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

GEOLOGIC ATLAS

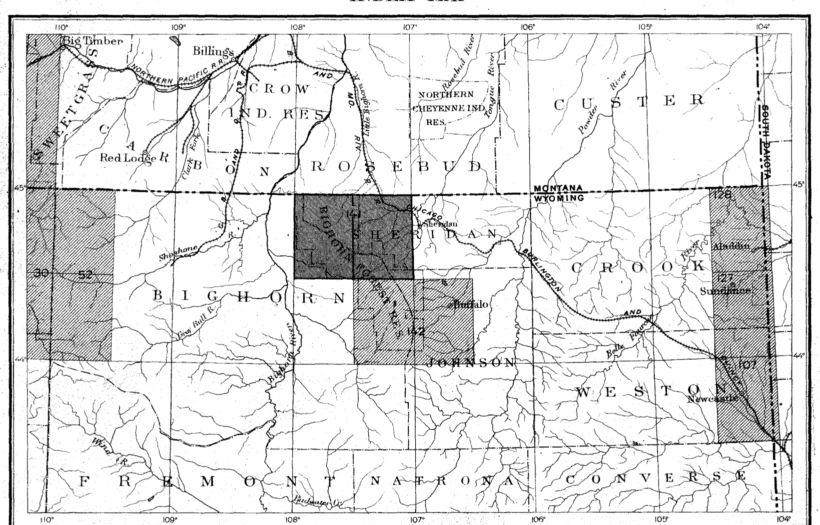
OF THE

UNITED STATES

BALD MOUNTAIN - DAYTON FOLIO

WYOMING

INDEX MAP



SCALE: 40 MILES-1 INCH

BALD MOUNTAIN-DAYTON 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).

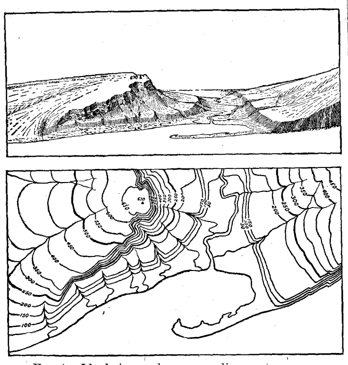


FIG. 1.—Ideal view and corresponding contour map.

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.)

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.
Cenozoic	Tertiary	Pliocene; Miocene; Oligocene; Eocene	T	Yellow ocher.
Mesozoic	Cretaceous		K	Olive-green.
Mesozoic	Jurassic		J	Blue-green.
Mesozoic	Triassic		Ћ	Peacock-blue.
Paleozoic	Carboniferous	Permian; Pennsylvanian; Mississippian	C	Blue.
Paleozoic	Devonian		D	Blue-gray.
Paleozoic	Silurian		S	Blue-purple.
Paleozoic	Ordovician		O	Red-purple.
Paleozoic	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:

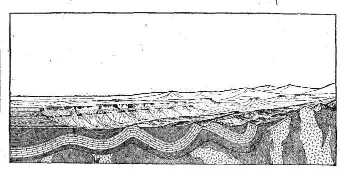


Fig. 2.—Sketch showing a vertical section at the front and a landscape beyond.

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:

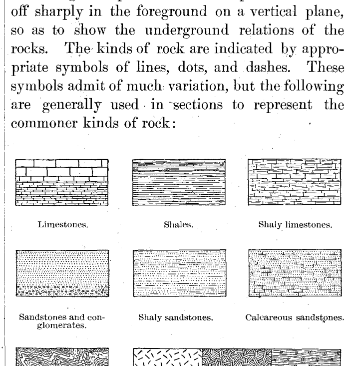


Fig. 3.—Symbols used in sections to represent different kinds of rocks.

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

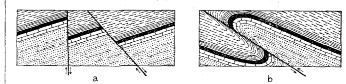


Fig. 4.—Ideal sections of strata, showing (a) *normal* faults and (b) a *thrust* fault.

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.

DESCRIPTION OF THE BALD MOUNTAIN AND DAYTON QUADRANGLES.

By N. H. Darton.

Glacial Geology by R. D. Salisbury.

INTRODUCTION.

Position and extent.—The Bald Mountain and Dayton quadrangles embrace the half of a square degree which lies between parallels 44° 30′ and 45° north latitude and meridians 107° and 108° west longitude. They measure approximately 34½ miles from north to south and 50 miles from east to west and their area is nearly 1699 square miles. They comprise the western part of Sheridan County, a small part of the northwest corner of Johnson County, and the northeast corner of Bighorn County, all in Wyoming. On the north they extend to the Montana boundary line, which lies a few seconds of latitude north of the forty-fifth parallel. The central and much of the western portion of the area is in the Bighorn Mountains, extending across them to the eastern margin of the Bighorn Basin. The northeastern portion is on the Great Plains, in the basin of Powder River.

Being parts of the Bighorn Mountains and of the Great Plains, these quadrangles exhibit many of the peculiarities of both, and a general account of these provinces will be given to afford a better conception of the relations and significance of the local features.

THE BIGHORN MOUNTAIN REGION.

CONFIGURATION.

General features.—The Bighorn Mountains, an outlying portion of the Rocky Mountain Range, extend from north-central Wyoming into south-central Montana. They rise out of the Great Plains, which here have an altitude of 4000 to 5000 feet, to heights that range from 10,000 feet to slightly over 13,000 feet in the higher summits. They trend north-northwest in the northern part of their course, nearly due north and south in their south-central part, and northeast-southwest toward their southern termination, which is at Bridger Creek. The uplift is in a measure continued westward by an east-west range known as the Bridger Range and the Owl Creek Mountains.

The northern end of the Bighorn Mountains is at the canyon of Bighorn River, but north of this canyon the same uplift is continued in the Pryor Mountains, a range of moderate elevation, which extends but a short distance. West of the Bighorn Mountains there is a wide area of plains known as the Bighorn Basin, which extends to the foot of the Shoshone Range on the west and to the Bighorn, Bridger, and Owl Creek ranges on the south. It is traversed by Bighorn River in a deep canyon having an altitude of about 3500 feet. The Bighorn Mountains rise abruptly from the plains, though they are flanked by several lines of low hogback ridges. Their salient features are the central area of high ridges of granite, the summit plateaus at the northern and southern ends of the uplift, the front ridge of sedimentary rocks, and the hogback ranges.

Central range.—The central area of the higher portion of the Bighorn Mountains is a region of rugged ridges rising toward the main divide along the center of the uplift. In the part of this divide that lies between the headwaters of Piney and Goose creeks on the east and Paintrock, Shell, and Tensleep creeks on the west the granite ridges rise in a cluster of high mountains culminating in Cloud Peak, which has an altitude of 13,165 feet.

In this high area the ridges rise from 3000 to 4000 feet above the valleys and the general configuration is very rugged, presenting some of the boldest alpine scenery in the country. There are many precipices over 1000 feet high, especially about the cirques among the higher summits. Several of these cirques contain glaciers, one of which, on the east side of Cloud Peak, has a length of nearly one-half mile. Extensive snow banks remain all summer in many of the higher portions of the range. The drainage of this area is peripheral and in the main direct. The divide and its numerous branch ridges present serrated outlines and are crossed by deep wind gaps. The higher parts of this central area exhibit strong erosion, due largely to the intensity of frost action, the steep declivity, and the abundance of water to carry off the débris. The topography is youthful, and the granite floor on which the sedimentary rocks were deposited has been so cut away by erosion that its original configuration can only be surmised. The higher region has been extensively glaciated, so that most of its topographic features are those characteristic of glacial erosion. The most marked of these are the many deep cirques that are cut back to or nearly to the main divide. Glacial deposits occur in the lower valleys of the central area, impeding the drainage by producing many small lakes. Other lakes occur in rock basins excavated in granite, mostly by glaciation.

The timber line is at an altitude not far below 10,000 feet, above which height the surfaces are mainly almost bare rock masses, in part disrupted from their original ledges. Many of the steeper slopes consist of talus of huge granite blocks.

Central plateau.—The sedimentary rocks arch over the northern and southern portions of the Bighorn Mountains, giving rise to an elevated plateau which has an altitude of about 9000 feet in its northern part and about 8000 feet in its southern part. It presents broad areas of tabular surface, especially near the divides, but is deeply trenched by numerous canyons, the most notable of which is that of Little Bighorn River. Much of the plateau surface is covered by forests which are interspersed with parks that are extensively utilized as grazing grounds for cattle and sheep during the short summer season. Portions of the plateau also extend northward and southward, partly encompassing the central granite area.

Front ridge.—Along the sides of the Bighorn Mountains there are abrupt slopes to the plains on the east and to the Bighorn Basin on the west. In some districts the central plateau terminates in high cliffs, but in others, especially along the eastern side of the mountains, it is flanked by a distinct ridge of "rim rock" that rises slightly above an inner valley but slopes steeply toward the plains. West of Sheridan and Buffalo this front ridge presents an imposing line of mountain slopes, in many places 2000 feet high, extending southward and southeastward. It is composed of sedimentary rocks that dip steeply to the northeast and east, and nearly everywhere it presents to the west a high cliff of limestone. (See figs. 6 and 7, illustration sheet 2.) Through this front ridge the creeks and rivers that rise in the central area find their way out to the plains, some of them in canyons having walls nearly 2000 feet high. The most notable of these canyons are those of Little Bighorn and Tongue rivers, on the east side of the mountains, and Shell, Paintrock, and Tensleep creeks, on the west side. Across the north end of the range Bighorn River flows in a deep canyon that terminates the mountains to which the name Bighorn is applied. This river also, in its upper portion, cuts across the southwest end of the Bridger Range, separating it from the Owl Creek Mountains.

Hogback ridges.—Along the foot of the Bighorn Mountains, on each side, there is a series of hogback ridges, which appear very insignificant in comparison with the great mountain slopes they flank. They are due to the outcrop of sandstones of moderate hardness and rise only from 100 to 200 feet above the adjoining valleys. These valleys mark the outcrop of the "Red Beds," which extend along the foot of the mountains, but owing to the steep dip of these beds and to their relative hardness the valleys are not so distinct as the Red valleys in the Black Hills and some other regions. The hogback rim is crossed by numerous valleys, or canyons, which divide it into level-topped ridges of various lengths, and in many places along the east side of the mountains these ridges merge into a continuous terrace capped by deposits of Quaternary gravels and sands extending from the foot of the higher slopes of the mountains.

Drainage.—From the higher portion of the Bighorn Mountains flow many large streams, those on the east side draining into Tongue River and its branches, mainly through Crazy Woman, Clear, Piney, and Big Goose creeks. Down the west slopes flow branches of Tensleep, Paintrock, Shell, and other creeks that cross the east side of the Bighorn Basin and empty into Bighorn River. This great stream, after traversing the Bighorn Basin from south to north, turns northeastward and crosses the north end of the Bighorn Mountains, finally flowing into the Yellowstone in southeastern Montana. One of its larger branches, Little Bighorn River, drains a portion of the plateau on the east side of the Bighorn Mountains near the Montana line and flows out of the mountains in a canyon whose walls are over 2000 feet high.

ROCKS.

The Bighorn Mountains are due to a great anticline of many thousand feet uplift, which has elevated a thick series of Paleozoic and Mesozoic sedimentary rocks high above the plains. (See figs. 4 and 5.) Owing to the deep erosion of the crest of this uplift the mountains present a central nucleus of pre-Cambrian granites, the sedimentary rocks forming the front ridges and the plateaus at either end. The formations exhibited in the Bighorn uplift are similar to those exposed extensively in other portions of the Rocky Mountain province and show great uniformity throughout the uplifted area. The granites are red and gray, massive in structure, and constitute the floor under sediments of Acadian (Middle Cambrian) age. These Cambrian rocks are sandstones, shales, and limestones, nearly a thousand feet thick, which apparently do not include sediments of Saratogan (Upper Cambrian) age. The Ordovician is represented mainly by a massive limestone of Trenton age, but the earliest Ordovician and part of the late Ordovician, as well as all the Silurian and Devonian, are not represented. The Carboniferous presents about 1500 feet of beds, belonging mostly to the Mississippian series, but extending up into the Pennsylvanian. Its ends in a persistent sandstone member that ordinarily constitutes the lower outer slope of the limestone front ridge. Next above come the "Red Beds," which extend around the foot of the mountains, as in the Black Hills and other uplifts of the Rocky Mountain province. They attain a thickness of over 1000 feet and are either all of Permian age or are in part Triassic. The marine Jurassic, which lies next above, is similar to that of the Black Hills and of southeastern Wyoming, containing an abundant middle to upper Jurassic fauna. It is overlain by the Morrison shales, only about 200 feet thick but remarkably persistent in the Rocky Mountain province. Representatives of the Dakota sandstone appear in the Bighorn uplift, but with greatly diminished development as compared with that seen on the Black Hills and in other regions farther south. The hard sandstone supposed to represent the Lakota formation is the most conspicuous feature of these beds. The great series of Upper Cretaceous shales attains a thickness of over 4000 feet in the plains adjoining the Bighorn Mountains. At the base is the Benton group, in which, however, the usual medial limestone member (Greenhorn) is not developed. The chalky element which is so conspicuous in the Niobrara farther south is absent, as are also the fossils which elsewhere characterize the formation. The presence of the Niobrara is indicated, however, by apparently unbroken sedimentation from the Benton to the Pierre. The latter has a thickness ranging from 2000 to 3500 feet near the Bighorn Mountains and presents the usual monotonous succession of gray shales with fossil-bearing concretions. It is terminated by a mass of sandstone, possibly representing the Fox Hills sandstone, which in turn is succeeded by a great development of fresh-water deposits comprising representatives of the Laramie and probably later formations. These fresh-water deposits occupy a wide area between the Bighorn Mountains and the Black Hills and also a large syncline in the Bighorn Basin. They consist of the usual succession of sandstones and shales, with extensive beds of lignite, but along part of the eastern side of the range they comprise conglomerate near the base, consisting of local materials, indicating uplift and erosion, probably in early Laramie time. The Tertiary system is not well represented in the Bighorn uplift. In the basin to the west are considerable deposits of the Wasatch, and along the southern end of the uplift there is a general overlap of the Bridger formation. In the mountains there evidently was extensive uplift and denudation in Tertiary time. Some small remnants of supposed Tertiary beds have been found high up in the range, but their identity is not established. The Quaternary deposits consist of high terraces and old alluvial fans along the lower slopes of the mountains, glacial detritus, and the alluvial plains along the streams, which merge into the flood plains of the present period. The higher portions of the Bighorn Mountains have been extensively glaciated, there having been two principal epochs of glaciation. Small glaciers still remain on the higher slopes near Cloud Peak.

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 the older rocks. The materials of the formations were derived mainly from the west and were deposited, layer by layer, either by streams on their flood plains or in lakes and, during earlier times, in the sea. Aside from a few very local flexures, the region has not been subjected to folding, but has been broadly uplifted and depressed successively. The general smoothness of the region to-day was surpassed by the almost complete planations of the surface during earlier epochs. Owing to the great breadth of the plains and their relatively gentle declivity, general erosion has progressed slowly notwithstanding the softness of the formations, and as at times of freshets many of the rivers bring out of the mountains a larger load of sediment than they carry to the Mississippi they are now building up their valleys rather than deepening them.

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

Drainage.—The northern portion of the Great Plains above described is drained by the middle branches of Missouri River, 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 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, Arkansas River, and the Rio Grande, which cross the plains to the southeast and afford 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 are Republican River, rising near the one hundred and fifth meridian, and extensive systems of local drainage in eastern Kansas and Nebraska.

TOPOGRAPHY OF THE QUADRANGLES.

Relief.—The Bald Mountain and Dayton quadrangles lie partly on the plains and partly in the Bighorn Mountains, which rise steeply along a northwest-southeast course that passes diagonally across the area. The plains are not smooth but present undulations, most of which have a magnitude of less than 300 feet from the bottoms of the valleys to the tops of the hills. The slopes are in most places gentle and the landscape is monotonous. Tongue River and the larger creeks cross the plains in wide, level-floored valleys, extending from west to east with gentle declivity. The altitudes above sea level range from 3600 to 4500 feet in greater part, with gradual increase toward the western margin. On looking over the plains region from a point of suitable height it will be seen that nearly all of the divide summits fall into a plane and that this plane rises gradually to the foot of the mountains. There is an exception to this in the ridges northeast of Parkman, near the northern margin of the Dayton quadrangle, where the southern termination of the Wolf Creek Mountains, a ridge of moderate eminence, rises out of the plains. The plains have been widely eroded along the present valleys and when closely examined their remnants will be found to have more or less slope into the larger valleys of the present day. Owing to its favorable configuration and the water supplies available from the mountain streams, the plains portion of the area contains a population of moderate size, engaged in agriculture and cattle raising.

The mountains rise 3000 feet above the plains, in a line of high, rocky ridges which abruptly attain altitudes averaging 7500 feet at the south and over 8000 feet at the north. This front ridge of the mountains is cut into knobs and short ridges by numerous canyons of streams passing out onto the plains, and behind these ridges is an elevated valley or succession of grassy saddles on the divides between the streams. Farther back is a wider area of higher mountains rising in ridges and knobs trending in various directions and attaining an altitude of over 10,000 feet in the west-central portion of the area. These constitute the main divide, beyond which the country slopes irregularly westward into the Bighorn Basin.

Owing to the length of the winters, the heavy snows, and the prevalence of frosts during summer nights the high lands are not suited for farming and are without permanent habitations. During the summer a few herders and prospectors live in the mountains, but the season is very short.

The principal topographic feature of the region about Bald Mountain is the elevated plateau at the northern extremity of the Bighorn uplift. This plateau has been extensively eroded and is traversed by numerous deep canyons, but the general plateau character is preserved in portions of the area. The main divide south of the head of Tongue River is a wide, flat-topped ridge, with an average altitude of 9600 feet. Toward the north the elevations increase somewhat and the central area is cut into rounded eminences and flat-topped buttes. Bald Mountain and Little Bald Mountain, 10,029 and 9894 feet above sea level, respectively, rise as huge rounded hills above a granite platform which has an average altitude of 9000 feet. (See fig. 10, illustration sheet 2.) To the north the main divide is continued in rounded slopes of shale with high summits capped by limestone ledges, having in Duncom Mountain an altitude of 9810 feet and in Sheep Mountain an altitude of 9837 feet above sea level. East of the main divide, in the northern portion of the region, there are wide areas of shale slopes surmounted by limestone cliffs rising into knobs from 8500 to 9000 feet high at the crest of ridges which slope northeastward. In Pass Creek Ridge and Fisher Mountain there rises another series of limestone ridges having a crest line about 8500 feet above sea level. From the crest of this ridge there is a steep slope northeastward to the plains, which begin at an altitude of about 5000 feet. The west face of the Bighorn Mountains in the Bald Mountain quadrangle is mostly very steep and consists of limestone cliffs and slopes presenting a declivity of about 2000 feet. Farther north, in the region adjoining Devil Canyon, this descent is interrupted by a wide shelf cut into ridges by canyons and having summits averaging from 6500 to 8200 feet above sea level. Across the southwestern portion of the Bald Mountain quadrangle there extends a representative area of the Bighorn Basin, underlain by shales and varying in altitude from 4000 to 6000 feet. This area is not smooth but is cut into ridges of moderate height and extensive badlands, and is traversed by several wide valleys of streams heading on the western slope of the mountains. Most of the streams in the mountain area have cut deep canyons, notably Shell Creek, which has canyon walls and slopes over 2000 feet high. Horse Creek has a short but deep canyon and Porcupine Creek passes through Devil Canyon, which has precipitous limestone walls that are in places 1500 feet high. On the east side of the Bighorn divide Tongue River runs for many miles in a wide valley having shale slopes surmounted by limestone cliffs and flows out into a wide alluvial flat on a granite floor. Farther east, however, in the Dayton quadrangle, it passes through the granite and the limestone front range of the mountain in a deep canyon. The most profound canyon in this area is that of Little Bighorn River, especially in the anticline of Dry Fork Ridge and Fisher Mountain, where the walls are nearly 2500 feet high, as shown in fig. 11 of illustration sheet 2.

Drainage.—The higher mountain region contains more or less snow throughout the year and receives a moderately copious rainfall, so that it is the gathering ground for numerous streams. The streams on the east side flow into the forks of Piney, Little Goose, Big Goose, and Wolf creeks and Little Bighorn and Tongue rivers, all large streams, which cut irregular valleys through the mountain country and pass out into the plains through profound canyons in the front ridge.

Little Bighorn River rises in several branches on the east slope of the summits east and north of Bald Mountain and, flowing northeastward, passes onto the plains at the Montana State line. From the south it receives the water of Dry Fork, which drains extensive slopes northeast of Little Bald Mountain. West Fork drains an area of moderate size north of the canyon of the Little Bighorn. Next north is Lodgegrass Creek, which flows to the north and northeast and joins Little Bighorn River in Montana. West Pass, Gay, and Stockade creeks, draining the northeast corner of the quadrangle, finally reach Little Bighorn River.

Tongue River rises on the east slope of Little Bald Mountain and flows eastward, draining only a small area of the Bald Mountain quadrangle. Fool Creek is its principal tributary.

