shale on either side of the dike is deflected abruptly downward for a few inches.

The Graneros shale outcrops for the most part in a broad, open trough, which on the south meets the overlying Greenhorn limestone in a more or less abrupt scarp, and on the north joins the Dakota slope without marked physiographic break. Northwest of the main gorge of the Cheyenne a large part of the shale area is occupied by the valley of Cheyenne River and some of its more important tributaries. Bordering these valleys on one or both sides is a well-defined series of stream terraces cut in the shale. These terraces are flat topped and are covered to a greater or less extent with alluvial deposits, which have protected them from extensive erosion; they are, however, considerably dissected by minor streams, which tend to form long, rather open and shallow valleys following the strike. The tendency of streams to follow the line of contact between a soft formation and a harder one beneath is seen again along the contact of the Graneros shale and the Dakota sandstone north and northwest of Edgemont.

South of the main Cheyenne gorge, where the rocks dip at a high angle, the Graneros shale forms a comparatively narrow pass in the hills, with drainage to the northwest and southeast. Just north of the pass a well-defined, short hogback ridge has been developed in the Graneros formation, owing to the local occurrence of sandstone in the steeply dipping shale. Two conical hills about 3 miles northeast of Maitland are the result of a similar occurrence of sandstone.

In the eastern part of the quadrangle the Graneros shale does not, in general, form a simple trough, but presents topographic features similar to those developed on the Pierre shale, with broad, rounded ridges and open valleys. Terraces occur locally along the larger valleys, as west of Hat Creek and along Cheyenne River. In the triangular area of Graneros shale southwest of Maitland the principal topographic feature is a broad, irregular ridge south of Plum Creek, trending north of east and having short drainage lines to the north and longer valleys to the south and east.

Greenhorn limestone.—On the plains south of the Black Hills slopes one of the most prominent features is a low but distinct north-facing escarpment which is due to the hard Greenhorn limestone in the middle of the Benton group. The escarpment is conspicuous west and south of Edgemont, where it presents the aspect shown in fig. 12 of the illustration sheet. In this region the rocks dip mostly to the southwest at low angles and the formation caps a table or shelf of moderate height. South of Plum Creek the outcrop is deflected far to the south by the Hat Creek anticline, and where the dips are steeper the edge of the limestone rises in a ridge or line of knobs which extend to Hat Creek southeast of Rumford. The escarpment is often covered by alluvium in its northeast corner, along Hat Creek Valley, but it becomes conspicuous again as the beds rise from the syncline east of Maitland. On the east side of this flexure, where the dips are steep, its course is again marked by a line of sharp-crested knobs of considerable prominence. The limestone is thin but persistent and is characterized by a large number of casts of *Inoceramus labiatus* (see fig. 11), a fossil which is of infrequent occurrence in the adjoining shales. It contains a considerable amount of clay and some sand, and appears to harden on exposure. It breaks out into hard, thin, pale-buff slabs, covered with impressions of the distinctive fossil. Its thickness averages about 50 feet, including some shaly beds in its upper portion. At its base it is distinctly separated from the black shales of the Graneros formation, as shown in fig. 12, but its upper beds grade into the Carlile shales through 6 or 8 feet of passage beds.

The Greenhorn formation is resistant to erosion, and this character, together with its occurrence above the soft Graneros shale, has given rise to some of the most prominent topographic features south of Cheyenne River. Where the dips are low, broad, flat-topped mesas have been formed. West of Edgemont the Greenhorn mesa averages about two-thirds of a mile in width, while southeast of Edgemont the average width of the broader part is between 1½ and 2 miles. Along Hat Creek south of Maitland the mesa is generally narrow, and is in part covered with wind-blown sand. These mesas are bordered by an irregular cliff, frequently more or less abrupt at the top, where it is capped by the Greenhorn limestone, a large part of the slopes consisting of the underlying Graneros shale. Characteristic views of these cliffs are shown in fig. 12 of the illustration sheet. The ragged margins of these tables are formed by the deep V-shaped embayments commonly found where erosion along the cliff has cut through a hard formation to the softer rocks beneath. With the general southerly dip of the rocks the cliff becomes gradually less prominent toward the south, along Cottonwood and Hat creeks, till the Greenhorn formation finally disappears beneath the valley alluvium.

Where the dips are steep the Greenhorn limestone forms a sharp and much serrated hogback ridge, or a line of rudely pyramidal or wedge-shaped hills (see fig. 9, illustration sheet). There are two lines of hills of this character, one north of Rumford, extending about 9 miles northwesterly; the other about 2½ miles east of Maitland, extending about 6 miles in a southeasterly direction. The western faces and the summits of these hills are of Greenhorn limestone, except in a few places, where short streams have cut through the limestone and exposed the shale. The lower part of the eastern slope is of Graneros shale. Streams have cut across these ridges at a number of points.

Carlile formation.—The outcrop of the Carlile formation, the uppermost member of the Benton group, occupies a broad area west and south of Edgemont, but is narrow on the sides of the Hat Creek and Cascade anticlines. The formation consists mainly of shales, with occasional thin layers of sandstone and sandy shales, and with numerous oval concretions at the top. Its thickness averages about 450 feet, or possibly slightly more. A typical section measured near the eastern margin of the quadrangle is given in the following table:

Section of Carlile formation southeast of Maitland, S. Dak.

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

The formation presents numerous exposures, except in portions of the valleys of Plains and Hat creeks, where it is covered by alluvium.

The Carlile merges into the Greenhorn, but the passage beds are thin. Fossils of typical upper Benton molluscan forms, including *Pryonocyclas wyomingensis* Meek, *Scaphites warreni* H. and M., *Inoceramus fragilis* H. and M., and *Fusus shumardi* H. and M., occur in considerable abundance in some of the Carlile beds

The Carlile formation is of moderate though variable hardness, being more resistant than the Niobrara chalk but less so than the Greenhorn limestone. Where the formation lies nearly flat and the exposures are therefore most extensive, it is characterized by irregular groups of low, rolling hills separated by open valleys and surmounting the plateau capped by the Greenhorn limestone. These hills are best developed in the western half of the quadrangle. Where the dips are steep, as north and east of Rumford and near the eastern margin of the quadrangle, the Carlile formation gives rise to a long, low, rounded, and inconspicuous ridge, more or less broken by drainage lines just west of the more prominent hills in the Greenhorn limestone.

Niobrara formation.—The Niobrara formation is a soft, shaly limestone or impure chalk, containing more or less clay and fine sand, and often including thin beds of hard limestone, which consists of aggregations of *Ostrea congesta* (see fig. 11, illustration sheet). In unweathered exposures it is usually lead-gray, but weathered outcrops are bright yellow, and therefore conspicuous, although, as the rock is soft, it rarely gives rise to noticeable ridges. Its thickness appears to average about 200 feet throughout. Outcrops of the rock are infrequent owing to the softness of the material and local wash on its slopes. Its outcrop extends across the southern middle part of the quadrangle, being spread out widely in the area of low dips in the gentle anticline in the valley of Cottonwood and Softwater creeks. It underlies part of Plains Creek Valley, is deflected south by the Hat Creek anticline, which it crosses just below Ardmore, and extends north along the east side of Hat Creek Valley to Bitter Creek, where it turns south in a narrow belt along the west side of the Cascade anticline.

As a rule the Niobrara chalk forms a simple, open valley between the Pierre shales on the one hand and the Carlile formation on the other. This valley is broadest where the rocks dip at a low angle and narrowest where the dips are steepest. The Niobrara lowland rises into the adjacent Carlile slopes without topographic break. The contact of the Niobrara and Pierre formations, however, is generally marked by an abrupt cliff, the upper part of which consists of Pierre shales, the lower slopes being cut from the soft Niobrara chalk. The cliff is due to the presence of several resistant concretionary layers near the base of the Pierre shales. These harder layers are separated by shale, and the differential erosion of the hard and soft rocks has occasionally developed rude terraces in the upper part of the cliff. This cliff is best developed where the dips are low, and least where the dips are greatest. The absence of the cliff near the Niobrara-Pierre contact west of Hat Creek is partly accounted for by a capping of gravel on the Niobrara chalk, which has made the rocks locally more resistant.

Near the western margin of the quadrangle, west of Alum Creek, a heavy deposit of terrace gravels on the Niobrara chalk has, to a greater or less extent, protected this formation from erosion, so that, instead of the single simple valley which elsewhere characterizes the formation, there are a number of flat-topped uplands with abrupt margins separated by moderately open valleys. West of Hat Creek the main drainage lines tend to follow the Niobrara trough. Between Alum Creek and Rumford the main drainage lines of the valley—Softwater and Plains creeks—follow very closely the contact between the Niobrara and Carlile formations. East of Hat Creek the streams flow for the most part across the Niobrara trough.

Pierre shale.—The Pierre shale crosses the southern portion of the Edgemont quadrangle, extending northward beyond Ash Creek on the east of the Hat Creek anticline and occupying an area of about 150 square miles southeast of the flexure. The formation consists mainly of a thick mass of dark-bluish-gray shales, which weather light brown and give rise to low, rounded hills sparsely covered with grass and not useful for agriculture. The drainage lines on it, as a whole, follow a northwest-southeast direction. West of Hat Creek the general surface rises to the north of west, with the dip culminating near the western margin of the quadrangle in an irregular ridge with northeasterly trend. This ridge, which contains the highest elevations in the southern half of the quadrangle, is largely due to structure, and its position closely corresponds to the anticlinal axis of one of the minor folds.

The greatest thickness of the Pierre shale is in the southeast corner of the quadrangle, where nearly 1000 feet are exposed, comprising about four-fifths of its total amount. In the syncline west of Ardmore there remains a thickness of about 600 feet. At the base of the Pierre shale is a very characteristic series of black, splintery shale, 150 feet thick, which rises in a steep slope above the Niobrara chalk lowlands. This steep slope is conspicuous along the east side of Hat Creek Valley, west and south of the railroad from Ardmore to Provo, and about the head of Alum Creek and its branches. The basal series contains three horizons of concretions, which exhibit a regular sequence throughout. The lower ones are biscuit shaped, hard, and siliceous. Those in the layers next above are similar in shape and composition, but are traversed in many directions by deep cracks filled with calcite and sometimes containing scattered crystals of barite. Next above there occur, in two or three layers, large lens-shaped concretions of carbonate of lime of light-straw color, showing beautifully developed cone-in-cone structure. These concretions appear not to be fossiliferous. At higher horizons the Pierre shale contains many concretions, generally of small size, which break into small pyramidal fragments, which are scattered more or less abundantly all over the surface. Some of the concretions are highly fossiliferous, containing distinctive fossils, of which the more abundant belong to the following species: *Baculites compressus, Inoceramus sagensis, Nautilus dekayi, Placenticeras placenta, Heteroceras nebrascense,* and an occasional *Lucina occidentalis.*

TERTIARY SYSTEM.

Chadron formation.—On the southern slopes of the Black Hills uplift there remain a few small outliers of sands and clays which appear to be remnants of a former extensive sheet of White River Oligocene deposits. The occurrence, farther north and east, of other larger remnants having similar relations and containing distinctive fossils, aids in the correlation. In the Edgemont quadrangle the principal areas are on the Dakota sandstone ridges 6 miles north and slightly east of north of Edgemont, at an altitude of 4050 feet; and in the ridge 3 miles west of north of Minnekahta station, at an altitude of 4400 feet. The more doubtful areas are in the Red Valley at the head of Red Canyon, at an altitude of 3900 feet, on the ridge east of the grindstone quarry, and on the ridges north of Craven ranch, at an altitude of 4250 to 4300 feet. The rock 6 miles north of Edgemont is a brown conglomeratic grit containing many small pebbles, capping an outlying area of Graneros shale. It occupies only a few acres and presents no evidence as to whether it represents the Chadron or Brule formation. For convenience it is mapped as the former. North of Minnekahta the deposit at one place is a conglomerate 15 feet thick, lying on 2 feet of white sandstone; and there are also fine-grained sands, or loams, with gravel streaks, and apparently some fuller's earth, similar to that of the Chadron formation, which has been mined a few miles north. Possibly other gravels and sand deposits in the northern part of Bradley Flat belong to this same formation, or have been derived from it. In the ridge north of Craven the material is sand and gravel. Along the ridge east of the grindstone quarry there are sands and gravels lying on outliers of Graneros shale and supposed to represent the Chadron formation.

QUATERNARY SYSTEM.

Residual gravels.—The oldest surficial deposits in this region are residual gravels, apparently remnants of the basal gravels of the Chadron formation, which are but slightly removed from their original position. The principal areas are on the higher terraces in Bradley Flat and north of Craven, the slopes northeast of Edgemont, the ridges extending southwest of Edgemont, and the divide east of Hat Creek in the southeast corner of the quadrangle. The materials consist of sand and gravel, mostly in a discontinuous coating and varying greatly in coarseness and composition. Possibly in some areas they represent remnants of early Quaternary or late Tertiary terraces, but their history is not clear.

