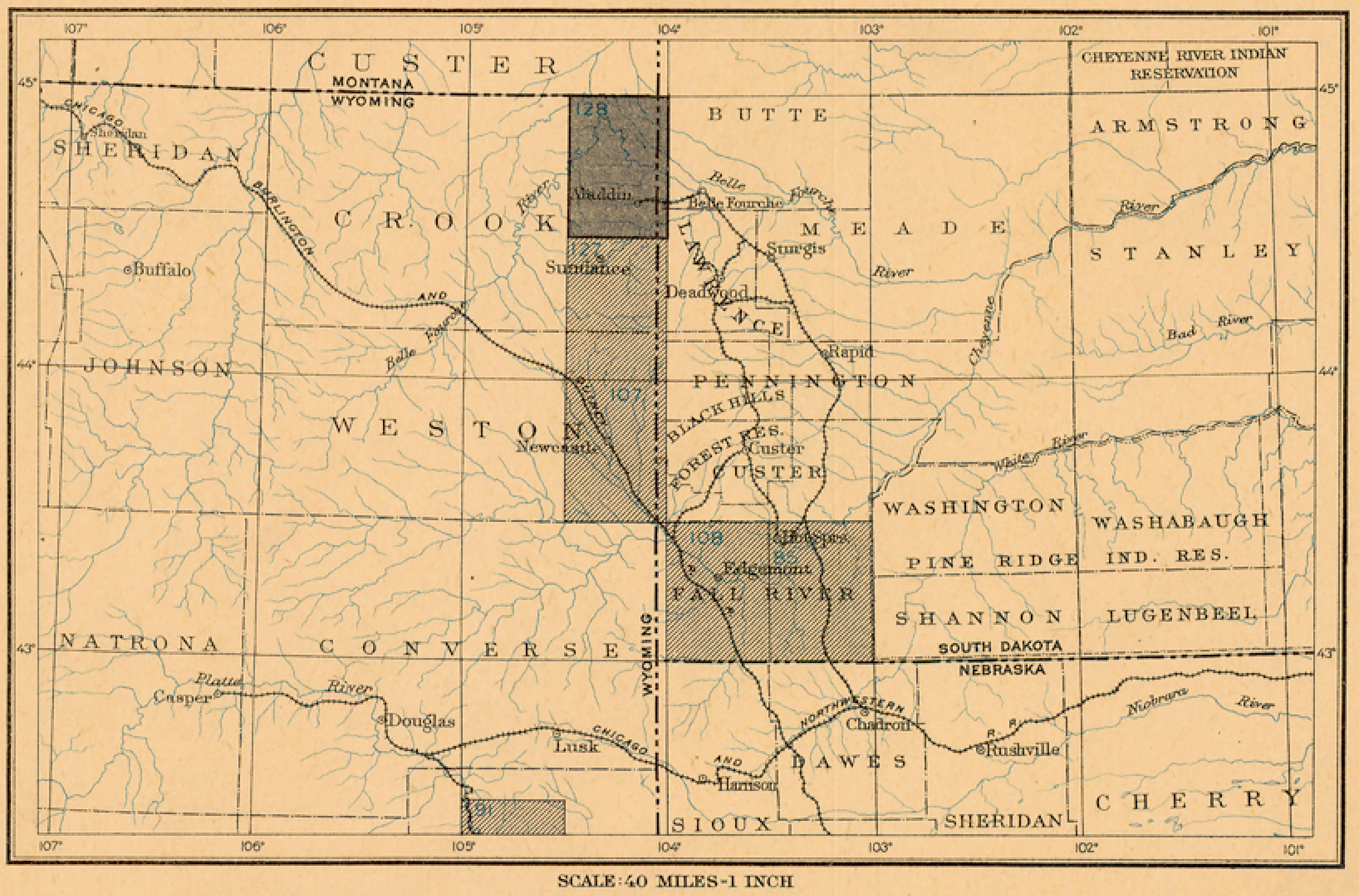
DEPARTMENT OF THE INTERIOR
UNITED STATES GEOLOGICAL SURVEY
CHARLES D. WALCOTT, DIRECTOR

GEOLOGIC ATLAS
OF THE
UNITED STATES

ALADDIN FOLIO

WYOMING - SOUTH DAKOTA - MONTANA

INDEX MAP



SCALE: 40 MILES-1 INCH

ALADDIN FOLIO

OTHER PUBLISHED FOLIOS

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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).

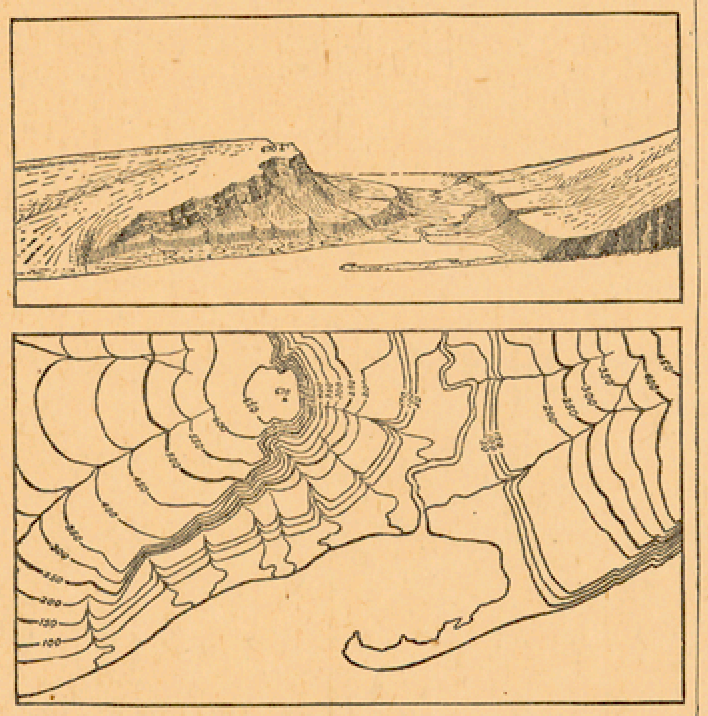


Fig. 1.—Ideal view and corresponding contour map.

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 ALADDIN QUADRANGLE.

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

GEOGRAPHY.

Position and extent.—The Aladdin quadrangle embraces the quarter of a square degree which lies between parallels 44° 30′ and 45° north latitude and meridians 104° and 104° 30′. It measures approximately 34½ miles from north to south and 25 miles from east to west; its area is 849.46 square miles. It comprises the northeast corner of Crook County, Wyo., a narrow strip of Butte County, S. Dak., and the extreme northwest corner of Lawrence County, S. Dak., on the east, and a little of Custer County, Mont., on the north. The southwestern half of the quadrangle lies on the slopes of the Black Hills, and the northeastern portion extends to the Great Plains. The district is drained by Belle Fourche River except a very small area in its northwest corner, which is crossed by Little Missouri River.

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

THE GREAT PLAINS PROVINCE.

General features.—The Great Plains province is that part of the continental slope which extends from the foot of the Rocky Mountains eastward to the valley of the Mississippi, where it merges into the prairies on the north and the low plains adjoining the Gulf coast and the Mississippi embayment on the south. The plains present wide areas of tabular surfaces traversed by broad, shallow valleys of large rivers that rise mainly in the Rocky Mountains, and they are more or less deeply cut by narrower 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 that slope gently eastward with the slope of the plains. These deposits lie on relatively smooth surfaces of older rocks. The materials of the formations were derived mainly from the west and were deposited, layer by layer, either by streams on their flood plains or in lakes, and, during earlier times, in the sea. Aside from a few local flexures, the region has not been subjected to folding, but has been broadly uplifted and depressed successively. The general smoothness of the region to-day was surpassed by the almost complete planations of the surface during earlier epochs. Owing to the great breadth of the plains and their relatively gentle declivity, general erosion has progressed slowly notwithstanding the softness of the formations, and as at times of freshets many of the rivers bring out of the mountains a larger load of sediment than they carry to the Mississippi, they are now building up their valleys rather than deepening them.

Altitudes and slopes.—The Great Plains province as a whole descends to the east about 10 feet in each mile from altitudes approaching 6000 feet at the foot of the Rocky Mountains to about 1000 feet above sea near Mississippi River. The altitudes and rates of slope vary considerably in different districts, particularly to the north, along the middle course of Missouri River, where the general level has been greatly reduced. West of Denver the plains rise to an altitude of 6200 feet at the foot of the Rocky Mountains, and maintain this elevation far to the north, along the foot of the Laramie Mountains. High altitudes are also attained in Pine Ridge, a great escarpment which extends from 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 Aladdin 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, Owl, Cheyenne, Bad, and White rivers. On the summit of Pine Ridge not far south of the escarpment is Niobrara River, which rises in the midst of the plains some distance east of the northern end of the Laramie Mountains. To the south are Platte River with two large branches heading far back in the Rocky Mountains, the Rio Grande, and Arkansas River, which crosses the plains to the southeast and affords an outlet for the drainage from a large watershed of mountains and plains. Between the Rio Grande and the Arkansas are Cimarron River and numerous smaller streams heading in the western portion of the plains. Between Arkansas and Platte rivers is Republican River, rising near the one hundred and fifth meridian, and an extended system of local drainage in eastern Kansas and Nebraska.

THE BLACK HILLS.

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

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

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

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

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

GEOGRAPHIC FEATURES OF THE QUADRANGLE.

Features pertaining to the Black Hills.—The Aladdin quadrangle presents some of the characteristic features of Black Hills topography, from the lower slopes of the northern limestone ridge to the hogback rim, and a wide area of rolling plains to the northeast. In the southeast corner of the quadrangle the land descends steeply from the high ridges and plateaus of the higher portion of the northwestern part of the Black Hills uplift. This slope is deeply trenched by the gorges of Sundance and Sand creeks and traversed by numerous canyons. The Red Valley is a prominent feature, having a width of 2 to 3 miles and presenting an undulating surface sloping rapidly eastward. Its upper portion is known as Government Valley, and farther east it is occupied by Redwater Creek, a branch of the Belle Fourche. In the region north of the Red Valley the hogback range is represented by an eastward-sloping plateau cut into high, narrow ridges and outlying mesas, capped by hard sandstone.

The highest of these plateau ridges is the northern prolongation of the Bear Lodge Mountains, which extend southward from the Belle Fourche to the high igneous uplift of the Warren Peaks region. The altitudes of this ridge are 4500 feet at the north end, 4700 feet west of Eothen, and 5850 feet at the southern margin of the quadrangle. The ridge forms a divide between the Beaver Creek drainage on the west and Deep Creek, Allen Creek, Hay Creek and many other branches of Redwater Creek on the east. On its eastern side it presents long branch ridges which, to the east and north, gradually sink beneath the plains and, to the south, rise steeply on the north side of the Red Valley. The eastward-sloping plateau character is strongly marked, but erosion has been so energetic that deep canyons and valleys have been cut, and some of the ridges are separated by deep cross valleys.

To the west the Bear Lodge Mountains present a steep escarpment deeply cut by canyons and descending into slopes which extend to the Belle Fourche Valley. Near the south end of the mountain, a short distance south of the southwest corner of the quadrangle, at the head of Blacktail and Beaver creeks, the Warren Peaks rise abruptly to an altitude considerably above 6000 feet. They are due to hard masses of igneous rock intruded in the center of the Bear Lodge uplift. Belle Fourche River crosses the hogback range in a wide valley below the mouth of Medicine Creek.

Features pertaining to the Great Plains.—The northeastward dip of the uppermost sandstones of the Black Hills series carries them beneath soft shales, and in the northeastern third of the quadrangle there is a wide area underlain by soft rocks presenting characteristic topography of the Great Plains. The valleys are wide and most of the slopes are gentle or not high. An occasional harder bed gives rise to a low escarpment or ridge, but it is an insignificant feature as compared with the higher ridges and mountains of the adjoining Black Hills. The elevation of the plains portion of the Aladdin quadrangle ranges from 3800 to 5100 feet in greater part. The principal stream is the Belle Fourche, which, soon after passing out of the hogback range on a northerly course, turns abruptly southeastward and skirts the uplift, flowing parallel to the strike of the rocks. Most of the minor streams also have their course in the same direction, from northwest to southeast, notably Kilpatrick, Middle, Chicago, Humboldt, Crow, Owl, and Lonetree creeks, east of the Belle Fourche. These streams occupy wide valleys separated by low ridges of shales.

From the west the river receives branches—Horse, Deep, Pine, Alum, and Oak creeks—which rise in the Bear Lodge Mountains and flow down the slope of the uplift, at first in canyons or deep valleys in the hogback range, and then in shallow valleys to their mouths.

One of the most notable topographic features in the quadrangle is the Stoneville Flats, a smooth-bottomed valley that extends completely across the low divide between Little Missouri and Belle Fourche rivers. Originally it was occupied by the upper part of the Belle Fourche, which then flowed northward into the Little Missouri. The flat is floored with a deposit of loam and gravel, some of which continues on the high terraces up the Belle Fourche, and to the north it merges into the alluvium lying along the Little Missouri. This change of course of the stream is a clear case of stream robbery, the lower Belle Fourche, with the advantage of steeper declivity, having cut back the head of its valley until in the present big bend it has captured the stream which originally flowed into the Little Missouri through the Stoneville Flats. Since that time the Belle Fourche Valley has been deepened about 100 feet, for there is a high bank of about that height in the bend of the river. In other words, a dam somewhat over 100 feet in height would turn back the waters of the upper Belle Fourche into the Little Missouri, but, on the other hand, a dam of very moderate height would deflect the waters of the Little Missouri across the Stoneville Flats into the Belle Fourche. There is but little erosion in these flats at present, but it is probable that a stream will eventually develop there that will cut across them and deflect the head of Little Missouri River into the Belle Fourche. Such a stream has already begun the excavation of a valley along the eastern side of the flats.

GEOLOGY.

DESCRIPTION OF THE ROCKS.

The strata coming to the surface in the Aladdin quadrangle have a thickness of about 4500 feet. The order of succession of the limestones, sandstones, and shales and their general characters are given on the columnar section sheet. The rocks are mainly sedimentary and range in age from Cambrian to Quaternary. A few small masses of igneous rocks appear in the southwest corner of the quadrangle, in the Bear Lodge laccolith.

Sedimentary Rocks.

CAMBRIAN SYSTEM.

DEADWOOD FORMATION.

Outcrop and rocks.—The lowest sedimentary formation seen in the Aladdin quadrangle is a small area of brown sandstone on the slope of Sheep Mountain, a spur of the Bear Lodge Range, exposed by a local uplift due to a fault apparently connected with igneous intrusion below. The rocks consist of brownish and dark-buff sandstones below, then thinner sandstones and shales, dirty buff and greenish-buff layers farther up, and at the top, 30 feet or more of grayish-green shales.

Correlation.—No fossils were obtained, but, from the character of the rocks and their association with the overlying limestones, it is inferred that they are undoubtedly at the same horizon as the Deadwood sandstones of middle Cambrian age which appear extensively farther south and east in the Black Hills, where they are seen lying on the Algonkian schists and granites.

ORDOVICIAN SYSTEM.

WHITEWOOD LIMESTONE.

The Whitewood limestone occupies a small area on the south side of Sheep Mountain. It is a massive pink rock lying on the upper green shales of the Deadwood formation and rising in cliffs 30 to 50 feet high. Its total thickness is about 60 feet and it constitutes the top of the southern end of the mountain, dipping northeastward under dark-gray sandy limestone of Carboniferous age. The only fossil observed in this limestone was *Maclurea magna*, an Ordovician form which occasionally occurs.

CARBONIFEROUS SYSTEM.

PAHASAPA LIMESTONE.