In the Bald Mountain area there are three principal drainage basins: The entire western slope drains into Bighorn River; the central-eastern portion into Tongue River, a branch of Powder River; and the northeastern area into the Little Bighorn, a branch of the Bighorn. The principal stream on the western slope is Shell Creek, which rises in snow-capped mountains in the northern slope of the higher portion of the Bighorn Mountains and flows nearly west, at first in a deep canyon, but finally in a wide, shallow valley that crosses the east side of the Bighorn Basin. It receives the waters of Cedar, Horse, and Beaver creeks and Red Gulch from the north and of White and Trapper creeks from the south, all flowing streams, which head high in the mountain slopes. Bear, Alkali, Five Springs, Cottonwood, Porcupine, Deer, and Trout creeks are all running streams, heading in the mountains and flowing westward directly into the Bighorn. Porcupine Creek, the largest of these streams, heads on the western slope of Bald Mountain and flows northwest, at first in a rocky valley and then in the very deep Devil Canyon, which extends nearly to Bighorn River.

The streams are well filled with trout, the mountains contain much game, the uplands support a splendid growth of grass, there are fine forests of pine, charming lakes abound in the higher areas, and the region is altogether most attractive.

GEOLOGY.

In the Bald Mountain and Dayton quadrangles there are two classes of rocks, sedimentary and crystalline, together with glacial deposits. The crystalline rocks are granites, which are penetrated by dikes, mostly of diabase; the sedimentary rocks comprise limestones, sandstones, shale, gravel, and sand, having a thickness in all of about 17,500 feet on the Dayton quadrangle and 5700 feet on the Bald Mountain quadrangle. They present the general characteristics, thicknesses, etc., given in the columnar section in the next column.

IGNEOUS ROCKS.

PRE-CAMBRIAN.

GRANITE.

Occurrence.—About half of the area of the Bald Mountain and Dayton quadrangles lies within the granite area of the central portion of the Bighorn uplift. This granite constitutes the higher portion of the mountains in the west-central and southern sections of the Dayton quadrangle, comprising the main divide and an extensive region of high, rugged ridges. In the Bald Mountain quadrangle the overlying sedimentary rocks hide the greater part of the granite and it appears only in irregular areas. The most extensive exposures are about Bald Mountain, in the anticline extending from Red Gulch westward to and beyond Medicine Mountain, in the valley of Porcupine Creek and Cookstove Basin, along Little Bighorn and Tongue rivers, and in the deeper portions of the canyons of Shell and Granite creeks. Smaller areas are exposed on Cedar Creek and the upper branches of Dry Fork east of Bald Mountain. In portions of the valleys of the branches of Goose Creek and in Penrose Park and some other areas the granite is hidden beneath glacial deposits, but in most of the mountain area it presents continuous outcrops. In places it is traversed by narrow black dikes, mostly of diabase.

Table showing general correlation of the formations in the Northwest.

Period.		Bighorn Mountains.	Black Hills.	South-central Montana.
Cretaceous.	Upper Cretaceous.	De Smet.	Laramie.	Laramie.
		Kingsbury.		
		Piney.		
		Parkman.	Fox Hills.	Montana.
		Pierre.	Pierre.	
		Colorado.	Niobrara. Carlile. Greenhorn. Graneros.	Colorado.
	Lower Cretaceous.	Cloverly.	Dakota. Fuson. Lakota.	Dakota.
		Morrison.	Morrison.	Cascade ?
Jurassic.		Sundance.	Sundance.	Ellis.
Triassic ?		Chugwater.	Spearfish. Minnekahta. Opeche.	Absent.
Carboniferous.	Permian ?			
	Pennsylvanian.	Tensleep.	Minnelusa.	Quadrant.
		Amsden.		
	Mississippian.	Madison.	Pahasapa. Englewood.	Madison.
Ordovician.		Bighorn.	Whitewood.	Jefferson ?
Cambrian.	Acadian.	Deadwood.	Deadwood.	Gallatin. Flathead.
Pre-Cambrian.		Granite.	Granite.	Granite.

Character and distribution.—The granites are of two principal varieties, a moderately coarse-grained red granite and a medium- to fine-grained gray granite, which merge into each other so gradually that it is difficult to draw any boundary between them. They are regarded as part of one great mass of probable batholithic character. The red granite has a light-grayish appearance at a distance, but on closer view it presents a more or less pronounced reddish tinge. The rock is traversed by several systems of widely spaced joints and weathers into bold, rounded forms. Its surface is in most places rough, owing to differential weathering by which the larger feldspar crystals become prominent, and these also give the rock a porphyritic appearance. In the Dayton quadrangle the red granite occupies a much greater area than the gray variety, reaching completely across the central region north of Tongue River Cabin and Morrow ranch and extending all along the west side of the area of crystalline rocks. The gray variety occupies a broad area along the main divide south of bench mark 9601, which extends along the southern boundary of the Dayton quadrangle to its southeast corner. The western edge of this area passes just east of Adelaide Lake, its northern edge passes along the slope south of Tongue River Cabin in irregular course, a mile south of Dome Lake, 2 miles southwest of Morrow ranch, and from Finger Rock northeastward to the overlying Deadwood sandstone at the mouth of Tepee Creek. Another area extends along the northeast margin of the crystalline rocks. It begins in a narrow point at Rapid Creek and, widening northward, passes on both sides of Walker Mountain and includes Black Mountain and part of the valley of Little Tongue River, northwest of that mountain. Northeast of Black Mountain it narrows to a width of about 1 mile and extends along the east side of the crystalline rock district to Tongue River, where it widens to 3 miles. North of Horse Creek it disappears beneath the Deadwood sandstone. A detached area of gray granite, of irregular crescentic form, occupies the divide and slopes west of Morrow ranch, the western end reaching a point 1 mile north of Dome Rock and the southern end lying 2 miles southwest of the ranch. Small irregular masses or streaks of gray granite appear here and there in the red-granite areas and red granite develops locally in the midst of the gray rocks. As above stated, there is generally a very evident transition from one variety to the other. On the two forks of Big Goose Creek, southeast of Walker Mountain, the change is rather abrupt and in places near Little Goose Creek it is moderately so. Both kinds of rocks present but little variation in character, except that the texture varies somewhat. Incipient schistosity in much of the gray granite indicates that this variety has been subjected to greater movement than the red granite. The increased development of biotite causes the darker color. At a few localities hornblendic minerals have developed in streaks and blotches in the granites in which they merge.

Near Little Goose Creek and on the divide south of that stream the granite is of dark-grayish color and very compact, but of varying coarseness. It shows considerable evidence of schistosity, becoming a gneiss locally, with the laminæ greatly crumbled in places. In this region red granite appears in small areas. Much of the gray granite weathers into slabs, and the jointing is usually vertical, but there is also a transverse system, and cleavage along the two sets of planes produces rectangular blocks with sharp edges. On this account the knobs of gray granite are as a rule much more jagged than those of red granite, which is more massive, is irregularly jointed, and usually weathers into rounded forms. In some places the red rock disintegrates so as to form level or gently rolling parks. Generally along the western side of the crystalline-rock area, near the western side of the Dayton quadrangle, the rock is red and moderately cross grained. A small mass of dark-gray granite occurs in the red granite 1½ miles southwest of the mouth of South Fork of Tongue River. A mile north of Morrow ranch there is a narrow area of a pegmatitic rock in the red granite, but apparently it is due to local, very coarse crystallization. In the gray-granite area on Tongue River the rock is very dark and weathers into rough, jagged surfaces. The deep canyon shown in fig. 5 of illustration sheet 1 is cut in this material. Black Mountain consists of typical gray granite.

In the northern portion of the red-granite district, southwest of Steamboat Point, the rock varies in hardness and in some places it disintegrates readily and small parks result. Toward the west it becomes harder, and in the ridge southeast of the mouth of South Fork of Tongue River and southwest of Rookwood, the rock is unusually hard and compact, so that it presents very rugged ledges. The transition from red to gray granite is well exhibited on Little Tongue River. The change is marked by gradual increase in the amount of biotite, causing darker color, and the rock gradually becomes harder, finer grained, and more compact.

In the Bald Mountain area the granite is all massive and in greater part of reddish color. It is traversed by joint planes that extend in various directions and is cut by occasional narrow dikes of diabase. At a few places the rock is gray, but the gray variety merges into the red. Most of the rock is coarse grained and weathers into bold, rounded forms. In small areas the granites have been converted into gneissic granite.

Petrography.—The principal constituents of the red granite are feldspar, quartz, and mica, with a few minor accessories. The feldspar is mainly orthoclase and microcline, but there is a small proportion of plagioclase—usually oligoclase. The orthoclase is commonly of reddish color, due to disseminated small particles of iron oxide. The microcline is sufficiently fresh to present the characteristic cross-hatched structure. Quartz generally occurs in rather prominent anhedra, although in some specimens it is arranged interstitially between the larger feldspars. The principal ferromagnesian mineral is biotite, often chloritized, and hornblende is sparingly found. Magnetite, although in small particles, is moderately abundant, and the individual crystals have taken shape without external interference. Minute crystals of apatite are recognizable in some specimens. The red granites are generally characterized by a relatively smaller proportion of the dark minerals and an increased amount of microcline.

The gray granites are generally uniform in color and texture, and in the kind, amount, and distribution of their component minerals. There are, however, local areas where the ferromagnesian minerals predominate, giving to the rock a very dark appearance, as is well illustrated in the region along Tongue River north of Rookwood. The usual color is dark gray, the texture is medium to fine, and incipient schistosity is in some places apparent. The principal constituents are feldspar, quartz, and biotite. The feldspars are orthoclase and a minor proportion of microcline. The soda feldspars range from albite to oligoclase. The quartz occurs in scattered irregular patches, often interstitially, and again as micrographic intergrowths with feldspar. Brown biotite occurs in considerable quantity, with inclusions of apatite; also a small amount of green hornblende. Magnetite and acute-angled crystals of titanite are common accessories and small anhedra of zircon are sometimes found. Chlorite and muscovite occur as alteration products of the biotite and feldspar. In a few cases schiller structure and rolling extinction of the quartz were noted, giving evidence of some strain to which the rock had been subjected.

In local areas the granites have been converted by pressure into a gneissic granite, and thin sections show small grains of quartz, biotite, and a few minor accessories, which surround the larger components in a typical gneissoid structure, the whole having a banded appearance when examined with a low power of the microscope. Micrographic intergrowth of quartz and feldspar is common, and secondary minerals frequently occur along the cleavage cracks of the feldspar. The quartz shows cloudy extinction, and microcline is seen interstitially arranged between larger constituents. The contained minerals of this gneissic granite are the same as those of the granite from which it was derived, with the addition of a few secondary products. In the vicinity of Dome Lake and north of Morrow ranch, on the west side of East Fork of Big Goose Creek, small areas of gneissic granite occur. Others are found at the north end of Walker Prairie and on the divide along the Dome Lake road near the west margin of the quadrangle.

Age.—On account of its massive structure, it is believed that the granite is of Algonkian age, for in most portions of the Rocky Mountain province the older granites have been extensively sheared. However, no contact with older schists and gneisses has been observed.

DIABASE.

Occurrence.—The granite above described is cut by numerous dikes of dark-colored diabase, some of which are intersected at various angles by white quartz veins. Most of the dikes range in width from 2 to 25 feet, though others are larger, and nearly all of them extend transversely or at a wide angle to the major axis of the main uplift.

The dikes, owing to superior hardness of the diabase, offer greater resistance to atmospheric agencies than the softer granites into which they have been intruded and consequently stand out in more or less prominent ridges that extend across the granitic areas. Much of the rock weathers into cubes 2 to 6 inches square, the ultimate product of decomposition being a reddish-brown residual soil which is in striking contrast to that derived from the lighter colored granites.

The dikes are most abundant in the ridges about the head of Little Goose Creek and adjoining North and South Piney creeks, in the southeast corner of the Dayton quadrangle. Several large ones extend in a rudely parallel course east of Finger Rock and Last Chance Lake, but they appear to terminate in slopes west of the trail on Little Goose Creek. Others occur along and near the main divide, mostly near the head of West Fork of Big Goose Creek and at points farther west. Another extends across portions of Township 55, in ranges 87 and 88, and several occur near the mouth of South Fork of Tongue River. Doubtless there are many small or short dikes which have not been discovered in some of the wide areas of down timber. Most of the dikes in the southwest corner of the Dayton quadrangle range from 5 to 20 feet in width and from a few hundred yards to 3 miles in length. A conspicuous dike having a width of about 55 feet extends across the main road east of the divide (bench mark 9601). It was traced for about 2 miles, and appears to end in the slopes to the south and in the 10,000-foot knob to the north. The dike extending northwestward from bench mark 9213, east of Antelope Butte, is similar, and was found to be nearly 3 miles long, possibly reappearing again near bench mark 9050, along a continuation of the same course. The longest dike extends nearly westward from a point near Walker Prairie almost to South Fork of Tongue River, a distance of 6 miles. Its width varies from 15 to 25 feet. The dikes near the mouth of South Fork of Tongue River are of variable width and length. The dike near the mouth of Tepee Creek is about 60 feet wide, and another mass near by, which appears to be a branch, is 25 feet wide.

Diabase dikes cut the granite at various points in the vicinity of Bald Mountain and on Porcupine and South Beaver creeks. A large branch dike was also observed on Little Bighorn River, where it cuts across the granite in the anticlinal ridge below the mouth of Dry Fork, and another dike crosses this stream near its headwaters, about 2 miles northeast of Duncom Mountain. One of the longest dikes begins northeast of the Bald Mountain cabins and extends due southwest for over 5 miles, disappearing under the Deadwood sandstone at either end and also for some distance under the Bald Mountain ridge. Its width is about 25 feet. A branch dike extends north-northeast from this one, in the granite plateau west of Bald Mountain, passes under the Deadwood sandstone for about a mile east of Medicine Mountain and appears to continue due north in one of the dikes crossing Porcupine Creek, having a length in all of at least 5 miles. There are several small dikes or chimneys of diabase near Fortunatus Mill, especially southwest of it. They are from 10 to 20 feet in diameter and of circular or elliptical outline. These smaller masses are mineralized somewhat with quartz and iron oxide.

Character.—The constituent minerals of the diabase are feldspar, augite, and quartz, with biotite, magnetite, chlorite, and apatite in smaller amounts. The feldspars range from oligoclase to labradorite. They are usually in lath-shaped crystals, which generally have clearly defined boundaries and contain a medium to high percentage of lime. Twin lamination according to the albite and Carlsbad laws is common and pericline twinning is sometimes seen. The common pyroxenic constituent is augite, which usually occurs without crystal outlines and in thin sections is nearly colorless. In some places it has altered to a fibrous serpentine. Quartz is present in scattered patches of varying dimensions and is often cracked and broken. A light-brown biotite occurs as an accessory but is usually chloritized. Magnetite and perhaps ilmenite occur, frequently in skeleton form. Needle-like crystals of apatite are not uncommon. Among bowlders in one locality on the south side of Tongue River, 5 miles north-northwest of Rookwood, there is much porphyritic diabase, consisting of large phenocrysts of feldspar surrounded by a fine groundmass of augite, plagioclase, and quartz, with the usual minor accessories. The dike from which it came was not located.

Age.—The diabase dikes are of pre-Cambrian age, for they are overlain unconformably by Cambrian sandstone.

Quartz veins.—Quartz occurs in veins in connection with the diabase dikes at several localities. The quartz shades in color from pale bluish to white, but parts of it are colored brown by oxide of iron, or green by malachite. Much of it is massive, but in places it crystallizes in large hexagonal prisms. The veins vary in width from a few inches to 20 feet and many share fissures containing igneous rock or occupy continuations of them. Some veins cross the dikes and in some areas there are veins which appear not to be connected with a dike. In one vein of white to bluish-white quartz, 20 feet wide, which extends a mile southwestward from a point near the mouth of Tepee Creek, the mineral is partly massive and partly in crystals. One of the largest veins runs southward for 5 miles from Walker Prairie up the valley of the southernmost prong of Wolf Creek. Near its northeastern end is a branch vein which extends for some distance southwestward, parallel to the main vein. A prominent vein occurs on the northwest slope of Black Mountain and some others appear north and east of Finger Rock.

PERIDOTITE.

In the ridge west of the lower portion of South Fork of Tongue River there is a long dike of peridotite which appears to be the only occurrence of rocks of this sort in the area. It is deeply decomposed, but the microscope shows that it consisted largely of olivine, diopside, and hornblende, with considerable magnetite. It is probably near the variety of peridotite known as wehrlite or lherzolite. It is overlain by Cambrian sandstone near its western end and although a few knobs of the igneous rock rise above this sandstone the relation is one of unconformable overlap on an uneven pre-Cambrian surface.

SEDIMENTARY ROCKS.

CAMBRIAN SYSTEM.

DEADWOOD FORMATION.

General relations and extent.—The surface of much of the higher portion of the northern part of the Bighorn Mountains consists of sandstones and shales of the Deadwood formation, which lie directly on the granite and other crystalline rocks. The formation has in most places a thickness of about 900 feet and, owing to the preponderance of soft materials, weathers in long, rounded slopes. Bald Mountain, which rises as a huge rounded mound about 800 feet above a platform of granite, as shown in fig. 10, illustration sheet 2, is the most notable example of this feature. Little Bald and Cone mountains are similar but smaller examples. In Sheep, Medicine, Duncom, and Hunt mountains there are long slopes of Deadwood beds capped by Bighorn limestone. East of Hunt Mountain the uplift is lower and the high central ridge, or plateau, is capped by limestones, Deadwood beds being extensively exhibited in the long slopes of the valleys of Tongue River and Cedar, Shell, and Granite creeks. The formation extends far eastward down the valleys of Lodgegrass Creek and Little Bighorn and Tongue rivers. It is brought prominently into view in the anticlinal ridge extending southeastward from West Fork of Little Bighorn River, especially in the deep canyon where this anticline is crossed by West Pass Creek and Little Bighorn River.

There are extensive exposures of the Deadwood formation on Tongue River below the mouth of Horse Creek, on Little Tongue River and its south fork, and on Wolf, Soldier, Big Goose, Rapid, and Little Goose creeks. Most of these streams cross the formation at a right angle, and the slopes of the canyons are sufficiently steep to give clear exposures of most of the beds, although ordinarily the shales are largely obscured by talus. In Walker Mountain an outlying area extends from Wolf Creek to Big Goose Creek, in greater part separated from the main monocline by a fault. North of Horse Creek the middle and upper members of the Deadwood formation are exposed in flexures which extend up Sheep Creek and pass near Freeze Out Point. The outcrops continue to the head of Sheep Creek and to the west side of Columbus Creek Canyon, the latter affording a clear and nearly complete section. On the slopes of Antelope Butte the entire thickness of the formation is represented, as the summit of this butte is capped by Bighorn limestone.

On the east side of the range the formation at most places dips gently northeastward and outcrops in a narrow zone of elevated valleys which generally have high granite ridges to the west or south and high limestone escarpments to the east and north. (See fig. 1, illustration sheet 1.) On the west side of the range the relations are similar to those on the east side, but the dip is in the opposite direction. The softness of the formation, as compared with the granite on one side and the very hard limestone on the other, causes the depressions or saddles, 300 feet or more in depth, in the divides between the streams that pass out of the mountains. Owing also to its softness, and possibly in part to its chemical composition, it is unfavorable to forest growth, so that trees rarely appear on its slopes.

General character and thickness.—The formation consists of a uniform succession of basal brown sandstone, and medial greenish sandy clays merging up into slabby pinkish and grayish limestones. Its total thickness is about 900 feet at most places, but appears to be only about 800 feet around Medicine Mountain, while in the lower portion of Shell Creek Canyon it increases locally nearly to 1500 feet. Farther south and east it is 900 feet.

Basal sandstones.—Owing to its hardness the basal sandstone generally is a prominent feature in the formation. It is a reddish-brown rock, usually coarse grained, merging into conglomerate at the base. It is massively bedded, in part cross-bedded, and varies in thickness from 20 to 50 feet. It lies on a remarkably smooth surface of granite, planed very evenly by early Cambrian erosion. This smooth surface is evident in all portions of the area but is most noticeable in the region about Bald Mountain, especially where the sandstone has been recently eroded so as to leave broad, tabular surfaces of bare granite, such as the wide shelf south of the mountain, shown in fig. 10, illustration sheet 2. In the vicinity of Fortunatus Mill and the old Bald Mountain mining settlement the basal Deadwood conglomerate constitutes the surface and is in part disintegrated to beds of bowlders and pebbles which contain small values in free gold. In portions of the region about Bald Mountain the basal bed is a 4-foot layer of deep-red, moderately coarse grained sandstone. It is overlain by 5 feet or more of red-brown conglomerate of quartz pebbles and from 5 to 10 feet of pale-buff sandstone streaked with red. West and southwest of Sheep Mountain the basal sandstones are 40 to 50 feet thick and of reddish-brown color.