Older terrace deposits.—The uplands bordering most of the larger valleys cut in the softer rocks are marked by a series of well-defined terraces, representing old floors of the valleys which they border; and like the present alluvial flats, they are more or less extensively covered with sand, silt, and gravel. There is a further resemblance in the fact that these deposits are best developed along the larger streams and in the softer rocks. They are seldom found, or at least are not extensively developed, in the narrow canyons in the harder rocks. The only well-defined terraces in the areas of the Dakota and Lakota formations, which are the hardest rocks of the quadrangle, occur as relatively narrow, gravel-strewn benches at various levels along the valley of Cheyenne River. On the other hand, the soft Graneros shale has been extensively terraced not only by the Cheyenne but by its more important tributaries.

The old terraces formed by Cheyenne River in the Graneros shales are broad and flat and at several places occur as much as 2 or 3 miles from the river. Practically the entire width of the Graneros exposure northwest of Edgemont consists of a series of terraces formed at successive stages by Cheyenne River as it cut its valley deeper and deeper. With the continued deepening of the valley of this river the previously formed alluvial flats have been more or less dissected by erosion, so that the present terraces are remnants of the old alluvial flats. Erosion has, at the same time, removed to a greater or less extent the deposits which originally covered the terraces.

The terraces bordering the valley of Cheyenne River are similar to those that occur along the other important streams of the quadrangle. Extensive terracing occurs in the Sundance and Spearfish formations along Hat, Cottonwood, Craven, and Red Canyon creeks and their main tributaries, while less pronounced terracing occurs along Beaver and Pass creeks, Hot Brook, Sheps Canyon, and a number of other streams, the terraces all being developed in wide portions of the valleys or in the softer rocks.

The sand and silt covering many of these terraces frequently rest on a layer of gravel which forms the base of the alluvial deposits and outcrops around the margins of the terraces. Where the sand and silt have been removed through erosion, as on many of the higher terraces, nothing but gravel is found. These resistant gravel caps serve to protect the underlying soft rocks from erosion, and so tend to preserve the terraces. It is to such gravel caps that the small outliers of Graneros shales northeast of Edgemont owe their persistence. The gravels of these terraces were carried to their present position by the streams which formed the terraces, and they therefore vary in character with the rocks through which the stream has flowed. Some of the terrace gravels are locally derived and are wholly of one kind of rock, as limestone or sandstone. In other cases the gravels are drawn from various sources and consist of mixtures of different rocks, among which are limestone, quartzite, sandstone, ironstone, quartz, chalcedony, and occasionally granite. In general the terrace deposits are thin, though west of Edgemont they are deep enough to supply gravel for local use.

Well-developed terraces occur at various levels up to about 200 to 300 feet above the present valley floors, though comparatively few are at an elevation of more than 150 to 200 feet.

On the Dakota sandstone slope at the northern margin of the quadrangle and east of Pass Creek there is a gravel deposit capping a small plateau remnant cut in Graneros shale about 400 feet above the nearest point on Pass Creek, but this is probably older than Quaternary. Northeast of Edgemont there are other deposits, in part on Graneros shale and in part on Dakota sandstone, which range in altitude from a little over 300 feet to about 700 feet above the flat at Edgemont, and which are believed to represent Oligocene sediments, possibly rearranged in later times; but perhaps, however, they are all of Quaternary age and were deposited by Cheyenne River during an early stage of its development.

The bowlder deposit capping the low divide just west of Chilson siding appears to represent an old channel of Chilson Creek, formed before the present Chilson Canyon led the drainage of this valley to the southeastward, and is doubtless of early Quaternary age.

Alluvial deposits.—Alluvial flats of greater or less extent occur along Cheyenne River and its branches. They are most extensive in the open valleys formed in the soft Graneros shales, while in the narrow, steep-walled gorges which the river has cut in the hard rocks of the Dakota and Lakota formations the flats are much more limited, both in length and in width. They are found in these formations, for the most part, in the bends of the river on the lower side of the curve, and are not continuous for any considerable distance.

The alluvial deposits consist of sand and silt with occasional layers of gravel. A section on Beaver Creek near the western margin of the quadrangle shows 10 feet of sandy alluvium lying on 3 feet of gravel which rests on Graneros shales.

The deposits in general are thin, seldom exceeding 25 feet in thickness even where they are most extensively developed. On this account and because of the depth of the more important stream channels below their alluvial flats, there are frequent exposures of the underlying rocks along the stream courses, especially on the outer margins of their meanders.

Deposits similar to those found along Cheyenne River also occur to a greater or less extent along all the stream courses of the quadrangle. They are most extensively developed along the larger stream courses and in valleys cut in the softer rocks. The small streams flowing in relatively narrow canyons in the harder rocks have formed correspondingly small alluvial deposits. All the canyons in the hard Dakota or Lakota rocks are narrow, giving little room for the development of alluvial flats. The same thing is true of the Minnekahta limestone area. On the other hand, the more important tributaries of Cheyenne River which flow through the softer formations are all bordered by comparatively wide alluvial benches. Such benches are well seen in the valleys of Pass, Moss Agate, Cottonwood, and Hat creeks, especially the last. Hat Creek, next to Cheyenne River, is the most important stream of the quadrangle, and its alluvial deposits are second in width only to those bordering the Cheyenne. Though thin they average about a mile in width for that part of the stream that lies within the limits of the quadrangle. Near Ardmore they contain a considerable amount of wash from Oligocene and Miocene formations brought down from the badlands and from Pine Ridge, a few miles to the south.

Excellent examples of the difference in the development of alluvial deposits on streams running in hard and in soft rocks are furnished by Chilson and Red canyons. The stream in the former, while flowing for the greater part of its length in a narrow canyon cut in the hard Dakota and Lakota rocks, has its headwaters in the broad Bradley Flat south of Minnekahta, developed in the much softer rocks of the Sundance formation. The stream from Red Canyon emerges from the narrow valley cut in the Dakota-Lakota hogback into the open alluvial flat northeast of Edgemont, developed in the soft Graneros shale.

One or two low terraces northwest of Edgemont have been included on the map with the narrow alluvial deposits bordering Cheyenne River. These terraces are only a little above the valley bottom bordering the river and are in reality a part of the alluvial floor of the valley. They are broad and are covered with alluvial deposits similar to those close to the river, the underlying rocks being exposed here and there along the edge of the terrace northeast of the river.

In the valley of Cascade Creek an unusual alluvial deposit occurs about one mile north of Cheyenne River. At this point the stream flows in a narrow trench which has been recently cut in the valley floor and which exposes the alluvial deposits to a depth of about 25 feet. At the top of the section thus formed there are about 2 feet of calcareous tufa, deposited by the waters from Cascade Springs; beneath the tufa are a few feet of horizontally bedded, light-colored clays with some scattered pebbles in layers; while the lower part of the cliff is composed of a dark-gray, fine-grained clay which exhibits a vertical columnar structure resembling that seen in cliffs of loess.

Dune sand—Wind-blown sand, derived mainly from the recent alluvial deposits of the flats bordering Cheyenne River, and probably also in part from the older terrace deposits, occurs at a number of points, the chief of which are as follows: Northwest of Moss Agate Creek, north and south of Edgemont, and bordering Hat Creek in the neighborhood of Maitland. The last occurrence extends nearly 6 miles south of Cheyenne River. The sands have been spread irregularly over the uplands by the prevailing northwesterly winds. These wind-blown deposits, though comparatively thin, exhibit typical sand-hill topography, with

Edgemont.

well-defined dunes and blow-outs, especially west of Moss Agate Creek, north of Edgemont, and northeast of Maitland.

STRUCTURAL GEOLOGY.

Structure of the Black Hills uplift.—The Black Hills uplift, if not eroded, would present an irregular dome at the northern end of the anticlinal axis which extends northward from the Laramie Range of the Rocky Mountains (see fig. 1). The dome is elongated to the south and northwest, has steep slopes on the sides, is nearly flat on top, and is subordinately fluted to a minor extent. The greatest vertical displacement of the strata, as indicated by the height at which the granite floor is now found, amounts to about 9000 feet. The subordinate flexures in the dome are mainly along the eastern side of the uplift, the most notable ones being in the ridge of Minnekahta limestone just west of Hot Springs, which may be regarded as a bifurcation of the southern edge of the dome. Another anticline of considerable prominence occurs 3 miles east of Hot Springs. The subordinate flexures are characterized by steeper dips

FIG. 1.—Black Hills uplift represented by contours on the surface of Minnekahta limestone. Where the Minnekahta limestone has been removed by erosion the calculated position of the contours is shown by broken lines. Long dashes indicate areas from which Minnekahta and overlying formations have been eroded; short dashes, areas from which all sedimentary rocks have been removed. Contour interval, 250 feet.

B, Bear Butte; B B, Black Butte; B L, Bearlodge Range; C, Crook Mountain; C P, Crow Peak; D, Deadwood; D T, Devils Tower; E, Elkhorn Ridge; E M, Edgemont; G, Green Mountain; H, Harney Peak; H S, Hot Springs; I N, Inyankara Mountain; M B, Little Missouri Buttes; N, Nigger Hill; N C, Newcastle; O L, Oelrichs; O W, Old Woman Creek; R, Rapid; S, Sundance; S T, Sturgis.

on their western side and gentler dips to the east. They merge into the general dome to the north and run out with declining pitch to the south. On the western side of the main uplift there is a marked local steepening of dips and at the north an abrupt deflection of the dome to the northwest, which is one of its most notable irregularities. To the south the dome is separated from a small local anticline, which is the extension of the Laramie Range uplift, by a shallow syncline extending northwest and southeast. In the northern Black Hills there are numerous local domes and flexures, due mainly to laccolithic igneous intrusions, of which the most prominent is that of the Bearlodge Range, but no similar features are indicated by the structure of the southern hills.

Faults are of rare occurrence, and none have been detected which amount to more than a few feet of vertical displacement, except where some of the igneous masses have dislocated the strata and elevated them unevenly.

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

Structure of the Edgemont quadrangle.—The principal structural features of this quadrangle are illustrated by the five structure sections on the structure-section sheet. Under the plains in the southwestern portion of the area, the strata lie in gentle undulations, but to the east and north they extend high on the southern slopes of the Black Hills dome, rising about 5000 feet in all from south to north. While there is a general slope to the south and southwest off the dome, it is traversed by anticlines pitching southward. The most prominent of these passes near Cascade Springs, where it is very steep; another less prominent one extends far to the south, up the valley of Hat Creek, while a small anticline extends up the valley of Cottonwood Creek southwest of Edgemont. In fig. 2 is shown the contour of the principal structural features of the Edgemont and Oelrichs quadrangles. The lines represent the altitude of the surface of the Dakota sandstone, which is supposed to be restored in the north-central portion of the area, from which it has been removed by erosion.

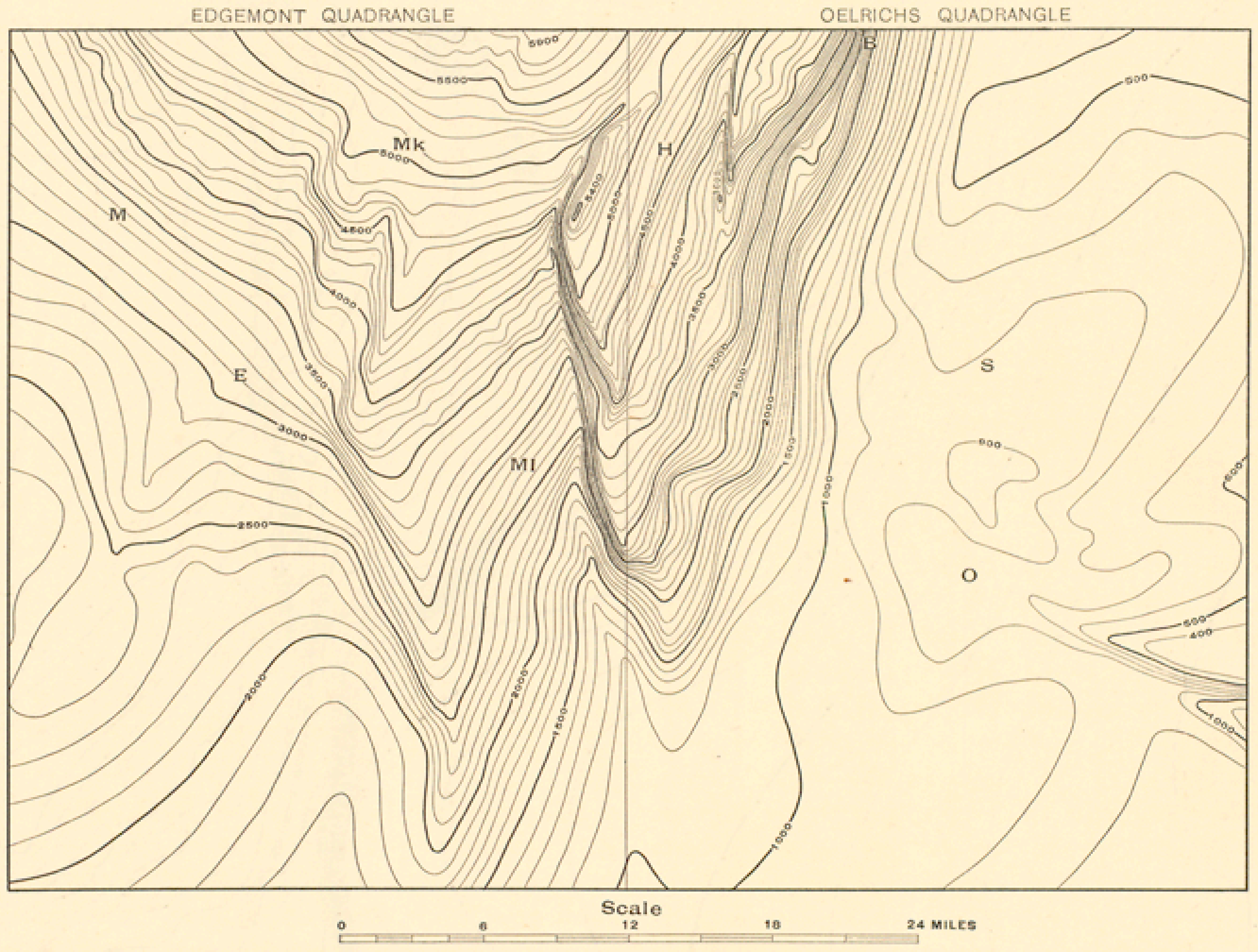


Fig. 2.—Diagram showing contour of surface of Dakota sandstone in Edgemont and Oelrichs quadrangles. The lines represent altitudes above sea level and are 100 feet apart vertically.
B, Buffalo Gap; E, Edgemont; H, Hot Springs; M, Marietta; Mk, Minnekahta; Mi, Maitland; O, Oelrichs; S, Smithwick.