The Englewood limestone, the earliest Carboniferous formation in this region, has not been definitely recognized in the Sheep Mountain uplift, but possibly it is represented in the sandy limestone layers at the base of the Pahasapa. The zone of outcrop of this horizon crosses the south end of Sheep Mountain and is cut off by faults on the east and west slopes of the mountain. Typical Englewood limestone in the areas farther south and east is of pale pinkish-buff color, thin bedded, and about 50 feet in thickness, and contains fossils of Mississippian age, believed to represent the horizon of the Chouteau. The following forms have been reported: *Orthothetes leptæna, Chonetes logani, Reticularia peculiaris, Syringothyris carteri, Leptæna rhomboidalis, Chonetes ornatus?, Productus* aff. *P. mesialis, Spirifer striatiformis, Spirifer mysticensis, Spirifer peculiaris?, Camarotœchia metallica?, Pugnax* n. sp., *Pterinopecten* sp., *Platyceras* sp.

The Pahasapa limestone is the "gray limestone" which is so prominent in the central portion of the Black Hills area. It appears on the summit and northern slopes of Sheep Mountain and at intervals in the southwest corner of the quadrangle, in the vicinity of the intrusive masses. The basal member exposed on Sheep Mountain is a dark-gray sandy limestone which may also comprise the Englewood limestone of the main Black Hills area.

The principal body of the formation consists of massive, light-colored limestones, weathering to a pale-bluish or dove tint. The total thickness on Sheep Mountain could not be determined, owing to variable dips, but it appears to be about 300 feet. In the outcrops farther west, about the heads of Beaver and Blacktail creeks, the entire thickness of the formation is not exposed, for the igneous rock has been intruded somewhat above the base of the formation.

The most extensive exposures of the Pahasapa limestone in this quadrangle are at the head of Lytle Creek, and it appears conspicuously also in the southeast corner of T. 53 N., R. 64 W., in canyons cut by small branches of Blacktail Creek.

The formation contains characteristic Mississippian fossils, but seldom in large numbers. The following are the principal forms which have been obtained: *Syringopora surcularia, Leptæna rhomboidalis, Schuchertella inæqualis, Chonetes gregarius?, Productus semireticulatus, Spirifer centronatus, Spirifer striatus* var. *madisonensis, Syringothyris carteri.*

MINNELUSA SANDSTONE.

Outcrops and character.—The Minnelusa sandstone is extensively exposed around the igneous uplifts in the southwest corner of the quadrangle, and is also cut into by the canyons of Redwater, Sundance, and Sand creeks. The lower and middle beds are gray and brown sandstones, with some impure limestone layers, and the top member is a conspicuous body of white sandstones of considerable hardness, which gives rise to prominent cliffs in the slopes and canyons.

In the canyons of Redwater and Sundance creeks the middle portion of the formation presents soft clayey sandstone or sandy shales of reddish and gray color, which weather in rounded forms on slopes surmounted by the typical white quartzite. The total thickness in this locality is about 450 feet. The formation is conspicuously exposed in a zone of outcrop that circles around the north end of the Bear Lodge uplift. In this quadrangle it appears prominently in the main canyon of Blacktail Creek and at the head of Lytle Creek. It occurs also on the eastern, northern, and western slopes of Sheep Mountain and appears at intervals along Beaver Creek. It has been greatly disturbed by igneous intrusives, one body of which, on Blacktail Creek, extends diagonally across the formation. In places masses of the quartzite have been detached by the igneous rock and carried to a considerable distance from the main mass of the formation. Some of these detached portions are considerably altered by the heat to which they have been subjected, so that they are hardened to a quartzite and somewhat darkened in color.

Age.—The Minnelusa formation has yielded no fossils in the northern Black Hills and, although it is believed to be in greater part of Pennsylvanian age, there is uncertainty as to its correlation.

OPECHE FORMATION.

Occurrence.—The Opeche formation is a thin series of red shales and red sandstones lying between the Minnekahta limestone and the white sandstone at the top of the Minnelusa sandstone. Its position usually is in a talus slope at the foot of the limestone cliff. It is exposed in the numerous canyons south and southwest of Beulah and encircles the north end of the igneous uplift of the Bear Lodge Range. It occurs in extensive exposures along the canyons of South Redwater, Sundance, and Sand creeks, and also appears at intervals at the head of Lytle Creek, in the canyon of Blacktail Creek, and about Sheep Mountain, especially on its eastern and northern sides.

Thickness and character.—The thickness averages from 50 to 75 feet, the amount decreasing gradually to the northwest. The material consists of moderately soft, red-brown sandstone, mainly in beds from 1 to 4 inches thick, and of red, sandy shale. At the top of the formation, for the first few feet below the Minnekahta limestone, there are shales which invariably have a purple color.

Age.—The age of the Opeche formation has not yet been definitely determined, as it has yielded no fossils. From the fact that the overlying Minnekahta limestone is of Permian age and that there are red deposits in the upper part of the Permian of the middle West, it is provisionally referred to that epoch.

MINNEKAHTA LIMESTONE.

Character and outcrops.—This formation, formerly known as the "Purple limestone," appears on the steep slopes of the anticline rising out of the Red Valley west and south of Beulah, and its outcrop encircles the north end of the igneous uplift of the Bear Lodge Range in the southwest corner of the quadrangle. The rock is of light-gray color, but has a slight pinkish or purplish tint, from which the name "Purple limestone" originated. It is thin, averaging less than 40 feet in thickness, but, owing to its hardness and flexibility, it gives rise to prominent ridges with escarpments presenting nearly the entire thickness of the formation. Ordinarily the cliffs appear to consist of massively bedded rock, but, on close examination, it is seen that this is divided into thin layers which are clearly defined by slight differences in color. On weathering, it breaks into slabs, usually 2 to 3 inches in thickness. In the slopes south and southwest of Beulah, the limestone is cut through by many canyons, so that it remains only on the intervening ridges. As the limestone dips beneath the Spearfish formation, it crosses the mouths of the canyons, giving rise to very characteristic constrictions or gates, a feature presented at many points in the southeast corner of the quadrangle.

The Minnekahta outcrop extends in a continuous ring around the igneous uplift of the Bear Lodge Range, except for a short distance on the southern end of Sheep Mountain, where it is cut out by a fault, and in places where it is buried beneath Tertiary deposits along the main Bear Lodge Ridge. Characteristic exposures of the formation are found in the southwest quarter of T. 53 N., R. 63 W., and in the township adjoining at the west.

Composition.—The composition of the Minnekahta limestone varies somewhat, mainly in the proportions of carbonate of magnesia, which usually is present in considerable amount, and of clay, which is always an ingredient. In some of the layers flakes of clay or very impure limestone give a mottled appearance to the weathered bedding planes of the rock.

Structure.—The limestone presents more local variations in the amount and direction of its dips than do the associated formations, for it is a thin, relatively hard bed of homogeneous rock lying between masses of softer shale, and consequently was much affected by local conditions of pressure. The thin layers of the limestone are often minutely crumpled and faulted, but in view of the large amount of deformation to which the formation has been subjected the flexures are but little broken.

Age.—The limestone is classed as Permian, from fossils which it has yielded in the southern Black Hills.

TRIASSIC (?) SYSTEM.

SPEARFISH FORMATION.

Character and outcrop.—The Spearfish formation, known also as the "Red Beds," consists of about 600 feet of red sandy shales with intercalated beds of gypsum. Its outcrop extends across the southeastern portion of the Aladdin quadrangle in a broad, treeless red valley and usually presents wide, bare slopes and high buttes of bright-red shale, with outcrops of snow-white gypsum in striking contrast. The sedimentary material is almost entirely sandy red shale, generally thin bedded, containing beds of gypsum, especially near the base of the formation.

The formation extends up the main Redwater Valley and Government Valley and around the north end of the igneous uplift in the Bear Lodge Mountains. In the Redwater Valley it extends northward to the base of Schoolmarm Butte and constitutes the lower parts of numerous buttes capped by the Sundance formation. In places it is covered by Quaternary deposits, mainly along the alluvial flats in the valleys. Along most of the slopes north of Government Valley and Beulah it outcrops in cliffs which are often conspicuous features on account of their brilliant red color.

Along the main range of the Bear Lodge Mountains the formation is covered by Tertiary deposits, but its entire thickness appears on both forks of Beaver Creek, on Blacktail Creek, and on the headwaters of Lytle Creek. In the southwest corner of the quadrangle, owing to the steeper dips, its outcrop is narrow and is rendered somewhat irregular by variations in structure. On the divide between Lytle Creek and the west fork of Blacktail Creek the formation is cut off by igneous rock for a short distance. The Spearfish beds are exposed along the central-western margin of the quadrangle, in the valley of the Belle Fourche and some of its branches. The most extensive exposures in that region are in the vicinity of the T+T ranch, where the red banks rise above the river at intervals, but pass beneath the water level near the mouth of Deer Creek, being carried down by the general northwesterly dip.

Gypsum.—Gypsum is a conspicuous feature in the Redwater Valley east and west of Beulah. The principal deposit of this mineral occurs mainly at a horizon about 100 feet above the base of the formation and appears to extend continuously, with a thickness of 15 to 22 feet. Other local deposits occur at or near the base of the formation.

Aladdin boring.—The deep boring at Aladdin entered "red beds" about 400 feet below the surface and, it is reported, penetrated them about 750 feet without reaching their base. Probably the boring passed entirely through the Spearfish formation and the Minnekahta limestone into the Opeche formation. Even if this is the case, it indicates that the thickness of the Spearfish formation is at least 650 feet.

Age.—The Spearfish deposits are distinctly separated from the Minnekahta limestone below by an abrupt change of materials. No fossils have been discovered in the Spearfish formation, and its precise age is unknown. From the fact that it lies between the Permian below and the marine Jurassic above it has been regarded as Triassic in age, but it may prove to be Permian. It is separated from the Sundance formation by a planation unconformity representing all of earlier Jurassic and probably part at least of Triassic time.

JURASSIC SYSTEM.

SUNDANCE FORMATION.

Outcrop and stratigraphy.—The Sundance formation is extensively exposed in the slopes north of the Red Valley and in the ridges lying between the foot of the Bear Lodge Mountains and the Belle Fourche.

The rocks consist of shales and sandstones which vary but little from place to place in order and character and have a thickness of about 380 feet to the southeast and 450 feet or more to the northwest. At the base are dark-gray or grayish-green shales, uniformly about 40 feet thick. They are moderately hard and in some places carry thin layers of sandstone. At some localities they are underlain by a local thin bed of sandstone. Next above is a series of buff, fine-grained sandstones, in greater part massively bedded and having a thickness of from 30 to 40 feet. This series is a very characteristic, conspicuous, and persistent member of the formation. It gives rise to tabular surfaces of considerable area, with marginal cliffs 25 to 40 feet high, which are often surmounted by long slopes of overlying softer beds. It is of buff or slightly reddish tinge, varies from massive to slabby in bedding, and some of the layers are strongly ripple marked, a characteristic feature of this horizon throughout the Black Hills. Its upper part merges into sandy shales of buff to gray color and these into soft, impure sandstones or sandy shales, mostly of reddish color, having a thickness of 50 to 150 feet. Then follows a member consisting of dark-gray and greenish-gray shales, 150 to 250 feet in thickness, containing occasional thin beds of highly fossiliferous limestones. Thin beds of sandstone also occur in these shales. Near their top the shales become more sandy, are not fossiliferous, and grade into a thin body of bright-buff sandstone, possibly representing the Unkpapa sandstone of the eastern Black Hills, which immediately underlies the Morrison shale. There is no evidence of unconformity at the top of the formation, but the change in character of sediments is abrupt and the apparent absence of Unkpapa sandstone would indicate a time break of considerable length between the Sundance and Morrison formations.

Local variations.—There is but little variation in the stratigraphy of the Sundance formation, but a number of local changes are notable. In the vicinity of Alva one thin bed of sandstone in the upper shale series is hard and massive and locally has a thickness of about 2 to 3 feet, but it thins out and is not noticeable in other portions of the region. The red sandy shales of the medial member of the formation are similar in color to red deposits of the Spearfish formation, but are of much paler tint. Their thickness averages 150 feet in the region about Table Mountain, but they thin rapidly to the west, and near Alva are only a few feet thick. The upper shale series, which is 150 feet thick about Table Mountain, increases in thickness to the west in proportion as the reddish series thins, reaching a thickness of 250 feet or more.

Fossils.—Fossils are abundant in the Sundance beds, particularly in the limestone layers in the upper shales, but some occur also in the basal shales. The most characteristic species is *Belemnites densus*, represented by hard, dark-colored, cigar-shaped bodies varying in length from 1 inch or less to 4 inches and having a radiated structure when seen in transverse section. These often weather out on the surface and form a conspicuous feature in most of the upper-shale outcrops. In the upper shales there also occur the following species: *Ostrea strigilecula*, *Avicula mucronata*, *Camptonectes bellistriatus*, *Astarte fragilis*, *Trapezium bellefourchensis*, *Pleuromya newtoni*, *Tancredia inornata*, *T. corbuliformis*, *T. bulbosa*, *T. postica*, *Dosinia jurassica*, *Saxicava jurassica*, *Ammonites cordiformis*, and *Pentacrinus asteriscus*. Occasional layers of limestone in the lower shales carry *Ostrea strigilecula*, *Camptonectes bellistriatus*, *Pseudomonotis curta*, *Psammobia prematura*, and *Belemnites densus*. All of these species are of upper and middle Jurassic age.

The Sundance formation is believed to be equivalent to the Ellis formation of Montana and the Yellowstone Park region.

CRETACEOUS SYSTEM.

MORRISON SHALE.

Character and outcrops.—The Morrison shale is a thin but persistent deposit of massive shale or clay lying between the Sundance formation and the Lakota sandstone. It has been called Beulah shale and Atlantosaurus beds, but the name Morrison has priority. Its color generally is a characteristic pale olive-green, ranging to faint greenish white, with local bands of dark gray and maroon. In fresh exposures some of the beds are darker and in some localities portions of the deposit are black. The thickness of the formation is variable, owing probably to local unconformity on its surface, and its measure is difficult to determine at most localities, owing to talus and landslides along the base of cliffs of Lakota sandstone. At Aladdin the formation appears to be about 60 feet thick. In the region south of The Forks the thickness is somewhat greater, and about Table Mountain and north of Eothen it is 150 feet or more. In the slopes about Alva the thickness is 100 feet, as nearly as can be ascertained. The shale includes thin beds of sandstone, mostly very fine grained and of light color. The thickest sandstone beds observed are east of the T+T ranch, where one bed about a foot thick extends for some distance. Nodules of hard clay occur in some of the beds. The formation is easily distinguished from the Sundance shales by its color and texture and the absence of marine fossils.

The formation outcrops extensively along both slopes of the northern extension of the Bear Lodge Mountains and the outlying ridges; in the ridge lying between Deer and Medicine creeks; in the basins at the heads of Pine, Alum, and Hay creeks; and in the ridges north and southeast of Aladdin. It also appears in the higher portion of the anticline east of The Forks.

Fossils and age.—The Morrison shale contains many bones of saurians believed to be of early Cretaceous age. One of the localities at which these are most abundant is 2 miles east-northeast of Eothen. The only molluscan fossils which it has yielded are a few shells of fresh-water forms. By some paleontologists the saurians of this formation are thought to be of later Jurassic age, but others class them as early Cretaceous.

LAKOTA SANDSTONE.