Shales and limestone.—The beds lying above the basal sandstones are several hundred feet of sandy shales of greenish-gray color, containing occasional sandstone layers, usually thin, but one that is 15 to 20 feet thick is persistent over a wide area in the Bighorn uplift. In the region about Granite Creek and for some distance down Shell Creek the shales lie directly on the granite. Some of the sandy layers contain the green granular mineral glauconite. Toward the top of the formation there are about 200 feet of slabby limestones of gray, buffish, and pinkish color, containing many layers and masses of a peculiar conglomerate characteristic of the horizon. This rock consists of flat limestone pebbles, often intermingled with twisted and broken thin layers of limestone, with a matrix of fine limestone and shale material. Most of the pebbles are so thickly covered with grains of glauconite that they appear to be green, but they are gray or pinkish inside, like the associated beds. They are clearly intraformational conglomerates. Fig. 3, illustration sheet 1, shows this highly characteristic conglomerate, which is similar to that described by W. H. Weed from the Highwood Mountains. On Wolf Creek the thickness of this member is about 300 feet and fossils occur in large numbers in its middle and near its base. Next below at this locality are 300 feet of gray and greenish shale, with occasional thin beds of limestone and sandstone, of which the lower beds carry fossils. These shales lie on a prominent ledge of brown to buff sandstone 50 feet thick, which gives rise to a cliff. It is filled with small white shells. It lies on 50 feet of a succession of thin-bedded brown and gray sandstones, followed by 35 feet of gray sandstone and shales; 6 feet of hard, brown, cross-bedded sandstone; 30 feet of brown sandstone and sandy shale; 20 feet of dirty-buff to brown and reddish, soft, cross-bedded sandstone containing much glauconite and many fossils; 12 feet of soft, greenish-gray sandstone; and 8 feet of buff sandstones with many fossils. This sandstone is underlain by 200 feet of shale, which is sandy and carries some thin sandstone beds above, but is purer and fissile below, and of dark-gray and greenish color. It lies on bodies of coarse-grained, cross-bedded, massive sandstone, from buff to brown in color, which rest on an irregular surface of granite. The thickness of the basal sandstone is 30 feet in places in this vicinity, but it is locally absent, especially a short distance to the north, where the shales are in contact with the granite. The basal sandstone here and at most other points contains trilobite remains.

Fossils.—Fossils occur in all portions of the Deadwood formation and all are Acadian (Middle Cambrian) forms. A small white oval shell known as *Dicellomus politus* is the principal species. It was found to be especially abundant in the section south of Wolf Creek, described above, where it occurs in the middle and lower parts of the limestone series, in limestone layers in the shale a short distance above the medial sandstone, and in the medial sandstone and underlying shales and sandstones. Casts of a small tribolite, *Ptychoparia oweni*, occur abundantly at some places in the basal sandstone and are also found in the middle of the formation. They occur in large number in the basal sandstone in a shallow cut on the Dome Lake road three-fourths of a mile northwest of bench mark 7423.

On account of the similarity between the rocks and fossils in this area and at the type locality in the Black Hills, the name Deadwood is used for the formation in the Bighorn uplift.

ORDOVICIAN SYSTEM.

BIGHORN LIMESTONE.

Relations and outcrops.—Probably the most conspicuous sedimentary formation in the Bighorn Mountains is this hard, massive limestone, which outcrops in huge ledges surmounting the long slopes of Deadwood rocks. It is in most places about 300 feet thick, this thickness comprising also an upper series of about 100 feet of softer, thinner-bedded limestone, and a thin deposit of white sandstone, which have been included in the formation mainly because of their Ordovician age.

On the western side of the mountains the principal exposures of the Bighorn limestone are in lines of cliffs which face inward on the higher slopes, cap some of the high ridges north of Bald Mountain, and extend along the sides of the valleys of Little Bighorn and Tongue rivers, Shell, West Pass, Cedar, and Lodgegrass creeks, Devil Canyon, and West Fork. It is brought up by the anticline southeast of Dry Creek and becomes a prominent feature in Dry Fork Ridge, which is due to that flexure. It outcrops extensively in this anticline in Little Bighorn Canyon. It reaches to and across the main divide from Duncom Mountain to Sheep Mountain, and in the high plateau lying between Tongue River and Cedar Creek, where it is largely covered by Carboniferous limestones. In Hunt Mountain the formation presents to the west a high, straight escarpment, which is visible from far out in the Bighorn Basin. For a short distance on either side of South Beaver Creek and for several miles north from Devil Canyon, the formation is cut out by faults. Near the mouths of the canyons of North Fork of Five Spring, Bear, and Horse creeks the formation is exposed for a short distance. Antelope Butte is capped by a small outlier of the massive limestone.

On the east side of the Bighorn Mountains the Bighorn limestone presents a prominent westward-facing escarpment along the crest of the limestone front ridge, which generally rises several hundred feet above slopes underlain by the softer Deadwood shales and limestones. (See figs. 6 and 7, illustration sheet 2.) There is a continuous exposure of the formation northward from the fault near Little Goose Creek, and an outlier of considerable extent forms the crest of Walker Mountain. For the greater part of its course the zone of outcrop is narrow, for the beds dip northeastward with moderate steepness. In the vicinity of Sheep Creek the limestones are spread out more widely by a shallow anticline and syncline. On the crest of the anticline, in the prominent butte known as Freeze Out Point, the formation attains an altitude of 8300 feet.

Lower limestone.—The massive limestone which constitutes the greater part of the formation is in most places of light-buff color, somewhat darker when weathered, filled with a coarse matted network of irregular siliceous masses, mostly from one-half inch to 1 inch in diameter. On weathering, this siliceous material stands out half an inch or more on the rock surface as a ragged network, the purer rock between having been dissolved, as shown in fig. 4, illustration sheet 1. This feature and the very massive bedding are characteristic. Owing to the softness of the underlying Deadwood shales and the hard, massive nature of the Bighorn limestone, the latter gives rise to high cliffs (see fig. 2, illustration sheet 1), with a talus of huge blocks of the limestone on the slopes below. In the canyons there are close, high walls where the stream crosses the formation and a vertical cliff as the rock rises in the slopes. In composition the rock is a true dolomite, and a representative specimen free from silica veins from near Hunt Mountain was found to consist of carbonate of lime (58.83 per cent) and carbonate of magnesia (40.82 per cent).

Upper limestone.—The upper portion of the formation consists of softer, purer limestones than the beds below; the bedding is thinner, the color is white to gray, and parts of the rock are very compact or fine grained. There is considerable variation in the local features of the member and its thickness ranges from 75 to over 100 feet. In the greater portion of the area it includes a bed of hard, massive dolomite with a network of silica similar to that seen in the great lower member, but less marked in character and only from 15 to 25 feet thick. It comprises also some shaly and sandy limestone beds, and in the lower part of Little Bighorn Canyon a bed of oolitic limestone appears near its base. At the top the formation is difficult to separate from the Carboniferous limestone. The total thickness of the Bighorn limestone averages about 300 feet, but it is somewhat greater than this in the lower part of Shell Creek Canyon. Here the upper series of the formation comprises two beds of massive siliceous limestone with shaly limestone intervening, and is separated from the massive lower member by white fine-grained limestones.

Basal sandstone.—Underlying the massive lower limestone in most portions of the northern Bighorn region there is a deposit of light-gray sandstone, which usually has a thickness of 25 feet. It is absent in the vicinity of Shell and Cedar creeks, and at Bear Rocks it is only about 4 feet thick. Farther south in the Bighorn uplift it contains fossil fish remains similar to those which occur in the Harding sandstone near Canyon, Colo.

Fossils and age.—The greater part of the Bighorn limestone yields but few fossils. The lower massive beds contain mostly fragments of maclurinas and corals. In the lower beds of the upper limestone member there is a persistent horizon of corals, in which the Ordovician variety of *Halysites catenulatus* is especially abundant, while toward the top there are fossils of Richmond fauna in moderate number at some localities. The coral-bearing limestone underlies the higher massive bed of siliceous limestone and in some places the corals are numerous and of large size. In portions of the region east of Bald Mountain some beds of reddish shaly sandstone separate the coral-bearing limestone from the great massive limestone below. The locality at which fossils were observed to be most abundant in the lower member is on the top of Medicine Mountain, in beds about 100 feet above the base of the formation. The forms from this place, as determined by E. O. Ulrich, are the following: *Streptelasma* sp. undet., *Protarea* n. sp. (massive), *Plectorthis plicatella ?*, *Dinorthis pectinella ?*, *D. subquadrata ?*, *Rhynchotrema capax ?* var., *Oxydiscus* sp. undet., *Liospira* sp. undet., *Trochonema* sp. undet. (near *T. robbinsi*), *Holopea excelsa ?*, and *Huronia* sp. undet., the group constituting a lower Galena-Trenton fauna, as nearly as can be ascertained.

On Soldier Creek road the lower member contains *Streptelasma corniculum* Hall, a species characteristic of the Galena-Trenton horizon of the Mississippi Valley.

In the fine section of Bighorn limestone exposed in Wolf Creek Canyon the 200 feet of massive limestone at the base is overlain by purer, softer limestones, in part very fine grained, in which were found *Rhinidictya*, *Dicranopora* near *fragilis*, *Ptilotrypa obliquata*, *Pachydictya* sp. undet., *Ptimitia* sp. undet., and numerous corals, all indicating Richmond age.

On Goose Creek the lower massive limestone is 160 feet thick and yielded a few maclurinas and coral fragments. Overlying it are 10 feet of fine-grained, cream-colored limestone, 42 feet of massive, hard, light cream-colored limestone, in part sandy and with small calcite geodes, and 4 feet of coarse-grained limestone filled with corals including a small-meshed species of *Halysites* and a *Columnaria* like *C. alveolata* Goldfuss, but with separate corallites. Above this are 6 feet of sandy and pure limestone layers, alternating; 40 feet of limestone, mostly soft, slabby, and fine grained; and 135 feet of massive, cream-colored limestones, cherty in the lower part, which appears to contain only a few indeterminate coral fragments and probably belongs to the Madison limestone.

From the upper beds of the formation at a point about 3 miles east of the Bald Mountain cabins the following fossils were collected: *Streptelasma* n. sp. with trilobate calyx, *Calapœcia canadensis*, *Favosites asper*, *Stromatocerium ?* n. sp., *Dalmanella testudinaria* var., *Leptæna unicostata*, *Rhynchotrema capax*. These were determined by E. O. Ulrich, who regards them as of Richmond age.

Near the divide at the head of Cedar Creek, one-half mile north of bench mark 9259, the upper member of the formation is about 160 feet thick; and in its upper beds the following forms were found: *Leptæna unicostata*, *Strophomena fluctuosa*, *Dinorthis subquadrata* (coarsely striated form), *Rhynchotrema capax*, while in the middle beds are *Halysites gracilis* (abundant), *Streptelasma* sp. undet., *Diplotrypa westoni*, *Dalmanella testudinaria* var. (*D. meeki* W. & S.), and *Zygospira* n. sp. (without radial plications). In the lower beds of the upper member, which lie on the thick, massive buff lower member of the formation, were the following fossils: *Streptelasma* n. sp., with trilobate calyx, *Dalmanella testudinaria* var., *Rhynchotrema increbescens ?*, *Trochonema umbilicata ?*, *Trochonema* sp. undet., and *Cyrtoceras* sp. undet. (near *C. lysander*). All these forms are of Richmond age.

It is believed that in the Bighorn uplift, between the massive lower member of the Bighorn and the upper member, there is a hiatus representing later Trenton, Utica, Eden, and Lorraine time, and, locally, perhaps also the earlier Richmond. The Bighorn limestone is approximately equivalent to the Whitewood limestone of the Black Hills and the Fremont limestone of Colorado.

CARBONIFEROUS SYSTEM.

MADISON LIMESTONE.

Relations and outcrop.—The greater part of the high front ridge flanking the Bighorn uplift consists of a thick mass of limestone of earlier Carboniferous age. It extends to the crest of the ridge at most places and presents high walls in the great canyons which traverse it at frequent intervals. Its thickness averages 1000 feet. Beginning at the great fault near Little Goose Creek, the outcrop of the formation extends northwestward in a zone varying in width from 1 to 2 miles in greater part, the local differences being due to variations in dip. North of Tongue River, where there is a low anticline and syncline, the formation is spread out widely in sloping ridges and plateaus, but it has been extensively removed over the crest of the anticline along Sheep Creek and about Freeze Out Point. An outlier of the formation constitutes the east slope of Walker Mountain, dropped by a fault which brings the limestone into contact with the granite on the east.

In the northeastern portion of the Bald Mountain quadrangle the Madison limestone constitutes the greater part of a high anticlinal front ridge and, owing to the gentle dip, it extends far up the flank of the central range. Little Bighorn River and West Pass and Lodgegrass creeks cut deep canyons into the formation in this area. In the northwestern portion of the Bald Mountain quadrangle the dips are mostly steep along the higher mountain slopes, so that the outcrop zone of the formation is not wide. Devil Canyon is cut through the limestone and affords notable exposures of the beds, which here dip gently to the west except near the granite, where they are upturned and faulted. About the headwaters of Tongue River, and especially to the south of that valley, the formation caps the plateaus, which here constitute the summit of the main range. This plateau is wide between Tongue River and Cedar Creek, where the beds lie nearly horizontal over an area of about 30 square miles. An outlier of this limestone caps a high cuesta sloping southward from Cedar Mountain to Cedar Creek. Along Shell Creek the formation has been widely removed and its edge presents high cliffs on the south side of that valley. From these cliffs a thick sheet of the limestone slopes gently downward to the south and west, where it is deeply trenched by White and Trapper creeks. All along the west side of the mountain, from the west margin of the quadrangle to Trapper Creek, the limestone dips steeply to the southwest, rising in high, rugged slopes 1000 to 2000 feet high, deeply trenched by many canyons, of which the deepest are on Shell and Horse creeks, where there are very fine exposures of all the beds.

The most extensive and most instructive exposures of the formation on the east side of the mountains are in the canyons, especially those of Tongue, Little Tongue, and Little Bighorn rivers and Big

Goose, Wolf, Soldier, Smith, Columbus, Shell, Horse, North Beaver, South Beaver, Porcupine, and Lodgegrass creeks, where most of the beds are exposed.

Character.—The Madison limestone comprises two principal members. The upper one consists of about 250 feet of light-colored, moderately pure limestone, massively bedded, which weathers to a light dove color and gives rise to pinnacled forms and caverns. It lies on the higher slopes of the front ridges, and parts of it are generally stained red by wash from the red shales of the overlying formation. The lower members consist of 700 to 800 feet of harder, darker colored limestones, mostly in beds less than 3 feet thick, which usually constitute the crest of the front ridge. Some of the beds are sandy, and shaly limestones appear locally. In general there is great uniformity in character throughout each member. The bottom of the formation is not distinctly marked, although there is a hiatus at its base, apparently representing all of Silurian and Devonian time.

Fossils and age.—The Madison limestone is sparingly fossiliferous in most beds and in all portions of the area, containing the same fauna from top to bottom. *Spirifer centronatus* is the most abundant form, usually occurring with *Chonetes loganensis, Seminula humilis, Eumetria verneuiliana,* and several species of *Camarotœchia.* The following fossils were collected in the lower part of Little Bighorn Canyon: *Spirifer centronatus, Rhipidomella michelini, Seminula humilis, Eumetria verneuiliana,* and *Camarotœchia* sp. In Madison limestone on Canyon Creek, *Spirifer centronatus* and *Chonetes loganensis* were collected. On the north side of Shell Creek Canyon the following fossils were collected from the middle of the formation: *Rhipidomella michelini, Spirifer centronatus, Seminula humilis, Eumetria verneuiliana, Schuchertella inæqualis, Syringothyris carteri?,* and *Camarotœchia herrickana.* These fossils were all determined by G. H. Girty. These are distinctive of the Mississippian series and very probably belong to the lower half, or Waverly group. The formation is closely equivalent to the Pahasapa limestone of the Black Hills and the Madison limestone of the region farther northwest.

AMSDEN FORMATION.

Relations and outcrop.—Overlying the Madison limestone there is a somewhat variable series of red shales, limestone, sandstone, and cherty beds which has been designated the Amsden formation. Its average thickness is 200 feet. Its outcrop extends along both sides of the mountains, usually flanking the limestone slopes. Where these slopes are gentle, as on the outer side of the range, in the northeast and southeast corners of the Bald Mountain quadrangle, the formation extends far up the spurs, but to the southwest, where the dips are steep, the outcrop zone is narrow. On the sloping plateaus on either side of Horse Creek the formation extends nearly to the main divide and presents extensive areas on both sides of White Creek. From North Fork of Five Springs Creek northward it underlies a number of sloping plateaus that constitute a wide bench on the mountain slope, but here it is largely covered by later sediments and is cut through by Devil Canyon and the valleys of Deer and Trout creeks. The syncline of Dry Creek Valley contains a long, narrow area of the formation, partly covered by later deposits. West of this valley, on the divides between branches of Dry Creek, the formation extends several miles up the slopes. A large area of it caps West Fork Ridge between Little Bighorn River and its west fork.

On the east slope of the uplift the Amsden formation outcrops along the higher outer slopes of the front ridge, with thickness gradually increasing from 150 feet in the north to 350 feet in the south. From East Pass Creek to the fault south of Little Goose Creek the formation dips eastward down the mountain slope in an outcrop zone which is narrow south of Little Tongue River and wider to the north, especially at the head of the branches of Amsden Creek and in the anticline and syncline on East Pass Creek.

Rocks.—The lower member of the Amsden formation consists of a mass of bright-red sandy shales, abruptly succeeding the top member of the Madison limestone, which is in many places stained red from the shale. This basal red shale varies in thickness from 50 to 100 feet and is often parted by 10 feet or more of hard, fine-grained, flesh-colored limestone, resembling lithographic stone. Next above are slabby limestones, in part containing extensive deposits of chert, which weathers out and at some places accumulates in large amount on the surfaces.

The thickness of the formation averages 200 feet about Devil Canyon and at the mouth of Horse Creek Canyon. At Shell Creek Canyon it is 174 feet, consisting of the following beds:

Section of Amsden formation on Shell Creek east of Shell, Wyo.

	Feet.
Pink sandstone (overlain by flesh-colored massive sandstone of Tensleep formation)	4
Light-red to maroon sandy shale	40
Gray sandy limestone, thin bedded at top and containing much chert	20
Red shale	75
Hard, fine-grained flesh-colored limestone	10
Red shale (lying on blue-gray Madison limestone)	25
	174

Near the base of the formation in this vicinity there are some very peculiar mammillary concretions of silica composed of thin, irregular sheets suggesting a coral in appearance but probably not of organic nature. They range in size from 6 inches to 2 feet in greater part. The local features of the formation vary considerably from place to place, but the basal red shales, lithographic limestones, and cherts are characteristic. On Little Bighorn River, on the east slope of the mountains, the formation is about 130 feet thick, consisting of about 30 feet of basal red shale, 25 feet of tan-colored sandy shale, 25 feet of massive white limestone, and 50 feet of alternating limestone, sandstone, and cherty beds, including a 7-foot bed of gypsum, the latter a most unusual feature. The limestones are pure white and very compact, like lithographic stone. These very compact white limestones form a characteristic feature of the region and, together with cherty beds, rise at many places in knobs that are separated from the adjoining higher mountain slope by depressions underlain by the red shale. About the heads of the branches of Amsden Creek, where the low dip and a low anticline and syncline carry the beds far up the mountain slope, a thin bed of dark-gray sandstone, with a few conglomeratic streaks, and 20 feet of red shales occur in the middle of the formation. In the canyon of Little Tongue River there is a particularly clear exposure of the formation, 190 feet thick, showing the following succession:

Section of Amsden formation on Little Tongue River.

	Feet.
Tensleep sandstone at top.	
Pinkish and greenish shales	20
Light-buff sandstone	6
Pink and green sandy shale	30
Light-gray sandstone	6
Light-maroon shale	10
Hard, cherty, sandy lime rock (weathers dark)	15
Red, pink, and maroon shale	25
Light-gray calcareous sandstones	12
Red shale	40
Pure white, very compact limestone	6
Red shale (lying on Madison limestone)	20
	190

On Wolf Creek, near the mouth of the canyon, the section measures 350 feet, including 100 feet of red shales and fine-grained red sandstone at the base. On Goose Creek the lower 165 feet comprises red sandy shales and some shales of lighter color overlain by an upper series of the typical white, compact limestones, with sandstone, shales, and cherty limestone intercalations. On Rapid Creek 280 feet of the formation were measured, comprising about 90 feet of basal red deposits and exhibiting considerable chert in the limestones and shale series above. Chert usually appears prominently in the upper portion of the Amsden formation throughout its extent and by weathering of the softer rocks accumulates in considerable amount at many places on the slopes.

Fossils and age.—Very few traces of organic remains occur in the Amsden formation in this region, and there is some uncertainty as to its age. Near Soldier Creek a few fragments of *Spirifer* and *Zaphrentis* were obtained from the lower limestone bed, and a *Menophyllum excavatum,* a Mississippian form. These were determined by G. H. Girty. From the upper cherty beds southwest of Buffalo Pennsylvanian species in moderate variety were obtained, including, according to G. H. Girty, *Productus nebraskensis* and *Edmondia nebraskensis.* This evidence indicates that, while the upper part of the formation is Pennsylvanian, the lower beds probably belong to the earlier Carboniferous division. The succession is apparently continuous.

TENSLEEP SANDSTONE.

Relations and outcrop.—This sheet of sandstone extends along both sides of the Bighorn Range, at many places in a low ridge on the lower slopes of the mountains. The thickness of the formation generally varies from 100 to 125 feet but is only about 30 feet in the northwest corner of the Bald Mountain quadrangle. The thickness increases rapidly toward the south, and in Horse Creek Canyon it is 150 feet. On Little Bighorn River it is about 100 feet, and some layers contain much carbonate of lime. On Tongue River the thickness is about 65 feet; on Wolf Creek and Goose Creek, 100 feet; on Rapid Creek, 125 feet; and on Little Goose Creek, about 150 feet. A narrow outcrop of the formation extends along the lower mountain slopes in the vicinity of Little Bighorn River and Pass Creek, and outliers occur on the higher slopes farther west, notably on West Fork Ridge. Areas also occur in the syncline on the east side of Dry Creek Valley. On the plateau of the divides extending west from the middle slope of the mountain from Willow Creek northward, the formation underlies extensive areas, but it is mostly covered by Chugwater red shales. Its thickness here is only 30 feet and it gives rise to an inconspicuous ledge. Small outliers of the formation occur high on the divides on either side of Bear Creek; also on the road east of Cloverly, on the divide north of the mouth of Shell Creek Canyon, and on the divide south of White Creek.