It will be seen from this diagram that in the Edgemont quadrangle there is a gradual rise of the strata from south to north and northeast. The greatest rise is near the northeast corner of the area. The uplift having been planed off by erosion, so that the land slopes less steeply than the strata, the outcrop zones of the formations cross the quadrangle from northwest to southeast, the oldest rocks reaching the surface in the northeast corner. Owing to the succession of north-south flexures by which the slope of the uplift is corrugated, the formations dip in varying directions and degrees of steepness, so that their rise is irregular. In a broad district about Edgemont and to the north and west the strata present regular, gentle dips to the southwest, the amounts varying from 100 to 200 feet to the mile, with marked increase up the slopes of the hogback range from Sheep Canyon to Pass Creek. On this monocline the formations from Niobrara to Minnelusa outcrop in regular order and present but few local variations in altitude, except along a local fault northeast of Cravens. This fault cuts the Spearfish and Sundance beds, trends southwest at right angles to the strike, and has a displacement of about 70 feet, with the drop on the north side. South of Edgemont the formations from upper Graneros to Pierre are involved in a broad, low anticline the axis of which extends up the valley of Cottonwood Creek. It rises on the general uplift, but does not appear in the Dakota sandstone outcrops. East and southeast of Edgemont the southeast-dipping monocline continues to Ardmore and beyond, separated from the Cottonwood Creek anticline by a low syncline presenting broad outcrops of Greenhorn, Carlile, Niobrara, and Pierre formations, pitching gently to the south. The monocline steepens rapidly 4 miles southeast of Edgemont, and then for several miles its slope is marked by a sharp ridge of Greenhorn limestone, dipping more steeply to the west-southwest, the angle being 18° for some distance. It is the western side of the Chilson anticline, which may be regarded as the prolongation of the main axis of uplift of the Black Hills dome. It separates from the general curve of the dome near Minnekahta station, attains prominence in the ridge east of Chilson, and arches the Dakota, Graneros, Greenhorn, Carlile, Niobrara, and Pierre formations, causing their outcrops to extend far to the south, as the pitch of the flexure carries them in succession beneath the surface. Cheyenne River cuts across the Dakota and Lakota sandstones in this anticline in a deep gorge, at the western entrance to which the sandstones rise with a dip of about 5°. To the south the Dakota sandstone extends across the arch, but in Chilson Canyon and northwest of Chilson it has been widely removed by erosion. At Parker Peak a small outlier of hard Dakota sandstone remains on the crest of the arch. West of this knob there is a small local anticline, and some local steepening of dips, which give rise to considerable complexity of relations in the vicinity of Matias Peak. On the east side of the Chilson anticline the strata dip so gently to the southeast that in the region east and southeast of Parker Peak the Dakota and Lakota sandstones are spread out broadly in a southward-sloping plateau, the north edge of which presents a high-level crest line south of the Red Valley between Minnekahta and Jones. To the south the beds east of the axis pass beneath the surface in regular order, but south of Cheyenne River the anticline becomes narrower and the dips on the east side gradually change to east-southeast. There is on this side the Coffee Flat syncline, in which Pierre shale and underlying formations extend far northward, which is succeeded on the east by the Cascade anticline. In the Coffee Flat syncline the Graneros shales extend across Cheyenne River, which has cut a wide plain in them, known as Coffee Flat, and a narrow basin of Dakota sandstone extends northward to a point 3 miles north of Cascade Springs. This syncline is prolonged for several miles to the northeast, finally dying out in the Minnekahta limestone north of Hot Springs. The high Cascade anticline rises abruptly, presenting steep dips on its western side, gentle dips to the east, a rapid pitch to the south, and from its culmination 4 miles north of Cascade Springs a gentle pitch to the northeast. This anticline extends the Minnekahta limestone far to the south, in a high ridge with steep western slopes, in places cut into by canyons so as to reveal the underlying Opeche and Minnelusa formations. This ridge is flanked on the west by a red valley which trends north and south and which, owing to the steep dips, is only a few hundred yards wide. West of this valley rise slopes of Sundance formation to a steep monoclinal ridge of Lakota sandstone, the dip of which is vertical in places. At Cascade Springs the southerly pitch of the flexure carries the Minnekahta limestone beneath the surface, and the Spearfish red beds cross the axis and extend northeastward to Hot Springs with gentle dips, so that their outcrop spreads into a typical red valley a mile or more in width, with a hogback range on its east side. South of Cascade Springs the Lakota-Dakota sandstone ridge continues as a prominent feature, rising steeply above a Graneros shale valley. It is trenched by two deep gorges, and presents steep dips to the west. Cheyenne River crosses these formations in a deep gorge, south of which they soon pitch beneath Graneros shale. This shale area is bordered by a ridge and by escarpments of Greenhorn limestone, which are specially prominent on the west flank of the arch, where the dips are 20° or more to the west-southwest. These hogback ridges are shown in fig. 9 on the illustration sheet.

MINERAL RESOURCES.

SOILS.

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

Distribution.—The portion of the Edgemont quadrangle which lies in the plains is underlain mainly by shales consisting largely of clay, but there are also along the valleys extensive areas that are covered by alluvium. The soils of the clay region vary somewhat with the different formations. Those of the Pierre shale give rise to a stiff gumbo, which is not only very barren in itself, but is acid because of decomposing pyrites, and is too sticky for working. It is covered with grass, which originally afforded an excellent pasturage, but in some areas it has been grazed down by excessive herding, and, as the soil is not rich, the grass will require some time to regain its former growth. The basal series along the margin of the Pierre shale is barren and sustains scarcely any growth. The Niobrara beds are calcareous and fertile, and their area, if supplied with water, would be highly productive. The Carlile formation gives rise to clay soils mostly, but they are more sandy than those of the Pierre and correspondingly more easy to work. The Greenhorn limestone presents rocky surfaces that have but little soil upon them. The Graneros shales are mostly harder than the Pierre shale, but they are particularly barren and often extensively gullied.

The hogback range has a generally rocky surface, with a sandy soil which supports a growth of grass and scattered pines. It is nearly all too high for irrigation, and in most seasons does not receive sufficient rainfall to be profitably farmed. The Red Valley has a barren soil, but in the southern portion of Bradley Flats there is a wide area of alluvium in which the soil is excellent. The slopes of Minnekahta limestone present extensive rock outcrops and are generally occupied by the marginal pine forests of the Black Hills, but on some of the more level plains there is a scanty but fertile soil, which supports a fine growth of grass. The Minnelusa sandstone area in the northeast corner of the quadrangle consists mainly of rolling hills with sandy soils that contain considerable lime and are in consequence moderately fertile. They are useful for grazing, but are too dry for agriculture.

It is in the wide alluvial valleys which traverse the shale deposits that the best soils are found, and there the land is level, usually well drained, and would be in every way adapted to agriculture if it were supplied with water. The largest areas are along Cheyenne River from Argentine to the mouth of the gorge 3 miles east of Edgemont. The river bottoms about the mouth of Plum Creek and Coffee Creek, the valleys of Hat Creek, Plains Creek, Cottonwood Creek, and Alum Creek, and portions of the alluvium along Cheyenne River are rather too sandy for cultivation, but there are extensive areas of sandy loam which are highly productive when properly cultivated. An irrigation ditch has been built along the south side of the river from the mouth of Beaver Creek to Edgemont, but is not in use. Along the foothills are numerous localities in which water could be stored and made available for irrigating flats along Cheyenne River and Hat Creek.

WATER RESOURCES.

SURFACE WATERS.

The flowing streams of the Edgemont quadrangle are Cheyenne River, Cascade Creek, Beaver Creek, and Hat Creek. Red Canyon contains a small flow of water near the mouth of Craven Canyon, and there are pools of water in other streams, especially Indian, Cottonwood, Moss Agate, and Pass creeks. Cheyenne River is a torrent during floods, but these occur only at long intervals. In midsummer its flow averages only from 10 to 15 second-feet at Edgemont. Along most of its course its freshet waters could be impounded if they were needed, but long and very substantial dams would be required to withstand the sudden heavy floods which follow the rains. Cascade Creek is a vigorous stream which is supplied entirely by the springs at Cascade, where a large volume of water issues from the Minnekahta limestone. The water is warm and contains a slight amount of mineral matter, as is shown by the following analysis (given in terms of the probable combinations), kindly furnished by the Burlington and Missouri River Railroad Company:

Analysis of water from Cascade Creek, South Dakota.

	Grains per U. S. gallon.
Sodium chloride	3.97
Sodium sulphate	.29
Calcium sulphate	119.84
Calcium carbonate	34.75
Magnesium carbonate	15.68

In the flat which this stream crosses to reach Cheyenne River some of the water has been employed for irrigation with most gratifying results, but only a portion of its volume is utilized. The volume of the creek at its mouth averages about 25 second-feet. Hat Creek rises in Pine Ridge, where it is fed by numerous springs, but in its long flow across the arid plains north it loses much of its water and at its mouth is usually a very small stream. Beaver Creek, which empties into Cheyenne River south of Argentine, is a flowing stream that averages about 5 second-feet during summer.

Irrigation.—On the plains adjoining the Black Hills there are usually long periods of drought in summer, so that irrigation is necessary for raising crops. In many of the valleys there are wide areas of fertile soils suitable for agriculture, and to portions of them it is practicable to carry water for irrigation. At present only a small area of land is being irrigated in the Edgemont quadrangle. The water of Cascade Creek and to a small extent that of Cheyenne River north and northeast of Maitland are used. Several years ago a reservoir was constructed at the mouth of Beaver Creek and a canal was built along the southwest side of the Cheyenne Valley to Edgemont, but the dam was washed out and the ditch is not now in use. With the expectation of having water, a number of farmers settled on the lands covered by the ditch, but most of them have given up their farms and left the region. With the construction of a suitable dam on the river and the installation of water storage in the many valleys and canyons of the region, irrigation could be practiced extensively and a community of considerable size be supported.

UNDERGROUND WATERS.

The occurrence of underground water in the Edgemont quadrangle is of interest mainly in the plains adjoining the Black Hills, under which there extend several thick sheets of water-bearing sandstone. Receiving water from rainfall at the surface in the hogback range, these sandstones conduct it underground along the eastward dip to a considerable depth within a comparatively short distance. Where the inclination of the strata diminishes away from the hills, as it generally does, there is a wide area beneath which the water-bearing beds lie at a depth that is within reach of the well borer. As the region is semiarid and the surface water often contains much "alkali," there is great need for underground waters at most places. In the columnar section are shown the relations of the principal water-bearing horizons. The principal water supplies are to be expected in the Lakota and Dakota sandstones. These strata are exposed over a wide zone in the hogback range, where, by imbibition and by sinkage from streams, they receive a considerable proportion of the rainfall, which very slowly flows in the permeable sandstones completely under the State of South Dakota and emerges in great springs and general surface seepage in the outcrops of Dakota and Lakota sandstones in the Missouri Valley in the southeast corner of the State. The altitude at which this water enters the beds is from 3000 to 3500 feet above sea in greater part; it emerges at the surface to the east at an altitude of about 1200 feet, and in the intervening country its head gradually diminishes from source to outflow. In eastern South Dakota numerous flowing wells, from 400 to 1000 feet deep, furnish large volumes of water from the Dakota and Lakota sandstones, and it is believed that this water is available in the region lying westward, up to the flanks of the Black Hills, under conditions which are set forth on the artesian water map of this folio.