General relations.—The Lakota sandstone is a conspicuous feature in the central and western portions of the Aladdin quadrangle, where, together with the Dakota sandstone, it rises in prominent cliffs above slopes of the underlying shales in the Bear Lodge Mountains and the high ridges about Aladdin and The Forks, and caps numerous buttes south and west of the main Bear Lodge Range. Owing to the low dips and numerous deep canyons which cut through the sandstone, its boundary is exceedingly irregular. The sandstone consists mainly of gray to buff, coarse-grained, massively bedded rock, usually of considerable hardness, and it has a thickness of 80 to 150 feet. In some places it disintegrates readily, a feature especially noticeable east-northeast of the T+T ranch.

Coal measures.—At and near the bottom of the formation occur local accumulations of coal in lens-shaped deposits, and there are thin layers of dark shales at various horizons.

In the vicinity of Aladdin the coals have been worked to some extent and apparently the principal deposits are at this place. There are two workable coal beds, one from 2½ to 3½ feet thick at the bottom of the formation and another thinner one about 10 feet higher, the two being separated by sandy clays and shales. Above the coals there are sandy shales for a thickness of nearly 60 feet, overlain by a massive, coarse-grained, cross-bedded sandstone which constitutes the main mass of the formation and gives rise to the prominent cliffs by which it is characterized. The underlying coal and shale series is extremely variable in thickness and occurrence. Owing to the slipping of the overlying sandstone and to talus derived from it the horizon is rarely exposed, so that it is difficult to ascertain its relations, except where excavations have been made. In some localities to the west and north it is known to be thin or absent.

Local sections.—At Aladdin Professor Jenney reports the following beds:

Section of Lakota formation at Aladdin, Wyo.

	Feet.
Fuson formation	73
Massive yellow sandstone, cross-bedded, forming cliffs	35
Conglomerate of small pebbles of flint and quartz	3
Breccia of angular fragments of sandstone and shale in white clay	3 to 10
Yellow sandstone	10
Massive gray sandstone, thin layers, forming cliffs	30
Drab clay shales with plant remains	2 to 5
Soft sandy shale with carbonized plants	2
Coal	1
Soft yellow sandstone	4
Drab clay shales	12
Coal	3
Drab clay shales (Morrison ?)	15
Total	193 to 203

The total thickness of Lakota beds in this section is about 115 feet. Half a mile farther west the thickness appears to be 183 feet, including 75 feet of beds penetrated by a shaft, but this estimate is probably considerably too great. The following beds are reported by Professor Jenney. Some of the upper ones may belong in the Fuson formation.

Section of Lakota formation in western part of Aladdin, Wyo.

		Feet.
	Talus (lower Fuson beds).	
	Yellow sandstone with iron concretions	12
	Sandstone, in part shaly	26
	Breccia of shale in white clay	3
	Soft yellow sandstone	6
	Massive yellow sandstone forming cliffs (typical Lakota)	30
	Shales, in part sandy	3
	Conglomerate, pebbles 1 to 2 inches, hard sandstone and siliceous limestone, and a few quartz pebbles	8
	Soft sandstones and sandy shales	20
Shaft.	Shales, clays, and soft sandstones	55
Shaft.	Coal	5
Shaft.	Clay and shales	13
Shaft.	Coal	2
	Total	183

The sandstones overlying the 3-foot breccia bed unite east and west of the section and form a cliff extending for some distance in both directions.

A section of the Lakota beds on the south side of the front ridge south of Aladdin, beginning at a slope of Fuson formation above and extending to light-colored Morrison clays below, is reported by Professor Jenney as follows:

Section of Lakota formation south of Aladdin, Wyo.

	Feet.
Massive yellow sandstone, cross-bedded	35
Yellow sandstone weathering in thin layers; cliffs	35
Clay shales and sandy shales	4
Soft yellow sandstone	2
Drab clay shales with plant remains	8
Coal	2
Gray clay	1
Soft sandstone, ocher colored, thick bedded	18
Soft yellow sandstone	8
Gray sandy shales	4
Soft yellow sandstone	3
Gray clay shales	4
Coal, impure and shaly	2
Yellow sandy shales	6
Drab clay	3
Coal	1
Gray clay	2
Gray clay shale	7
Carbonaceous shale with thin layers of coal	1
Gray sandy shales	15
Carbonaceous shales with fossil plants	3
Soft yellow sandstone, iron stained	1
Morrison light clays.	
Total	165

Some excellent sections of Lakota beds are afforded by coal prospects north of The Forks, mainly in a tunnel run into the hillside about 60 feet and in two shafts sunk to a depth of 90 feet. These are 1½ miles and 2 miles north of The Forks, respectively. Data for the following combined section are reported by Professor Jenney:

Section of Lakota beds north of The Forks, Wyo.

		Feet.
Tunnel.	Coarse gray sandstone	5
Tunnel.	Massive yellow sandstone, cross-bedded	30
Tunnel.	Massive soft yellow sandstone, thin-bedded, underlain by two thin beds of coal 9 inches and 1 foot thick at the tunnel	40
Shafts.	Drab clay shales	20
Shafts.	Shaly coal	1
Shafts.	Sandstone	1
Shafts.	Alternating beds of shales and sandstone	12
Shafts.	Coal	½
Shafts.	Black shale	2
Shafts.	Sandstone	3
Shafts.	Coal and shale	1
Shafts.	Clay	3
Shafts.	Sandstone	2
Shafts.	Black clay shale, changing to gray shale at base	12
Shafts.	Sand rock	2
Shafts.	Shale with plants	2½
Shafts.	Sand rock	6
Shafts.	Morrison clays.	
	Total	143

Fossil plants.—Many remains of plants have been collected from the lower shale series at various localities in and near the Hay Creek coal field. The sandstone contains much fossil wood and marks the horizon from which numerous cycads have been obtained in various portions of the Black Hills. These curious plants consist of an oval trunk extending a short distance out of the ground, with leaves on long stems growing out of its surface. The fossil cycad ordinarily consists of the petrified trunk, which shows the deep scars of the former sockets of the leaf stems. Some specimens of these found in this quadrangle are said to have been obtained northeast of Harding Gulch, near the north end of the Bear Lodge Mountains.

FUSON FORMATION.

General relations and character.—Lying between the massive sandstones of the Lakota and Dakota formations, there is a series of shales and thin-bedded, soft sandstones which have been designated the Fuson formation. Much of the material is a sandy shale with thin sandstone layers, having in all a thickness of 60 to 100 feet. The formation is generally concealed by talus from the overlying beds, but usually its position is indicated by a well-defined slope between the sandstone cliffs.

On the Belle Fourche near the mouth of Medicine Creek the upper portion of the formation is exhibited in many places, but the lower portion, as in other parts of the quadrangle, is generally concealed. Farther north the shales are mostly replaced by sandstones. These occur more often near the middle of the formation, but are frequently observed near its bottom and occasionally toward the top. The local sections are extremely variable. Two miles south of Aladdin the formation includes a bed of sandstone measuring 8 feet in thickness and another 3 feet. Near Eothen the sandstone comprises nearly half the thickness of the formation. The upper beds usually show an abrupt transition through purple and red clay and yellow and gray carbonaceous shales, with thin ironstone and sandstone layers, to the massive Dakota sandstone above.

Thickness.—The thickness of the formation at Aladdin is 70 to 100 feet, west of Carroll it is 80 feet, 2 miles east of Eothen it is 60 feet, and near Alva and near the VVV ranch it is 100 feet.

Local sections.—Near the headwaters of Pine Creek the formation comprises, according to Professor Jenney, the beds mentioned in the accompanying table.

Section on north side of Pine Creek near its forks.

		Feet.
Dakota	Massive gray sandstone, weathering in large blocks, red to black on surface	30
Fuson	Light-gray sandy shale, base not exposed	5
Fuson	Unexposed slope (probably shale)	30
Fuson	Yellow sandstone, weathering brown	4
Fuson	Gray clay shales, base covered	4
Fuson	Unexposed slope	28
Fuson	Yellow sandstone, thin bedded	8
Fuson	Gray sandy shales	2
Fuson	Clay shales with imperfectly preserved plants	2
Fuson	Unexposed slope	6
Fuson	Yellow sandstone, thin bedded.	3
Fuson	Gray sandy shales with well-preserved plants; low bluff	14
Fuson	Unexposed slope to Pine Creek	5
	Total	111

The basal gray sandy shales near this section yielded a large collection of fossil plants. On the south side of the creek half a mile southwest some of these beds are again exposed, together with lower ones.

Oak Creek, near its junction with Alum Creek, cuts through the Dakota sandstone and reveals the greater part of the Fuson formation. The following beds are reported by Professor Jenney:

Section in Oak Creek Canyon near Alum Creek.

		Feet.
	Top of plateau.	
Dakota	Red sandstone, much denuded	2
Dakota	Carbonaceous shale with thin coal	1
Dakota	Red sandstone	10
Fuson	Shales and sandstones on partly exposed slope	60
Fuson	Carbonaceous black shale	1
Fuson	Drab sandy shales with finely preserved plant remains	4
Fuson	Yellow sandstone	3
Fuson	Drab clay and sandy shales	2
Fuson	Gray sandstone	7
Fuson	Gray sandy shales	5
Fuson	Black carbonaceous shale; base of cliff, creek bottom	4
	Total	99

The following section at the Robbins ranch, a mile above the preceding section, illustrates some of the stratigraphic variations in the formation:

Section at the Robbins ranch, on Oak Creek.

	Feet.
Dakota sandstone.	
Unexposed slope with outcrops of sandstone	60
Soft massive sandstone, weathering thin bedded	15
Black carbonaceous shale and clay	3
Light-purplish sandstone	10
Gray clay shales	2
Reddish-purple sandstone and sandy shales, with iron concretions	4
Soft yellow sandstone	6
Clay shales and sandy shales, with well-preserved plants	2
Gray shales	3
Carbonaceous black shale	3
Drab clay	3
Sandstone	5
Talus to Oak Creek	20
Total	136

In this section the formation appears to have a thickness of about 110 feet, but the top and bottom are not clearly exposed. The typical plant horizon noted in the previous sections lies 102 feet below the supposed base of the Dakota sandstone. In the Robbins prospect tunnel, a mile southeast, the plant horizon is 117 feet below the Dakota ledges, and 122 feet of the formation are exposed, to or very nearly to its base.

On the south branch of Hay Creek the formation is mostly obscured by talus, so that instructive exposures are rare. At Aladdin the following beds are reported by Professor Jenney:

Section of Fuson formation at Aladdin, Wyo.

	Feet.
Dakota sandstone	30+
Talus	15
Yellow-brown sandstone	5
Talus	12
Yellow-brown sandstone	6
Purple clays, partly exposed	20
Yellow sandstone, thin bedded	15
Massive Lakota sandstone	45
Total	148+

The thickness is only 73 feet. Half a mile farther west the formation appears to be 102 feet thick, comprising the usual succession of shales and clays with beds of soft brown sandstone, 6 to 15 feet thick, but its limits are somewhat indefinite. On the south side of the ridge a mile south it is 70 feet thick.

Fossils and age.—The plant-bearing horizon is apparently continuous over a wide area in the region lying between Pine and Hay creeks and southward. From it Professor Jenney has obtained a large number of finely preserved plant remains, which have been described by Ward and Fontaine.[1] According to Ward the age of the plants from the Fuson formation is Lower Cretaceous.

DAKOTA SANDSTONE.

General relations.—All the larger, higher ridges in the central and western portions of the Aladdin quadrangle, including the crest of the Bear Lodge Mountains, are capped by the Dakota sandstone. It also rises in a ridge of considerable prominence in the anticline east and north of The Forks. Owing to the thinness of the formation and the deep canyons by which it is traversed, its outlines

[1] Nineteenth Ann. Rept. U. S. Geol. Survey, pt. 2, 1899, pp. 521-946.

are very complex. It lies nearly level along the Bear Lodge Range and dips gently to the northeast in the center of the quadrangle. Its outcrop crosses the Belle Fourche just below the mouth of Spring Creek, where the sandstone, dipping to the northeast, passes beneath the Graneros shale.

Character.—The rock consists mainly of a massive, cross-bedded, buff-brown sandstone of varying thickness, usually hard and highly resistant to erosion. It weathers to a reddish-brown color at most places. In the Bear Lodge Range and farther north its thickness is from 120 to 140 feet, but it thins gradually to the east, and south and southeast of Aladdin it is not over 60 feet thick.

Its characteristic feature is its reddish-brown cliffs of massive sandstone, with nearly vertical cleavage and roughly columnar structure, but in places where the rock is softer this feature is less pronounced. It nearly always contains many thin streaks and lenses of ironstone, and throughout its course it is in most places distinctly more ferruginous than the Lakota sandstone, as well as harder and more massive.

Near the Robbins ranch, on Oak Creek, the Dakota sandstone is 78 feet thick, according to Professor Jenney, comprising at the top 25 feet of sandstones and sandy gray shales, underlain by 3 feet of black shales with poorly preserved plant remains, 10 feet of thin-bedded sandstone, and, at the base, 40 feet of massive sandstone of yellow to gray color, weathering reddish and brown. Below is a 60-foot slope, probably nearly all Fuson, with only a few sandstone layers outcropping, and then a succession of Fuson sandstones and shales.

In the vicinity of Aladdin the Dakota beds capping the cliff are about 70 feet thick and consist mostly of soft gray and yellowish sandstone, thin bedded for the lower 15 feet.

Fossils and age.—In this region the Dakota has yielded no satisfactory fossils, but in other portions of the Black Hills it has been found to contain remains of dicotyledonous plants of later Cretaceous age.

GRANEROS SHALE.

The Graneros shales underlie a wide area in the northeastern half of the Aladdin quadrangle, extending from the slopes of Dakota sandstone to the north side of the valley of Crow Creek in a belt averaging 15 miles in width. The formation also extends southward in the syncline north of Aladdin. The rocks are mostly shales and are separable into three divisions—a lower member of black fissile shales, aggregating nearly 300 feet in thickness; a member, of about the same thickness, of dark-gray shales of hard texture, which weather to a distinct grayish-white color and contain numerous fish scales; and an upper member of softer dark shales about 200 feet thick. The upper and middle series merge indefinitely, but between the middle and lower members there appears to be a nearly continuous layer of soft buff sandstone, from 6 to 10 feet in thickness, which apparently represents the oil sand of the Newcastle region and the sandstone lenses near Rapid and Hermosa. The most southern outcrop of this sandstone in the Aladdin quadrangle is at the ford of the Belle Fourche a short distance below the mouth of Horse Creek. From this locality it outcrops along the line of round-topped hills which extends in a northwestern direction nearly to the Belle Fourche at a point due east of the mouth of Bushy Creek. Beyond this point it was not observed.

Much of the Graneros outcrop is covered by sod, but there are many areas which are bare and eroded into gullies and low badlands. The middle member of the formation outcrops in a large area along the Belle Fourche and the narrow outlying ridges parallel to that stream, an area which owes its width to the low anticline extending northward from the Dakota sandstone ridge east of The Forks. The outcrops of the middle member are conspicuous owing to their light-gray slopes, often with but little sod, but bearing numerous small pines and scrubby oaks. Some of the shale has a bright-yellowish appearance on the joint planes, a feature which is characteristic of this member of the formation throughout eastern Wyoming. The shales are hard and do not break readily into thin layers, and some portions which contain much fine sand are solidified into hard layers; consequently the member is a ridge maker. They are the Mowry beds of the Bighorn Mountain region.

In the upper portion of the upper shale series of the formation, about 20 feet below the top, there occur scattered biscuit-shaped concretions, which are conspicuous in most outcrops. They are mostly 1 to 6 feet in diameter, and are iron stained and weathered to a grayish-yellow color.

GREENHORN LIMESTONE.