For the greater part of its course along the east side of the mountains it dips east-northeast. Here, owing to its thinness, steep dips, and low position on the mountain slope, it is cut through by nearly every little canyon and draw, which gives its outcrop a very jagged outline. On East Pass Creek it arches over the point of an anticlinal ridge and its outcrop offsets to the west in the syncline beyond. South of Little Goose Creek it is cut off by the fault. Outcrops of the formation are almost continuous, its white ledges being conspicuous features, especially farther south, as the thickness increases. In many canyons leading out of the mountains from Tongue River southward it gives rise to a narrow constriction, or gateway.

Rocks and fossils.—The predominant rock is white to buff sandstone in thick massive beds, cross-bedded, and often weathering into irregular pinnacled forms. Where the formation is thick its lower portion includes 50 feet or more of softer buff to flesh-colored sandstone, not clearly separable from the upper member of the underlying Amsden beds, although the latter are mostly in thinner beds. The upper sandstone at many places contains a few thin, limy layers, similar to those which in other districts have yielded Pennsylvanian fossils.

TRIASSIC SYSTEM (?)

CHUGWATER FORMATION.

General relations and outcrops.—This formation consists of the characteristic series of "Red Beds" which are so extensively developed in central-western United States. In this region they reach a thickness of 1200 feet and extend along the lower slopes on both sides of the Bighorn Mountains. Where the dip is steep, as in the region from Five Springs to South Beaver creeks, near Horse Creek, and along the east side of the mountains south of Tongue River the outcrop zone is narrow, but from Little Bighorn River to Pass Creek, along Shell and Trapper creeks, and in the plateaus north of Willow Creek there are wide areas in which the high hills and buttes of red sandstones and shales are conspicuous features. Small areas occur also in the syncline on the east side of Dry Creek.

The formation presents but little variation in character, consisting mainly of the usual soft, massive fine-grained red sandstone, merging into red shale. Toward the top it includes two or three thin beds of limestone, and near the bottom more or less gypsum and two thin beds of limestone. The color is a brilliant red, which renders the outcrop a notable feature in the landscape, especially in the slopes adjoining the larger cross valleys. At its base it begins abruptly as a body of red shale lying on the Tensleep sandstone; at the top there are red shales which give place to dark shales or sandstone of the Sundance formation, and although there is a hiatus between the two formations, there is no discordance of dip and but little evidence of channeling.

The thickness averages 1200 feet on the east side of the range, being about 1100 feet on Columbus Creek, 1200 feet on Smith Creek, 1250 feet on Wolf Creek, 1200 feet on Big Goose Creek, and 1140 feet on Hurlburt Creek. Farther south the thickness rapidly increases to about 1200 feet and does not vary greatly from this amount to Little Goose Creek and beyond. North of Columbus Creek the amount gradually decreases to about 800 feet at the Montana line. On the west side of the mountains the thickness is about 700 feet.

East slope.—On the east side of the mountains the Chugwater formation extends along the base of the steeper slope of the front ridge in an outcrop zone from one-quarter to one-half mile wide in greater part. In Red Gulch and on Pass Creek the formation has a thickness of about 800 feet, consisting mainly of bright-red sandy shales and soft sandstones. About 30 feet above the base there is the bed of limestone about 4 feet thick, thin bedded and of purplish-gray color, which is so persistent along both sides of the mountains. A short distance above there is more or less gypsum in red shales and then a thin bed of impure, massive limestone in places 20 or more feet thick, which weathers to a porous or cellular buffish-gray rock. Upon this lies a thick mass of red sandy shales, merging above into soft sandstones. The top of the formation consists of red shales containing two or three thin beds of white limestone, fine grained and moderately thin bedded, the uppermost of which is separated from the overlying gray Sundance beds by about 40 feet of red shale.

The limestones in the red shales in the upper part of the formation are in a series that ranges in thickness from 70 to 240 feet, the amount increasing toward the south. There are three or four beds, from 3 to 8 feet thick, separated by 16 to 100 feet of red and purplish shales. Near Columbus and Smith creeks the beds containing the limestone aggregate 70 feet in thickness, with four beds of limestone, the top one, 6 feet thick, being a short distance below the Sundance contact. Two thinner beds, separated by 4 feet of red shale, occur in the middle of the series and a 5-foot bed of hard gray limestone lies at the base. The lower limestone bed of this series is generally the thickest, and farther south it is so thick and hard that it gives rise to a small but sharp ridge or escarpment in the Red Beds ridge. Near Hurlburt and Little Goose creeks it is 8 feet thick and lies 180 feet below the top of the formation. The overlying beds are alternating red and purple shales, with several thin intercalated beds of limestone, some of which contain fossils. On Little Rapid Creek the upper series is 240 feet thick, comprising the thick, hard bed of limestone at the base, a thinner bed near the middle, and another thin bed about 40 feet below the top.

From Tongue River southward the limestone in the basal shales lies about 15 feet above the base of the formation. It is thinly laminated and of purplish color and its occurrence and appearance strongly suggest that it is an attenuated representative of the Minnekahta limestone of the Black Hills, the underlying red shales being equivalent to the Opeche red beds of that district. Some distance above is a persistent bed of impure limestone about 3 feet thick, which weathers to a spongy texture and dirty-buff color.

The principal gypsum horizon in the Chugwater formation on the east slope of the mountains lies within 60 to 100 feet of the bottom of the formation.

West slope.—On the west side of the mountains the succession is similar to that on the east side, but the total thickness is somewhat less, averaging about 700 feet. The characteristic features are the bright-red sandy shales, merging into massive, soft red sandstones above. Near the base is the thin-bedded purplish limestone layer; not far above is the more massive limestone weathering porous, here thicker than on the east side of the range; and near the top are several thin layers of white limestone. A typical section is as follows:

Section of Chugwater formation near Alkali Creek, northwest of Cloverly, Wyo.

	Feet.
Dark-red shales (overlain by Sundance gray shales with Jurassic fossils)	60
White limestone with red-shale partings	10
Red shale	20
Thin-bedded, fine-grained, light-colored limestone	10
Red shale	60
Red sandy shale	50
Red sandstone; some red shale	224+
Green shale	20
Massive limestone, weathering porous	50
Red shale, not well exposed	40
Thin-bedded purplish limestone	6
Red shale, not well exposed	80
Tensleep sandstone.	

In Red Gulch east of Cloverly the lower portion of the formation is well exposed, consisting of the following beds:

Section of lower member of Chugwater formation east of Cloverly, Wyo.

	Feet.
Limestone, weathering porous (overlain by about 500 feet of red shales and sandstones)	20
Green shale	15
Limestone, weathering porous	6
Green shale	10
Limestone, weathering porous	4
Red shale	35
Thin-bedded purplish limestone	10
Red shales with gypsum	125
Tensleep sandstone.	

On the plateaus on either side of Devil Canyon and in areas farther north the lower Chugwater beds are extensively exposed, lying nearly level or dipping gently westward. There are from 200 to 400 feet of red shales and red sandstones remaining, underlain by 25 to 30 feet of gray limestone that weathers to a porous texture, 10 feet of red shale, 6 feet of slabby limestone, and 60 feet of bright-red shale lying on Tensleep sandstone, here only about 30 feet thick. On North Beaver Creek the limestone that weathers with porous texture grades up into thin-bedded white limestone having in all a thickness of about 50 feet. Below are 85 feet of red shales, 8 feet of slabby gray limestone, in part purplish, and 100 feet of basal red shales lying on the Tensleep sandstone. All the beds dip steeply to the west, and there are many good exposures in road cuts. On Horse Creek the lowest limestone is 8 feet thick, thin bedded, and of purplish tint, and is separated from the Tensleep sandstone by 100 feet of red shale. Between Horse Creek and Shell Creek the formation appears to thicken somewhat, locally. About 125 feet above the base there is a 6-foot bed of slabby gray to purplish limestone, then 30 feet of red shales capped by several feet of the gray limestone weathering porous. Kidney-shaped concretions which have weathered out of this lower series are abundant here and at other localities.

At the mouth of Shell Creek Canyon the following basal beds are exhibited:

Section of lower beds of Chugwater formation on Shell Creek, east of Shell, Wyo.

	Feet.
Limestone, weathering porous (under 600 feet or more of red shales and sandstones)	4
Red shale	25
Thin-bedded purplish limestone	6
Red shale	25
Gypsum	12
Purplish sandy shale	4
Red shale (on 75 feet of Tensleep sandstone)	20

Three miles southeast of Shell post-office there is the following succession: Limestone weathering porous, several feet of gypsum, 2 feet of compact white limestone, and the basal red shale, including the thin-bedded purplish limestone. Here this purplish limestone is overlain by a 2-foot layer of dark-gray conglomerate containing pebbles of flinty material.

Age and fossils.—Evidence as to the age of the Chugwater formation in the Bighorn region is not entirely satisfactory. As the formation overlies the Pennsylvanian Tensleep sandstone and is overlain by the Sundance formation, which contains later Jurassic fossils, it is believed that it represents either the Permian or the Triassic, probably comprising all of the former and possibly part of the latter. Farther north, in the Bighorn Basin, Jurassic marine fossils occur in limestones among red shales overlying the main body of the Chugwater formation but doubtless separated from it by an obscure unconformity. The formation comprises in its lower portion a limestone horizon and succession so closely resembling the supposed Permian of the Black Hills and a part of the Laramie Range that they are believed to be the same. Near Thermopolis supposed Permian fossils occur in a limestone member only 150 feet below the top of the formation. On this evidence the formation should be regarded as mainly of Permian age, but possibly the upper beds are Triassic.

Fossils were obtained from the limestones in the lower portion of the formation at several points on the western slope of the Bighorn Mountains, but unfortunately they are not sufficiently complete or distinctive to be classed, except as either Permian or Triassic. On Beaver Creek the lower limestone contains an abundance of pelecypod shells, more or less deformed by compression, which do not show the hinge structure and muscle scars clearly enough to be determined. According to George H. Girty they resemble the genus *Schizodus* of the Carboniferous, one being like *S. wheeleri* and another like *S. symmetricus*, both being of reduced size, but they may possibly be some other genus of Mesozoic age. Near Kane post-office, a short distance west of the limits of the Bald Mountain quadrangle, numerous but ill-preserved and diminutive fossils were obtained. These show no generic characters, and even the outline is in most cases indistinct. According to Dr. Girty one small shell closely resembles *Myalina swallowi* of the Pennsylvanian, but it may possibly have been a *Pteria* or *Bakewellia* or a Mesozoic *Mytilus* or *Modiola*. Another species suggests, by its shape, *Astartella*, possibly *A. gurleyi*, but has a more projecting anterior end. On Trapper Creek this last form occurs abundantly and with it a compressed and imperfectly preserved gasteropod which may be *Bulimorpha*. All these suggested genera are based on characters of outlines and also might be interpreted as Mesozoic forms, but Dr. Girty and Dr. Schuchert, who examined the fossils, are inclined to believe that they are Permian, as in the similar beds in the Black Hills.

Some poorly preserved fossils were found in two or more thin layers of the middle bed of the upper limestones of the formation between Columbus and Smith creeks. According to T. W. Stanton, who examined these fossils, they comprise numerous obscure specimens that may be an ostracod crustacean, many small bivalves resembling *Astarte*, and a few small naticoid gasteropods, which are not sufficiently characteristic to determine the age of the beds.

JURASSIC SYSTEM.

SUNDANCE FORMATION.

Relations and outcrop.—This marine Jurassic formation consists of soft gray sandstone and green shales averaging about 250 feet in thickness. Its outcrop extends in a narrow zone along both sides of the Bighorn Mountains. On the west side of the mountains there are steep dips and a narrow outcrop north of Beaver Creek, but the dips diminish toward the south, especially in the region north of Shell, where the outcrop spreads out over a wide area in the hills at the foot of the mountains. The area is 2 miles wide where it crosses Shell Creek at Shell, but the formation is covered by alluvium near the creek. Toward the south its width diminishes somewhat. The outcrop extends far down North Beaver Creek, owing to low dips and to a local anticline and fault and reaches nearly to Cloverly. Southeast of that place this anticline trends southeastward, and where it crosses the next valley south the formation is again exposed. The anticline southeast of Sheldon's ranch brings up the formation for some distance in the hills south of Shell Creek.

On the east side of the mountains the Sundance formation extends continuously from the Montana line near Red Gulch to the fault south of Little Goose Creek, presenting frequent outcrops. It is covered for short distances by superficial deposits along the larger streams and on some of the divides between Little Tongue River and Hurlburt Creek. Its thickness varies from 250 to 350 feet in greater part, the amount increasing southward to Rapid Creek and then slightly diminishing again, to 300 feet, on Little Goose Creek.

The formation lies unconformably on the red beds of the Chugwater formation, but, as explained above, there is no discordance in dip and rarely any marked evidence of erosion, yet there was a long interval between the deposition of the two formations, comprising early and middle Jurassic time and probably part if not all of Triassic time.

East slope.—Throughout its course there is a basal shale followed above by a bed of highly fossiliferous sandstone and limestone, a thick body of dark-gray fossiliferous shales, and, at or near the top, a hard bed of sandy limestone overlain by a softer sandstone. The sandstone and limestone near the bottom and near the top at some places give rise to ridges or cliffs of considerable prominence. The basal shale is sandy, is generally about 30 feet thick, and contains numerous shells of *Gryphæa calceola* var. *nebrascensis*, which weather out on the slope. It lies on a few feet of red shale, or directly on the thin limestone in the top of the Chugwater red beds. To the north there is at many places near the base of the formation a soft, gray, fossiliferous, calcareous sandstone, 3 to 5 feet thick, and, at the base, a couple of feet of dark shale. At most localities the basal sandy beds are overlain by a somewhat calcareous sandstone, which often merges into limestone and is filled with broken shells. Its thickness varies from 6 to 15 feet and to the north it contains a local shale parting. In places it abruptly thickens and suggests a local oyster reef. Its most notable exposure is on the western face of a ridge just northwest of Little Goose Creek, where it dips steeply eastward and rises for 70 or 80 feet up the steep slope as a bare sheet of limestone, forming a rather striking feature in the topography. Next above is a mass of dark-colored shales varying in thickness from 120 to 275 feet, the amount gradually increasing southward. These shales contain thin beds of fossiliferous limestone and a few small lens-shaped concretions. *Belemnites densus* is the most conspicuous fossil and occurs in great abundance in places on the shale slope. The top member of the formation is a series comprising a hard calcareous and fossiliferous sandstone below and some soft sandstone above. In thickness the member varies from 30 to 40 feet, of which the top sandstone comprises from 25 to 30 feet or more. It is massive to thin bedded, greenish buff in color, and not prominent, while the underlying fossiliferous limestone usually stands out as a distinct ridge. These upper sandstones are seen in the vicinity of Wolf Creek and Little Tongue River.

West slope.—On the west side of the Bighorn Mountains the Sundance formation is so variable in constitution that no two sections are closely alike. Soft greenish-gray sandstones predominate in its lower portion and there is a thick mass of green shales above. Usually several hard layers of sandstone or impure limestone occur at intervals, giving rise to prominent ledges, which generally are highly fossiliferous. Some typical sections are as follows:

Section of Sundance formation on Horse Creek, 5 miles north of Shell, Wyo.

	Feet.
Morrison shale.	
Brown sandstone; hard at base, soft at top; very fossiliferous	25
Soft greenish-brown sandstone	25
Green shale, many fossils; belemnites at base, large oysters above	50
Dark-brown and light-gray sandstones alternating; no fossils	20
Light-gray sandstone	25
Green shales, very fossiliferous	38
Brown sandstone, fossiliferous	1½
Light-brown sandstone, fossiliferous	2
Green shale, fossiliferous (on dark-red shale of Chugwater)	12
	198½

Section of Sundance formation on west side of mouth of Trapper Creek, south of Shell, Wyo.

	Feet.
Morrison shale.	
Alternating brown sandstone and green shale	20
Dark-brown fossiliferous sandstone, hard, thin bedded	12
Dark-green fossiliferous shale with thin-bedded sandstone at base	115
Light-green sandy shale	50
Light-colored sandy clay	3
Dark-maroon sandy clay	2
Green sandy shale with numerous small oysters	20
Gray sandstone	1
Green shale (on Chugwater red shale)	20
	243

Section of Sundance formation on Alkali Creek.

	Feet.
Green shale (overlain by Morrison shale)	25
Green thin-bedded sandstone	5
Brown fossiliferous sandstone	6
Green shale with belemnites and oysters	115
Thin-bedded gray limestone	16
Green shale (on Chugwater red shale)	75
	242

Section of Sundance formation on east side of Red Gulch south of Little Bighorn River.

		Feet.
Impure limestone (overlain by Morrison formation)		35
Light greenish-buff soft sandstone, cross-bedded		20
Greenish shales with thin fossiliferous limestone beds		100
Soft, greenish-buff, massive limy sandstone, some hard layers, fossils		40
Dark-greenish shales, few sandy and limestone concretions, many fossils		120
Gray, moderately hard sandstone	Prominent ledge makers.	5
Dark shale		15
Hard gray to buff sandstone		6
Sandy shale with many *Gryphæa calceola* in lower part		20
Gray sand		5
Dark shale (on Chugwater red shale)		2
		368

Fossils.—Fossils are abundant in all exposures of the Sundance formation. One of the most conspicuous forms is *Belemnites densus*, a cigar-shaped fossil mostly from 3 to 4 inches in length, smooth on the outside, with a radiated structure within. They occur mainly in sandy layers in the upper shale member and often weather out on the surface, so as to be a notable feature. In the lower sandy shales there are large numbers of a small oyster-like shell, *Gryphæa calceola* var. *nebrascensis*, and in the hard layers higher up are found *Campectonectes bellistriatus*, *Ostrea strigilecula*, *O. engelmanni*, *Dosinia jurassica*, *Eumicrotis curta*, *Trigonia elegantissima*, *T. americana*, *T. conradi*, *T. montanaensis*, *Pentacrinus asteriscus*, and other forms. These were determined by T. W. Stanton. The formation is equivalent to the Ellis formation of Montana and the Yellowstone Park region and may be correlated with the lower part of the European upper Jurassic.

CRETACEOUS SYSTEM.

MORRISON FORMATION.

Outcrop.—This formation consists of fine-grained sediments of fresh-water origin, which succeed the marine Jurassic deposits. It outcrops on the inner slope of the line of low hogback ridges extending along the east side of the mountains and also in a wide area in the valleys of Shell, Beaver, and Horse creeks, and along a portion of the valley of Alkali Creek. These wide areas on the west side of the mountain are due to low dips, but along the foothills for a few miles northwest and southeast of Alkali Creek and on the east side of the mountains the strata are steeply upturned and the outcrop is very narrow. On the high terraces on the east side of the mountains and in the wider valleys the formation is extensively hidden by Quaternary sands and gravels. Where it is bare it usually gives rise to a shallow valley lying between a knob of Cloverly sandstone and the ridge due to the upper sandstone of the Sundance formation.

General character and relations.—The principal material is hard clay or massive shale of peculiar chalky appearance, varying in color from pale greenish gray to maroon; at the top, under the Cloverly sandstone, the clay is usually dark gray or black. Several thin beds of greenish-gray or buff sandstone occur, the more persistent one near the middle generally being 10 to 20 feet thick and giving rise to a low ridge. The sandstone is mostly thin bedded and of light-gray color, and the beds have a peculiar wavy surface, suggestive of incipient cross-bedding.

The Morrison beds lie on sandy shales or sandstone at the top of the Sundance formation with apparent conformity, and perhaps there is transition from one formation into the other. Possibly some of the soft greenish-buff sandstone lying above the hard fossiliferous layer in the upper part of the Sundance formation in the Wolf Creek and Little Tongue River regions belongs to the Morrison formation.

Thickness.—The thickness averages 200 feet to the northeast, but is less to the south, being 150 feet on Amsden Creek, 120 feet on Little Tongue River, and less than 100 feet on Wolf Creek. It increases again to 200 feet at Little Rapid Creek. West of the mountains the thickness averages about 300 feet.

East slope.—Exposures are numerous on the divides from the Montana line to Amsden Creek, from south of Tongue River to beyond Wolf Creek, and at intervals from Big Goose Creek to Beaver Creek. One of the best is on Little Tongue River. Owing to the softness of the clay, the exposures are seldom complete. The medial sandstone is most conspicuous just north of Soldier Creek and near Tongue River, where it is 20 feet thick, nearly white, and massive. On Wolf Creek it is separated from the Cloverly sandstone by 40 feet of green and red clay or massive shale. Just south of Little Rapid Creek the interval is 70 feet, occupied by 45 feet of green and maroon shales capped by 25 feet of dark shales. Near Columbus Creek two beds of sandstone occurring in the clays are so hard as to give rise to ridges of moderate prominence.

West slope.—South of Shell and southeast of Cloverly a massive, light-colored sandstone occurs near the base. South of Shell this bed is 20 feet thick and moderately hard. It is separated from the Sundance beds by reddish shale and overlain by massive greenish sandy clay. Southeast of Cloverly it is of light-buff color, 40 feet thick, moderately coarse grained, and has lenses of conglomerate near the top. The pebbles of this conglomerate are dark and consist mostly of quartz. In places the sandstone is bright red, like some of the sandstone in the Cloverly formation. It is overlain by green sandy shale of lighter color than the Sundance shale. A typical section of the formation on Alkali Creek is as follows:

Section of Morrison formation on Alkali Creek.