The depth of the uppermost water-bearing sandstone beneath the surface at any point is shown by patterns of color, each one of which represents a vertical distance of 500 feet; thus one represents depths from 0 to 500 feet, the next from 500 to 1000 feet, and so on. In the areas in which the head of water is sufficient to afford surface flow the pattern is printed in blue, and where a flow may not be expected it is printed in green. Unfortunately, the area of flow is relatively restricted, lying mostly within the immediate vicinity of the valley of Cheyenne River above Marietta. There are also drawn on the sheet lines representing intervals of 100 feet, which show the height to which the underground waters may be expected to rise above sea, or, in other words, their head. These lines afford means for ascertaining how near the surface the water may be expected to rise in wells which do not afford a flow, and also the pressure of the water in the area of the flow. The depth below the surface at which water would stand in a well in the non-flowing area may be found by subtracting the altitude of head from the altitude of the land, shown by the brown contour lines on the base map. It will be noticed that the altitude to which the water may be expected to rise increases to the west, for in that direction the sources of supply are very much higher than they are to the south, where Cheyenne River crosses the hogback range.

On the columnar section sheet are shown the formations which must be penetrated, and these can be recognized by their characteristics as described in the table and by the fossils referred to below. From the areal geology map can be ascertained in which formation the well is started. Two of the most important fossils for determining the geologic horizon are *Ostrea congesta* and *Inoceramus labiatus* (see fig. 11, illustration sheet). The former occurs crowded together and constitutes thin layers of limestone in the upper portion of the Niobrara chalk beds, which, although bright yellow when exposed on the surface, are of a pale blue-gray color when first brought out by the well boring. *Inoceramus labiatus* is characteristic of the Greenhorn limestone, which is hard and of buff color on the surface, as seen in the many outcrops in the escarpment just east of the hogback range, but is of dark-gray color and soft texture underground. The zone of concretions and the thin layers of sandstone in the Carlile formation will be encountered by the well borer and recognized by their hardness and their stratigraphic relations. In most areas it will be necessary to bore deeply into the Dakota and possibly also into the Lakota sandstone to reach the principal water horizon.

Several wells have been bored in the Edgemont quadrangle. Some of these have been successful and others have failed to yield water.

Edgemont wells.—In Edgemont and its vicinity a number of wells were sunk several years ago for water from the Dakota sandstone. They nearly all obtained supplies for pumping, but, owing to the low level of the outcrops of the Dakota sandstone in the vicinity, the water did not have sufficient head to flow. The water did not prove satisfactory for use in locomotives, and all the wells except the deep one at the railroad roundhouse have been abandoned.

The records of two wells are given in figs. 3 and 4. One of the wells at the roundhouse, of which the log is given in fig. 3, has a depth of 1125 feet, but is now filled to the depth of 700 feet. Water of bad quality was found in the white sand at 295 feet and in the sandstone at 977 feet. Fairly good water, rising to within 60 feet of the surface, is now obtained from the sandstone which begins at a depth of 509 feet. It contains 239 grains of solid matter per gallon, of which 9.33 grains are lime. The log appears to be a fairly reliable one, indicating Dakota sandstone from 295 to 350 feet, Fuson formation 350 to 430 feet, Lakota formation 430 to about 652 feet, Morrison shales 652 to 802 feet, Sundance shales and sandstones with the characteristic red series 957

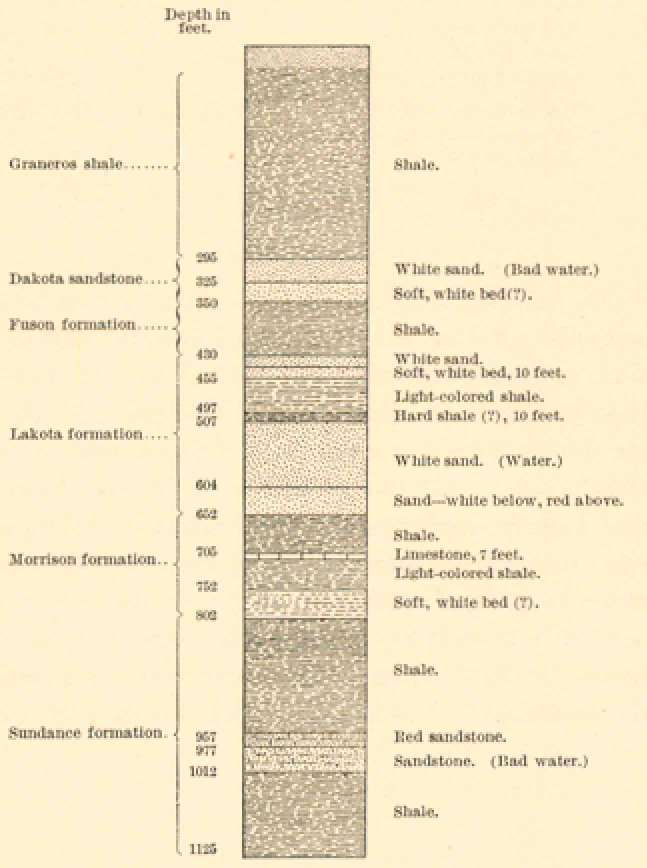


Fig. 3.—Log of deep well at Edgemont, S. Dak.

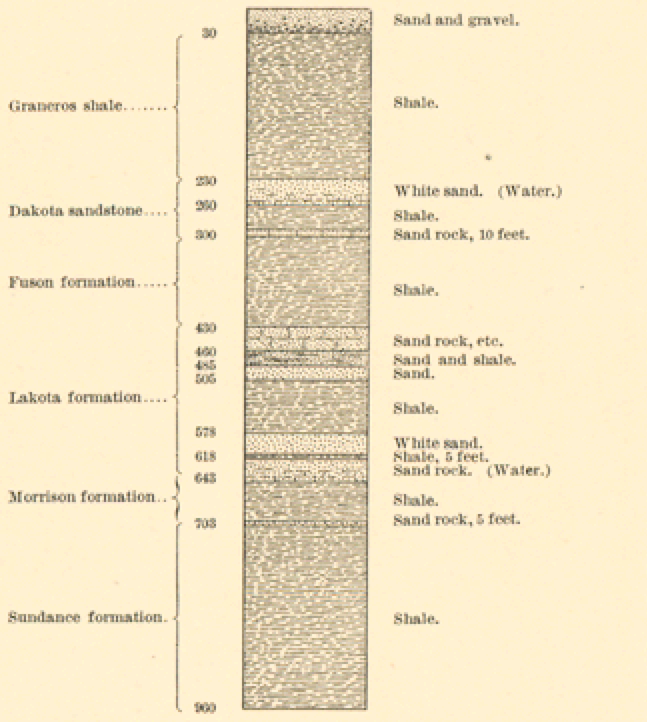


Fig. 4.—Log of deep boring at the railroad Y north of Edgemont, S. Dak.

to 977 feet, and the bed of buff sandstone 977 to 1012 feet, with the basal dark shales thence to 1125 feet, which is probably not far above the top of the red beds of the Spearfish formation. The well at the north end of the Y across the river from Edgemont has a depth of 960 feet, and probably ends in Sundance shales, but the record appears not to be reliable in its details. Some water was found in the white sand at 230 feet, and in sandstones at 290 and 430 feet. At 578 feet a sandstone begins which yields a good supply of water, rising to within 30 feet of the surface. A thin sand rock at 703 feet also yields water, but its volume is small.

Minnekahta boring.—Several years ago the Burlington and Missouri River Railroad Company made a deep boring at Minnekahta station to obtain a water supply for locomotives. A depth of 1348 feet is said to have been attained, but no satisfactory amount of water was found. The log, which is given in fig. 5, is clearly an unreliable one and very unsatisfactory for the identification of the geologic formations. No clue is given as to the location of the Minnekahta formation, which should be expected to begin at about 300 feet below the surface. The red sands from 743 to 908 feet are doubtless in the Minnelusa formation. At a depth of 1348 feet the boring should be near the granite or schist bed rock, for the thickness of the formations from the middle of the Spearfish to the base of the Cambrian is not much more than this in the surface exposures in the region to the north. The references to gypsum at various depths in the boring are mistakes as to the identity of the material, excepting those near the top. It is to be deeply regretted that the log is not more accurate, for it could have thrown important light on the stratigraphy.

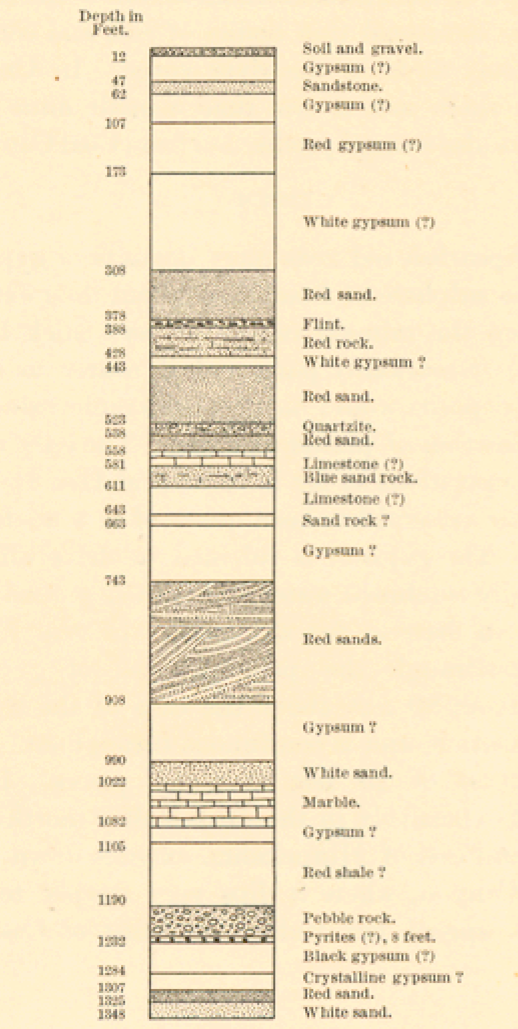


Fig. 5.—Log of deep boring at Minnekahta, S. Dak.

Ardmore boring.—At Ardmore, on the Burlington and Missouri River Railroad, near the southern border of the quadrangle, the railroad company has made a boring to a depth of 1500 feet without obtaining water. The hole is entirely in shale, except about 40 feet of white sand containing thin partings of black shale. This boring begins just about at the top of the Niobrara formation, and apparently penetrates very nearly to the Dakota sandstone, the sandstone bed reported probably being in the lower Graneros shales. As Ardmore is at an altitude of 3557 feet and the water-bearing Dakota sandstone outcrops about Edgemont are at an altitude of 3400 feet, there is no possibility of a flow at the former place, but probably a supply of water for pumping could be obtained by deepening the boring into the the Dakota sandstone. The estimated altitude to which the water would rise in such a well is about 3450 feet.

Argentine well.—This station is a water-tank siding on the Burlington and Missouri River Railroad, in the northwest corner of the quadrangle. The well is on the south side of Pass Creek, a short distance west. It is a flowing well 550 feet deep, yielding a fairly large volume of water, but of a quality not satisfactory for locomotives, as the following analysis will show (the probable combinations of the components are given):

Analysis of artesian water from Argentine, S. Dak.

	Grains per U. S. gallon.
Sodium sulphate	39.90
Potassium sulphate	.90
Calcium sulphate	4.20
Calcium carbonate	6.00
Magnesium carbonate	4.00
Alumina and iron oxide	.05
Silica	.19
Total solids	55.24
Organic matter	.55

This analysis was furnished by the railroad company. The log of the boring was not obtainable. The well begins in Graneros shale and undoubtedly obtains its water supply from the Lakota sandstone, which outcrops in the high ridge to the east.

COAL.

The Lakota formation contains local coal basins, but no large amount of coal has been found in any of them. The principal openings have been made on the north bank of Cheyenne River, in the NW. ¼ of NE. ¼ sec. 24, T. 9 S., R. 3 E., where there are two tunnels 75 feet or more in length about 30 feet above the river, from which a small supply of coal has been obtained. The bed is 5 feet thick for some distance, but it averages much less. It thins out to the east and gives place to sandstone, as may be plainly seen in the bluffs below the river, and it grades into very coaly shale to the northwest. The mine product was in part light-weight bituminous coal of good quality, containing thin, bony layers, and only a moderate amount of pyrite. To the east only a trace of coal was found in the Lakota formation, but to the north there are occasional thin bodies of coal and considerable coaly shale in the river gorge. In Craven Canyon there was at one time a small mine, and there was also a small production from Coal Canyon.

GYPSUM.

The Spearfish red beds carry deposits of gypsum (hydrous sulphate of lime) throughout their extent, and often the mineral occurs in very thick beds. These are remarkably pure, and if nearer to market the deposits would be of considerable value for the production of plaster of Paris. The only commercial operations so far have been at Hot Springs where the mineral has been quarried to a moderate extent. The gypsum is calcined to drive off the chemically combined water and is then ground and packed in barrels for shipment. In the Edgemont quadrangle the principal bed of gypsum occurs about 80 feet above the base of the Spearfish formation, and is continuous throughout, with a thickness of 25 feet at many places. It is exposed extensively in the Red Valley northwest, north, and east of Minnekahta, extends down Alabaugh Canyon, where it dips very steeply to the west, is spread out widely southeast of Cascade Springs, and passes northward up the valley east of the anticline to Hot Springs.