This thin series of limestones usually gives rise to the outermost escarpment of the Black Hills uplift, forming a low but distinct line of bluffs due to the hardness of the rock as compared with the softness of the surrounding shales. This feature, however, is less distinct than usual in the Aladdin quadrangle, though the formation extends across its northeast corner in the slopes north of Crow Creek.

The thickness of the Greenhorn limestone averages 40 feet or less, the limits being somewhat indefinite. Beds of passage into the adjoining formations are the limy shales, but in the center of the Greenhorn limestone there are found about 20 feet of thin-bedded sandy limestones, with some shale intercalations. The rock contains the very characteristic fossil *Inoceramus labiatus*, but here only in small numbers and usually fragmentary.

CARLILE FORMATION.

The Carlile formation occupies the higher parts of the divide between Crow and Owl creeks, the beds dipping gently northeastward. It has a thickness of about 400 feet, as nearly as can be estimated from the low dips in the zone of outcrop. The rocks are chiefly black fissile shales similar to those of the lower Graneros, but include a nearly persistent bed of thin gray sandstone about 100 feet above the base, some biscuit-shaped concretions in the basal shales, and occasional scattered concretions higher up. At its top it appears to present a transition series to the Niobrara formation of alternating dark- and light-colored shales, so that the limits of the formation are not distinctly marked. Molluscan fossils of typical upper Benton forms occur in some of the concretions and also in thin layers of sandy limestone.

NIOBRARA FORMATION.

This formation outcrops in the valley of Owl Creek, in a zone about $1\frac{1}{2}$ miles wide. It dips gently to the northwest and has a thickness of about 200 feet, as nearly as can be determined. The rock consists mainly of soft limy shales with occasional thin layers of limestone consisting almost entirely of shells of the very distinctive fossil *Ostrea congesta*. The fresh material is light gray to pale buff in color, but on weathering changes to a rich creamy yellow, which is characteristic of the Niobrara. Owing to the softness of the materials, the formation is seldom well exposed. It lies mainly in the lower slopes of the valley and merges into the underlying formation, its weathered wash extending down the slopes in such way that it can not be accurately mapped. Moreover, much of its area is covered by sod, and along Owl Creek it is extensively overlain by local alluvial deposits.

PIERRE SHALE.

Lower members of this formation extend from the higher slopes north of Owl Creek to the northeast corner of the quadrangle. The material is a soft, dark-colored shale containing small calcareous concretions, which weather out on the surface into small, brownish, angular fragments. The lowermost members are dark and fissile, rising in badland slopes above Owl Creek Valley. The outcrop area of the Pierre shale is a region of low, rounded hills, sparsely covered with grass, and not very useful for agriculture. The thickness of the shales in the Aladdin quadrangle is between 450 and 500 feet, as nearly as can be estimated. Typical Pierre fossils occur sparingly in the valley of Lonetree Creek and farther northeast.

TERTIARY SYSTEM.

SAND, GRAVEL, AND CONGLOMERATE.

Distribution.—In the higher portions of the Bear Lodge Range there are remnants of Tertiary deposits that are believed to represent the White River formation of the region east and south of the Black Hills. They extend from an altitude of 4800 feet up to an apparent shore line at 6000 feet, having a regular slope downward to the north and northeast. The most extensive deposits are on the main axis of the Bear Lodge Mountains and on the high ridge lying between Beaver Creek and Lame Jones and Blacktail creeks. These areas are high plateaus underlain mainly by Dakota sandstone, and their capping consists of sands and gravels having in places a thickness of 200 feet or more. Some small outlying masses occur on buttes between the branches of the forks of Redwater Creek, on the slopes of the high ridges at the head of Blacktail and Lytle creeks, and at altitudes of 3800 to 4100 feet south and southeast of Beulah. One of the largest exposures of the formation is on the west edge of a terrace at the head of Blacktail and Lytle creeks, a short distance west of the main road, where it occurs in a steep, bare slope over 100 feet high. Other extensive exposures occur along the east side of the terrace on the Bear Lodge Mountains a short distance west of Sheep Mountain.

Materials.—The material of these deposits consists largely of fine-grained loam of buff color, with occasional hardened or nodular layers and more or less admixture of bowlders, gravel, and sand. In some places the loam merges into an impure fuller's earth, similar to that which is characteristic of the Chadron formation (*Titanotherium* beds). Near the greater igneous areas the deposits contain a large amount of igneous rock, mostly in angular masses from 1 to 6 inches in length. Beds of bowlders often occur at the base and at intervals higher up.

Upper beds.—At the top of these deposits there is generally a capping of bowlders and sand, constituting the surface of the terrace. Whether the cap is a part of the underlying beds or a separate deposit was not ascertained, though there is no evidence of unconformity between them. In some localities, especially southwest of Beulah and in places in the Bear Lodge Mountains, the top beds are conglomerate, the bowlders and pebbles of which represent the rocks of the adjoining slopes south. The matrix is mostly lime and sand. In the extensive exposures west of Sheep Mountain the upper beds are a breccia of angular igneous rocks in a lime matrix. A similar breccia is also exposed at the top of the terrace at the head of Blacktail and Lytle creeks.

QUATERNARY SYSTEM.

The Quaternary formations of the Aladdin quadrangle comprise alluvial deposits along the stream valleys and upland gravels and sands occupying old terraces which are remnants of a previous epoch of topographic development.

Older terrace deposits.—The older terrace deposits cap nearly all the slopes of moderate height adjoining the valley of the Belle Fourche, and small areas extend up the Red Valley and the valleys of Beaver, Lame Jones, and Hay creeks. They mark the course of old streams which have since cut to lower levels, and undoubtedly they were originally much more extensive, but with the degradation of the country a large amount of the material has been removed or widely scattered, especially in areas where it was thin. One of the most notable of the earlier terraces is Stoneville Flats, which marks the original course of the Belle Fourche, above its bend, to the Little Missouri. This terrace merges into the valley of the latter stream, but the Belle Fourche has cut its new valley down to a level about 100 feet lower than its original bed. The extension of this terrace level southward up the Belle Fourche is defined for some distance by gravel-capped benches that stand 80 to 100 feet above the present stream.

There are also higher terrace levels along the valley and on the divide east of Stoneville Flats, indicating a still earlier stage of the valley development. A portion of the divide between the Belle Fourche and Crow Creek valleys is capped by gravels and similar high-terrace remnants, which extend far southward to the basin of Graneros shale south of the mouth of Deep Creek. These finally reach across the divide to Hay Creek east of Aladdin. In the Red Valley there are numerous small remnants of earlier terrace deposits on both sides of the Redwater Valley, and in the upper portion of Government Valley they spread out in an area of considerable extent. On the divide between the headwaters of Lame Jones and Blacktail creeks there are a number of high-level gravel deposits which stand at an unusually high altitude. The materials of the earlier terrace deposits consist mainly of gravels and sands, but include more or less loam, not unlike the alluvial deposits but with a larger amount of coarse-grained material. The thickness of the terrace deposits varies from 15 feet to a thin sprinkling of pebbles, the larger amount being exceptional. In many areas these deposits are thin and of such indefinite limits that they can be mapped only approximately.

Alluvium.—The principal alluvial deposits are in the wide valleys excavated in the Graneros and Spearfish shales, but narrow areas of recent alluvium extend up nearly all the valleys and merge into the general talus and wash on the hill slopes. Only the larger alluvial areas are represented on the map. The most extensive of these lie along the valleys of the Belle Fourche, Crow Creek and its branches, Little Missouri River, and Kilpatrick, Owl, Redwater, and Hay creeks.

The materials of these deposits are mainly loams and sands, with some admixture of coarse materials, all of local derivation. Along Redwater Creek there is considerable reddish material derived from the Spearfish red shale. Along the Belle Fourche the alluvium contains considerable sand, and along the other valleys of the shale area in the northern portion of the quadrangle the alluvium consists mainly of clay from the adjoining slopes. The deposits vary from 15 to 20 feet in thickness in most places, the thickest deposits being found along the Belle Fourche and the Little Missouri.

Igneous Rocks.

By W. S. Tangier Smith.

ALGONKIAN INTRUSIVES.

GRANITE.

Occurrence.—Granite is found in the Bear Lodge Mountains, in the southwest corner of the Aladdin quadrangle, where it occurs in the main igneous area of the Bear Lodge uplift. In most of the occurrences in the uplift, especially to the southward, the granite is found as definite inclusions in later igneous rocks or as part of an igneous breccia. It is believed that the larger areas also are of the nature of included masses, notwithstanding the dike-like form of some of them and the lack of suitable exposures to prove that they are not later dikes in the porphyry. This interpretation seems the more probable as none of the granitic rocks of other parts of the Black Hills are known to be of post-Cambrian age.

The granite inclusions within the laccolith south of the margin of this quadrangle are common and in places abundant, especially in the igneous breccias (not shown on the map). They vary greatly in size, ranging from microscopic fragments of the different minerals composing the granite to oblong areas a quarter of a mile or more in length. The largest body of granite (only the northern end of which appears in this quadrangle) extends for more than 3 miles along the eastern side of the laccolith, on the headwaters of Beaver and Redwater creeks. It has a strike and dip roughly paralleling those of the Cambrian rocks just east of it, and is probably an uplifted rather than an included mass. For the greater part of its course it is overlain by a thin bed of quartzite forming the base of the Deadwood formation, which, however, is separated from the succession of sedimentary rocks to the east by porphyry sheets.

Within the main igneous area the granite was noted only between the area of Cambrian rocks and the center of the laccolith. This admits of two interpretations: (1) that the granite is of post-Cambrian age, and was originally intruded beneath the Cambrian without penetrating it; or (2) that it is of pre-Cambrian age. The absence of other pre-Cambrian rocks such as occur in the Nigger Hill uplift of the Sundance quadrangle to the south suggests the former interpretation, though the possibility of the occurrence of a considerable body of granite underlying this area, as well as analogy with other parts of the Black Hills, gives weight to the second hypothesis.

Outside the main laccolith small, scattered inclusions of fine-grained biotite-granite occur at one point in a long, narrow phonolite area which extends along the western flank of the uplift and of which only the northern extremity appears in this quadrangle, on Lytle Creek. Also, inclusions of medium-grained granite and other rock fragments are numerous in an intrusive sill of porphyry toward the head of the easternmost fork of Blacktail Creek, about $1\frac{1}{2}$ miles north of the southern margin of the quadrangle, the granite inclusions at this point having a maximum noted length of $1\frac{1}{2}$ feet.

Description.—The Bear Lodge granite is a light-gray rock, consisting of quartz and one or more species of feldspar. Magnetite, apatite, and zircon occur in very small amounts as accessories. Although mica as a rule is either wanting or present only as an accessory, yet at one point, near the eastern edge of the large granitic area near the eastern margin of the laccolith, biotite is so abundant as to form one of the essential constituents of the rock. The feldspars are microcline, microperthite (not always present, though sometimes found in considerable amount), albite, and occasionally oligoclase in variable amounts. Orthoclase or microcline—very rarely albite—is the dominant feldspar. Quartz is always common or abundant.

The granites are at times, though not usually, porphyritic. The more or less tabular feldspar phenocrysts reach a maximum length of between 3 and 4 cm. The rocks are, on the whole, rather fine grained. In most of the occurrences the individual anhedra reach a maximum length of between one-half and 1 cm., the average diameter of the grains being usually in the neighborhood of 2 mm. Rarely the granite is much finer grained than this, as for example toward the north end of the large area referred to above. The general fineness of the grain, together with the poverty in mica, would ally these rocks with the aplites rather than with the typical granites.

TERTIARY IGNEOUS ROCKS.

General relations.—In the southwest corner of the Aladdin quadrangle is the north end of the Bear Lodge laccolith, a large mass of igneous rocks intruded beneath the sedimentary strata and raising them in an elevated dome. The summit ot this dome has been removed by erosion, revealing the igneous rocks in an area of several square miles. The principal plane of intrusion of the main laccolith was low in the Deadwood formation, in places at or below its base, but northward it rises across the Pahasapa limestone into the middle of the Minnelusa beds. At this horizon it is irregular, however, cutting across the beds upward and downward. Some thin sheets are intruded at higher horizons than the main laccolith, and two large igneous masses farther northwest rise across the Minnelusa formation to the Minnekahta limestone on the head of Blacktail Creek, and into the lower beds of the Sundance formation on Lytle Creek. Numerous small dikes also appear cutting across beds from Pahasapa to lower Sundance. The principal structural relations are shown in sections E-E and F-F of the structure-section sheet. The uplift is in general a dome, elongated to the northwest, with many local irregularities of dip due to displacement by the igneous rock.

The rocks of the intrusion comprise chiefly syenite-porphyry, with a minor though still important amount of phonolite, and a number of occurrences of pseudoleucite rocks.

As the igneous masses found in the southwest corner of the quadrangle form a part of the larger Bear Lodge laccolith, the principal rock types found here are considered, in the following descriptions, not as individual occurrences, but in their relation to the uplift as a whole.

SYENITE-PORPHYRY.

The principal laccolith of the Bear Lodge Mountains and most of the associated smaller masses about the flanks of the uplift consist of porphyry which is on the whole so rich in orthoclase as to be appropriately termed syenite-porphyry. There is, however, much variation among the Bear Lodge porphyries, and locally they are perhaps monzonite-porphyry. In a large part of this mass there is also a strongly trachytic texture, so that it might be aptly designated trachyte-porphyry in some places.

These rocks have a yellowish, reddish, or grayish color, and as seen in surface exposures are in general greatly altered, usually showing minute cavities due to the leaching of some of the minerals of the rock. Fresh porphyry occurs on the northern and northwestern flanks of the laccolith in intrusive sheets, and also locally within the main igneous mass.

In this fresher porphyry—which is not to be considered typical for the laccolith as a whole—there are phenocrysts of feldspar and ferromagnesian minerals with a minor proportion of magnetite. Apatite and sometimes titanite occur as accessories. Sometimes the ferromagnesian minerals are in excess of the feldspar, sometimes the reverse. The former comprise one or more of the following: a pale-green augite (in one instance associated with a little ægirite-augite), brown to green amphibole, and biotite. Each of these, except the ægirite-augite, is at some point the dominant ferromagnesian mineral, though as a rule the biotite is subordinate when found with the augite or amphibole. The feldspar is orthoclase or oligoclase or both. Occasionally the oligoclase occurs with a thin orthoclase mantle. The groundmass of this porphyry, though sometimes granular or trachytic-granular and occasionally relatively coarse grained, is in general composed chiefly of a fine- or very fine-grained trachytic felt or orthoclase, the minute laths showing more or less fluidal arrangement. Sometimes a second generation of augite is found in subordinate amount, and in some places micropoikilitic areas are common in the groundmass.

The weathered porphyry, which is more typical of the Bear Lodge Mountains and especially of the main igneous mass, differs somewhat from that just described. It is nearly always porphyritic. Phenocrysts are sometimes numerous, or even abundant, while again they are few and scattered. They consist essentially of feldspar, the ferromagnesian minerals which in most of these rocks were originally present to a limited extent having been weathered out. The rock shows great variability both in grain and in the kind, size, and abundance of its phenocrysts, the variations occurring sometimes even within a few yards. Frequently some of the surface fragments contain, in addition to small feldspar phenocrysts, large, scattered, tabular crystals of sanidine, while in others all the phenocrysts are small, so that on casual inspection the rock appears to be nonporphyritic. These sanidine phenocrysts reach a maximum length of 2.5 cm. or more. The character of the feldspar phenocrysts and of the groundmass of these rocks is similar to that of the fresher rocks just described.

The chief products of the weathering of these porphyries are muscovite, kaolin, and limonite.

IGNEOUS BRECCIA.