	Feet.
Pale green massive shale (overlain by Cloverly sandstone)	50
Thin-bedded gray sandstone, brown on surface	15
Pale-green massive shale	5
Blue-black shale	10
Maroon massive shale	10
Variegated massive shale	45
Thin-bedded gray sandstone	6
Variegated massive shale, drab, purple, and maroon	65
Pale green to white sandstone	6
Pale-green and maroon massive shale	85
Pale-green massive sandstone	45
Red sandy shale (lying on Sundance formation)	40
	382

This thickness is somewhat greater than the average.

Fossils and age.—Bones of large dinosaurs occur at many places in the Morrison beds and they appear to be the same as those found in the formation in other regions. Opinions are divided as to whether these remains are of late Jurassic or early Cretaceous age, but from the stratigraphic relations of the formation in other uplifts it is provisionally placed in the early Cretaceous.

CLOVERLY FORMATION.

Relations and outcrops.—This formation consists of massive sandstone overlain by sandy clays and is supposed to represent the formation usually referred to as Dakota sandstone. It underlies a large part of the southwestern portion of the Bald Mountain quadrangle and on the east side of the mountains it outcrops in a narrow zone of low hogback ridges from which, with gentle northeast dip, it passes beneath the Colorado shales. West of the mountains it is in most places overlain by several hundred feet of Colorado shale, but crops out extensively about Cloverly and along Alkali and Beaver creeks. South of Shell Creek it rises with the upward pitch of the syncline southwest of Shell and outcrops in an irregular zone extending east and west for several miles. In the anticline east of Sheldon's ranch it appears on the north side of Shell Creek for a short distance, pitching down to the north under Colorado shales. Along the foot of the mountain north of Cloverly it dips steeply for some distance, but on Alkali Creek and about Cloverly and farther south it dips gently to the west. In the lower portion of Beaver Creek Valley the rocks are covered by alluvium, except a small sandstone outcrop on the east side of the valley near its junction with Shell Creek Valley.

The formation has been named from the extensive and characteristic exposures about Cloverly. The sandstone may be conformable to the Morrison formation, although there is an abrupt change in the nature of the sediments at the contact, with local lenses of conglomerate in the basal beds.

East slope.—The lower half of the Cloverly formation is characterized by coarse-grained, massive, partially cross-bedded sandstone, in greater part firmly cemented and locally conglomeratic at the base. The sandstone consists almost entirely of quartz sand of unknown origin. The color is usually pale buff to light brown, but in some places it is light gray or white. Nearly every outcrop bears a few pine trees, which do not grow on outcrops of the adjoining formations. This sandstone ranges in thickness from 30 to 60 feet, but a notable exception to this limit is seen just north of Little Tongue River, where it is about 200 feet thick and includes a considerable mass of conglomerate at its base. On West Twin Creek its thickness is 100 feet. East of Little Rapid Creek, where the rock is too soft to rise above the slope, its thickness is only 22 feet. To the north there are two and possibly three beds of sandstone separated by shale. On Big Goose Creek the main bed of sandstone is 30 feet thick, but about 30 feet above and 30 feet below are additional sandstone beds, 10 to 15 feet thick, separated by dark shale. East of Little Tongue River, for several miles, there are exposures of 45 feet of light-colored sandstone parted by $3\frac{1}{2}$ feet of highly carbonaceous shale, which has been prospected for coal at several points. It contains many flat pine needles converted into coal. On the ridge just north of East Twin Creek the sandstone is in part slabby and some layers are carbonaceous and contain plant fragments.

On the east slope of the ridge due to the basal Cloverly sandstone there is a body of clays, generally less than 100 feet thick, which, owing to their softness, are rarely exposed. The clearest exposure is in the slopes a few rods east of West Pass Creek, where this member has the unusually great thickness of about 120 feet. At the base there are gray clays overlain by a succession of white sandy clay, maroon clay, light ash-gray clay, dark-gray clay, and a thin bed of light-gray clay, nearly white at the top. Above this are 30 feet of dark-gray clay merging upward into 50 feet of dark-gray shales capped by 10 to 15 feet of buff sandstones, supposed to represent lower beds of the Colorado formation but possibly belonging to the Cloverly. To the south there are occasional small outcrops of reddish or ash-colored clays above the basal sandstone member, but only one complete cross section was observed. This is at the foot of a low knob on the summit of the ridge next east of Little Rapid Creek, and an outcrop exhibits 30 feet of pale-green and maroon clays lying on 22 feet of the coarse basal sandstone and overlain by dark shales and thin sandstones of the basal Colorado beds.

At the top of the formation there are, in places, beds of gray to buff sandstone. North of East Twin Creek and south of Columbus Hill this sandstone is about 6 feet thick and it appears again at Smith Creek. Between Little Tongue River and Wolf Creek it is 10 feet thick.

In the northeast corner of the Bald Mountain quadrangle the basal member is a coarse, cross-bedded, hard, buff sandstone. It is overlain by about 100 feet of massive shales or clays of brown, reddish, and light-gray colors, with few sandy and concretionary layers and at the top by several feet of soft buff sandstone.

West slope.—West of the Bighorn Mountains the formation presents the usual succession of gray to buff sandstone below and massive shale or hard sandy clay above, with thickness varying from 50 to 125 feet. To the east and north of Cloverly the formation consists of sandstone which outcrops extensively in cliffs of buff-colored massive beds, mostly of moderately coarse-grained material. It is here 50 to 125 feet thick. To the west the middle and lower portions of this sandstone change to a maroon color and some clay is intermixed with the sand. This rock weathers into badlands.

Section of Cloverly formation $1\frac{1}{2}$ miles west of Cloverly, Wyo.

	Feet.
Light-buff sandstone (overlain by Colorado shale)	10
Tan-colored sandstone	10
Maroon clay	4
Reddish tan-colored sandy shale	10
Drab sandy clay	10
Deep-maroon sandy clay	20
Hard tan-colored sandstone	3
Deep-maroon to purple variegated clay	12
Lens of maroon sandstone	3
Deep-maroon sandy caly	20
Olive-green, soft, cross-bedded sandstone with hard layers (lying on maroon and drab-gray Morrison shale)	10
	112

North of Sheldon's ranch 52 feet of the formation is exposed, consisting of 15 feet of olive-green sandstone lying on Morrison beds, 20 feet of deep chocolate-brown soft sandstones, 2 feet of gray soft sandstones, and, at the top, 15 feet of massive brown sandstone, all weathering into badlands.

West of Shell the formation consists of brown sandstone at top, maroon sandy shale in the middle, and massive buff sandstone at the base. Usually the formation terminates abruptly at the top as far north as Alkali Creek, where its upper limit is marked by a 10-inch ledge of hard sandstone, but to the northwest there is a transition series of a few alternating beds of shale, sandstone, and dark-gray shale.

Correlation.—The Cloverly formation is believed to represent the Lakota sandstone, Fuson formation, and Dakota sandstone of the Black Hills region. Apparently the Dakota sandstone (Upper Cretaceous) is not well developed, although local masses of sandstone appear in some places above the clay member. Possibly also it is represented by transition shale beds and thin sandstones at the top of the formation. However, as there is apparently no unconformity between the Cloverly and Colorado sediments, some representative of the Dakota horizon must be present. So far the formation has not yielded any fossils which throw light on its age, for only a few fragments of leaves and pine needles have been observed. On the basis of the above correlation, it represents the last deposits of the Lower Cretaceous and the earliest deposits of the Upper Cretaceous.

COLORADO FORMATION.

General relations and outcrop.—The lower lands on either side of the Bighorn Mountains are underlain by a wide belt of Colorado and overlying shales. West of Cloverly, from Shell Creek northward, there is a broad area of these shales in a shallow syncline or basin, the western side of which rises in Sheep Mountain. In this area the Colorado shales are about 1400 feet thick and on Stockade Creek their thickness is somewhat greater. On the east side of the mountains the formation outcrops in a narrow zone extending from northwest to southeast, with a width varying from $1\frac{1}{2}$ miles at the north, where the dips are moderate, to less than one-half mile south of Beaver Creek, where the dips are steep. The formation outcrops extensively, but in some of the valleys and along most of the divides north of Tongue River it is more or less widely covered by Quaternary deposits. Some of its most complete exposures are in the vicinity of Columbus Peak and on other divides north of Tongue River. East of the mountains its thickness varies from 1700 feet in the vicinity of the Montana line to about 1050 feet near the great fault which cuts it off east of Little Goose Creek, the amount diminishing gradually but with considerable local variation. On Wolf Creek a thickness of about 1400 feet was measured. The formation lies in apparent conformity on the Cloverly.

The upper limit of the Colorado formation is somewhat indefinite, for there is a continuous succession of gray shales from the Mowry beds to the Parkman sandstones. Its top is placed arbitrarily at the base of the beds containing Pierre fossils, or about 400 feet above the horizon of concretions with the *Prionotropis* and similar ammonites which characterize the upper member of the Benton shales in other regions.

General character.—The Colorado formation consists mainly of dark-gray fissile shales, which toward the bottom contain thin layers of brown sandstone, and near the middle a series of hard shales and fine-grained gray sandstones which have been separated as the Mowry member. The lowest 100 to 200 feet of the shales include many thin beds of brown sandstone and in some areas thin local deposits of buff sandstone. The sandstone weathers brown on the slopes and gives a characteristic rusty appearance to the outcrops of this portion of the formation. In this "rusty series," from 60 to 200 feet above the base of the formation, there is a persistent horizon in the shale containing numerous globular concretions, mostly from 1 inch to $1\frac{1}{2}$ inches in diameter, which accumulate in considerable number in places on the shale slopes. They have a radiated crystalline structure and a dark-gray color, and consist of impure phosphate of lime, evidently a replacement of the iron sulphide marcasite. They occur through a vertical interval of only 3 or 4 feet in the shale, but appear in greater or less number in all exposures. Above the "rusty series" is a variable thickness of dark-gray shales, mostly very fissile, with occasional thin, lenticular masses of sandstone. Lens-shaped concretions occur in this series, some consisting of carbonate of lime and others of carbonate of iron. They vary in diameter from a few inches to several feet.

Above the shales just described lie from 50 to 150 feet of thin-bedded, hard dark-gray sandstones and hard gray shales of the Mowry member. These weather light colored and, owing to their hardness, form bare ridges of considerable prominence. Most of these beds contain large numbers of fish scales, a characteristic feature, and occasionally fish teeth and bones. By some observers this member was supposed to be Niobrara, but it lies below beds containing distinctive Benton fossils, and in regions farther south it is contained in the Graneros shale, the lowest division of the Benton group.

The Mowry member merges upward into shales which, on the west side of the mountains, contain beds of hard sandstone. A few hundred feet below the top of the formation lens-shaped lime concretions, of buff color when weathered, occur at one or two horizons in the shales. Most of these concretions are 2 to 4 feet in diameter and many of them contain remains of *Prionotropis woolgari*, a species of mollusk that is characteristic of the upper part of the Benton (Carlile beds) in an extensive area in the Rocky Mountain province. This fossil is an ammonite with spines on the outer margin of its whorls, and most specimens found in this region are a foot or more in diameter.

East side of the mountains.—The Colorado formation presents but few notable exceptional features in the slopes east of the mountains. The basal "rusty series" averages about 200 feet thick and the zone of spherical concretions which it contains lies near its top. The Mowry member is usually about 150 feet thick and outcrops at many places in high ridges, notably in the prominent Columbus Peak, southwest of Parkman. The base of this member lies 1400 feet above the base of the formation on West Twin Creek, 1000 feet on Wolf Creek, 850 feet on Little Rapid Creek, and 700 feet on Hurlburt Creek, the decreasing amount being due to gradual diminution in the thickness of the underlying shales. Above the Mowry member the rocks are all shales, 600 feet or more thick, containing near their middle large buff-colored concretions, with *Prionotropis woolgari*, specimens of which are particularly abundant in the vicinity of Twin Creek, from Columbus Creek to Amsden Creek, and in the slopes adjoining Wolf Creek. Above this horizon are gray shales supposed to represent the Niobrara formation. They extend to the Pierre shale, with its characteristic fossils.

West of the mountains.—The salient features of the Colorado formation west of Cloverly are as follows: At the base, lying on buff sandstones of the Cloverly formation, are about 100 feet of dark-gray to black shales, with thin brown sandstone layers, weathering to a rusty color. The shales usually begin abruptly on top of the Cloverly sandstone, but without sign of unconformity. Globular concretions of impure phosphate of lime, averaging an inch in diameter, occur in a few feet of the lower shales about 60 feet above their base, a feature which is characteristic at this horizon on both sides of the mountains. Above this basal "rusty series" are about 200 feet of black, fissile shales, mostly of splintery texture, capped by 25 feet of hard, sandy shale and thin-bedded dark sandstone representing the Mowry member of the east side of the mountains and weathering to the same light-gray color. These beds merge upward into 30 feet of dark shales, followed by a series of alternating shales and hard, slabby sandstones capping a high ridge and extending down the western slopes of this ridge. The sandstone layers are from 6 inches to 3 feet thick, of dark-gray and light blue-gray color. This series probably represents the upper part of the Mowry beds. At its top there is an extensive bed of light-colored soft sandstone, 10 feet thick. This is overlain by several hundred feet of dark-colored soft shales, with a few black concretions, succeeded by light-colored shales with several sandstone layers. At the top are 100 feet of sandy buffish-colored shales, with brown concretions containing *Metoicoceras gibbosus*, *M. whitei*, and *Inoceramus fragilis*, believed to mark the top of the Benton group. The total thickness is about 1200 feet. On the higher ridges in this vicinity the section is continued by about 200 feet of gray shale, supposed to represent the Niobrara formation.

On either side of the syncline south of Shell Creek, south of Sheldon's ranch, the sandstones in the Colorado formation give rise to a ridge of considerable prominence, which extends far to the southeast. A section of the eastern ridge not far south of Shell Creek shows a succession of 550 feet of dark shales at the base, 80 feet of light-gray fissile shale, 110 feet of alternating layers of hard blue sandstone and shale, 250 feet of gray shale, 30 feet of thin-bedded rusty sandstone, partly concretionary, 25 feet of white sandstone, and 30 feet of shale containing *Metoicoceras*—1075 feet in all.

These fossil-bearing shales dip westward beneath 400 feet or more of shale, mostly dark colored, but in part weathering to a light-yellow color, a feature characteristic of the Niobrara formation in other regions. No determinable fossils were found in it. This upper member passes beneath fossiliferous Pierre shale.

Correlation.—The Colorado formation in the Bighorn region comprises the Benton group and the Niobrara formation of the Rocky Mountains and of the Great Plains farther south and east. The Benton group in those regions consists of Graneros shale, Greenhorn limestone, and Carlile shale, but these subdivisions have not been found in the vicinity of the Bighorn Mountains, owing mostly to the lack of development of the middle limestone. In the Black Hills and farther south the Mowry member occurs considerably below the middle of the Graneros shale, while in the Bighorn uplift it lies only about 600 feet below the top of the Colorado formation, so that in this interval there are representatives of the upper Graneros, Greenhorn, and Carlile deposits. The occurrence of the concretions, with *Prionotropis* and other ammonites, indicates the presence of the member which is characteristic of the top of the Carlile formation in other regions, and as there is no evidence of hiatus in any portion of the Colorado formation in the Bighorn region it is reasonable to believe that the subdivisions are all present, but in attenuated form and with the Greenhorn limestone horizon not characterized either by lime sediments or the distinctive fossil *Inoceramus labiatus*.

The gray shales at the top of the formation probably represent the Niobrara, but the only evidence of the existence of this formation in the Bighorn region is the apparently continuous sedimentation from the Benton to the Pierre shales. The shales seem to contain no carbonate of lime, so that they lack the characteristics which distinguish the Niobrara in the region farther south. The thickness of the beds between the highest Benton and the lowest Pierre fossils is about 400 feet, and no organic remains have been found in this interval.

Fossils occur rarely in the Colorado formation in the Bighorn region. The ammonites and a few specimens of flat *Inoceramus* in its top are the principal remains, except the large numbers of fish scales in the Mowry member.

PIERRE SHALE.

Outcrop and character.—The Pierre shale in the Dayton quadrangle underlies a zone of lowlands that extends along the east side of the foothills of the Bighorn Mountains, with a width of 3 miles for a long distance south of Dayton, gradually narrowing to one-half mile as the dips steepen, in the vicinity of Little Goose Creek. A small area occupies the shallow syncline south of Sheldon's ranch on Shell Creek. Throughout its course and thickness the formation consists of a great mass of dark-colored shale, with a few thin layers of sandstone and numerous scattered calcareous concretions. Its thickness averages about 3500 feet. At the base there is no definite line of separation from the shales at the top of the Colorado formation, but at the top there is a rapid change to the Parkman sandstone. About 1000 feet below the top of the formation, especially in the region north of Wolf Creek, there is a thin layer of buff sandstone which is persistent for some distance, attaining, in its maximum development, a thickness of 20 to 30 feet. It is partly concretionary. In the region north of Columbus Peak there is a very characteristic zone of lens-shaped, calcareous concretions, which extends to the northwest corner of the quadrangle, passing just southwest of Slack.

Fossils.—The Pierre shale is sparingly fossiliferous throughout, the fossils usually occurring in the concretions. *Baculites compressus* and *Scaphites nodosus* are the most abundant forms, but many other characteristic Pierre species also occur.

PARKMAN SANDSTONE.

Outcrop and character.—Above the Pierre shale lies a thick deposit of sandstone carrying a marine fauna. This is here designated the Parkman sandstone, from extensive exposures near Parkman, Wyo. The outcrop of this sandstone extends diagonally across the Dayton quadrangle, passing just west of Parkman, through Dayton, and 2 miles west of Beckton to the fault east of Little Goose Creek. Its width at the north is 3 miles. Toward the south, as the dips increase, it narrows and also approaches within $1\frac{1}{2}$ miles of the base of the mountains, while near Parkman it lies nearly 5 miles from them. The material is a very massive, soft sandstone of buff color, with darker, harder, concretionary portions. It comprises some beds of slabby gray sandstone, especially near Rapid Creek. Its course usually is marked by a ridge that rises with moderate prominence above the rolling lands of Pierre shale to the west. The transition from the Pierre shale to the Parkman formation is abrupt, but the Parkman merges above into the Piney beds. The thickness is about 350 feet. The most extensive exposures are in the ridge extending from northwest of Parkman nearly to Dayton. Scattered outcrops occur from Tongue River to Little Goose Creek, with intervals in which the formation is hidden by high terrace gravels.

Fossils.—Fossil shells are of frequent occurrence in the region south of Wolf Creek, but they appear to be rare to the north. The following forms were determined by T. W. Stanton:

Cardium speciosum M. and H., *Ostrea glabra* M. and H., *Avicula linguiformis* E. and S., *A. nebrascana* E. and S., *Liopistha* (*Cymella*) *undata* M. and H., *Thracia subgracilis* Whitfield, *T. subtortuosa* M. and H., *Tellina equilateralis* M. and H., *Lunatia subcrasa* M. and H., and *Sphæriola cordata* M. and H. This fauna was formerly believed to be of Fox Hills age but it is now known to occur, in part, at least, at other horizons. On this account the Parkman sandstone can not be definitely correlated with the Fox Hills sandstone.

PINEY FORMATION.

The name Piney formation is proposed for the lowest formation of the thick series of fresh-water sandstones and shales of Upper Cretaceous age lying in the great basins adjoining the Bighorn uplift. The name is derived from Piney Creek, northwest of Buffalo, on which the beds are extensively developed. The formation outcrops along the foot of the east side of the mountains, in a zone which is 4 miles wide on the Montana line and narrows gradually to less than one-half mile on Little Goose Creek. This variation in width is due mainly to the gradual change from low dips on the north to very steep ones on the south.

In the vicinity of Parkman, where the formation is most extensively exposed, it consists of alternating layers of greenish and black coaly shales, with a layer of pale-greenish-gray sandstone at the base and several layers of massive sandstone higher up in the hills, east of the railroad. The sandstone which is regarded as the basal bed is 8 feet thick and has been quarried to some extent for building one-fourth mile south of Parkman, on the east side of the railroad. It is overlain by dark shales with coal streaks and numerous plant fragments. Owing to the low dips in this area, the outcrop of the beds is wide. On Smith Creek, where the beds is 30°, the upper beds of the Piney formation comprise 100 feet of purplish to rust-colored, massive sandstone underlain by 100 feet of greenish-blue clay and this by a second bed of sandstone, giving rise to a low ridge. The thickness of this bed could not be ascertained, and there are two heavy ledges below, which outcrop in low ridges farther west. The total thickness in this section is about 2000 feet, but farther south it is somewhat greater. In the vicinity of Rapid Creek the Piney formation is composed of alternating layers of white sandstone, ironstone concretions, light-yellowish clay, and thin beds of leaf-bearing shales with thin seams of coal; dark-brown clay also occurs in places. Toward the base of the formation the sandy layers become harder, outcropping in massive ledges, and at the base is a layer of light-greenish-gray, compact sandstone lying on the Parkman sandstone. In this vicinity the strata dip to the northeast at an angle of about 30° and the thickness of the Piney formation is over 3000 feet.

Correlation.—The few fragmentary fossil plants found in the Piney formation do not afford any definite evidence as to its age. From its general stratigraphic relations, however, it is believed to represent part of the Laramie formation.