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

Analysis of gypsum from near Cascade Springs, South Dakota.

	Per cent.
Lime (CaO)	32.44
Magnesia (MgO)	.33
Alumina (Al_2O_3)	.12
Silica (SiO_2)	.10
Sulphur trioxide (SO_3)	45.45
Carbon dioxide (CO_2)	.85
Water (H_2O)	20.80
Total	100.09

BUILDING STONE.

No building stone, so far as known, is now being quarried in the Edgemont quadrangle, although Dakota sandstone has been used in several buildings in Edgemont and Cascade Springs, and there are a number of quarries a few miles east of the quadrangle. Of the rocks available, the Dakota and Lakota sandstones are best adapted for building purposes. Though ranging from a soft sandstone to a hard quartzite, they are for the most part only moderately hard. The beds are massive, easily worked when freshly exposed, and readily accessible. The colors, which are mostly permanent, vary from pale gray or nearly white to buff and occasionally reddish. The amount available is large, but its extensive occurrence elsewhere, as a rim entirely surrounding the Black Hills, and at numerous points along the Rocky Mountain front and in the Great Plains region, together with the expense of long-distance shipments, restricts its use largely to local purposes.

The Unkpapa sandstone, which has also been quarried in the Oelrichs quadrangle, is extensively represented in this quadrangle. The rock is massive, fine grained, and easily dressed, but is rather soft. It is usually characterized by delicate colors. Some of the beds are buff, gray, or nearly white, in solid colors; others are banded or mottled, with red, gray, buff, purple, and other tints. One bed on the east side of Sheps Canyon appears a dazzling white at a distance, but near at hand is seen to be tinted a delicate pink.

In addition to these rocks, some of the buff slabby sandstones in the lower part of the Sundance formation might prove serviceable locally for building purposes, and in fact have been so used at Hot Springs, in the Oelrichs quadrangle.

GRINDSTONES.

About 3½ miles north-northeast of Edgemont an upper member of Dakota sandstone has been quarried to some extent for grindstones. The product was not large and at present the quarry is not in operation, but a good supply of the stone appears to be available and the quality is excellent. The conditions for working are favorable, as the beds are in a high bank on the north side of Red Canyon, with plenty of room for the disposal of waste. Considerable stripping is necessary. The dip is to the southwest at a low angle. The quarry is shown in fig. 10 on the illustration sheet. Portions of the sandstone at the grindstone quarry above described are of fine uniform grain and of such character as to be suited for giving the finest edge to tools. Shipments have been made and the material is said to have been received with great favor by tool finishers and cutters, and some of it is entirely satisfactory for sharpening razors.

LIMESTONE.

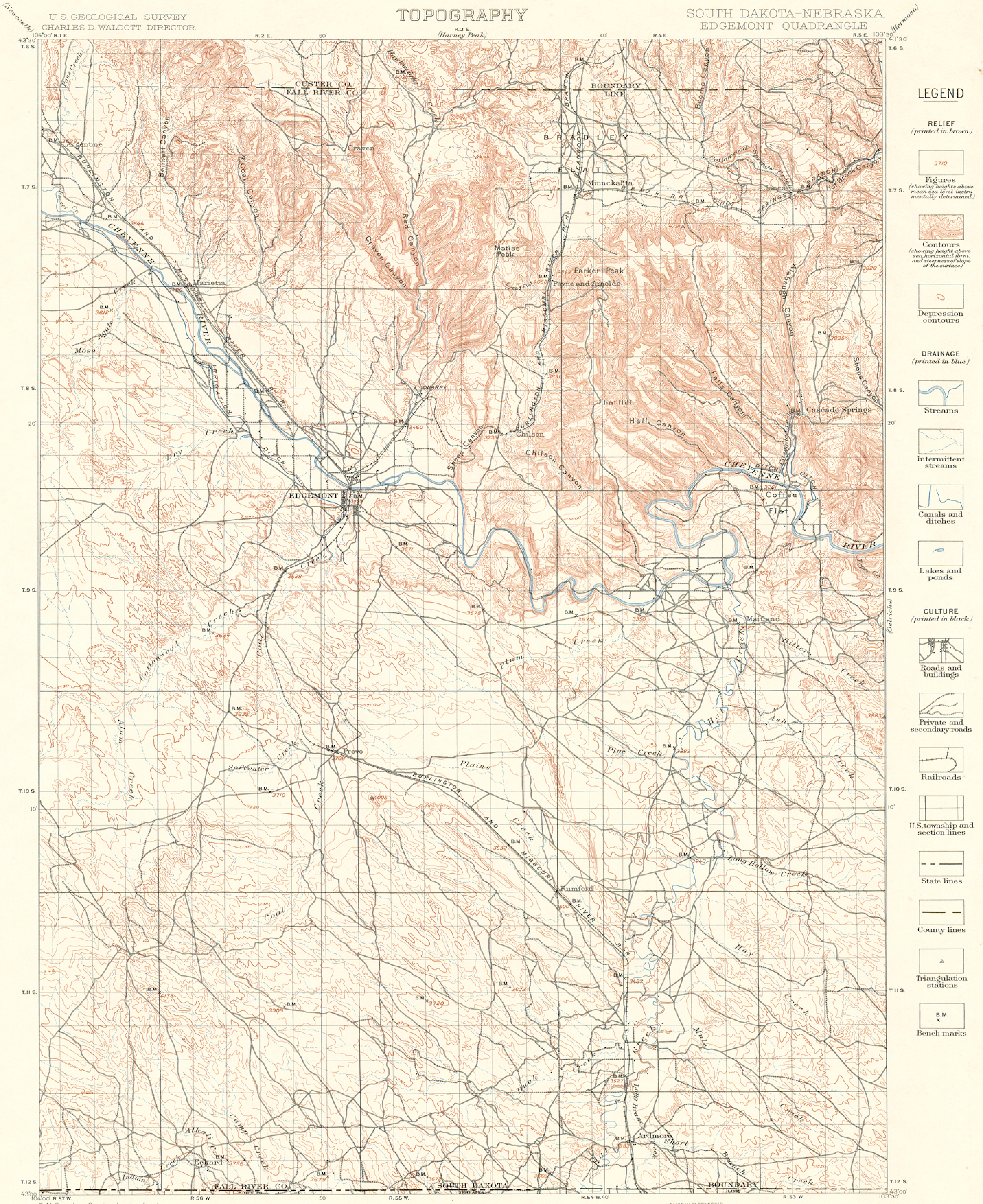
Limestone for making lime and for other purposes may be obtained in abundance from the Minnekahta formation, and the Minnewaste limestone is also available for such uses in the region south and southeast of Cascade Springs.

April, 1903.

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

TOPOGRAPHY

SOUTH DAKOTA–NEBRASKA
EDGEMONT QUADRANGLE



E. M. Douglas, Geographer in charge.
Triangulation by E. M. Douglas and A. F. Dunnington.
Topography by A. F. Dunnington.
Surveyed in 1900.

APPROXIMATE MEAN DECLINATION 1900.

Scale 1/125000

Contour interval 50 feet.
Datum is mean sea level.

DIAGRAM OF TOWNSHIP

Edition of July 1903.

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

AREAL GEOLOGY

SOUTH DAKOTA–NEBRASKA
EDGEMONT QUADRANGLE

LEGEND

SEDIMENTARY ROCKS
(continued)

CARBONIFEROUS

Permian series ?

- Cmk — Minnekahta limestone *(very thin-bedded gray limestone in massive ledges)*
- Co — Opeche formation *(bright-red sandy shale; purplish at top)*

Pennsylvanian series

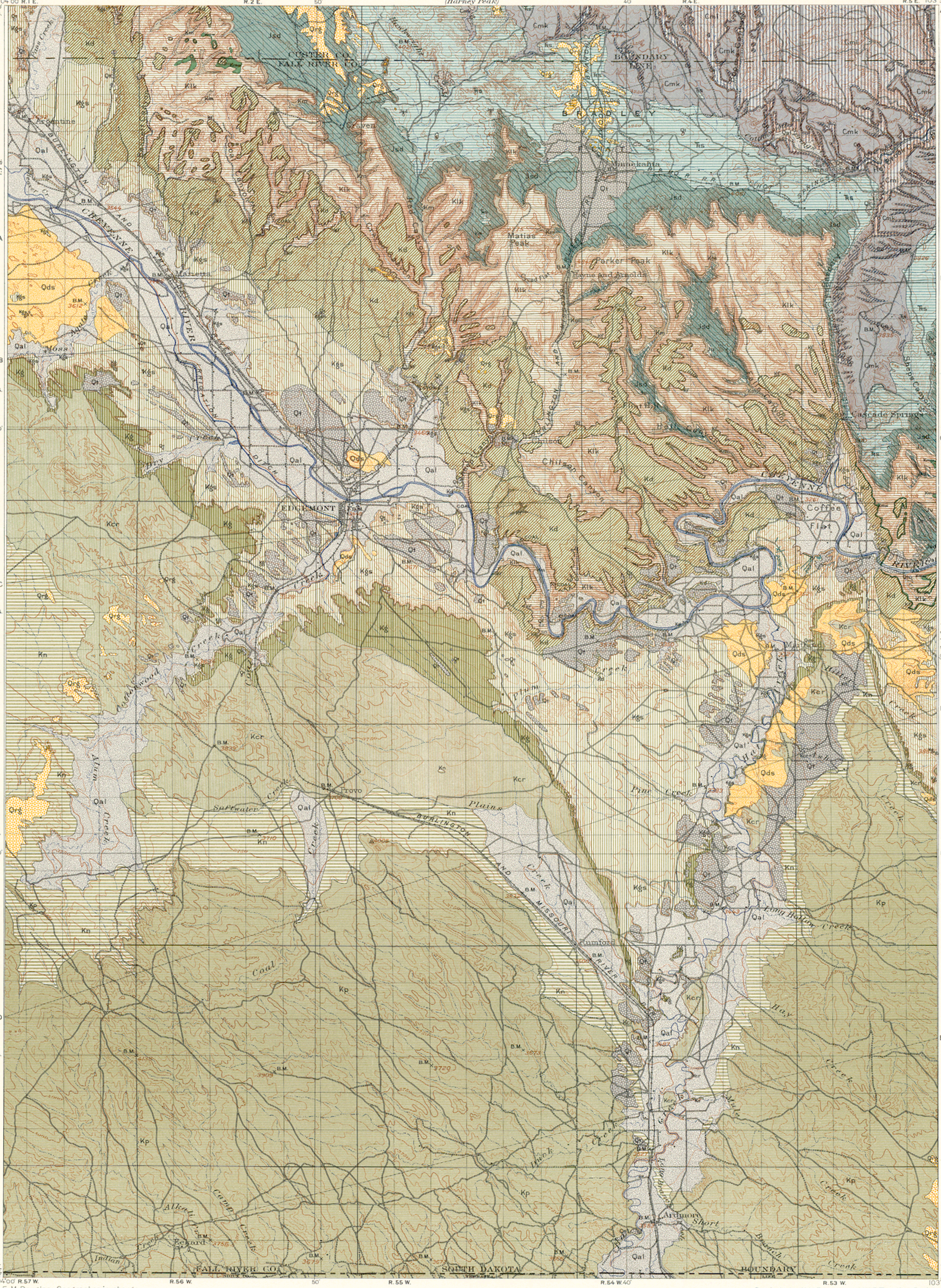
- Cml — Minnelusa sandstone *(red, yellow, and gray calcareous sandstone)*

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

Faults

Sections

⚒ *Coal mines and stone quarries*
× *Coal prospects*



E. M. Douglas, Geographer in charge.
Triangulation by E. M. Douglas and A. F. Dunnington.
Topography by A. F. Dunnington.
Surveyed in 1900.

APPROXIMATE MEAN DECLINATION 1900.

Scale $\frac{1}{125000}$

Contour interval 50 feet.
Datum is mean sea level.
Edition of Dec. 1903.

DIAGRAM OF TOWNSHIP

Geology by N. H. Darton and W. S. Tangier Smith.
Surveyed in 1900 and 1902.

LEGEND

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

QUATERNARY

Recent

- Qds — Dune sand
- Qal — Alluvium *(only the larger deposits represented)*

Pleistocene

- Qt — Older terrace deposits *(sand, gravel, and loam)*
- Qrg — Residual gravel *(from Chadron formation)*

TERTIARY

Oligocene series

- Tc — Chadron formation ? *(sandstone, gravel, and loam)*

UNCONFORMITY

CRETACEOUS

Upper Cretaceous series

- Kp — Pierre shale *(dark-gray shale or clay with concretions)*
- Kn — Niobrara formation *(impure chalky limestone or calcareous clay; weathers light buff)*

Benton group

- Kcr — Carlile formation *(gray shale and thin sandstone)*
- Kg — Greenhorn limestone *(impure slabby limestone)*
- Kgs — Graneros shale *(black fissile shale)*

- Kd — Dakota sandstone *(massive buff sandstone with thinner beds at top)*

Lower Cretaceous series

- Kf — Fuson formation *(massive sandy clay of various colors)*
- Kmw — Minnewaste limestone *(massive gray limestone)*
- Klk — Lakota formation *(massive buff sandstone with clay intercalations and local coal beds)*
- Km — Morrison formation *(gray, maroon, and purple clay)*

UNCONFORMITY

JURASSIC

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

UNCONFORMITY

TRIASSIC ?