Many of the fissures through which the porphyries have passed must have contained more or less broken rock. The intrusion of the magma itself undoubtedly, in many instances, produced a brecciation of the walls of its conduit; and where there have been successive igneous intrusions, these breccias include previously intruded porphyry as well as older igneous or sedimentary rocks. Such breccias in a matrix of the intruding rock are common associates of the igneous intrusives of the northern Black Hills, being found most often along the margin of the mass. In the Bear Lodge Mountains they occur both within the main laccolith and in connection with several of the minor intrusives, especially on the east side of the uplift. They have been noted on the ridge and slopes west of the private road near the northwest corner of the quadrangle. Also in an intrusive sheet of porphyry toward the head of the easternmost fork of Blacktail Creek, about $1\frac{1}{2}$ miles north of the southern margin of the quadrangle, are many fragments of various rocks (including granite, as already mentioned).

The Bear Lodge breccias in general contain abundant fragments of granite and various facies of the Bear Lodge porphyries, together with numerous fragments of minerals from the coarser-grained rocks, especially granite, all in a reddish, yellowish, brownish, or grayish matrix, which as a rule constitutes but a small part of the rock. The rock as a whole is always greatly weathered, and minute cavities, due to the leaching out of minerals, especially the ferromagnesian constituents, are common both in the matrix and in many of the included rock fragments. The matrix usually contains abundant microscopic grains of red or yellow iron oxide, sometimes so numerous as to render the matrix almost opaque in thin section. The clearer parts of this matrix, as seen with a high power under the microscope, show a faintly polarizing granular or somewhat felted feldspar aggregate.

PHONOLITE.

Phonolite is of relatively common occurrence as dikes or small masses within the Bear Lodge laccolith and in sheets and minor laccoliths on the flanks of the uplift. These rocks are occasionally so much weathered that they can not be distinguished with certainty from the weathered syenite-porphyries. Three definite occurrences of these rocks have been noted in this quadrangle—one a considerable body near the western margin and about $2\frac{1}{2}$ miles north of the southern margin; another adjacent to Lytle Creek, at the southern margin; and the third on Beaver Creek, $1\frac{1}{2}$ miles north of the southern margin. Of these, the first extends across the divide from the west fork of Blacktail Creek, having a surface exposure of about a square mile. It has an irregular form and cuts across formations from the Pahasapa limestone to the Sundance shales. The occurrence near Lytle Creek is the north end of a long and comparatively narrow mass which cuts across the Carboniferous rocks and extends for more than 3 miles along the flank of the uplift. That on Beaver Creek occurs as a sheet 20 to 25 feet thick, intruded between the Opeche and Minnelusa formations.

The phonolites of the Bear Lodge uplift as a whole are moderately light gray to very dark gray in color, usually with a slight, sometimes decided, greenish tinge, and rarely a light-slate gray. In general they are massive, though in one instance they are fissile, almost slaty.

These rocks are always porphyritic, most of them decidedly so, and they frequently contain numerous coarse, tabular sanidine crystals which reach a maximum length of 3 cm. or more. The phenocrysts are sanidine (or perhaps soda-orthoclase), anorthoclase, augite, ægirite-augite, sometimes with augite centers or ægirite rims or both. An altered and undeterminable feldspathoid or group of feldspathoidal minerals, melanite-garnet, magnetite, titanite, apatite, and rarely zircon also occur as phenocrysts. Feldspar or the feldspathoid is most common, though locally ægirite-augite is most abundant. Brownish or brownish-yellow melanite is sometimes common; magnetite is generally unimportant; while titanite and apatite are common accessories in most of the rocks.

The groundmass of the phonolites is always fine grained, sometimes granular, more often trachytic, and usually showing flow structure. It is composed mainly of alkali-feldspar laths, together with more or less ægirite or ægirite-augite or both, sometimes augite, one or more feldspathoids, frequently a small amount of magnetite, and rarely a little garnet. Usually only one feldspathoid has been noted, most often a second generation of the one occurring among the phenocrysts. Nephelite occurs in the groundmass of some of the rocks, being occasionally abundant, in clear, colorless, short, hexagonal prisms.

NEPHELINE-SYENITE-PORPHYRY.

A syenite-porphyry of very variable texture, and in part at least containing what is probably altered nephelite, is found nearly 2 miles east of the western margin of the quadrangle and $1\frac{1}{2}$ miles north of its southern margin, near the head of Blacktail Creek, occurring here apparently as two sheets, outcropping 200 to 300 yards apart. This porphyry contains numerous syenitic segregations, aside from which the rock is porphyritic, though not markedly so. Of two porphyritic facies which were noted, one has phenocrysts of orthoclase and magnetite with occasional biotite. In the other and more typical facies the phenocrysts consist of augite and magnetite, rarely orthoclase. The fine-grained groundmass of both facies is sometimes granular, sometimes trachytic, and is composed of orthoclase with subordinate augite and magnetite. The augite in the first-mentioned facies forms minute granules, and this and the magnetite are frequently so aggregated as to suggest a derivation from hornblende by resorption. The syenitic and nonporphyritic portion of the porphyry has a trachytic texture and, in addition to the orthoclase, augite, and magnetite, contains a considerable amount of brown amphibole, which often forms a narrow, irregular border about the augite. The apparently altered nephelite (?) of these rocks was noted in the second porphyritic facies and in the syenitic portions, but not in the first facies.

PSEUDOLEUCITE ROCKS.

Close to the northern margin of the Bear Lodge laccolith, nearly a mile north of the southern border of the quadrangle, there is a considerable body of rock called here pseudoleucite-porphyry. A second occurrence of this rock is found, apparently as an intruded sheet, on the east fork of Beaver Creek, $1\frac{1}{4}$ miles north of the southern border and about $1\frac{3}{4}$ miles east of the western border of the quadrangle. In addition, loose blocks of pseudoleucite-porphyry were noted near the western border of the quadrangle nearly 2 miles north of its southern border, on the slope east of Lytle Creek. These rocks are always much weathered, and are usually light gray with more or less of a reddish or yellowish tinge, though sometimes dark gray. As nearly as can be determined from their present condition, they were originally holocrystalline and porphyritic, with many phenocrysts of leucite and a minor proportion of some ferromagnesian mineral and magnetite. In addition to these minerals, the rock on Blacktail Creek contains small orthoclase crystals, as well as scattered phenocrysts of nephelite (?), while in the occurrence near Lytle Creek nephelite and garnet appear to have been present as phenocrysts.

The groundmass in some of the rocks, and probably in all, consisted essentially of a trachytic aggregate of orthoclase—the only determinable constituent of the groundmass. All these rocks now consist of little more than an aggregate of orthoclase, mostly secondary. In the most-altered rocks the aggregates of the phenocrysts differ in no respect from those of the groundmass, the pseudoleucite phenocrysts being indistinguishable in polarized light, and the feldspars passing without break from the crystals into the groundmass. In addition to the feldspar, muscovite in scattered and aggregated microscopic flakes and secondary iron oxide are common.

These rocks are very similar to some of the pseudoleucite-porphyries of the Mineral Hill region, in the Sundance quadrangle, just south of this.

A much-altered pseudoleucite-nephelite-syenite-porphyry occurs on the east side of Lytle Creek nearly three-fourths of a mile north of the southern margin of the quadrangle. It is a hypidiomorphic-granular, somewhat porphyritic, mesocratic rock, with the light minerals a little in excess of the dark, and consists essentially of pseudoleucite, nephelite, feldspar, pyroxene, iron oxide, and probably garnet. Apatite occurs as an accessory. The pseudoleucite phenocrysts, the only porphyritic mineral, constitute the largest element of the rock, although they are not numerous. In the hand specimen they appear as small, light-gray, nearly white spots, with sometimes a slight reddish tinge, having the form of leucite. They are comparatively small, reaching a maximum diameter of about 7 mm. They consist of granular aggregates of untwinned feldspar with rather weak polarization. This feldspar is somewhat clouded with decomposition products, and contains microscopic flakes of muscovite, most often arranged in parallel lines, and doubtless due to the original intergrowth of some other mineral with the untwinned feldspar. A second generation of pseudoleucites, each usually consisting of a single grain of feldspar, occurs in the groundmass of the rock. In addition to its occurrence in the pseudoleucites, untwinned or rarely simply twinned feldspar is a common constituent of the groundmass, occurring in granular aggregates as a residual crystallization among the other minerals. These feldspars differ from those of the pseudoleucites in being clear and in containing numerous inclusions of the other minerals of the rock. Nephelite more or less altered is abundant, occasionally in idiomorphic forms. The pyroxene consists of augite and ægirite, the former in moderately long prisms and largely altered to secondary products, the ægirite in numerous minute needles. Iron oxide is common as magnetite and also, to judge from decomposition products, as ilmenite. What is apparently a considerably weathered garnet is a common constituent of the rock.

STRUCTURAL GEOLOGY.

Structure of the Black Hills uplift.—The Black Hills uplift, if not eroded, would present an irregular dome rising on the north end of an anticlinal axis extending northward from the Laramie Range of the Rocky Mountains (see fig. 1). It is elongated to the south and northwest, has steep slopes on the sides, is nearly flat on top, and is subordinately fluted. The greatest vertical displacement of the strata, as indicated by the height at which the granite and schist floor is now found, amounts to about 9000 feet. The minor flutings of the dome are mainly along the eastern side of the uplift, the most notable ones being in the ridge of the Minnekahta limestone just west of Hot Springs. Another of considerable prominence occurs 3 miles east of Hot Springs. These subordinate flexures are characterized by steeper dips on their western side and gentler dips to the east. They merge into the general dome to the north and run out with declining pitch to the south. In the northern hills there are numerous local domes and flexures, due mainly to laccolithic igneous intrusions, but no similar features are indicated by the structure of the southern hills.

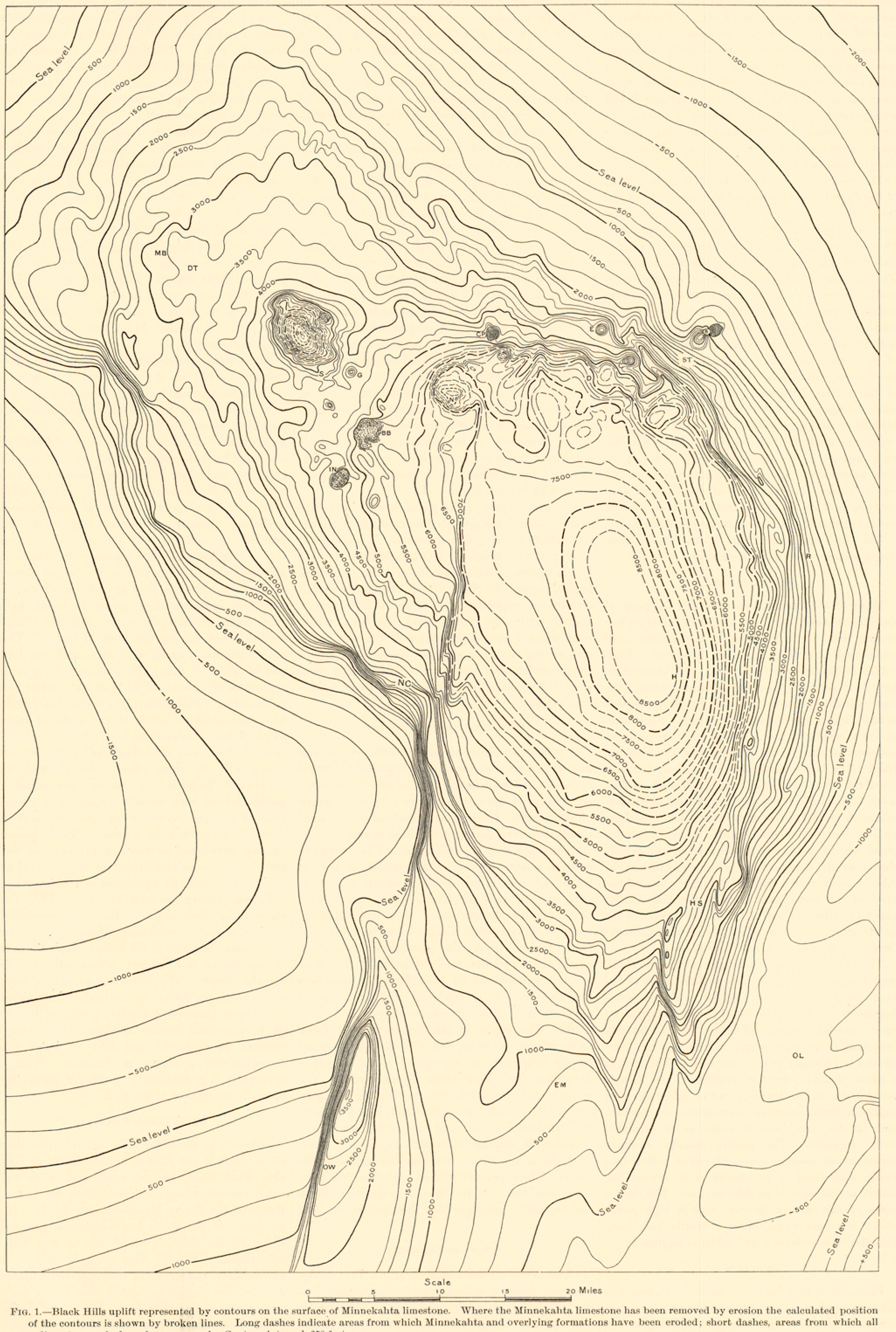


Fig. 1.—Black Hills uplift represented by contours on the surface of Minnekahta limestone. Where the Minnekahta limestone has been removed by erosion the calculated position of the contours is shown by broken lines. Long dashes indicate areas from which Minnekahta and overlying formations have been eroded;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

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

Faults are rarely observed; only a few have been found which amount to more than a few feet in vertical displacement, and these are short breaks due to igneous intrusion.

Structure of the Aladdin quadrangle.—The Aladdin quadrangle embraces a portion of the northern margin of the Black Hills uplift, with rocks dipping northeastward. There are several local irregularities in this monoclinal structure, consisting mainly of variations of strike and pitch and the presence of several low, diagonal undulations of the strata. The rate of slope is generally about 150 feet to the mile, but varies considerably. Near the igneous uplift in the southwest corner of the quadrangle the slope is much steeper, and in the region between the Belle Fourche and Owl Creek and about the northern extension of the Bear Lodge Mountains it is much less. The igneous mass in the southwest corner of the quadrangle is a dome rising steeply above the general Black Hills uplift, due to a laccolithic intrusion which has locally uplifted the strata. In the southeast corner of the quadrangle there is the declining margin of another smaller dome, which rises to a considerable height in the Nigger Hill uplift in the Sundance quadrangle. These two domes are separated by a shallow syncline in the area known as Government Valley. North of the Nigger Hill uplift there is a well-marked anticline which extends northward to the Belle Fourche and ends near the mouth of Kilpatrick Creek. This anticline is especially prominent on Hay Creek near The Forks and for 5 or 6 miles farther north, and it causes the extension of the Dakota sandstone ridge northwest to Alum Creek. The dips are gentle on the eastern side of this arch, but on the western side they are steep and the strata descend into a syncline holding a wide basin of lower Graneros shales that extend southward to Middle Fork of Hay Creek. South of Hay Creek the south end of this basin contains a wide area of Lakota sandstone that extends southward to the northern margin of the Dry Creek Valley. About Aladdin the dips are moderately steep and toward the north-northeast. North and west of Eothen the dips diminish greatly in amount and the Dakota and underlying formations are spread out in a broad area in which the strata dip very gently northeastward. It is on this monocline that the Bear Lodge Mountains extend far to the north, their height and prominence being due to the capping of the Dakota sandstone. To the west, along the valley of the Belle Fourche, where the land is much lower, the Sundance formation extends over a wide area, its strata dipping gently northward. In much of the wide area of plains underlain by shales in the northern and northeastern parts of the quadrangle, the strata dip gently northeastward, but the monocline is interrupted by a wide, shallow syncline in the valley of Kilpatrick Creek, and by two low anticlines that rise in the ridges between this valley and that of Crow Creek. The dips in this syncline and the anticlines are so low that the strata appear to lie horizontal, but the presence of the flexures is clearly indicated by the distribution of the formations, especially of the hard beds in the middle of the Graneros formation. There is no relation between the drainage and the structure, except that in the northeastern part of the quadrangle the streams mostly flow southeastward, along the strike of the softer beds in the shale series.