KINGSBURY CONGLOMERATE.

Along a portion of the central-eastern slope of the Bighorn uplift the Piney formation is overlain by a thick mass of coarse conglomerate which is the product of a local uplift of later Cretaceous time. For this formation the name Kingsbury conglomerate is proposed, from Kingsbury Ridge, southwest of Buffalo, in which it is most extensively developed. The northern termination of the conglomerate is in the southeast corner of the Dayton quadrangle and the most northerly exposures are on the slopes southeast of Beaver Creek. From this point the conglomerate thickens and, on Jackson Creek and farther south, it has a thickness of several thousand feet. In Little Goose Creek Valley it is buried beneath Quaternary deposits. The conglomerate is in layers 6 to 12 feet thick, interbedded with dark-greenish to light-yellow sandy clays. Layers of coarse gravelly sandstone also occur, which usually grade into the conglomerates. These coarser rocks in places give rise to prominent ridges, but in others are so disintegrated that their horizon is marked by beds of gravel. The materials of the conglomerates are mostly light-gray to yellow limestones and darker colored chert, with very rare pebbles of granite. The limestones and chert have the character of the Madison and Amsden formations, from which they were undoubtedly derived. Many of the pebbles are in a disintegrated state and most of them show evidence of more or less shearing. The beds dip from 30° to 45°, the amount being greatest in the lower beds near Beaver Creek. The dips decrease considerably in the upper beds. The age of the Kingsbury conglomerate has not been ascertained, but it is supposed to be late Cretaceous.

DE SMET FORMATION.

General features.—The great series of coal measures occupying the northeast quarter of the Dayton quadrangle consists of sandstones and shales, several thousand feet thick, for which the name De Smet formation is proposed. A typical locality is about Lake De Smet, northwest of Buffalo, where there are extensive exposures. For the greater part of its extent in the Dayton quadrangle the De Smet formation lies on the Piney formation, but farther southeast it is underlain by a thick mass of Kingsbury conglomerate, described above, and it is probable that this conglomerate develops out of its lower portion.

The De Smet formation has a thickness of 4000 feet or more, for its beds dip eastward at angles ranging from 3° to 8° under a district 15 miles wide, in the northeast corner of the Dayton quadrangle.

Coal measures.—The most extensive exploration of the coal measures in this area has been made at the Dietz mine, near the mouth of Big Goose Creek, a short distance east of the quadrangle. The section given in fig. 1 is found in the drifts and shafts.

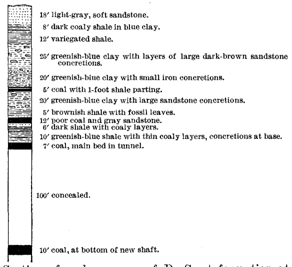


FIG. 1.—Section of coal measures of De Smet formation at Dietz coal mine.

On Owl Creek and the divide farther north the coal measures contain a coal bed 18 feet thick, which is extensively mined at a point 2 miles northeast of Beckton. The top 3 feet is a mixture of shale and coal. The coal outcrops across the divide toward Soldier Creek, but appears to thin out rapidly in that direction, being only 6 feet thick in an abandoned mine on the north slope. The coal outcrop farther south encircles the hill lying between the mouths of Owl and Big Goose creeks and the coal is opened extensively at the Big Goose coal mine, on the east side of the hill. The bed here is 14 feet thick. About $2\frac{1}{2}$ miles farther southeast, on the east side of Beaver Valley, this bed has a thickness of 21 feet, without parting. This is at Nelson Brothers' coal mine, on the east side of Beaver Creek, 2 miles above its mouth, where the same bed of coal is worked as at the Big Goose and Owl Creek mines. The strike of the beds is northwest-southeast in this region and the dip is about 4°. The coal thins in every direction from the Nelson mine. The overlying beds exposed at intervals down Goose Creek are soft sandstones and shales with coaly layers. A partial section is as follows:

Section of coal measures on Big Goose Creek, in northwest corner of T. 55, R. 84.

	Feet.
Yellow clay	10
Leaf-bearing shale	7
Coal with thin shaly partings	3
Dark leaf-bearing shale	15
Coal with thin shaly partings	3
Black coaly shale and blue clay	4
Reddish sand	4
Yellow sandy clay with ironstone concretions, to level of Big Goose Creek	30

At a coal prospect 3 miles northeast of Wolf post-office, there is a layer of coal 1 foot thick. It is overlain by dark-reddish shales containing plant remains and lies on blue clay.

At one time coal was worked on North Dry Creek 2 miles south of Tongue River, but as the opening has caved in the beds could not be measured. In the bed of the creek near by 4 feet of coal are exposed, overlain by dark-brown leaf-bearing shales. The bottom of the coal bed is below the creek and its thickness could not be ascertained. Apparently it is the bed which was worked in the mine. The coal is of good quality and is easily mined.

About 3 miles east of Ranchester, at a point south of bench mark 3698, a draw on the south side of Tongue River exposes the following beds, having a very low dip:

Section 3 miles east of Ranchester.

	Feet.
Rust-colored shale	2
Gray sandy shale	5
Coaly shale, plants	6
Red and gray shale	6
Sandstone, rust-colored	2
Coal	1
Blue shale	1
Coal	1
Gray shale	10
Talus to river	9

These beds appear again north of the river along the divide between Sixmile and Early creeks. On the summit of this ridge several thin layers of coal are exposed, ranging in thickness from 1 to 4 inches, separated by 20 to 25 feet of bluish-green clay with ironstone concretions. On the north side of Early Creek, 3 miles northeast of Ranchester, the next higher beds are exposed, as follows:

Section on north side of Early Creek.

	Feet.
Clinker bed	10
Pale greenish-yellow clay	50
Red sandstone	4
Bluish-green clay	15
Gray sandstone	6
Light-yellow sandy clay	25
Bluish clay	15
Coaly shale, leaf impressions	8
Coal	4
Dark-gray shale	1
Coal	10
Bluish-green clay and shale	40
Coaly shale with thin coal streaks	20
Talus and red, clinkerlike rock	10
Light-brown clay with ironstone	20
Shale with plant fragments	2
Coal	$\frac{1}{3}$
Coaly shale	$2\frac{1}{2}$
Coal	1
Coaly shale	2
Coal	1
Blue-green clay	6
Coal	1
Dark clay and shale.	

The upper beds of this section cross Tongue River just east of the mouth of Early Creek, where the coal is mined in small amount. The thickness of the bed varies from 5 to $6\frac{1}{2}$ feet. This coal is also mined to some extent for local use on the ridge farther northwest. A section of a part of the De Smet formation in the ridge east of Parkman is given in fig. 2.

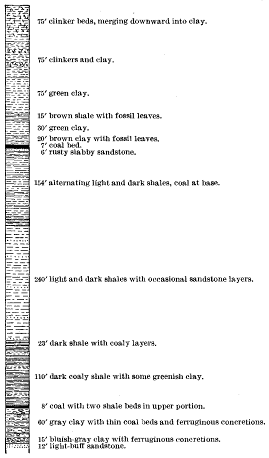


FIG. 2.—Section of a portion of the De Smet formation east of Parkman, Wyo.

The clays of the coal measures contain many ironstone concretions as well as rust-colored sandstone concretions. Both kinds weather out on the slopes and in places accumulate in thick deposits as the clay washes away.

Clinker beds.—The clinker beds present great variety of color, due mainly to different degrees of oxidation of the materials. Brick-red predominates and there are purplish and maroon tints. The partly burned clays are of canary-yellow, pale-red, and maroon tints. Much of the rock resembles a slag and shows that it has been completely fused by the heat of the burning coal. In some portions of this region, but outside of this quadrangle, coal is still burning, the combustion in most places being deep in the bank but indicated by the smoke and steam and the heat of the surface.

In the northeast corner of the Dayton quadrangle the upper clinker beds occur in a series consisting of a thick deposit of light-yellow sandy clay, overlain by layers of massive red sandstone, above which is a considerable thickness of greenish-yellow clay capped by the clinker bed, in all about 100 feet. The clinker is burned to various bright colors—red-green, light and dark yellow, red, red-brown, pink, and gray. The sandstones outcrop at many places, but at most of these they are too soft to be prominent.

Correlation.—It has been generally supposed that part at least of the De Smet formation is of Laramie age, but there is no definite evidence on which to base correlation. A few plants collected from it appear to be forms that range from Laramie to Fort Union, and until a detailed investigation is made of the formation in its wider extension no statement can be made as to its precise age.

TERTIARY SYSTEM.

The only evidence of Tertiary deposits found in the region are two narrow areas of peculiar sands capping low divides on the north side of Tongue River Valley. One, which is traversed by the main Tongue River road, begins 1¾ miles north of bench mark 7885 and extends about a mile, or nearly to Fool Creek. Its altitude is 7800 feet. The other occupies an area of a few square rods on the divide at the head of East Fork of Dry Creek, a mile north of bench mark 8670. Its altitude is 9000 feet. Both lie on limestones. The material of these deposits is a white, buff, and flesh-colored loam or sandy clay of somewhat chalky texture, resembling portions of the White River formation and including some streaks of gravel and limestone fragments. The thickness was not determined but it is 30 feet at least and possibly considerably more. No fossils were observed in it, and the only evidence of its Tertiary age is the peculiar aspect of the deposit and its occurrence in the old divides, a characteristic of Oligocene sediments in the other mountainous regions of the Northwest. Possibly there are other deposits of this kind in other divides, but they were carefully sought for along every line traveled and none were found. There is some trace of a similar deposit in the low divide just south of Shell Creek, near the southeast corner of the Bald Mountain quadrangle, but it is not well exposed and appears to be wash or drift from a former glacier. If these remnants are of Tertiary age, their precise correlation of course can not be suggested on the present meager evidence.

QUATERNARY SYSTEM.

GLACIAL GEOLOGY.*

By ROLLIN D. SALISBURY.

There is evidence that the Bighorn Mountains were occupied by glaciers during two glacial epochs, and there is some suggestion that there were glaciers at a still earlier time. The Glacial history of these mountains is complex, and the great glaciers which have left the most distinct records were the successors of earlier ones, the marks of which have been partly effaced by weathering and erosion. Several small glaciers remain in the higher portions of the Bighorn Mountains—the diminutive remnants of much more extensive bodies of ice which formerly occupied the principal valleys of the highlands. Because of the unequivocal nature of the phenomena connected with the last epoch of glaciation, and the obscure nature of the phenomena connected with earlier glaciation, it is best not to follow the chronological order but to consider first the record of the last Glacial epoch.

THE LAST GLACIAL EPOCH.

Evidences of glaciation.—The phenomena which point with certainty to recent glaciation in the Bighorn Mountains are (1) the great body of drift which occupies many of the valleys and which has both the disposition and the constitution of true glacial drift; (2) the shapes of the valleys in which the drift lies; (3) the smoothed and striated surface of the rock of the sides and bottoms of the valleys where the drift occurs; and (4) the peculiarities of drainage in these valleys, especially the numerous lakes and the narrow gorges of the streams where they break through the greater bodies of drift. Some or all of these distinctive marks characterize the recently glaciated mountain valleys.

Extent of glaciation.—By means of these criteria it has been determined that the principal valleys of the range were recently glaciated. Glaciers occurred within an area 40 miles long by 27 miles wide, but within this area less than one-third of the surface (about 300 square miles) was covered by moving ice. Within the limits of the Dayton quadrangle the extent of the ice was about 75 square miles. The associated snow fields, which have left no very definite record, probably covered additional areas of considerable extent.

It is possible that at the time of maximum glaciation snow and ice were essentially continuous from the northernmost limit of the ice in the valley of Tongue River (latitude 40° 41′) to its southernmost limit in the valley of Tensleep Creek (Cloud Peak quadrangle, latitude 40° 6′); but the continuity was probably interrupted by a few peaks and narrow divides whose slopes were too steep to permit the lodgment of snow, and by numerous precipitous slopes along the sides of valleys which were occupied, but not filled, by ice. The westernmost point reached by the ice was in the valley of Shell Creek (longitude 107° 32′), and the easternmost was in the valley of the north and south forks, respectively, of Clear Creek (Fort McKinney quadrangle, longitude 106° 58′). From the snow fields in the upper parts of the range glaciers descended all the principal valleys. The number of sources from which moving ice started was little short of 100, and of these about one-fifth were within the area of the Dayton quadrangle. In descending, various glaciers united as their valleys joined, so that at the time of maximum glaciation the number of separate systems of glaciers, as determined by the number of lower termini, was but 19. Three of these glaciers, those in the upper basins of (1) West Fork of Big Goose Creek (Dome Lake Glacier), (2) Tongue River (Tongue River Glacier), and (3) Willitt Creek (Willitt Glacier), were wholly within the Dayton quadrangle. The lower parts of three others, namely, those in the basins of Shell Creek (Shell Creek Glacier), East Fork of Big Goose Creek (Lighter Glacier), and North Fork of South Piney Creek (Kearney Lake Glacier), also extended into this quadrangle. The general facts concerning these glaciers are shown in the following table:

Glaciers wholly or in part in the Dayton quadrangle.

Name of glacier.	Maximum area.	Maximum length.	Altitude of sources.	Altitude of termini.
	Sq.mi.	*Mi.*	*Ft. above sea.*	*Ft. above sea.*
Shell Creek Glacier.....	35.2	14	10,200+	7500
Dome Lake Glacier.....	19.5	8	10,000+	8000
Lighter Glacier..... ...	18.6	9	10,500+	8000
Kearney Lake Glacier..	18.4	12	11,500+	7800
Tongue River Glacier...	9.6	6	9,800+	8400
Willitt Glacier..........	4.0	4	10,200+	8900

The largest of these glaciers had an area nearly as great as that of the largest glacier of Switzerland at the present time.

Distinctive features of glaciated valleys.—The valleys that have been recently vigorously glaciated exhibit the following distinctive features:

1. The upper ends of many of them are cirques—that is, they end bluntly above against high, steep cliffs—and they are bordered on both sides, for a greater or less distance, by cliffs of the same sort.

2. They are likely to have rounded bottoms, especially if deep; that is, they are somewhat U-shaped in cross section.

3. Their upper parts are relatively free from loose material, except talus of recent origin.

4. The bed rock in their bottoms and along their sides shows the grooves, the striæ, and the polishing and planation effected by the ice, and bosses of rock within them have rounded forms (roches moutonnées).

5. The drift, or moraine matter, is most abundant near the lower limit of ice advance, but is found in lesser quantity far above the terminus of the ice, and in some valleys all the way to their sources.

6. The morainal matter is disposed largely as terminal and lateral moraines. The former cross the valleys about where the glacier ended, and many of them rise several hundred feet above the bottoms of the valleys just outside. The latter are generally continuous with the former, and lie along the sides of the valleys for considerable distances above them. There are often subordinate lateral and terminal (recessional) moraines inside the outer and major ones.

7. Many of them contain lakes which range in position from the heads of the valleys to the terminal moraines below. This distribution of the lakes is well shown in the valley of West Fork of Big Goose Creek, both above and below Dome Lake. Some of them are the result of glacial erosion, and some of glacial deposition.

These features are not all conspicuous in every valley which the ice occupied, for where the basins of the glaciers were broad and shallow, as in this area, rather than narrow and deep, as in the higher part of the range farther south, some of the above features are poorly developed, or even absent altogether. Thus there are no well-developed cirques in this area, few valleys were effectively rounded out, and some of them were not effectively cleaned out in their upper parts; but in all there is striated rock, in all there was some concentration of drift at or near the ends and edges of the glaciers, and in all there are ponds and lakes.

Dome Lake Glacier.—The area covered by this glacier was a broad basin, whose rim has an elevation of about 10,500 feet. The glacier was wide, but the ice was relatively thin and weak as compared with that of Lighter Glacier to the east and with most of the glaciers of the higher part of the range farther south. The ice was derived from two principal and several subordinate tributaries, but none of these have well-developed cirques, and the configuration of most of them was but little changed by glaciation. Glacial erosion was most severe in the valley south of Dome Lake, where many of the lakes probably occupy rock basins. Striæ are found up to within 100 feet of the divide at the head of this valley, and the effects of nivation are found still higher. The basin of the western branch of this glacier suffered less erosion, and its upper portion was not effectively cleaned out. Though numerous outcrops of rock (roches moutonnées) occur, drift is perhaps as nearly continuous in this basin as in any other in the whole region.

Terminal moraines are distinct, but not massive, both at the main northern terminus and at the terminus of the little offshoot east of Heart Lake. In both places they possess the rough, hummocky-kettly surface characteristic of such moraines. The kettles of the main terminal moraine are rather sharply marked, depths of 30 to 50 feet and slopes of 35° to 38° being not infrequent. This moraine has an outer bench, on which are two lakes in drift depressions. A narrow valley train extends down the valley from the terminal moraine. Lateral moraines are poorly developed, but that at the northwest, for a mile or more above the terminal moraine, is distinct, as is that on the south side of the east lobe.

All the lakes in the area of the western arm of this glacier appear to be in drift basins or to be held in by drift dams. Dome Lake appears to occupy a drift basin, and its outlet has been lowered but a few feet since the beginning of its history. The lake is being gradually filled by a delta at the debouchure of its inlet. Four small flats within the area of this glacier (see areal geology sheet) represent old lake basins.

The drainage of the basin was somewhat deranged by the ice. The lower course of the tributary stream which joins the main creek at the crossing of the stage road west of bench mark 7998 appears to have been shifted northward by the deposition of the terminal moraine, though the displacement was probably not more than one-fourth mile. It is probable also that the drainage east of Heart Lake was shifted. The pre-Glacial drainage at this point was probably northwestward to West Fork of Big Goose Creek. Just west of its terminus this glacier obstructed a tributary valley, giving rise to a shallow lake which was largely filled by wash from the ice.

Willitt Glacier.—The small glacier which occupied the shallow basin at the head of Willitt Creek descended between 1 and 2 miles beyond the main catchment basin. Its ice was probably never more than 500 to 600 feet thick. The form of the basin was not greatly altered by glaciation, but the erosive action of the ice was sufficient to round off the irregularities of its bottom, developing roches moutonnées. Above the altitude of 9500 feet the rock of the basin is relatively bare, but lower down the rock is more and more masked by drift. Lateral moraines were developed on both sides of the glacier, but they are nowhere massive. Down the valley they merge into the terminal moraine with characteristic topography. The outer face of this moraine is about 125 feet high and the inner about one-third as much. A low recessional moraine within the main terminal moraine once formed a dam for a small lake.

It is probable that the course of Willitt Creek was slightly changed (in sec. 15) by the deposition of drift. Formerly it probably continued southward through sec. 15, joining the main valley farther south than now.

Tongue River Glacier.—The glacier in the valley of South Fork of Tongue River occupied a broad, open basin, 300 to 1000 feet deep. The ice was relatively thin, and its movement was therefore feeble. Cirques were not developed at the heads of the valleys and there are no lakes in rock basins. Glaciation did not seriously alter the topography and no considerable part of the basin was well cleaned out by the ice. Drift is prevalent throughout the basin, but is rarely thick enough to conceal the topography of the rock beneath. The lateral moraines are feeble, though the lateral moraine on the west serves as a barrier for a small lake. A small lake was also formed east of the north end of this glacier. Its basin was filled with sediment from the glacier, or from the basin of the stream that was obstructed. The terminal moraine has a height of only 30 to 40 feet, and from it leads a poorly defined valley train. No recessional moraines and few lakes occur within the terminal moraine.

Shell Creek Glacier.—The principal sources of this glacier were south of the Dayton quadrangle. Its basin, like that of the Tongue River Glacier, was broad and open, and no cirques were developed

*This account of the glacial geology is based on the work of assistants, especially Eliot Blackwelder, who was aided by W. H. Emmons and F. W. DeWolf.

at its sources within the Dayton quadrangle. In keeping with the character of the basin, the glacier was broad and feeble, and its limits were often ill defined. The basin is separated by low cols from the basin of Dome Lake Glacier, and the snow fields of the two basins were probably continuous, though there is no evidence of ice movement across the cols. Striæ are found, however, no more than 100 feet below the cols on either side.

In the upper part of the basin there is relatively little drift, but it increases in importance below, though, except near the principal moraines, it nowhere conceals the rock for large areas. The north lateral moraine is not strong, though it may be traced readily for several miles east of the crossing of Willitt Creek. It often fails of the well-defined ridge form characteristic of lateral moraines. The south lateral moraine has better definition east of the stage road. For some distance it caps the crest of a rock ridge which seems to have been just high enough to keep the ice from spreading southward. Where the south edge of the glacier crossed the tributary valley developed along the outcrop of the weak Cambrian shales, it moved up the valley for a short distance, leaving a well-defined terminal moraine. The ice, and later the moraine, ponded the valley, making a small lake, now extinct. Below this point the lateral moraine is not well defined, the topography through the Paleozoic terranes not being such as to favor the lodgment of drift, especially from a weak glacier. Furthermore, landslides of Cambrian shale have obscured the limit, which may once have been better defined than now. In several places along the south side of this glacier talus from the Paleozoic formations has completely covered the edge of the drift.

Conforming to the shape of its valley, the glacier became pointed below, and since it was also thin, its terminal moraine is weak. Its relief is only 10 to 15 feet, and it differs from the moraines farther east in that it contains Paleozoic material. No distinct recessional moraines appear in this basin. A considerable area within the terminal moraine is largely covered by drift (ground moraine), though the underlying rock is the dominant factor in the configuration of the surface. Roches moutonnées appear, even at the inner edge of the terminal moraine. All this is consistent with the feeble glaciation of the basin.