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

Legend is continued on the left margin.

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

STRUCTURE SECTIONS

SOUTH DAKOTA–NEBRASKA
EDGEMONT QUADRANGLE

LEGEND

SEDIMENTARY ROCKS
(continued)

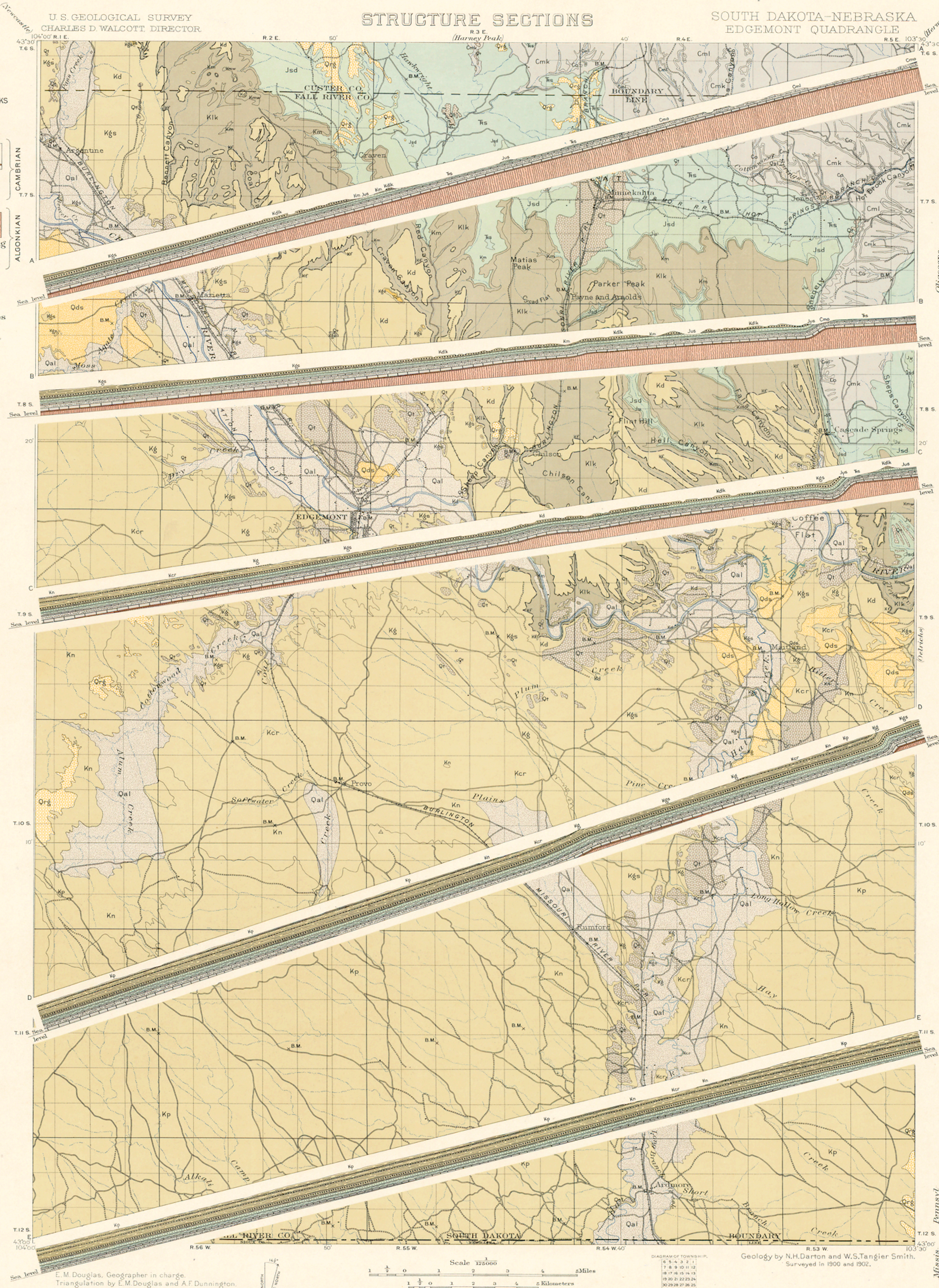
SHEET SYMBOL / SECTION SYMBOL

CAMBRIAN
- Deadwood sandstone (does not outcrop in this quadrangle)

ALGONKIAN
- Schist including granite (do not outcrop in this quadrangle)

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

Faults



E. M. Douglas, Geographer in charge.
Triangulation by E. M. Douglas and A. F. Dunnington.
Topography by A. F. Dunnington.
Surveyed in 1900.

APPROXIMATE MEAN DECLINATION 1900.

Scale $\frac{1}{125000}$

Miles / Kilometers

Edition of May 1904.

DIAGRAM OF TOWNSHIP.

Geology by N. H. Darton and W. S. Tangier Smith.
Surveyed in 1900 and 1902.

LEGEND

SEDIMENTARY ROCKS

SHEET SYMBOL / SECTION SYMBOL

QUATERNARY
- Recent
  - Qds — Dune sand
  - Qal — Alluvium (only the larger deposits represented)
- Pleistocene
  - Qt — Older terrace deposits (sand, gravel, and loam)
  - Qrg — Residual gravel (from Chadron formation)

TERTIARY
- Oligocene series
  - Tc — Chadron formation? (sandstone, gravel, and loam)

UNCONFORMITY

CRETACEOUS
- Upper Cretaceous series
  - Kp — Pierre shale (dark-gray shale or clay with concretions)
  - Kn — Niobrara formation (impure chalky limestone or calcareous clay; weathers light buff)
  - Benton group
    - Kcr — Carlile formation (gray shale and thin sandstone)
    - Kg — Greenhorn limestone (impure slabby limestone)
    - Kgs — Graneros shale (black fissile shale)
- Lower Cretaceous series
  - Kd — Dakota sandstone (massive buff sandstone with thinner beds at top) — Combined with Lakota formation on sections
  - Kf — Fuson formation (massive sandy clay of various colors) — Combined with Lakota formation on sections
  - Kmw — Minnewaste limestone (massive gray limestone) — Combined with Lakota formation on sections
  - Klk / Kdlk — Lakota formation (massive buff sandstone with clay intercalations and local coal beds)
  - Km — Morrison formation (gray, maroon, and purple clay)

UNCONFORMITY

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

UNCONFORMITY

TRIASSIC ?
- Trs — Spearfish shale (red sandy shale)

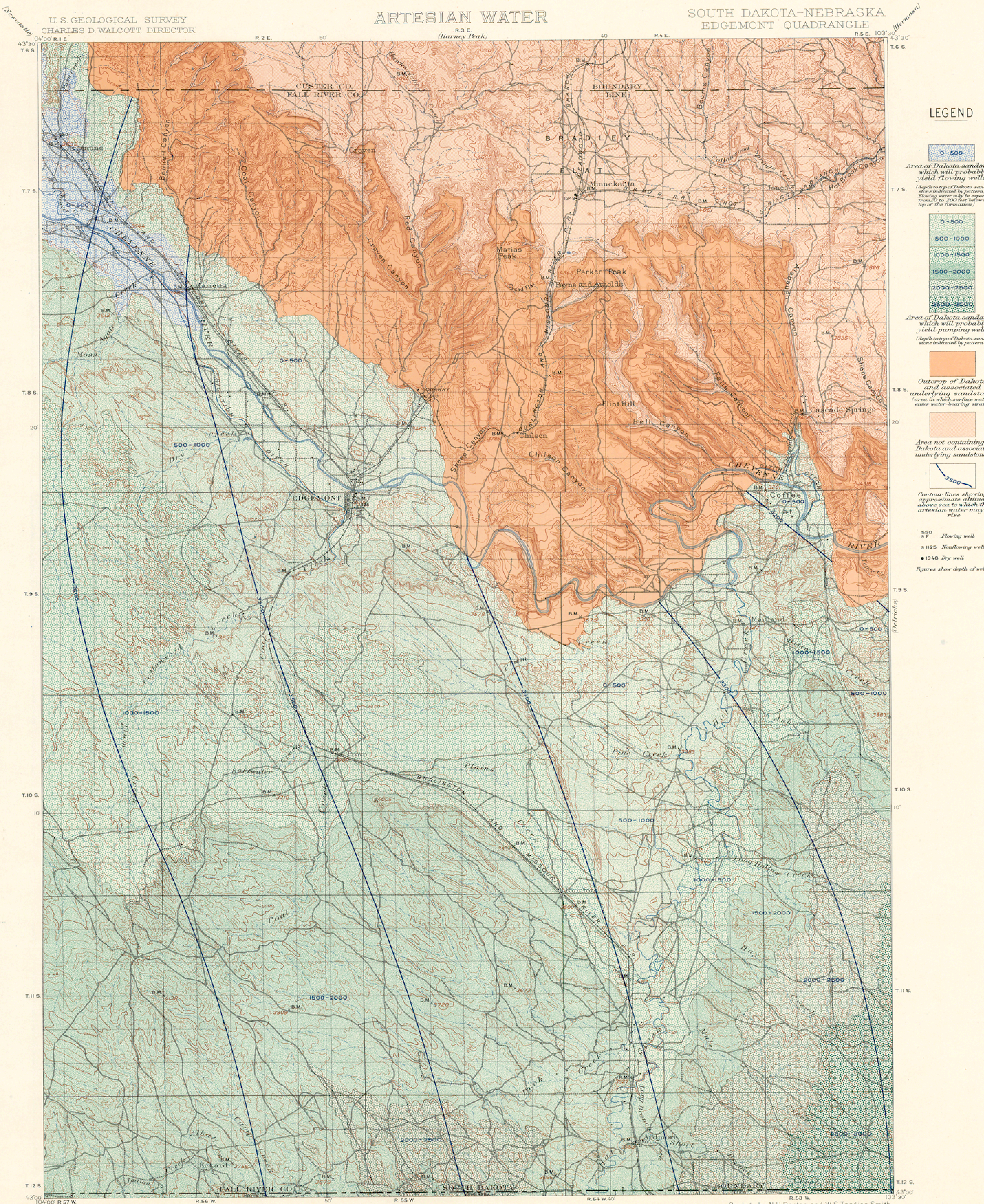
CARBONIFEROUS
- Permian series ?
  - Cmk / Cmo — Minnekahta limestone (very thin-bedded gray limestone in massive ledges)
  - Co — Opeche formation (bright-red sandy shale, purplish at top) — Combined with Minnekahta limestone on sections
- Pennsylvanian
  - Cml — Minnelusa sandstone (red, yellow, and gray calcareous sandstone)
- Mississippian
  - Pahasapa and Englewood limestones (do not outcrop in this quadrangle)

Legend is continued on the left margin.

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

ARTESIAN WATER

SOUTH DAKOTA–NEBRASKA
EDGEMONT QUADRANGLE



E. M. Douglas, Geographer in charge.
Triangulation by E. M. Douglas and A. F. Dunnington.
Topography by A. F. Dunnington.
Surveyed in 1900.

APPROXIMATE MEAN DECLINATION 1900.

Scale $\frac{1}{125000}$

Contour interval 50 feet.
Datum is mean sea level.
Edition of May 1904.

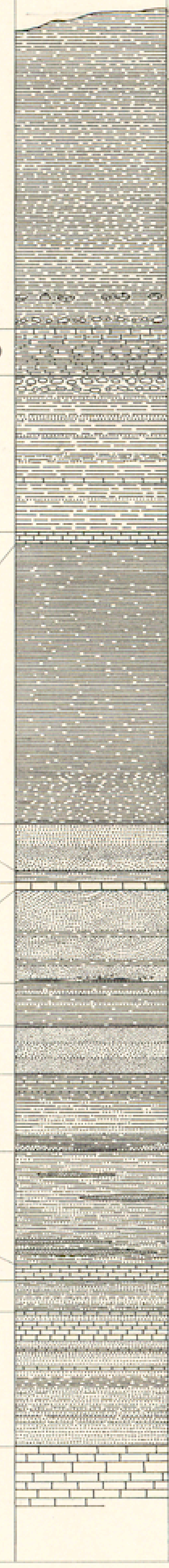
DIAGRAM OF TOWNSHIP

Geology by N. H. Darton and W. S. Tangier Smith.
Surveyed in 1900 and 1902.

COLUMNAR SECTION

GENERALIZED SECTION FOR THE EDGEMONT QUADRANGLE.

SCALE: 1 INCH = 500 FEET.