The only faults discovered are some local uplifts connected with the igneous intrusions in the southwest corner of the quadrangle. In Sheep Mountain there is an uplifted block of strata which is cut off on the south by profound faulting, but connected on the north by a steep upturn of the strata. The fault circles around the southern half of the mountain and dies out rapidly to the north on both sides. At its maximum development, southward, it brings Cambrian sandstones into contact with the lower portion of the Spearfish formation, a vertical displacement of about 1500 feet. This uplift is probably due to the intrusion of a laccolithic mass of igneous rock, a small outcrop of which appears near the southern base of the mountain, in the Sundance quadrangle. The main intrusion of the Bear Lodge Mountains, in the southwest corner of the quadrangle, presents many irregularities in the structure of the uplifted sedimentary beds. The igneous rock cuts irregularly across the strata at many places and some of the beds have been torn away from their normal places. The most notable example of this is on the east fork of the headwaters of Blacktail Creek, where a small mass of the Sundance formation and underlying beds are several hundred feet out of place.

GEOLOGIC HISTORY.

GENERAL SEDIMENTARY RECORD.

The rocks appearing at the surface within the limits of the Aladdin quadrangle are mainly of sedimentary origin—that is, they were deposited by water. In the southwest corner of the quadrangle appear a few small masses of igneous rocks and the margin of the Bear Lodge laccolithic intrusion. The sedimentary rocks 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 Cambrian time to the present. 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 generally indicate open seas and scarcity of land-derived sediment. The fossils that strata contain may belong to species known to inhabit waters which are fresh, brackish, or salt, warm or cold, muddy or clear. The character of the adjacent land may be shown by the character of the sediments derived from its waste. The quartz sand and pebbles of coarse sandstones and conglomerates, such as are found in the Lakota formation, whatever their original source in crystalline rocks, have been repeatedly redistributed by streams and concentrated by wave action on beaches. Red shales and sandstones such as make up the "Red Beds" usually result directly from the revival of erosion on a land surface long exposed to rock decay and oxidation and hence covered by a deep residual soil. Limestones, on the other hand, if deposited near the shore, indicate that the land was low and that its streams were too sluggish to carry off coarse sediments, the sea receiving only fine sediment and substances in solution. The older formations exposed by the Black Hills uplift were laid down from seas which covered a large portion of the central-western United States, for many of the rocks are continuous over a vast area. The land surfaces were probably large islands of an archipelago, which was to some degree coextensive with the present Rocky Mountain province, but the peripheral shores are not even approximately determined for any one epoch, and the relations of land and sea varied greatly from time to time. Pursuing these general ideas in greater detail, one finds that the strata brought to view by the Black Hills uplift record many local variations in the ancient geography and topography of the continent.

BRIEF GEOLOGIC HISTORY.

Cambrian submergence.—One of the great events of early North American geologic history was the wide expansion of an interior sea over the western-central region. The submergence reached the Rocky Mountain province during early 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 form the shore are numerous exposures of these sediments containing much local material. Subsequently, the altitude being reduced by erosion and the area possibly being lessened by submergence, the islands yielded the finer-grained muds now represented by the shales which occur in the upper portion of the Cambrian in some areas. In many regions the land surface of crystalline rocks was buried beneath the sediments.

Ordovician-Devonian conditions.—From the close of Cambrian to the beginning of Carboniferous time the Black Hills area presents a scanty geologic record, the Silurian and Devonian being absent to the south, and only a portion of the Ordovician being present to the north. This is probably because there was an extensive but very shallow sea, or land so low as to leave no noticeable evidence of erosion. Whether it remained land or sea, or alternated from one to the other condition, the region shows no evidence of having undergone any considerable uplift or depression until early in Carboniferous time, when there was a decided subsidence, 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 latter part of the Carboniferous the conditions were so changed that fine sand was brought into the region in large amount and deposited in thick but regular beds, apparently with much calcareous precipitate, and more or less ferruginous material, as is indicated by the color of many beds of the Minnelusa formation. Minnelusa deposition is believed to have been followed by an uplift, which appears to have resulted in ponding saline water in lakes, in which accumulated the bright-red sands and sandy muds of the Opeche formation. The Minnekahta limestone, which is the next in sequence, was deposited from sea water, and from its fossils we know with a fair degree of certainty that it is a product of the latest Carboniferous or Permian time. It was laid down in thin layers and to a thickness now represented by only 40 feet of the limestone, yet the very great uniformity of this formation over the entire Black Hills area is an impressive feature, probably indicative of widespread submergence.

Deposition of red beds.—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 600 feet, as now represented by the formation, which is so uniformly of a deep-red tint that this was undoubtedly the original color. It is present not only throughout the extent of the formation, but also through its entire thickness, as is shown by deep borings, and therefore is not due to later or surface oxidation. Either the original material of the sediments was red or it was colored during deposition by the precipitation of iron oxide. At various times, which were not synchronous throughout the region, accumulation of clay was interrupted by chemical precipitation of comparatively pure gypsum, free from mechanical sediment, in beds ranging in thickness from a few inches to 30 feet. It is believed that these beds are the products of evaporation during an epoch of little or no rainfall and consequently of temporarily suspended erosion; otherwise it is difficult to understand their nearly general purity. The Spearfish red beds have been supposed to represent the Triassic, but there is no direct evidence of this and, in part at least, 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 together with earlier Jurassic time and was succeeded by the deposition of the later Jurassic series.

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 the Spearfish red shales are overlain by Jurassic shale which was deposited in moderately deep water. This is followed by the ripple-marked sandstone, evidently laid down in shallow water and probably the product of a time when sedimentation was in excess of submergence, if not during an arrest of submergence. The red color of the upper part of the medial sandy series in some portions of the Black Hills appears to show a transient return to arid conditions similar to those under which the Spearfish 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 marine conditions gave place to fresh-water bodies, probably through widespread uplift. The new products were the thick body of fine sand of the Unkpapa sandstone, now a prominent feature in the eastern portion of the Black Hills, but apparently 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 waters 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 first deposits now 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 slight local uplift. 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, which is of coastal and possibly estuarine origin. This formation consists mainly of coarse sands spread by strong currents in beds 30 to 40 feet thick, but includes several thin partings of clay and local accumulations of vegetal material. Next there was deposited a thin calcareous series, represented by the Minnewaste limestone, but apparently it was laid down in a local basin in the southern portion of the Black Hills. This was followed by a thin but widely extended sheet of clays of the Fuson formation, marking the end of earlier Cretaceous time. After the deposition of these clays there was a return to shallow waters and strong currents, as in Lakota time, and coarse sands of the Dakota formation were accumulated. At the beginning of the Benton there was everywhere in the region a rapid change of sediment from sand to clay.

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

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

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

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

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 produced mainly by increased tilting to the northeast. This rearrangement has caused several streams that were 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 numerous elevated saddles to mark the southeasterly 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 Pleistocene high-level deposits, seem to be cut more deeply than they would be in simply grading their profiles to the level of Missouri and Cheyenne rivers. Wide, shallow valleys have developed in the soft deposits, and canyons of moderate extent and depth in the harder rocks. Erosion has progressed in the main without local deposition, but in some cases, with the shifting of channels, there have been accumulations of local deposits on small terraces at various levels.

ECONOMIC PRODUCTS.

SOILS.

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

Distribution.—The arable lands of the Aladdin quadrangle are underlain mainly by shale and alluvium. Most of the shale gives rise to a clay soil which is not only barren in itself but is acid from decomposing pyrites and is too sticky for agricultural use. It is covered with grass, which originally afforded excellent pastures, but in some areas has been grazed down by excessive herding. As the soil is not rich and the climate is semiarid, the grass grows slowly and, after close grazing, requires some time to regain its former growth. In almost all the wide valleys in the shale region there are alluvial deposits which are usually fertile. Along the Redwater below Beulah, the Belle Fourche, the Little Missouri, Stoneville Flats, Crow Creek, Middle Creek, and Owl Creek these deposits are wide and are well suited for agriculture wherever they can be irrigated. Along the Little Missouri and in the valleys in the northeast corner of the quadrangle the deposits contain so much clay that their soil is mostly gumbo, derived from the shale of the adjoining slopes. In the valley of the Belle Fourche there are many wide alluvial tracts and, although in many places the soil is rather too sandy and much damage is done by freshets, there are several areas in which hay is raised satisfactorily. Along the Redwater there are numerous fields, many of alfalfa, irrigated by the creek water. In the Red Valley, especially the part known as Government Valley, dry farming has been carried on to some extent, but, owing to the scant rainfall and lack of water for irrigation, crops are uncertain. The soils of the Tertiary plateaus in the southwest corner of the quadrangle are fertile and the land is so high that it receives considerable rainfall. There are several excellent farms on the portion of the plateau west of Beaver Creek, on which wheat and other grains are raised. Farther north, along the Bear Lodge Mountains, there are many areas of alluvial lands suitable for agriculture, but the soil derived from the underlying Dakota sandstone is rather too sandy to be regarded as fertile. The slopes of Minnekahta limestone south of Beulah, in part overlain by Spearfish red shales, are farmed at a number of localities with satisfactory results. Soils derived from the Sundance formation are usually fertile, but some of them contain too much clay to be of use and most of the area presents very irregular topography. On the hill slopes the climatic conditions are too arid for agriculture and water is not available for irrigation.

WATER SUPPLY.

SURFACE WATER.

The average annual rainfall in the Aladdin quadrangle is probably somewhat less than 15 inches, but the amount of rain falling on the elevated Bear Lodge Mountains is considerably more than this. A part of the precipitation is in the form of snow and the remainder falls mostly in heavy showers of short duration, during the spring and early summer months. The Bear Lodge Mountains, which extend to a high altitude, catch many showers that do not fall on the adjacent plains and have also a greatly increased snowfall. As most of the surface of the country has a thin soil and only limited areas present porous rocks, the water of rains and melting snows runs off rapidly, usually in freshets that follow storms or the rapid melting of snow, the latter taking place during warm spells in the spring. In consequence of these conditions there is but little running water in the region during the greater part of the year. Springs are rare and of small volume in the lower lands.

A large amount of run-off in this region could be saved by dams and made available for irrigation. There are suitable dam sites at many localities, especially in the higher slopes. As the evaporation in this region is about 6 feet each year, a large amount of water would have to be impounded to compensate for this loss. There are many excellent dam sites along the creeks flowing eastward into the Belle Fourche, especially at points where the Dakota sandstone crosses the streams; but, judging by the experience of a number of dams in the plains region northeastward, more or less water can be held in almost all portions of the area.

The Belle Fourche.—This river carries a large volume of water during times of freshet, but is a very insignificant stream during the dry periods of midsummer. Its normal flow varies from about 2 to 15 second-feet, so far as observed, and occasionally portions of its course go dry. It drains a large watershed in the plains of eastern-central Wyoming, and probably the total volume of water which it carries in a year is very large. It receives numerous tributaries from the western and northern sides of the Black Hills, including some streams of considerable volume. Its waters are not used to any extent for irrigation because of the difficulty of maintaining head-gates and ditches during times of freshet. Its course is winding, and although there are alluvial flats within most of its bends, these are cut into small areas by the meanders, which in their outer curves usually impinge on the steep slopes of the valley.

Little Missouri River.—This stream crosses the extreme northwest corner of the quadrangle and ordinarily carries but a small volume of water. It is subject to freshets, however, and, although its watershed is not large, flows of considerable volume occasionally pass down the stream during the spring and early summer.

Redwater Creek.—Redwater Creek drains a large portion of the Red Valley in the southeastern portion of the quadrangle and also receives several branches from the limestone region to the south. The main creek rises north of Sheep Mountain and carries a small volume of water, which is augmented by a similar small flow from the North Redwater. Near Beulah the stream is joined by South Redwater and Sundance creeks, which ordinarily do not flow at their mouths, and by Sand Creek and Bear Gulch, two living streams which bring a large volume of water from the limestone region lying farther south. Sand Creek rises in large springs about 4 miles south of Beulah, flows through a canyon for some distance, and, joining the Redwater a short distance north of the village, triples or quadruples its volume. North of Beulah the stream flows through an alluvial valley about half a mile wide, extending into South Dakota, in which the waters are used extensively for irrigation, and there are many fine fields of alfalfa.

Beaver Creek.—Beaver Creek is a small stream which empties into the Belle Fourche near the western margin of the quadrangle. It has a number of branches heading in small springs along the west slope of the Bear Lodge Range, and flows continuously from head to mouth, except possibly for short periods during the driest seasons. Its waters are used to some extent for irrigation, but the alluvial flats in its valley are narrow and not always well located for agriculture.

Hay Creek.—This stream has several branches, which rise on the eastern slope of the Bear Lodge Mountains, and carries a small volume of water through Aladdin and eastward into South Dakota. The water is used to a small extent for irrigation at a number of points about The Forks and farther east.

The creeks of the northeastern third of the quadrangle either are dry during the summer or contain only scattered pools and springs. These are serviceable for stock, but ordinarily contain too much alkali to be satisfactory for that use.

UNDERGROUND WATERS.

Throughout the quadrangle there are prospects of water supplies from wells of greater or less depth. The series of formations, as shown in the columnar section, includes several beds of water-bearing sandstone which receive water supplies at the surface in the higher ridges and slopes of the Black Hills. The sandstones are carried underground in the general outward dip on the flanks of the hills and, owing to the relative steepness of this dip, soon attain considerable depth. In most portions of the area water-bearing beds at one horizon or another lie at a depth that is within reach of the well borer. As the region is semiarid, with an inadequate supply of surface waters or with waters of bad quality in most localities, there is considerable need for underground waters. The principal water-bearing horizons rise above the surface of the slopes of the Black Hills in regular succession, as already described. They outcrop in wide zones encircling the uplift, and receive a large amount of water not only from the rainfall on their surface but from streams which at many points sink into them in whole or in part in crossing their outcrops. The sinking of the streams in this manner is observed in almost every valley leading out of the central area. Few of the streams carry into Cheyenne River more than a small portion of the whole original run-off of their watersheds, for much of it sinks underground in crossing the sandstones, particularly those of the Minnelusa, Lakota, and Dakota formations. The water thus absorbed by the sandstone passes far beneath the surface as the water-bearing beds descend on the slopes of the Black Hills uplift.

Dakota-Lakota sandstones.—The Dakota and Lakota sandstones are the principal formations in which water supplies are to be expected in the northeastern half or plains portion of the Aladdin quadrangle. They pass beneath the overlying shales with dips that vary considerably in amount (see structure-section sheet), which finally carry them to a depth of about 1500 feet in the northeast corner of the quadrangle. The depth to the top of the Dakota sandstone is indicated approximately on the artesian-water sheet. In various portions of the country surrounding the Black Hills the Dakota-Lakota horizon has been penetrated by wells, which usually obtain flows of greater or less volume, and in most cases of satisfactory quality. The nearest wells to the Aladdin quadrangle are those in the vicinity of Belle Fourche, a short distance to the east. Undoubtedly the same water-bearing sandstones underlie the northern and northeastern portions of the Aladdin quadrangle, and they will probably yield flowing wells in the lower lands.