Lake Adelaide and the associated ponds probably occupy parts of pre-Glacial valleys obstructed by drift. All the lakes are now being filled.

The north margin of the glacier obstructed several ravines on the north, giving rise to basins which were occupied by small lakes. These became extinct, partly by filling, and partly by the erosion of their outlets. Their sites are shown on the map.

Lighter Glacier.—The glacier in East Fork of Big Goose Creek was formed by the union of glaciers heading in the valleys of the two branches of East Fork of Big Goose Creek and in Cross Creek. The first two united at the south border of the Dayton quadrangle, while that of Cross Creek remained separate 2 miles farther north. Lateral moraines are well marked, though not of great size, on both sides of both lobes of this glacier. Below the union of the two glaciers there is an interlobate or medial moraine, made by the union of the adjacent lateral moraines of the converging glaciers. Toward the north it merges into the ground moraine.

The west lateral moraine of the valley of Big Goose Creek obstructs two creeks, and the east lateral moraine of the valley of Cross Creek obstructs one, giving origin to small lakes. Below, the lateral moraines merge into the terminal, with no sharp line of demarcation. The terminal moraine is rather massive and has the hummocky topography characteristic of terminal moraines, with a surface relief of 30 to 50 feet. The crest of the terminal moraine is nearly 400 feet above the valley outside, and its outer slope is marked by a bench less than halfway up. The inner face of the terminal moraine declines about 50 feet to a broad flat which probably represents the site of a temporary lake, the basin of which was largely filled by inwash while the ice lay in the valley above. Ground moraine covers a part of the area within the terminal and lateral moraines, but outcrops of rock are of common occurrence.

A narrow valley train extends down the valley from the terminal moraine. At the moraine it has a steep gradient, which decreases rapidly down the valley. A second slight valley train descends the valley of Cross Creek east of the terminus of the glacier.

Apart from the obstruction of a few creeks by moraines there was one notable change in drainage, a result of the deposition of the drift. In pre-Glacial time Cross Creek was probably a tributary of Big Goose Creek, being diverted to Little Goose Creek by a morainic deposit.

Glacier in valley of North Fork of South Piney Creek.—During the later part of the Glacial epoch the glacier that occupied North Fork of South Piney Creek, at the extreme southeast corner of the Dayton quadrangle, pushed out about one-half mile into the Dayton quadrangle. Only the outer part of its terminal moraine appears on this map. It rises about 200 feet above the valley outside, and, as in many other cases, there is a moraine bench a mile wide on its outer slope, about 90 feet below the crest. A small amount of gravel washed out from the moraine appears along the creek.

Névé deposits.—Under the term nivation Matthes (Twenty-first Ann. Rept. U. S. Geol. Survey, pt. 2) has described certain phenomena of these mountains that deserve mention in this connection. In many valleys and against many cliffs where glaciers, or at any rate well-defined glaciers, did not exist, snow accumulated in quantity. In some places the snow merely made great snowdrifts, many of which, no doubt, persisted from year to year. Fine material washed down from above was deposited beneath and about the snow, while the snow itself tended to prevent the removal of the loose material beneath it by water. Where cliffs projected above snowdrifts, débris rolled down over the snow and lodged below. The result was the accumulation beneath and about the snow of considerable quantities of loose material. Although the snow and ice in such positions had in some cases no motion, it may have had motion in others. It is conceived that this motion was at some places merely a slow creep, but at others it may have been incipient glacier motion, too feeble to leave demonstrative record of itself. In still other places there were doubtless snowslides. Furthermore, the accumulated débris itself was subject to sliding, and the fine mud even to flowing, during the summer seasons when the edges of the accumulations were free from snow and ice and unfrozen. The result of all these processes was the accumulation of débris, not distinctly glacial, but with decided peculiarities of topography, often slightly ridged, in some places marked by low mounds, occasionally simulating mud streams. Similar phenomena elsewhere have been called "talus glaciers." Nivation affected both valleys and basins, as well as benches on slopes, where there was no distinct glacial movement, and also the heads of some valleys that were distinctly glaciated below. Illustrations are found in several places in this area, and doubtless occur in some places not shown on the map.

Post-Glacial erosion.—Post-Glacial erosion has been slight throughout this area. Only where the streams cross moraines are their post-Glacial channels deeply cut. East and West forks of Goose Creek and South Piney Creek have cut narrow gorges 70 to 100 feet deep where they cross the terminal moraines. The other streams have done still less, and, except at the moraine crossings, their erosive work has been inconsiderable.

OLDER DRIFT.

In several of the valleys in the north end of the Bighorn Mountains, beyond the outside of the terminal moraines of the last stage of the Glacial epoch, there is a considerable body of older drift. Some of it is of glacial origin, but in the absence of exposures it is not always possible to separate that which is glacial from that which is fluviatile.

In the valley of North Fork of South Piney Creek there is a considerable body of such drift. It was apparently deposited by a glacier made up of the union of glaciers from North and South forks of South Piney Creek. The drift is found along both sides of the creek to and beyond the edge of the Dayton quadrangle. On the east it is scattered and ill defined. On the west it is more abundant and its character is better defined. That west of Penrose Park is certainly glacial. Two shallow ponds in Penrose Park may be relics of early Glacial topography, but they are the only features of this sort observed.

There are some peculiarities of drainage in this region which perhaps afford an argument for early glaciation. North Fork of Piney Creek has only one tributary from the southeast for more than 9 miles, and many from the west. It may be that the former tributaries of the North Piney from the east were filled by the older drift, and it is quite possible that the main stream itself was shifted westward at the same time.

The results of weathering and erosion in the period following early Glacial time are seen not only in the destruction of the drift topography, but in the decayed exteriors of bowlders, and in their burial, probably in considerable part by material weathered from them and by material derived from surface bowlders which have disappeared. Bowlders are everywhere much less prominent on the surface of the old drift than on the new. In general, it may be said that rock outcrops within the area mapped as old drift are rare upstream, but increase in number and prominence down the valley.

The relations of the old drift to the bed rock and to the later drift near the southern border of the Dayton quadrangle are suggested in fig. 3. If the drift here referred to be all early Glacial, and

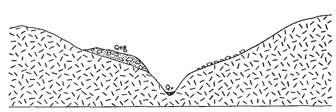


FIG. 3.—Cross section of South Piney Creek Valley.
Showing relation of valley train (Qv) of later Glacial age to the older Glacial drift (Qeg).

not partly fluviatile and of uncertain age, South Piney Creek, according to observations by Mr. Blackwelder, has cut its valley 400 to 600 feet in solid rock since the early part of the Glacial epoch.

There is also a considerable body of older drift outside the moraine of the last Glacial epoch in the valley of East Fork of Big Goose Creek. It extends about 3 miles beyond the new drift, covering a wedge-shaped area down the valley. Similar drift lies outside the new drift on the west, 3 miles above the terminal moraine. The old drift nowhere has the undulatory topography of the new, but it contains glaciated bowlders and locally constitutes ridges which are perhaps remnants of lateral moraines, as one-fourth mile east of Morrow ranch. It is not certain that all the area mapped as old drift is covered by material deposited directly by the ice, for sections showing the real nature of the material were found at only one point.

Old drift is found again in the valley of West Fork of Big Goose Creek, outside the newer drift. The limits of the extramorainic drift are obscure, being nowhere distinctly marked topographically, and the area mapped is to be regarded as the area within which it occurs, rather than as a district entirely covered by it. Its original extent was probably greater than the map shows. Glaciated stones are found in this drift three-fourths of a mile beyond the new moraine. The most considerable development of the drift appears to be along the main creek, between elevations of 7500 and 7800 feet. The drift here appears to be locally as much as 100 feet thick and has been deeply dissected by valleys which, in their breadth, are in striking contrast with the valleys in the late Glacial drift.

There may be a little old drift on the east side of the area occupied by the late Tongue River Glacier, but in the absence of exposures it could not be certainly identified and is not mapped. There is probably a considerable area of it between Shell Creek Glacier and Willitt Glacier, and north of the latter. Its limits are, however, not well defined, and it was nowhere definitely determined to be glacial. It is so classed on the basis of surface similarity to other bodies of the older drift. An isolated deposit of drift, supposed to be old, occurs near the head of a small branch of White Creek, 2 miles southwest of the termination of the Shell Creek moraines, in the Bald Mountain quadrangle. The material consists of gravel and bowlders, mainly of granite.

HIGH TERRACE GRAVELS.

Extending from the foot of the front ridges of the Bighorn Mountains there are remnants of relatively smooth slopes that represent a former plain of gradation. This plain has been cut through by the streams that flow out of the mountains and is deeply dissected by local draws and creeks. Some portions of it merge into the higher terraces of the streams, but the most characteristic remnants occupy the high divides, where they present tabular surfaces, some of which, on the east side of the mountains, are of considerable extent. These surfaces are covered by gravels and sands, locally 20 to 30 feet thick, consisting of materials derived from the adjacent mountain slopes, in places reddened by the admixture of clay from the Chugwater red beds. The most extensive deposits are found along the north side of Soldier and Hurlburt creeks, extending up to the edge of the precipitous mountain slopes and presenting smooth surfaces sloping eastward. Every divide from the Montana line to Little Goose Creek exhibits more or less of this old plain, or plains, and apparently it was originally continuous over the entire region south of Tongue River and much of the country northwest of Ranchester. Apparently it did not cover the district north of Sixmile Creek, north of Ranchester, and north and northeast of Parkman. Part of the divide between Tongue River and Fool Creek is capped by several terrace remnants. One of these, north of bench mark 8142, is nearly a square mile in area and lies about 300 feet above Tongue River. It consists of coarse gravel and bowlders, in places cemented into conglomerate. The terrace is smooth on top and slopes gently to the northeast toward other smaller remnants of similar deposits, the largest of which is north of Fool Creek and extends to bench mark 7469. These deposits undoubtedly mark a former course of Tongue River, which flowed along the wide valley through which the lower part of Fool Creek has since cut a shallow canyon. Apparently this depression was at one time filled with Tertiary deposits which have since been removed, except the small remnant described in a previous paragraph.

On the west side of the mountains there are various high terrace remnants which mark the course of higher stages of the present drainage ways. Along the lower portion of Shell Creek Valley there is a broad higher terrace rising about 100 feet above the present alluvial bottom, but restricted to the south side of the valley. In places it has been cut through by branches of the creek, but broad areas still remain, especially below the mouth of Beaver Creek. Similar terraces of the same epoch extend along Beaver Creek Valley south of Cloverly, mainly on its west side, along the lower course of Horse Creek, along the west side of Bear Creek west of Cloverly, and for some distance along the south side of Alkali Creek Valley. From outlying masses on the divide west of Bear Creek it is evident that part of the former drainage of Bear Creek once flowed directly southwestward where now it makes the sharp turn to the south. In this turn also there is a broad area of deposits, from 50 to 100 feet above the creek, indicating a former southerly course at a higher level. All these deposits consist of loam, sand, and gravel of local derivation. There are also on the west side of the mountains some remnants of deposits that are still earlier than those just described. These consist of small areas of red conglomerate on either side of the mouth of Shell Creek Canyon, 300 feet above the creek, and gravel and bowlder caps on the high ridges 2 miles southwest, 1 mile east, 3 miles northeast, and 3 miles north-northeast of Cloverly. A mass of loam and sand, with many granite bowlders, probably of this same period, caps the divide just south of South Beaver Creek, just west of the steep granite slopes. On the divide south of Devil Canyon the "Red Beds" are capped by an area of gravels and sands about one-half square mile in area, presumably of early Quaternary age.

ALLUVIUM.

East of the mountains.—In the larger valleys east of the mountains there are bottom lands of moderate width floored with alluvial deposits. These are wide along Tongue River from Dayton eastward and on Wolf Creek in the vicinity of Wolf. Narrow areas extend along the valleys of

Soldier, Big Goose, Little Goose, Smith, Pass, and Beaver creeks. More or less wash and alluvium lie in the valleys of the smaller streams, but the areas of many of these are too small and irregular to be represented on the map. The alluvial deposits along Tongue River have a width of about 1 mile near Dayton and for some distance eastward. They consist of sandy loam derived from the mountains farther west and are made up of small particles of various rocks. Their thickness varies from 10 to 30 feet in greater part. In places the material is predominantly sandy and streaks of bowlders appear locally. The alluvium in Wolf Creek and the other larger valleys is similar in character.

In the mountains.—Most of the streams in the higher portion of the Bighorn Range flow in canyons or narrow valleys where there is but little deposition of alluvium. Erosion greatly predominates over deposition and although small amounts of alluvium accumulate in the broader portions of some of the streams they are narrow and usually transient. The only area of this material in the highlands sufficiently large to be shown on the geologic map is in the valley of Tongue River, in R. 89 W. In this portion of its course the stream flows through a wide bottom occupied by alluvium, which is of moderate thickness and in places is one-half mile wide. This deposit is due to the sluggish erosion at the contact of the granite and the Deadwood sandstone, the hard underlying rock not yet having been trenched for the first few miles.

West of the mountains.—In the lower lands west of the mountains, which are underlain by shales and soft sandstones, the streams have cut wide valleys and have laid down extensive beds of alluvium. The principal deposit, which lies along Shell Creek, is about 1 mile in average width and from 10 to 40 feet thick. Beaver Creek is bordered by narrow alluvial flats, which widen to about a quarter of a mile below the mouth of Red Gulch. In its course through the "Red Beds" Trapper Creek has cut a narrow alluvial valley, which merges into that of Shell Creek a short distance above Shell post-office. The alluvial materials are of local origin and vary in character according to the variations in the composition of the formations traversed by the streams. Along Beaver Creek and in the valley 3 miles southwest of Shell the deposits contain much red detritus derived from the Chugwater formation. Most of the deposits on Shell Creek are of dark-gray color, since they consist largely of materials brought from the granite, the Deadwood formation, and the overlying limestones in the mountains at the east.

STRUCTURAL GEOLOGY.

STRUCTURE OF THE BIGHORN UPLIFT.

The Bighorn Mountains are due to a great anticline, showing an uplift of many thousand feet, which rises in south-central Montana and extends southeastward and southward about 125 miles into central Wyoming. It lifts a thick series of Paleozoic and Mesozoic formations high above the plains and, owing to the deep erosion of its crest, presents a central nucleus of pre-Cambrian granites from which sedimentary rocks dip at different angles on either side. The most elevated portion of the uplift is in latitude 44° 30′, where one of the granite summits, Cloud Peak, has an altitude of 13,165 feet above sea level, or about 9000 feet above the adjoining plains. In fig. 4 are shown the configuration of the principal structural features of the uplift. The greatest vertical displacement of the strata, as indicated by the height at which the granite floor is now found, with moderate allowance for erosion, amounts to about 25,000 feet. For the greater part of its course the anticline is relatively simple in form, but it shows numerous local variations in the steepness of its sides, and presents irregularities in the shape of its top as well as abrupt breaks due to extensive faults. In general, its eastern side is much steeper than its western, especially in the central portion of the uplift. At the north, both sides are relatively steep and the top is remarkably flat. In the highest part of the uplift, which is probably near Cloud Peak, the sedimentary rocks have been removed over a considerable area and we can only conjecture the form which the flexure would have if the eroded portions of the granite and the overlying sedimentary beds were restored. In this region there is apparently a long, uniform rise from the west, a similarly gentle downward grade to the east for some distance, and then the steep dips which are now found in the foothills on that side. In its southern extension the uplift is relatively even crested but exhibits a local doming of moderate prominence near its southern termination. The main uplift bears a number of subordinate flexures, the most notable being the one in Dry Fork Ridge east of Bald Mountain. It is an anticline rising about 2500 feet on the northeast-dipping limb of the main anticline. Small anticlines and synclines extend southeastward out of the range near Mayoworth, Greub, and Houck, and northward at No Wood, Bigtrails, and Hyattville. There are a number of faults in the uplift, some of them extending along the strike and others crossing it at various angles. The most notable fault is northwest of Buffalo, where the strata are displaced 9000 feet. This dislocation was effected mainly in Laramie time and its eastward extension is covered by Laramie or later deposits. Other profound faults of this variety extend along the east side of the range west of Buffalo. A prominent fault crosses the uplift east of Tensleep, varying in throw from 500 to 1000 feet, with the drop on the south side. South of this fault is a great hook-shaped displacement, with one branch of the fault line extending southward along the west side of the crest of the mountain to the southern termination of the uplift, and the other branch extending eastward and southeastward out of the mountain. Along the north-south branch there is an uplift of 500 to 2000 feet on the east side, while on the other branch there is a downthrow of about the same amount on the west side, so that the faulted block has revolved slightly. The axis of this movement passes half way between Mayoworth and Tensleep. Near the southern end of the uplift the north-south fault divides into several irregular faults.

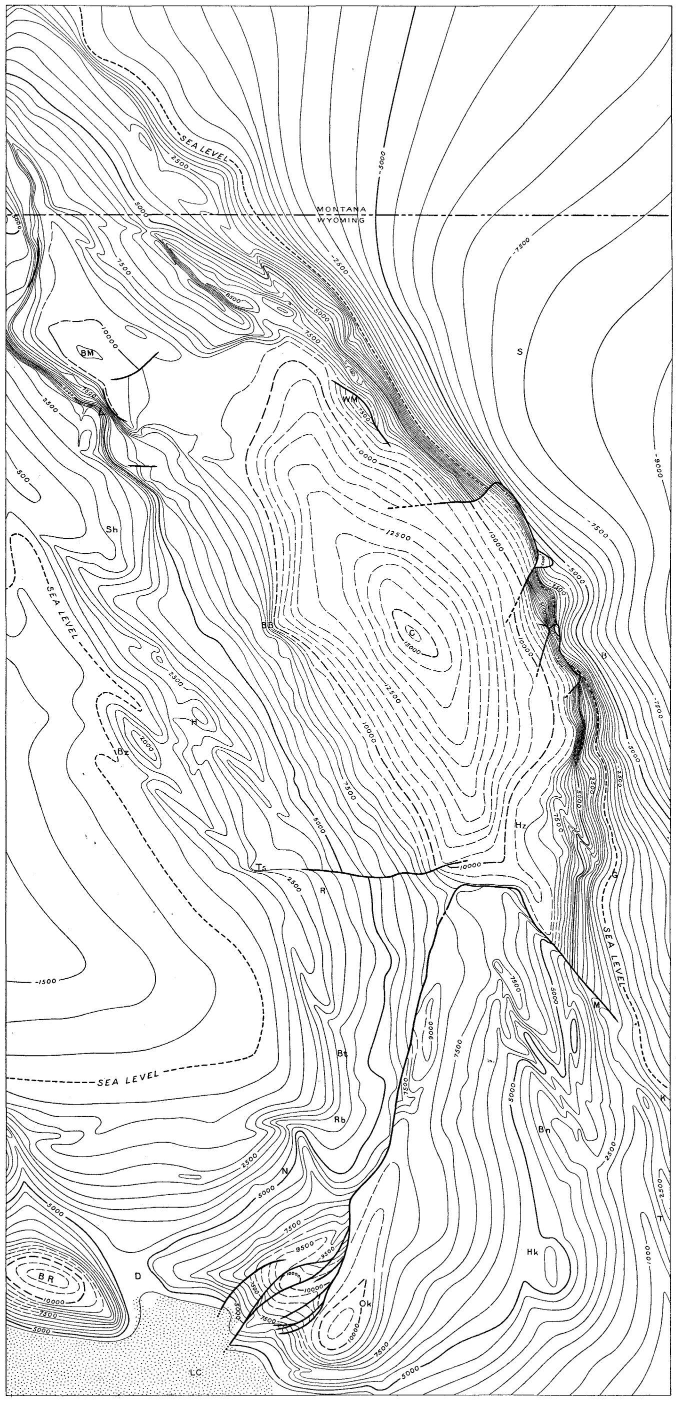


FIG. 4.—Diagram showing configuration of the Bighorn uplift by contours drawn at the base of the Madison limestone. Dashed lines indicate areas from which all sedimentary rocks have been removed by erosion; heavy lines are faults; dotted pattern represents area covered by Tertiary deposits.

Scale: 1 inch=10 miles. Contour interval is 500 feet. Datum is sea level.

B, Buffalo; BB, Black Butte: BM, Bald Mountain; Bn, Barnum; BR, Bridger Range; Bt, Bigtrails; Bz, Bonanza; C, Cloud Peak; D, Deranch; G, Greub; H, Hyattville; Hk, Houck; Hz, Hazelton; K, Kaycee; LC, Lost Cabin; M, Mayoworth; N, No Wood; Ok, Okie's store; R, Rome; Rb, Redbank; S, Sheridan; Sh, Shell; Ts, Tisdel's ranch; WM, Walker Mountain.

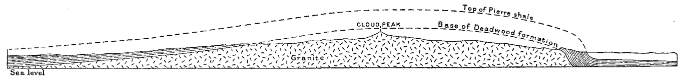


FIG. 5.—East-west section across the highest part of the Bighorn Mountains, showing the extent of erosion of the uplift.

Vertical and horizontal scales: 1 inch = 10 miles.

In the Bald Mountain region there are several local faults with displacements which are mainly along the strike and follow the steep upturn along the western margin of the uplift. Another local strike fault extends along the east side of Walker Mountain.

STRUCTURE OF THE DAYTON QUADRANGLE.