Period.		Formation Name.	Symbol.	Thickness in Feet.	Columnar Section.	Depth to Dakota Sandstone.	Character of Rocks.	Character of Topography and Soils.
CRETACEOUS	UPPER CRETACEOUS	Pierre shale.	Kp	1000+		2600 2400 2200 2000 1800 1600	Dark-gray shale or clay, weathering brown or buff and containing many fossiliferous concretions. Scattered concretions which give rise to "tepee buttes." Black fissile shale containing numerous concretions, in part cone-in-cone.	Wide rolling plains with shallow valleys and low ridges. Soil thin, clayey, and infertile. Supports thin growth of grass. Small, sharp hills, "tepee buttes."
		Niobrara formation.	Kn	100–200			Gray calcareous shale, weathering yellow, and impure chalk containing many *Ostrea congesta* near the top.	Valleys or flats with fertile soil.
		Carlile formation.	Kcr	500		1400 1200 1000	Light-colored shale with numerous large concretions. Gray shale with sandy shale and thin sandstone layers. Bed of impure limestone.	Low rocky ridges and bare shale slopes.
		Greenhorn limestone.	Kg	50			Thin-bedded, hard limestone, weathering creamy white, and filled with *Inoceramus labiatus*.	Small bare ridges and flat uplands.
		Graneros shale.	Kgs	870		800 600 400 200 0	Dark shale, very fissile below, with scattered concretions.	Wide valleys. Thin sterile soil except where covered by alluvium.
		Dakota sandstone.	Kd	150			Sandstone, thin bedded above, massive below. Weathers reddish brown.	Rocky slopes and cliffs. Soil very thin.
	LOWER CRETACEOUS	Fuson formation.	Kf	30–50			Massive, buff to purple, sandy shale.	Slopes below cliffs of Dakota sandstone.
		Minnewaste limestone.	Kmw	0–25			Light-gray limestone.	Even surfaces, nearly bare.
		Lakota formation.	Klk	300			Massive, cross-bedded sandstone and shale. Local coal beds near base.	Rocky slopes and high cliffs. Soil very thin.
		Morrison shale.	Km	0–125			Massive shale, gray, greenish, and maroon, with thin beds of fine-grained white sandstone.	Slopes below cliffs.
		UNCONFORMITY						
JURASSIC		Unkpapa sandstone.	Ju	0–200			Fine-grained massive sandstone, white, pink, purple, and buff.	Bare cliffs.
		Sundance formation.	Jsd	250			Greenish-gray shale with thin limestone beds. Reddish sandy shale and sandstone. Buff sandstone, in part slabby and ripple marked. Dark shale with beds of red to buff massive sandstone locally below.	Long slopes with much talus cover.
		UNCONFORMITY						
TRIASSIC?		Spearfish shale. ("Red Beds.")	Ꮶs	400			Red sandy shale with gypsum beds.	Wide red valley. Poor soil.
CARBONIFEROUS	PERMIAN?	Minnekahta limestone.	Cmk	50			Thin-bedded gray limestone.	Rocky slopes and cliffs.
		Opeche formation.	Co	100			Red sandy shale and soft red sandstone.	Slopes below cliff.
	PENNSYLVANIAN?	Minnelusa sandstone.	Cml	450			Reddish, buff, white, and gray sandstone, with some shale and limestone in upper portion.	Broad ridges, open valleys, and canyon walls. Sandy soil.
	MISSISSIPPIAN	Pahasapa limestone.					Massive gray limestone.	Does not reach the surface.

N. H. DARTON,
W. S. TANGIER SMITH,
Geologists.

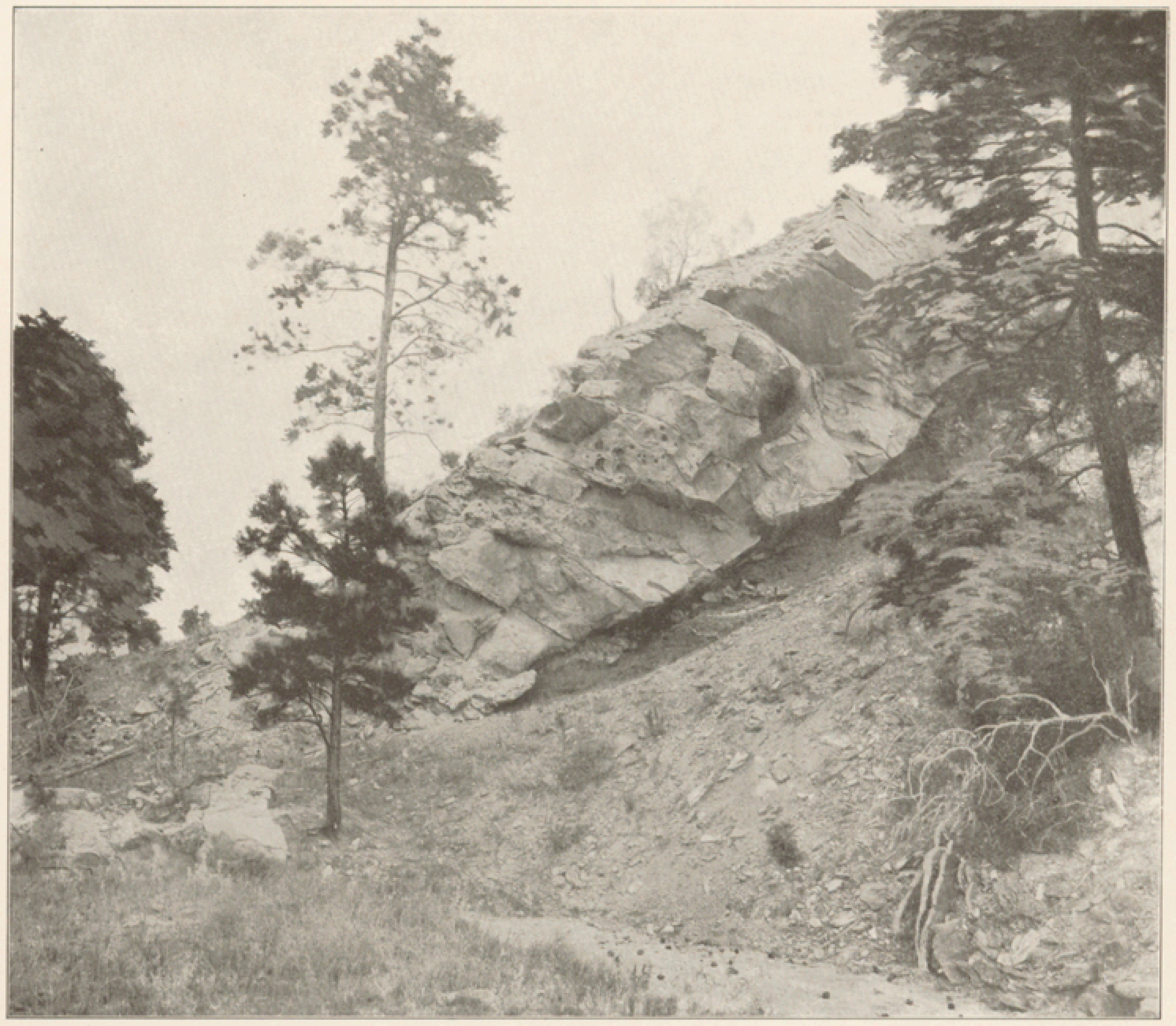


FIG. 6.—SANDSTONE DIKE IN GRANEROS SHALE.
Two and one-half miles northeast of Maitland, S. Dak.

FIG. 7.—FOSSIL TREE TRUNK FROM LAKOTA SANDSTONE.
Three miles southwest of Minnekahta, S. Dak., looking east toward Parker Knob.

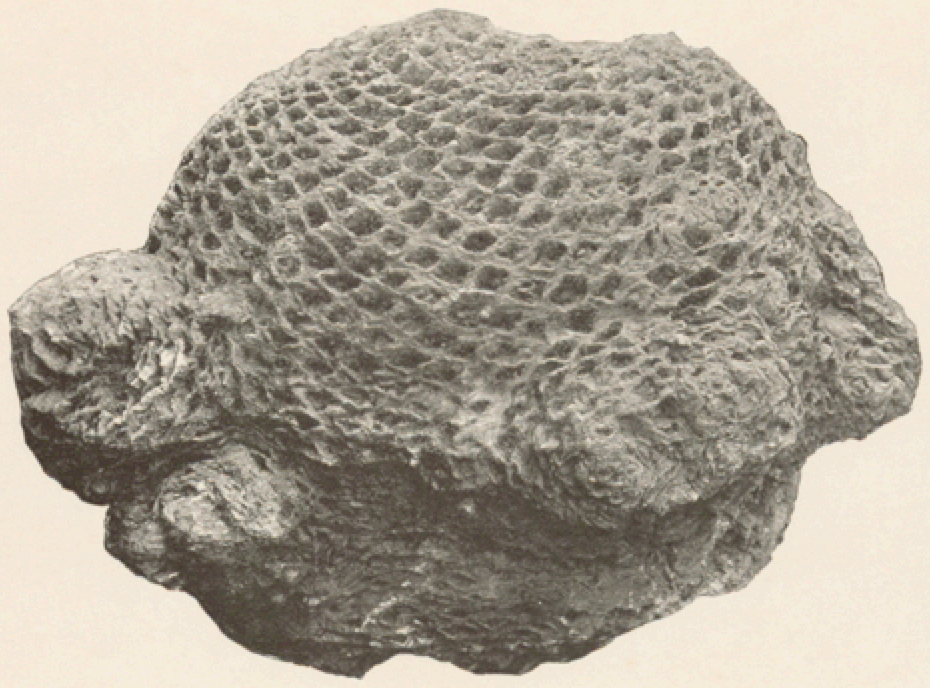


FIG. 8.—CYCAD TRUNK FROM THE LAKOTA FORMATION.
Cycadeoidea pulcherrima, from Cycad Flat, southwest of Minnekahta, S. Dak.

FIG. 9.—SERRATED RIDGE DUE TO STEEP-DIPPING GREENHORN LIMESTONE.
Southeast of Maitland, S. Dak., looking east.

FIG. 10.—GRINDSTONE QUARRY IN UPPER BEDS OF DAKOTA FORMATION.
North of Edgemont, S. Dak.

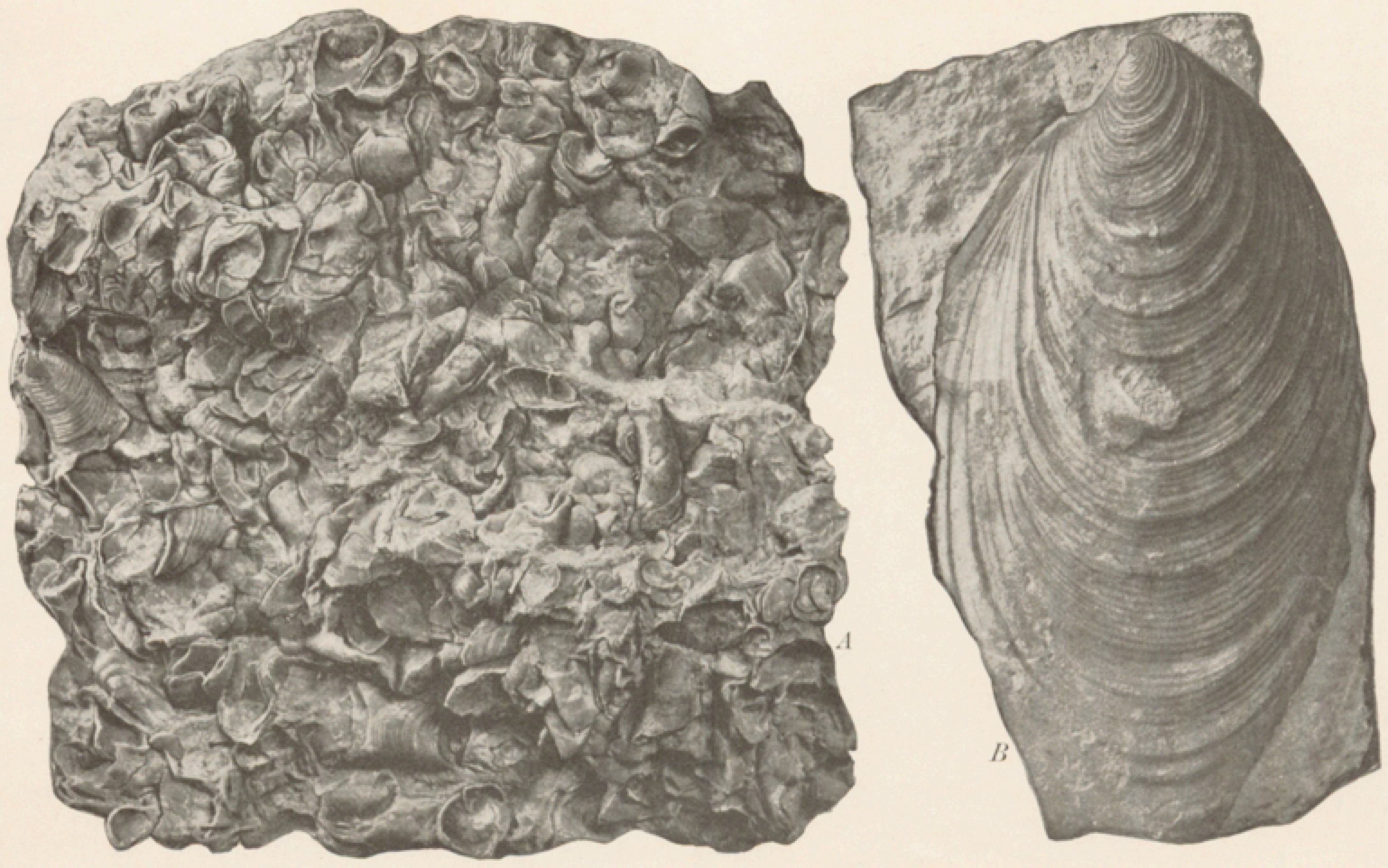


FIG. 11.—CHARACTERISTIC FOSSILS OF NIOBRARA FORMATION (*A*) AND GREENHORN LIMESTONE (*B*), IMPORTANT GUIDES IN WELL BORING.
A, Ostrea congesta; *B*, Inoceramus labiatus.