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

Minnelusa formation.—In its outcrops the Minnelusa formation appears to consist of very porous sandstone, likely to imbibe much surface water and to constitute a water-bearing horizon available for deep wells. The numerous springs which sometimes emerge from the upper sandstone furnish a further indication of its properties in this regard. The formation was penetrated by a deep boring at Cambria and there found to consist of a very fine-textured rock, with the sand grains so closely cemented by lime that the interstices were filled up, without leaving room for much water. The rock appears to be of much coarser grain and less calcareous to the north, especially the upper bed of white sandstone, which is conspicuous in the outcrops south and southwest of Beulah, and in the Bear Lodge uplift it is probable that the formation will yield water in the Aladdin quadrangle. The depth to its top is shown on the artesian water sheet, from which it will be seen that there is a considerable area in the southern, southwestern, and west-central portions of the quadrangle in which the formation can be reached by wells 500 to 1500 feet deep in an area in which there is no water to be had in the Dakota-Lakota horizon. As the sandstone rises high on the slopes of the central portion of the Black Hills, if it contains water the pressure or head should be sufficient to afford a flow in all areas of moderate elevation in the southern and western portions of this quadrangle.

The only attempt to obtain deep-seated waters in this quadrangle was in a deep boring made at Aladdin several years ago. This boring reached a depth of 1150 feet, but it was practically a dry hole. It is stated to have been entirely in the red beds, which were entered at 400 feet. Probably it penetrated the Opeche red sandstones and was discontinued very near the top of the upper sandstone of the Minnelusa formation. It is unfortunate that this bed was not entered and tested as to its water content.

Pahasapa limestone.—Except in the small area of igneous rocks in its southwest corner, the Aladdin quadrangle is underlain by the Pahasapa limestone. In this formation a large supply of water was obtained in a deep boring at Cambria, and possibly the water-bearing horizon continues to this region. Its depth in the Red Valley ranges from 600 to 1000 feet, but the amount rapidly increases northward, and at Aladdin the top of the formation should lie about 1500 feet below the surface. It lies at great depth in the central and northern portions of the quadrangle.

Deadwood sandstone.—Below the Pahasapa limestone is a series of shales and sandstones which probably contain a water supply. They are brought to the surface by a fault at the south end of Sheep Mountain, but in other portions of the quadrangle lie too deeply buried beneath the surface to be reached by ordinary boring operations.

COAL.

At Aladdin, in the lower portion of the Lakota formation, there are deposits of coal which are worked to a considerable extent. A branch railroad extends from the mines down Hay Creek to connect with the Northwestern system near Belle Fourche. The shipments in 1902 amounted to about 10,000 long tons, and the product is a good soft bituminous coal, suitable for locomotive and domestic use. The principal basin lies along and north of Hay Creek, thinning and merging into more impure beds laterally. Two principal beds are worked, a lower, 3 to 5 feet thick, and an upper, 2 feet thick, the two being separated by about 10 to 20 feet of sandy shales. The deposits are broken by a number of small faults which add greatly to the difficulties of mining.

The mines comprise four openings in the lower slope of the ridge on the north side of the Hay Creek Valley, at Aladdin. They begin at the coal outcrop under a steep cliff of Lakota sandstone and two of them extend northward for nearly a quarter of a mile along the coal beds, which dip very gently to the northeast. One small opening is on the upper coal bed, which is about 2½ feet thick, but it is usually thinner. The principal workings are on the lower bed, which varies from 2½ to slightly over 3½ feet thick in the mines. In one of the earlier mines a thickness of 6 feet was found at one point. The coal basin appears to extend over an area of considerable size about Hay Creek, and numerous prospect holes show beds of pure coal which, in most portions of the area, are only a foot or less in thickness. It is possible that other basins may be found in the quadrangle, for the coal horizon is above ground all along both sides of the Bear Lodge Mountains north of the head of Redwater Creek, in the basins of Pine, Oak, Deep, Hay, and North Redwater creeks, and on the slopes on the south side of Medicine Creek. The horizon is at the base of the Lakota formation, and this line is shown on the areal geology sheet. But little prospecting has been done outside the valley of Hay Creek. The coal horizon is usually hidden by talus from the sandstone cliffs above, and when coal is present in the lower Lakota beds it often crumbles or burns away at the outcrop and the overlying sandstone sinks down into its place for some distance. At a number of localities in the outcrop area of basal Lakota beds, as above mentioned, there are exposures of an apparently complete series of beds down to the Morrison contact, showing little or no trace of coal, probably indicating that if coal beds are present west and north of the Hay Creek basin they are of limited extent.

GYPSUM.

The Spearfish formation carries deposits of gypsum—a hydrous sulphate of lime—throughout its extent, and the mineral occurs in beds sufficiently thick and pure to be of value if nearer to market. When gypsum is calcined in a moderate heat to drive off the greater portion of the chemically combined water, and is then ground, the product is plaster of Paris. The principal gypsum deposit in the Aladdin quadrangle occurs about 100 feet above the base of the Spearfish formation. Its average thickness is at least 15 feet, and it outcrops continuously through Government and Redwater valleys to the eastern margin of the quadrangle. The only commercial operations so far have been at Hot Springs and Sturgis, on the opposite side of the Black Hills, where progress has been greatly handicapped by the expense of the marketing product.

LIMESTONE.

Limestone for lime or other purposes may be obtained in abundance from the Pahasapa and Minnekahta formations. Both of these limestones are exposed along the slopes of the igneous uplift of the Bear Lodge Mountains, and the Minnekahta limestone appears extensively on the slopes south and southwest of Beulah, where it has been quarried to a small extent for lime making. There are thin layers of limestone in the Sundance formation throughout its extent, and there is one larger of considerable thickness on the slopes of Table Mountain.

June, 1904.

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

TOPOGRAPHY

WYOMING-SOUTH DAKOTA-MONTANA
ALADDIN QUADRANGLE

E. M. Douglas, Geographer in charge.
Triangulation by A. F. Dunnington.
Topography by W. H. Herron.
Surveyed in 1901.

APPROXIMATE MEAN DECLINATION 1902.

Scale $\frac{1}{125000}$

Contour interval 50 feet.
Datum is mean sea level.

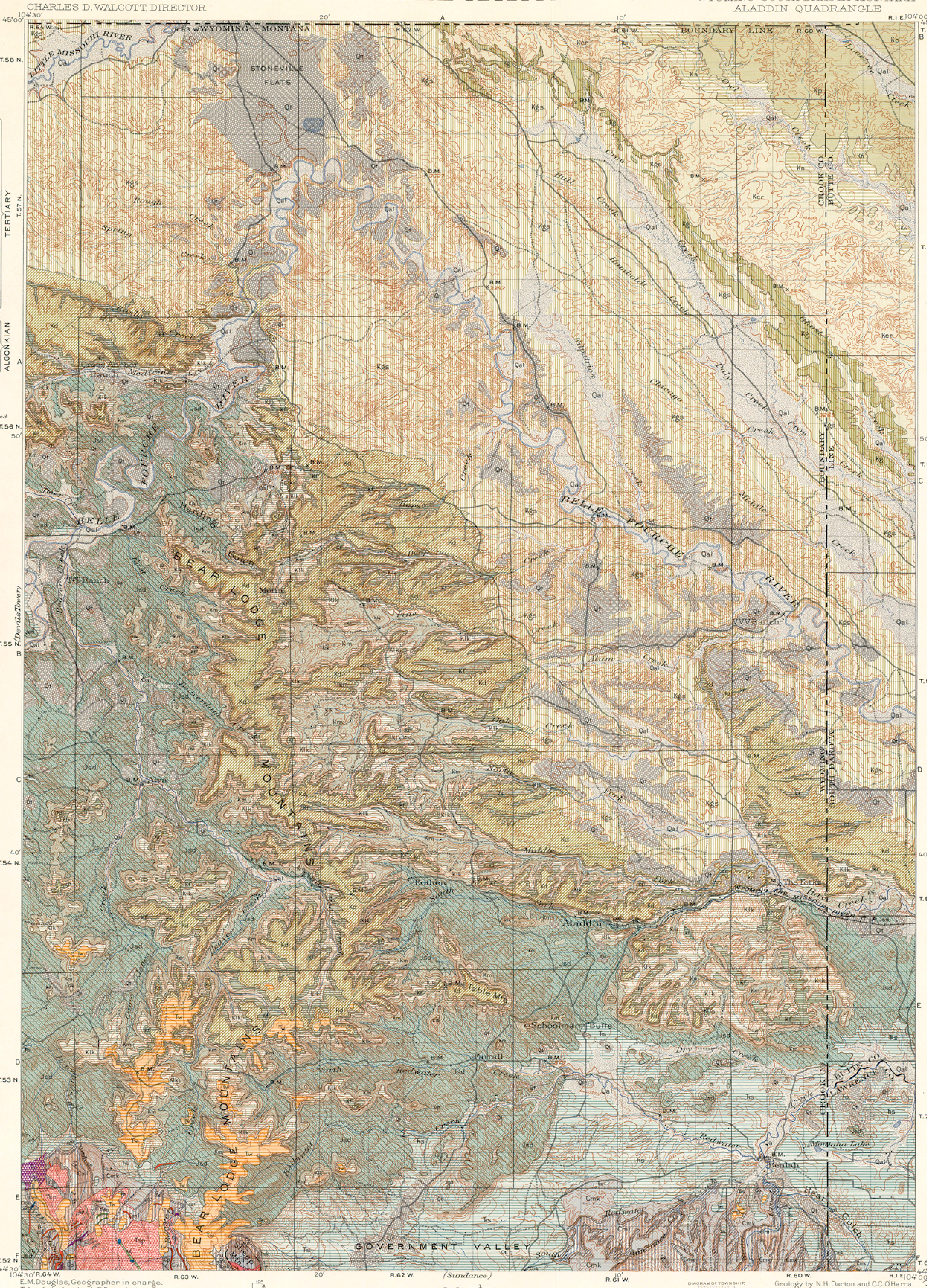
DIAGRAM OF TOWNSHIP

Edition of May 1903. reprinted May 1905.

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

AREAL GEOLOGY

WYOMING-SOUTH DAKOTA-MONTANA
ALADDIN QUADRANGLE



E.M. Douglas, Geographer in charge.
Triangulation by A.F. Dunnington.
Topography by W.H. Herron.
Surveyed in 1901.

TRUE NORTH / MAGNETIC NORTH 15°
APPROXIMATE MEAN DECLINATION 1902.

Scale $\frac{1}{125000}$

1 ½ 0 1 2 3 4 5 Miles

1 ½ 0 1 2 3 4 5 Kilometers

Contour interval 50 feet.

Datum is mean sea level.

Edition of Aug 1905.

DIAGRAM OF TOWNSHIP.

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

Geology by N.H. Darton and C.C. O'Harra.
Surveyed in 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 — Qal — Alluvium *(sand and loam; only the larger deposits represented)*

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

TERTIARY

Tw — Sand, gravel, and conglomerate *(possibly of White River age)*

UNCONFORMITY

CRETACEOUS

Upper Cretaceous

Kp — Pierre shale *(dark-gray shale and clay with concretions)*

Kn — Niobrara formation *(limy shale and impure chalk)*

Benton group

Kcr — Carlile formation *(gray shale and thin sandstone)*

Kg — Greenhorn limestone *(impure slabby limestone)*

Kgs — Graneros shale *(dark fissile shale)*

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

Lower Cretaceous

Kf — Fuson formation *(shale and sandstone)*

Klk — Lakota sandstone *(massive buff sandstone with coal bed locally near base)*

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

UNCONFORMITY ?

JURASSIC

Jsd — Sundance formation *(buff sandstone and red and greenish-gray shale)*

UNCONFORMITY

TRIASSIC ?

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

CARBONIFEROUS

Permian ?

Cmk — Minnekahta limestone *(very thin-bedded gray limestone)*

Co — Opeche formation *(bright-red sandy shale)*

Pennsylvanian

Cml — Minnelusa sandstone *(gray, red, and buff, limy sandstone)*

Mississippian

Cp — Pahasapa limestone *(massive gray limestone; possibly includes at its base a representative of the Englewood limestone)*

UNCONFORMITY

ORDOVICIAN

Ow — Whitewood limestone *(massive buff limestone)*

CAMBRIAN

Cd — Deadwood formation *(brown sandstone and green shale)*

Legend is continued on the left margin.

LEGEND

(continued)

IGNEOUS ROCKS

(Areas of igneous rocks are shown by patterns of triangles and rhombs)

TERTIARY

Tp — Phonolite

Nepheline-syenite-porphyry

Pseudo-leucite-porphyry

Tsp — Syenite-porphyry

ALGONKIAN

Ag — Granite *(coarse grained; inclosed in syenite-porphyry)*

Faults

40° Strike and dip of stratified rocks

Sections

⚒ Coal mines

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

STRUCTURE SECTIONS

WYOMING-SOUTH DAKOTA-MONTANA
ALADDIN QUADRANGLE

LEGEND
(continued)

IGNEOUS ROCKS

SHEET SYMBOL | SECTION SYMBOL

TERTIARY

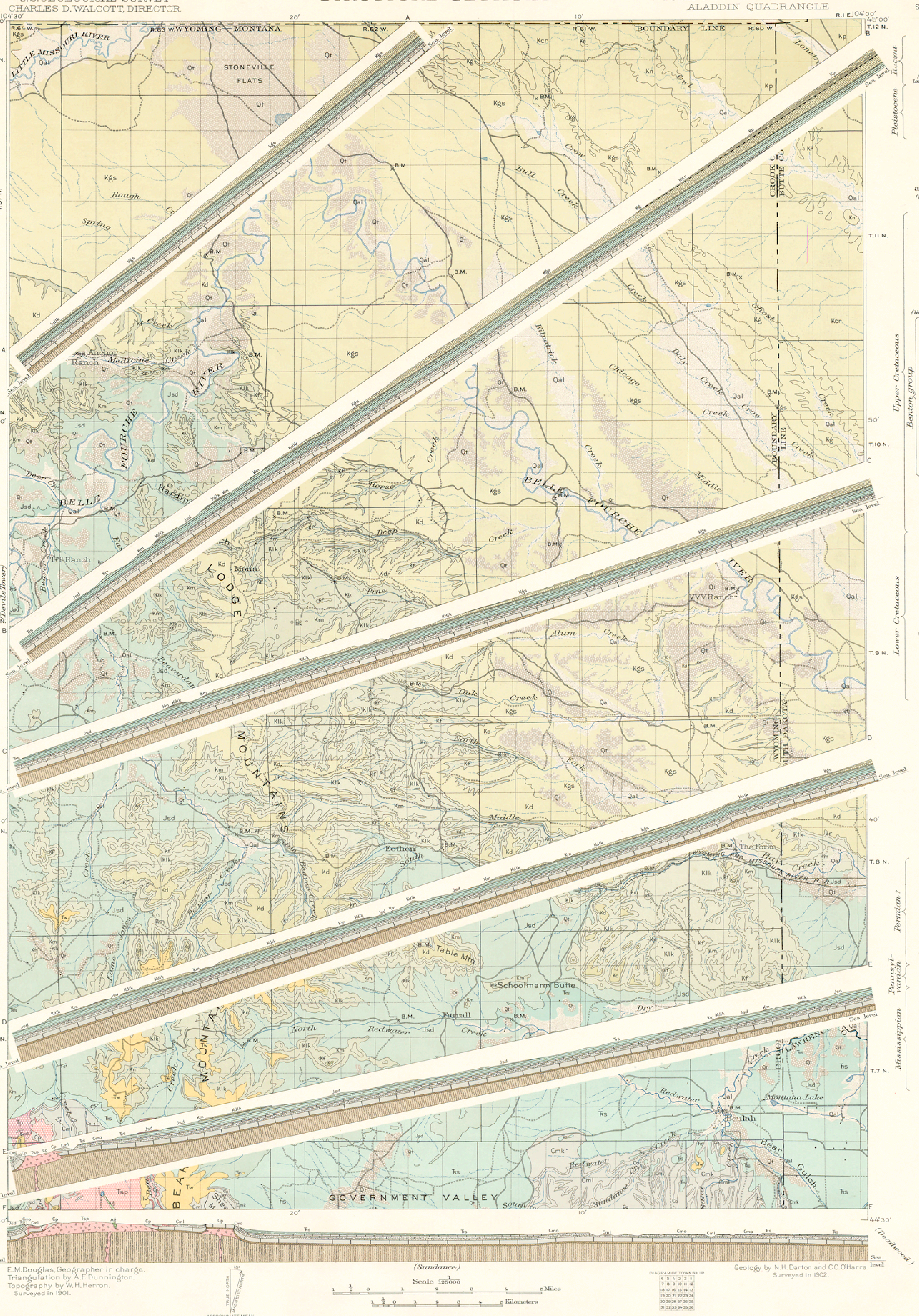
- Tp — Phonolite
- Nepheline-syenite-porphyry
- Pseudo-leucite-porphyry
- Tsp | Tsp — Syenite-porphyry *(includes in sections laccoliths not exposed at the surface whose composition is not known)*

ALGONKIAN?