FIG. 12.—GREENHORN LIMESTONE ON GRANEROS SHALE.
South of Edgemont, S. Dak. Shows characteristic alternation of limestone and shale in the Greenhorn and abrupt change of sediments at top of the Graneros.

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

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

It is often difficult or impossible to determine the age of an igneous formation, but the relative age of such a formation can sometimes be ascertained by observing whether an associated sedimentary formation of known age is cut by the igneous mass or is deposited upon it.

Similarly, the time at which metamorphic rocks were formed from the original masses is sometimes shown by their relations to adjacent formations of known age; but the age recorded on the map is that of the original masses and not of their metamorphism.

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

Symbols and colors assigned to the rock systems.

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

Patterns composed of parallel straight lines are used to represent sedimentary formations deposited in the sea or in lakes. Patterns of dots and circles represent alluvial, glacial, and eolian formations. Patterns of triangles and rhombs are used for igneous formations. Metamorphic rocks of unknown origin are represented by short dashes irregularly placed; if the rock is schist the dashes may be arranged in wavy lines parallel to the structure planes. Suitable combination patterns are used for metamorphic formations known to be of sedimentary or of igneous origin.

The patterns of each class are printed in various colors. With the patterns of parallel lines, colors are used to indicate age, a particular color being assigned to each system. The symbols by which formations are labeled consist each of two or more letters. If the age of a formation is known the symbol includes the system symbol, which is a capital letter or monogram; otherwise the symbols are composed of small letters. The names of the systems and recognized series, in proper order (from new to old), with the color and symbol assigned to each system, are given in the preceding table.

SURFACE FORMS.

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

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

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

THE VARIOUS GEOLOGIC SHEETS.

Areal geology map.—This map shows the areas occupied by the various formations. On the margin is a *legend*, which is the key to the map. To ascertain the meaning of any colored pattern and its letter symbol the reader should look for that color, pattern, and symbol in the legend, where he will find the name and description of the formation. If it is desired to find any given formation, its name should be sought in the legend and its color and pattern noted, when the areas on the map corresponding in color and pattern may be traced out.

The legend is also a partial statement of the geologic history. In it the formations are arranged in columnar form, grouped primarily according to origin—sedimentary, igneous, and crystalline of unknown origin—and within each group they are placed in the order of age, so far as known, the youngest at the top.

Economic geology map.—This map represents the distribution of useful minerals and rocks, showing their relations to the topographic features and to the geologic formations. The formations which appear on the areal geology map are usually shown on this map by fainter color patterns. The areal geology, thus printed, affords a subdued background upon which the areas of productive formations may be emphasized by strong colors. A mine symbol is printed at each mine or quarry, accompanied by the name of the principal mineral mined or stone quarried. For regions where there are important mining industries or where artesian basins exist special maps are prepared, to show these additional economic features.

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

The geologist is not limited, however, to the natural and artificial cuttings for his information concerning the earth's structure. Knowing the manner of formation of rocks, and having traced out the relations among the beds on the surface, he can infer their relative positions after they pass beneath the surface, and can draw sections representing the structure of the earth to a considerable depth. Such a section exhibits what would be seen in the side of a cutting many miles long and several thousand feet deep. This is illustrated in the following figure:

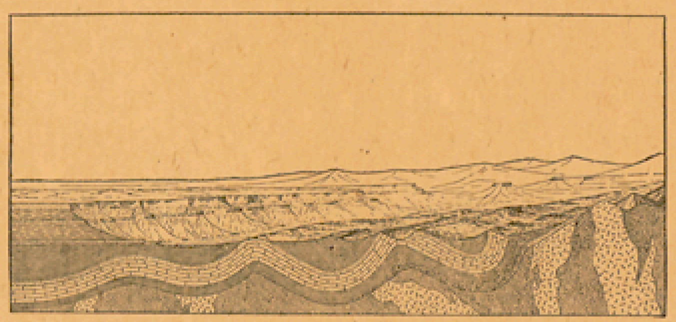


Fig. 2.—Sketch showing a vertical section at the front and a landscape beyond.

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

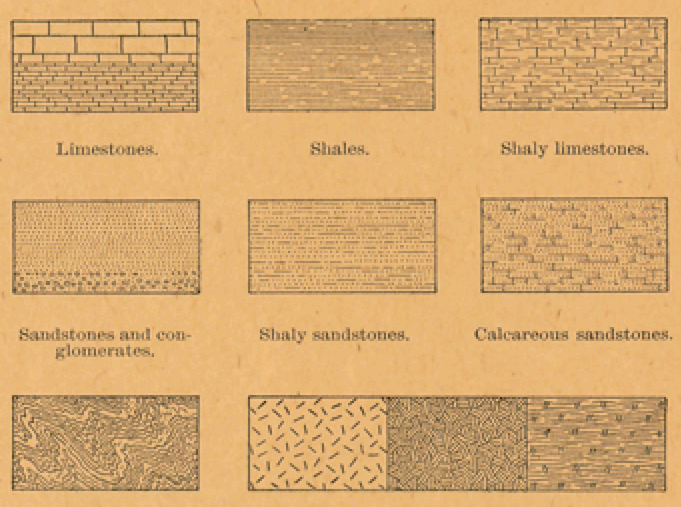


Fig. 3.—Symbols used in sections to represent different kinds of rocks.

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

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

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

On the right of the sketch, fig. 2, the section is composed of schists which are traversed by masses of igneous rock. The schists are much contorted and their arrangement underground can not be

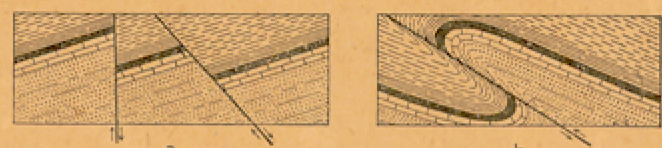


Fig. 4.—Ideal sections of strata, showing (a) *normal* faults and (b) a *thrust* fault.

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

The section in fig. 2 shows three sets of formations, distinguished by their underground relations. The uppermost of these, seen at the left of the section, is a set of sandstones and shales, which lie in a horizontal position. These sedimentary strata are now high above the sea, forming a plateau, and their change of elevation shows that a portion of the earth's mass has been raised from a lower to a higher level. The strata of this set are parallel, a relation which is called *conformable*.

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

The horizontal strata of the plateau rest upon the upturned, eroded edges of the beds of the second set at the left of the section. The overlying deposits are, from their positions, evidently younger than the underlying formations, and the bending and degradation of the older strata must have occurred between the deposition of the older beds and the accumulation of the younger. When younger rocks thus rest upon an eroded surface of older rocks the relation between the two is an *unconformable* one, and their surface of contact is an *unconformity*.

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

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

Columnar section sheet.—This sheet contains a concise description of the sedimentary formations which occur in the quadrangle. It presents a summary of the facts relating to the character of the rocks, the thickness of the formations, and the order of accumulation of successive deposits.

The rocks are briefly described, and their characters are indicated in the columnar diagram. The thicknesses of formations are given in figures which state the least and greatest measurements, and the average thickness of each is shown in the column, which is drawn to a scale—usually 1000 feet to 1 inch. The order of accumulation of the sediments is shown in the columnar arrangement—the oldest formation at the bottom, the youngest at the top.

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

CHARLES D. WALCOTT,

Director.

Revised January, 1904.

PUBLISHED GEOLOGIC FOLIOS

No.*	Name of folio.	State.	Price.†
			Cents.
1	Livingston	Montana	25
2	Ringgold	Georgia–Tennessee	25
3	Placerville	California	25
‡ 4	Kingston	Tennessee	25
5	Sacramento	California	25
‡ 6	Chattanooga	Tennessee	25
‡ 7	Pikes Peak	Colorado	25
8	Sewanee	Tennessee	25
‡ 9	Anthracite-Crested Butte	Colorado	50
10	Harpers Ferry	Va.-W. Va.-Md.	25
11	Jackson	California	25
12	Estillville	Va.-Ky.-Tenn.	25
13	Fredericksburg	Maryland-Virginia	25
14	Staunton	Virginia-West Virginia	25
15	Lassen Peak	California	25
16	Knoxville	Tennessee-North Carolina	25
17	Marysville	California	25
18	Smartsville	California	25
19	Stevenson	Ala.-Ga.-Tenn.	25
20	Cleveland	Tennessee	25
21	Pikeville	Tennessee	25
22	McMinnville	Tennessee	25
23	Nomini	Maryland-Virginia	25
24	Three Forks	Montana	50
25	Loudon	Tennessee	25
26	Pocahontas	Virginia-West Virginia	25
27	Morristown	Tennessee	25
28	Piedmont	Maryland-West Virginia	25
29	Nevada City Special	California	50
30	Yellowstone National Park	Wyoming	75
31	Pyramid Peak	California	25
32	Franklin	Virginia-West Virginia	25
33	Briceville	Tennessee	25
34	Buckhannon	West Virginia	25
35	Gadsden	Alabama	25
36	Pueblo	Colorado	50
37	Downieville	California	25
38	Butte Special	Montana	50
39	Truckee	California	25
40	Wartburg	Tennessee	25
41	Sonora	California	25
42	Nueces	Texas	25
43	Bidwell Bar	California	25
44	Tazewell	Virginia-West Virginia	25
45	Boise	Idaho	25
46	Richmond	Kentucky	25
47	London	Kentucky	25
48	Tenmile District Special	Colorado	25
49	Roseburg	Oregon	25
50	Holyoke	Mass.-Conn.	50
51	Big Trees	California	25
52	Absaroka	Wyoming	25
53	Standingstone	Tennessee	25
54	Tacoma	Washington	25
55	Fort Benton	Montana	25
56	Little Belt Mountains	Montana	25
57	Telluride	Colorado	25
58	Elmoro	Colorado	25
59	Bristol	Virginia-Tennessee	25
60	La Plata	Colorado	25
61	Monterey	Virginia-West Virginia	25
62	Menominee Special	Michigan	25
63	Mother Lode District	California	50
64	Uvalde	Texas	25
65	Tintic Special	Utah	25
66	Colfax	California	25
67	Danville	Illinois-Indiana	25
68	Walsenburg	Colorado	25
69	Huntington	West Virginia-Ohio	25
70	Washington	D. C.-Va.-Md.	50
71	Spanish Peaks	Colorado	25
72	Charleston	West Virginia	25
73	Coos Bay	Oregon	25
74	Coalgate	Indian Territory	25
75	Maynardville	Tennessee	25
76	Austin	Texas	25
77	Raleigh	West Virginia	25
78	Rome	Georgia-Alabama	25
79	Atoka	Indian Territory	25
80	Norfolk	Virginia-North Carolina	25
81	Chicago	Illinois-Indiana	50
82	Masontown-Uniontown	Pennsylvania	25
83	New York City	New York-New Jersey	50
84	Ditney	Indiana	25
85	Oelrichs	South Dakota-Nebraska	25
86	Ellensburg	Washington	25
87	Camp Clarke	Nebraska	25
88	Scotts Bluff	Nebraska	25
89	Port Orford	Oregon	25
90	Cranberry	North Carolina-Tennessee	25
91	Hartville	Wyoming	25
92	Gaines	Pennsylvania-New York	25
93	Elkland-Tioga	Pennsylvania	25
94	Brownsville-Connellsville	Pennsylvania	25
95	Columbia	Tennessee	25
96	Olivet	South Dakota	25
97	Parker	South Dakota	25
98	Tishomingo	Indian Territory	25
99	Mitchell	South Dakota	25
100	Alexandria	South Dakota	25
101	San Luis	California	25
102	Indiana	Pennsylvania	25
103	Nampa	Idaho-Oregon	25
104	Silver City	Idaho	25
105	Patoka	Indiana-Illinois	25
106	Mount Stuart	Washington	25
107	Newcastle	Wyoming-South Dakota	25
108	Edgemont	South Dakota-Nebraska	25

* Order by number.
† Payment must be made by money order or in cash.
‡ These folios are out of stock.

Circulars showing the location of the area covered by any of the above folios, as well as information concerning topographic maps and other publications of the Geological Survey, may be had on application to the Director, United States Geological Survey, Washington, D. C.