- Ag | Ag — Granite *(coarse grained; included in syenite-porphyry)*

Faults

Strike and dip of stratified rocks



LEGEND

SEDIMENTARY ROCKS

SHEET SYMBOL | SECTION SYMBOL

QUATERNARY

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

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

TERTIARY
- Tw — Sand, gravel, and conglomerate *(possibly of White River age)*

UNCONFORMITY

CRETACEOUS

Upper Cretaceous

- Kp | Kp — Pierre shale *(dark-gray shale and clay with concretions)*
- Kn | Kn — Niobrara formation *(limy shale and impure chalk)*

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

Lower Cretaceous

- Kd | Kdlk — Dakota sandstone *(brownish sandstone, mostly massive)*
- Kf — Combined with Dakota sandstone on sections — Fuson formation *(shale and sandstone)*
- Klk — Combined with Dakota sandstone on sections — Lakota sandstone *(massive buff sandstone with coal bed locally near base)*
- Km | Km — Morrison shale *(massive sandy shale, gray, greenish, and maroon)*

UNCONFORMITY?

JURASSIC
- Jsd | Jsd — Sundance formation *(buff sandstone and red and greenish-gray shale)*

UNCONFORMITY

TRIASSIC?
- Trs | Trs — Spearfish formation *(red sandy shale with beds of gypsum; "Red Beds")*

CARBONIFEROUS

Permian?
- Cmk | Cmo — Minnekahta limestone *(very thin-bedded gray limestone)*
- Co — Combined with Minnekahta limestone on sections — Opeche formation *(bright red sandy shale)*

Pennsylvanian
- Cml | Cml — Minnelusa sandstone *(gray, red, and buff limy sandstone)*

Mississippian
- Cp | Cp — Pahasapa limestone *(massive gray limestone; possibly includes at its base a representative of the Englewood limestone)*

UNCONFORMITY

ORDOVICIAN
- Combined with Deadwood formation on sections — Whitewood limestone *(massive buff limestone)*

CAMBRIAN
- Cdw — Deadwood formation *(brown sandstone and green shale)*

ALGONKIAN
- Schist *(does not outcrop in this quadrangle)*

Legend is continued on the left margin.

E. M. Douglas, Geographer in charge.
Triangulation by A. F. Dunnington.
Topography by W. H. Herron.
Surveyed in 1901.

Scale 1/125000

Approximate mean declination 1902.

Edition of Dec. 1905.

Geology by N. H. Darton and C. C. O'Harra.
Surveyed in 1902.

U.S. GEOLOGICAL SURVEY
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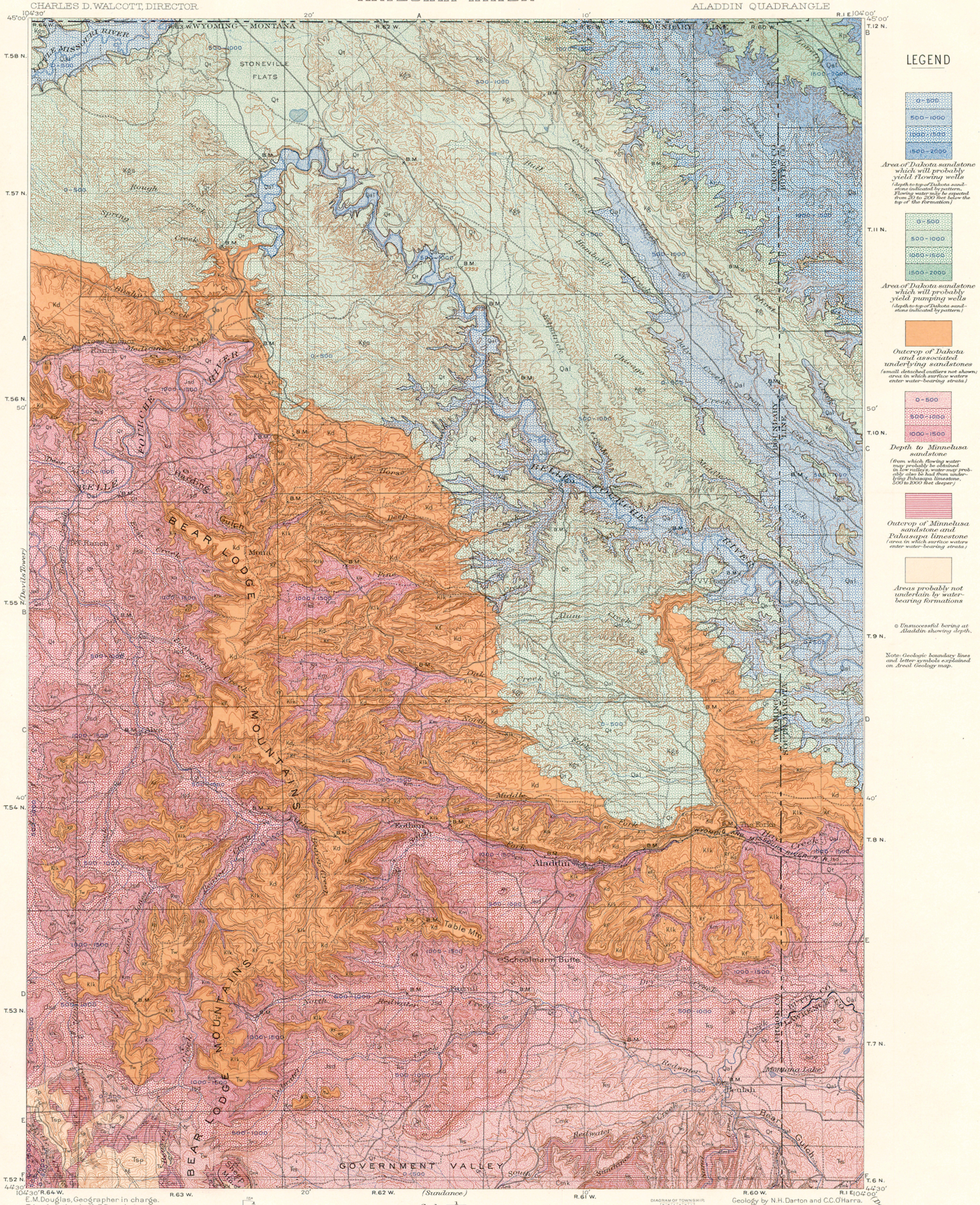
ARTESIAN WATER

WYOMING–SOUTH DAKOTA–MONTANA
ALADDIN QUADRANGLE



E. M. Douglas, Geographer in charge.
Triangulation by A. F. Dunnington.
Topography by W. H. Herron.
Surveyed in 1901.

Scale $\frac{1}{125000}$

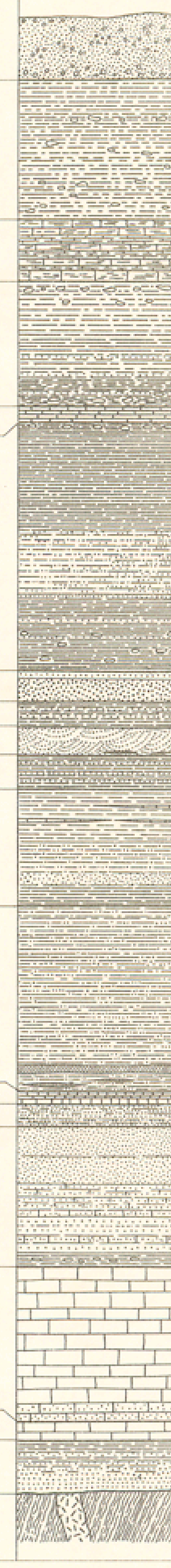
Contour interval 50 feet.
Datum is mean sea level.

Edition of Nov. 1905

Geology by N. H. Darton and C. C. O'Harra.
Surveyed in 1902.

COLUMNAR SECTION

GENERALIZED SECTION FOR THE ALADDIN QUADRANGLE.
SCALE: 1 INCH = 500 FEET.

System.	Series.	Formation Name.	Symbol.	Columnar Section.	Thickness in Feet.	Character of Rocks.	Character of Topography and Soils.
TERTIARY	OLIGOCENE ?	Sand, gravel, and conglomerate.	Tw		200	Sand, gravel, and bowlders.	Plateaus with fertile soils, usually forested.
		UNCONFORMITY					
CRETACEOUS	UPPER CRETACEOUS	Pierre shale.	Kp		450+	Dark, soft shale with numerous small concretions.	Wide valleys with thin acid soils, usually well sodded.
		Niobrara formation.	Kn		200	Soft, impure limestone and limy shale with thin limestone masses filled with *Ostrea congesta*.	Valleys with fertile soil.
		Carlile formation.	Kcr		400	Numerous concretions. Gray shale with thin beds of sandstone.	Low, rolling hills with thin, poor soil.
		Greenhorn limestone.	Kg		50	Thin-bedded, hard, gray, impure limestone with *Inoceramus labiatus*.	Low ridges and benches. Thin, sandy soil.
		Graneros shale.	Kgs		800	Gray shale with concretions near top. Hard, sandy shale, weathering light gray. Local thin layer of soft sandstone. Dark shale with concretions and occasional thin sandstone layers.	Wide valleys with rolling hills. Soil mostly thin or clayey.
		Dakota sandstone.	Kd		60–140	Buff sandstone, mostly massive; weathers reddish brown.	Caps numerous mesas and sloping plateaus. Sandy soils.
	LOWER CRETACEOUS	Fuson formation.	Kf		60–100	Shale and sandstone.	In slopes between Dakota and Lakota cliffs.
		Lakota sandstone.	Klk		80–100	Gray to buff, massive, cross-bedded sandstone.	Cliffs on sides of mesas and plateaus. Sandy soils.
		Morrison shale.	Km		60–150	Massive gray, buff, and maroon shale, thin sandstones, and concretions.	Slopes at base of Lakota cliffs. Clay soils.
		UNCONFORMITY ?					
JURASSIC		Sundance formation.	Jsd		350–400	Grayish-green shale with thin limestone layers. Reddish sandstone and sandy shale. Massive, buff, soft sandstone. Dark, grayish-green shale.	Slopes with thin but fertile soil. Buttes and benches.
		UNCONFORMITY					
TRIASSIC ?		Spearfish formation.	Trs		550–650+	Red, sandy shale with thin beds of gypsum.	Wide valley, "Red Valley." Thin, barren soil.
CARBONIFEROUS	PERMIAN?	Minnekahta limestone.	Cmk		40	Thin-bedded, gray limestone.	Sloping plateaus margined by cliffs. Thin but rich soils.
		Opeche formation.	Co		70	Red, soft sandstone.	Steep slopes beneath cliffs of Minnekahta limestone.
	PENNSYLVANIAN	Minnelusa sandstone.	Cml		400–500	White to gray, massive sandstone. Red, limy sandstone and sandy shale. Sandstone with much lime in some beds. Red shale with concretions.	Cliffs in canyons. Steep slopes in canyons and on sides of Bear Lodge laccolith.
	MISSISSIPPIAN	Pahasapa limestone.	Cp		500–	Massive, light-colored limestone. Sandy limestone, possibly Englewood.	Mountain summits and slopes on sides of Bear Lodge laccolith.
		UNCONFORMITY					
ORD.		Whitewood limestone.	Ow		60	Massive, hard limestone, mottled pink.	Cliffs on south end of Sheep Mountain.
CAMBRIAN		Deadwood formation.	€d		50–300	Green shale. Brown sandstone.	Cliffs on south end of Sheep Mountain.
ALGONKIAN ?		Schist and granite.	As Ag			Schist not exposed at the surface. Granite in small detached masses.	

N. H. DARTON,
C. C. O'HARRA,
Geologists.

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.......	....	Ꞃ	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......	Є	Brick-red.
	Algonkian	....	A	Brownish-red.
	Archean	....	Æ	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:

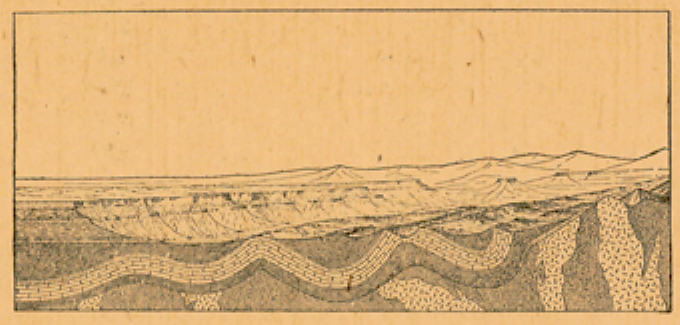


Fig. 2.—Sketch showing a vertical section at the front and a landscape beyond.

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:

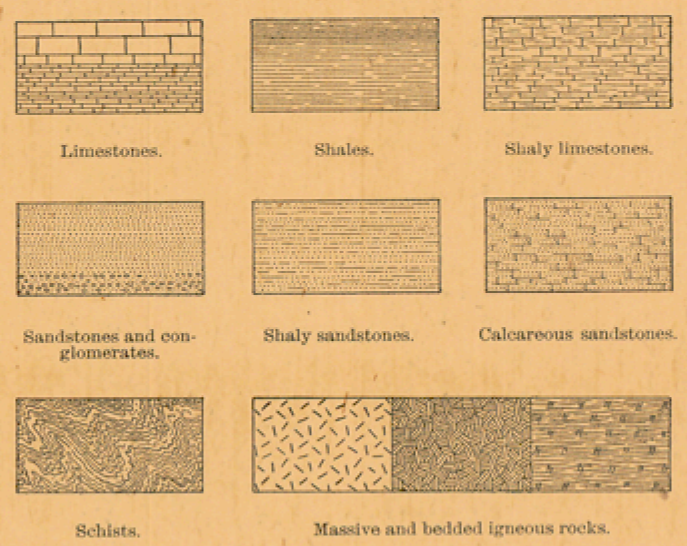


Fig. 3.—Symbols used in sections to represent different kinds of rocks.

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.

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