General features.—The structure of the Dayton quadrangle presents four general features: (1) The broad area of low, northeasterly dips in the northeast quarter of the quadrangle; (2) the rise of the beds with rapidly increasing dip on the flanks of the Bighorn uplift; (3) the broad anticlinal summit of the Bighorn uplift, pitching to the northwest and denuded of sedimentary rocks in the granite region to the south; and (4) the margin of the westward-dipping strata on the west side of the uplift. It is probable that the sedimentary rocks originally arched over the central area and had moderate dips in this district. The principal structural features of the quadrangle are shown in the cross sections on the structure-section sheet.

Plains area.—In the wide region east of the mountains, underlain by the De Smet formation, the strata have a low general dip to the northeast with a few local variations. In the district around Ranchester and farther east the dips are from 3° to 4°. In the outcrop zone of the Piney formation the dips vary from 10° in the vicinity of Parkman to 50° or more on Little Goose Creek, there being a gradual increase of steepness from north to south.

In the zone of exposures of the Parkman sandstone west of Parkman the dip averages 10°; near Dayton it is increased to 20°, an inclination which continues as far south as Beaver Creek, with slight local variations. Thence southward it increases rapidly in amount and is more than 45° from Jackson Creek to the fault which cuts off the sedimentary beds southeast of Goose Creek. In general the dips increase materially between the outcrops of Parkman sandstone and the foot of the mountains, especially toward the south. The Chugwater formation presents dips averaging 13° on Twin Creek, 18° on Columbus Creek, 20° on Amsden Creek, 40° on Tongue River, 36° on Wolf Creek, 40° on Soldier Creek, and 38° on Big Goose Creek, and the strata are nearly vertical from Jackson Creek to beyond Little Goose Creek.

Front ridge.—The figures just given represent also the average dips of the steep rise of the strata in the front ridge on the east side of the Bighorn uplift in this district, except that the dip diminishes considerably toward the west, along the west side of the front ridge. In general this ridge presents a fine example of moderately steep monoclinal structure, with but slight variation from a north-west-southeast strike. On Columbus Creek a gentle anticline, with corresponding syncline, develops high on the slope of the monocline. These trend north-northwestward and pitch steeply toward East Pass Creek. The anticline gives rise to a high ridge of Madison and overlying beds on the east side of that creek, and the creek valley follows the syncline for some distance on Chugwater, Tensleep, Amsden, and Madison beds. In the axis of the anticline a small area of Bighorn limestone is revealed at the bottom of the canyon of Columbus Creek. Near the mouth of Tongue River Canyon there is a prominent bulge of the front-range strata toward the east. Other irregularities in the general monocline are a small syncline and anticline in the Chugwater and Sundance formations on Smith Creek and a small flexure of similar shape in the limestones and sandstones on the mountain slope along and near the main road east of Little Goose Creek. From Little Tongue River southeastward to and south of Soldier Creek there is a sharp anticline and syncline on the monocline, which are well exhibited in Elephant Foot and on Wolf Creek. (See fig. 9 of illustration sheet 2.) This anticline is faulted at one or two points, notably on Soldier Creek and in the slopes on the southeast side of Wolf Creek, as shown in fig. 8 of illustration sheet 2. The dislocation is about 300 feet with upthrow on the east side. Another fault, of but small amount, is seen in the Deadwood formation south of Rapid Creek. Farther southeast, near Little Goose Creek, the entire monocline is cut off by a profound fault trending northeastward and bringing up the crystalline rocks far above their normal position. It has nearly 10,000 feet vertical displacement near the eastern margin of the quadrangle.

Walker Mountain.— In Walker Mountain, between Wolf Creek and Big Goose Creek, the Deadwood formation and Bighorn and Madison limestones occur in an outlying area due to a fault. The faulted block is tilted at a moderate angle to the northeast, in which direction the fault increases in throw. The general structure is synclinal, with the eastern limb cut off by the fault, except at the south, in the slopes on the north side of Big Goose Valley, where the Deadwood beds exhibit a syncline and anticline, the latter connected with the monocline of the main front ridge.

Flexures north of Tongue River.— North of Tongue River the sedimentary beds arch over the granites in two low anticlines pitching to the northwest. One of these develops into the Pass Creek anticline north of Freeze Out Point and extends to the Red Beds on East Pass Creek. It exhibits a low arch of Tensleep sandstone on that creek. The other anticline passes up the south side of Sheep Creek Valley and merges into the great anticline of Dry Fork Ridge west of the quadrangle. The intervening syncline is exhibited by westerly dips in Bighorn limestone on the west slope of Freeze Out Point and easterly dips in Deadwood and Bighorn beds along Sheep Creek. The syncline next west holds a thick mass of Madison limestone in the prominent ridge southwest of Sheep Creek. It deepens or pitches to the northwest.

Western margin.—Along the western margin of the Dayton quadrangle south of Tongue River the Deadwood sandstone dips gently westward on the western margin of the flat portion of the crest of the main uplift, but in the southwest corner of the quadrangle there are steeper dips in a projection of the western front ridge, in which the Deadwood beds pass under the Bighorn and Madison limestones.

STRUCTURE OF THE BALD MOUNTAIN QUADRANGLE.

General relations.—The Bald Mountain quadrangle extends across the Bighorn uplift some distance north of its highest portion. The salient features in the region are the steep rise of the beds on the west side of the uplift and the great breadth and flatness of its summit. The most elevated portion of the uplift lies near the crest of the present mountain range, but for a breadth of 10 miles the top of the arch is nearly flat and has but little pitch to the north and to the southeast. Toward Bald Mountain the beds rise in a low dome, while in the region on either side of Tongue River, especially toward the south for many square miles, they lie nearly level.

Dry Fork anticline.—On the eastern limb of the general uplift there is, in Dry Fork Ridge, a prominent anticline, which for some distance raises the beds about 2500 feet above the general slope. It strikes northwest-southeast and its higher portion has a length of 15 miles from West Fork of Little Bighorn River to Tongue River. Its top is nearly level for the greater part of the distance and it pitches down gradually at each end. On the west side, for the greater part of its course, the dips are nearly vertical, and on the east side they are about 12°. This anticline is finely exposed on Little Bighorn River, which crosses it in a canyon having walls nearly 2500 feet high. In this canyon the granite is exposed for nearly a mile, and in the axis of the flexure the stream has cut into it for nearly 1000 feet. Above the great cliffs of granite there are long slopes of Deadwood shales that extend upward to limestone walls in which the entire thickness of Bighorn and Madison limestones is exhibited. The principal features of this great exposure are shown in fig. 11 of illustration sheet 2. North of Little Bighorn River the flexure pitches rapidly downward, but it is traceable with diminished height across West Fork and thence northwestward across Lodgegrass Creek. In the canyons of these two creeks the flexure is exhibited in upper Deadwood beds and in the Bighorn and Madison limestones. South of Little Bighorn Canyon the anticline gives rise to the high Dry Fork Ridge, which is capped by Madison limestone dipping gently northeastward under a regular succession of beds, those of the Amsden formation extending far up the low divides. The underlying Bighorn limestone also appears along the crest of the ridge in high cliffs facing southwestward and surmounting slopes of Deadwood limestones and shales on the crest of the anticline. These limestones and shales are extensively bared by West Pass Creek and they pitch southeastward beneath the Bighorn limestones near the eastern margin of the Bald Mountain quadrangle.

Slopes west of Dry Fork.—West of the anticline there is a syncline holding Amsden, Tensleep, and Chugwater beds in a shelf extending along the east side of Dry Fork Valley. The western limb of this syncline is a long, gentle monocline, continuous to the crest of the main uplift. On this monocline there are long slopes of Madison limestone, overlain by Amsden beds on the divides; below are Bighorn limestone and Deadwood beds. Lodgegrass Creek, Little Bighorn and Tongue rivers, and branches of Dry Fork cut deeply into this monocline, all but the former revealing the granite in portions of their courses. Little Bighorn River has a notable canyon, cut deeply into the Deadwood beds, which are exposed to a point below the mouth of Dry Fork. Tongue River has cut a wide valley, in part with granite floor, which exhibits extensive slopes of Deadwood beds.

Crest of the uplift.—On the top of the main Bighorn uplift in this quadrangle the beds lie nearly level, except toward Bald Mountain, where there is a low dome. The pitch is such that, on the headwaters of Little Bighorn River, the beds are about 500 feet higher than in the divide south of Tongue River. Accordingly, as the elevation of the higher lands is relatively uniform, the divide south of Tongue River is capped extensively by Madison limestone, which extends nearly to Little Bald Mountain, while in the region about Bald Mountain the Deadwood shales and sandstones and granite occupy most of the surface. The higher summits from Duncom Mountain northward and north of Little Bald Mountain are capped by irregular areas of Bighorn limestone. The dome which culminates in Bald Mountain rises about 600 to 700 feet above the level of the wide, flat top of the Bighorn uplift. It is elongated to the northwest and south, having a curved strike. Toward the south it narrows gradually in Hunt Mountain, and as it pitches down on the headwaters of the east branches of Red Gulch it is a steep-sided anticline. This anticline is well exhibited in the Bighorn and Madison limestones at a point where they arch over it at the eastern termination of the outcrop of Deadwood formation. The flexure is traceable eastward for several miles on the plateau of Madison limestone and, where it crosses Cedar Creek, at the forks of that stream, a small area of granite is revealed in its axis. East of this point it extends up Cedar Creek Canyon, becoming very low in the divide at the head of that stream.

West slope.—In the region bordering Shell Creek Canyon the beds on the slope of the uplift dip gently westward for a long distance, with a noticeable increase of steepness near the mouth of White Creek Canyon. This steepening of dips along the west slope increases toward the north, the dip being 20° at the mouth of Shell Creek, and 50° or more on Horse Creek and farther north. These steep dips are in a narrow zone along the mountain front and affect mainly the Amsden, the Madison, and the underlying formations. This zone of steep dips interrupting the prevailing gentle slope of the strata is a characteristic feature along the northwest slope of the Bighorn uplift. On South Beaver Creek two of these zones coalesce, and here there is still further uplift in a local overthrust and fracture. Northwest of this locality the western side of the uplift has moderately gentle dips near the crest, very steep dips in a zone about a mile wide in which strata from Colorado to Deadwood are nearly vertical, and then a wide area of very gentle westerly dips extending out under the Bighorn Basin, giving rise to broad outcrops of the Colorado and associated formations.

North of North Fork of Five Springs Creek the average strike is nearly north and the general westerly slope of the main Bighorn uplift gives place to two zones of nearly horizontal dip, separated by two zones of steep dips, causing huge steps in the mountain slopes. The westernmost of these zones of steep dip lies west of the margin of the quadrangle. Between the two is a plateau of moderate elevation capped by almost horizontal Chugwater, Tensleep, and Amsden beds deeply trenched by Devil Canyon and Deer and Trout creeks. The first cuts through into the Bighorn limestone. Along the east side of this plateau there is a steep rise of the strata, partly aided by a fault extending from Devil Canyon to Cookstove Basin. In this rise the granites appear, extensively capped to the east by Deadwood sandstone, shales, and limestone, and in places by Bighorn limestone, on the gently rounded crest of the central axis of the main uplift.

Flexures east of Sheep Mountain.—In the vicinity of Sheep Mountain the crest of the flexure is flat but of much less width than in the regions farther south, and this narrowed anticline continues far to the north with but slight diminution in altitude. There is a sharp local flexure on the east side of the central anticline, exhibited in the Bighorn limestone cliff on the east side of Lodgegrass Creek southeast of Sheep Mountain. It is traceable to the head of West Fork, beyond which it dies out. Another similar anticline develops in the valley of Little Bighorn River 3 miles northeast of the Bald Mountain cabins and extends southeastward across the next divide. It lifts the granite floor so high that it is revealed by erosion in the Little Bighorn Valley and again in the next depression to the south.

Flexure east of Cloverly.—In the canyon of North Beaver Creek there is a small local twist in beds, shown in the Madison limestone and Amsden beds, as illustrated in fig. 12 of illustration sheet 2. It consists of a shallow syncline, which pitches out rapidly in the limestone slopes, with an anticline which extends down Beaver Valley to Cloverly and then, trending eastward, finally broadens out and is lost in Red Gulch. It exhibits the Sundance formation along nearly all its course. Northeast of Cloverly it develops into a fault for a short distance.

Basin area.—The area of low dips belonging to the Bighorn Basin province extends from Alkali Creek southward, giving place to a series of low flexures near Shell Creek west and southwest of Shell post-office. There is a syncline rising toward the south, the axis of which crosses Shell Creek 3 miles below Shell, holding the entire thickness of Colorado shales. Next west is a low anticline, which also rises toward the south. Its axis crosses Shell Creek just east of Sheldon's ranch, where it is finely exhibited in Cloverly and Morrison beds. Southeast of this ranch the Sundance formation is brought up for a short distance by this flexure. Farther west, in the southwest corner of the Bald Mountain quadrangle, there is a shallow syncline, exhibited in the Colorado formation and Pierre shales, the former rising in high ridges on either side. The dips on the ridge on the east side are about 30°.

Faults.—The strata are broken by but few faults in the Bald Mountain quadrangle. The principal displacement is one extending northward along the western slope of the mountain from south of Devil Canyon to beyond Deep Creek. The strata are dropped on the west side and apparently the fault hade is vertical. The fault develops rapidly in the steep-dipping strata and, along the greater part of its course, the middle beds of the Madison limestone abut against the granite. On the north side of Devil Canyon, on the line of section A–A of the structure-section sheet, the throw is over 1200 feet, an amount which continues to Deer Creek, beyond which the fault rapidly diminishes and gives place to a flexure. Along the fault the limestone is shattered and upturned.

On South Beaver Creek, along the west side of the mountain, there is an overthrust fault having a throw of about 1500 feet, in which the granite has been pushed up over the middle beds of the Madison limestone. (See fig. 6.) The hade is to the northeast at an angle of about 50°, and the granite-limestone contact is clearly exposed for several yards on the south side of the creek. This fault has a length of about 2 miles, dying out rapidly in either direction. The narrow anticline in the valley of North Beaver Creek develops into a fault that extends for some distance northeast of Cloverly and brings the middle Sundance beds up against the lower portion of the Morrison. On the divide south of the mouth of the canyon of South Beaver Creek there is a short ridge of Madison limestone lying a quarter of a mile west of the fault above described. It rises out of a terrace of bowlders which so covers the ridge that structural relations could not be determined. It is in line of strike of Chugwater outcrops not far away on either side but undoubtedly is brought up by a local fault, possibly a branch of the one to the east. A fault of small amount crossing Horse Creek Canyon a short distance above its mouth is exhibited in Bighorn, Madison, and Amsden beds. It was traced for about 2 miles along a nearly east-west course and found to have downthrow on the south side.

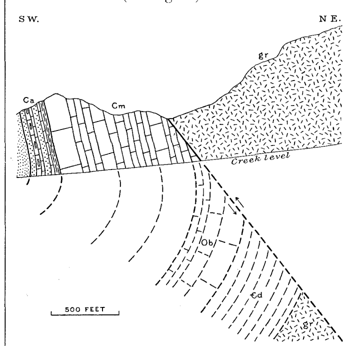


FIG. 6.—Fault on South Beaver Creek. Looking northwest.
gr, granite; Ꞓd, Deadwood formation; Ob, Bighorn limestone; Cm, Madison limestone; Ca, Amsden formation.

A fault crosses the crest of the Bighorn axis east and south of Little Bald Mountain, with a length of about 4 miles and general northeasterly course. It is exhibited in Deadwood, Bighorn, and Madison beds, which are downthrown on the south side. It amounts to about 400 feet where greatest, which is on the divide north of the head of Tongue River, where the Madison limestone abuts against the Bighorn and Deadwood beds.

Landslides.—On most of the steeper slopes of the Deadwood formation there are extensive landslides, many of them consisting of large masses of Bighorn limestone. They are due to the softness of the shales, which, when wet, become so plastic that they can not sustain a heavy load. These landslides are prominent features along both sides of the canyon of Little Bighorn River, where some of the masses are 1000 feet long. Along Shell, Cedar, and Granite creeks they are numerous and large. Smaller ones occur on West Pass, Lodgegrass, and other creeks.

Sandstone dike.—A small dike of sandstone cuts the Colorado shale on the divide between Bear and Alkali creeks about 6½ miles west-northwest of Cloverly. Its width is 6 feet and its course is east-northeast, but it could be traced only a short distance. It consists of brownish sandstone, apparently derived from the underlying Cloverly formation. Such dikes are not unusual in the Colorado shale in other regions. They were formed of wet sand derived from underlying sandstone, which was forced up into cracks in the shales under the pressure of a heavy load of overlying strata, since removed by erosion.

GEOLOGIC HISTORY.

The general sedimentary record.—The rocks appearing at the surface within the limits of the Bald Mountain and Dayton quadrangles comprise granites of pre-Cambrian age overlain by a thick series of sedimentary strata. The latter consist mainly of sandstones, limestones, shale, sandy loam, and gravels, all presenting more or less variety in composition and appearance. The principal materials of which they are composed were originally gravel, sand, or mud derived from the waste of older rocks, or chemical precipitates from salty waters.

These rocks afford a record of physical geography from middle Cambrian time to the present. The composition, appearance, and relations of the strata show 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 flats were deposited as sands and muds in shallow water; pure limestones generally indicate open seas and scarcity of land-derived sediment. The fossils that the strata contain may belong to species known to inhabit waters which are fresh or brackish or salt, muddy or clear. The character of the adjacent land may be shown by the nature of the sediments derived from its waste. The quartz sand and pebbles of coarse sandstones and conglomerates, such as are found in the Deadwood, Tensleep, Cloverly, Parkman, Piney, and De Smet formations, had their original source in crystalline rocks, but in part, at least, 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 Bighorn 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 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. By elaborating these general ideas further, in greater detail, one finds that the strata brought to view by the Bighorn uplift record many local variations in the ancient geography and topography of the continent.

Cambrian submergence.—One of the great events of early North American geologic history was the wide expansion of an interior sea over the western-central region. The submergence reached the Rocky Mountain province in Acadian (Middle Cambrian) time and for a while was marked by an irregular shore line. From the ancient crystalline rocks of these shores waves and streams 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. There are numerous exposures in which these sediments, containing much local material, may be seen abutting against the surface of the crystalline rocks that formed these shores. The central portion of the Bighorn Mountains and Black Hills may have been islands in the earlier stage of this period, and the Laramie Range and front range of the Rocky Mountains were lands rising out of the Cambrian sea. After these earliest shore-line conditions, the higher lands were reduced by erosion and, the area possibly being also lessened by submergence, some of the islands yielded the finer grained muds now represented by the shales and limestones which occur in the upper portion of the Cambrian, but in many regions the land surface of crystalline rocks was buried beneath the sediments. The limestone conglomerates at the top of the Deadwood formation indicate recurrence of shallow-water conditions, probably marking the beginning of emergence which lasted through the later part of Cambrian time and the earlier part of Ordovician. During this time the area here considered was probably part of the land extending northward from the Laramie Range.

Ordovician sea.—In Black River-Trenton time the northern part of the Bighorn area was submerged, at first with deposition of sand and then with extensive deposition of lime carbonate, now constituting the greater part of the Bighorn formation. After this epoch there was an uplift, resulting probably in widespread emergence. This was followed, in late Ordovician time, by submergence, during which Richmond deposits accumulated in at least part of the area.

Silurian-Devonian conditions.—From the close of Ordovician to early Carboniferous time the Bighorn Mountains present no geologic record, the Silurian and Devonian being absent. 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 Bighorn area, but generally throughout the Rocky Mountain province.

Carboniferous sea.—Under the marine conditions of the early Carboniferous there were laid down calcareous sediments which are now represented by nearly a thousand feet of limestone, known as the Madison limestone. As no coarse early Carboniferous deposits occur, it is probable that no crystalline rocks were then exposed above water in this region, although in regions farther south the limestone, or its stratigraphic equivalent, was deposited immediately upon them. Later in Carboniferous time the conditions changed and a sheet of red shale of wide extent was deposited, followed by alternations of pure limestones and sandy limestones, and local sand deposits several hundred feet thick, constituting the Amsden formation. This deposition was followed by an uplift in which there were shallow waters and strong currents, which deposited a thin but extensive sheet of sand, represented by the Tensleep sandstone. In the southern portion of the Bighorn area this condition gave place to deposition of clay and then carbonate of lime, now constituting the Embar formation. Then followed a period of uplift which culminated, in late Carboniferous or Permian time, in a widespread lake of saline water in which the Chugwater formation accumulated. This great mass of red shales, with its extensive interbedded deposits of gypsum, presumably products of an arid climate, accumulated to a thickness of over a thousand feet in parts of the area. There is such uniformity of the deep-red tint that this is undoubtedly the original color. It is present not only over the entire outcrop of the formation but also throughout its thickness, as is shown by deep borings. It is therefore not due to later or surface oxidation. This deposition of red mud was interrupted from time to time by chemical precipitation of comparatively pure gypsum, in beds ranging in thickness from a few inches to 30 feet and usually free from mechanical sediments. It is apparent that these beds are the products of evaporation while mechanical sedimentation was temporarily suspended, a condition indicating greatly diminished rainfall; otherwise it is difficult to account for their nearly general purity. Most of the red deposits were laid down in shallow water, so that subsidence must have kept pace with deposition most of the time. At an early stage in the deposition of the "Red Beds" there was widespread interruption in the shale sedimentation, and a thin but wonderfully persistent bed of limestone, known as the Minnekahta, was laid down. This is only a few feet thick in the Bighorn Mountain region, but in the Black Hills and some other localities it is 50 feet thick. It contains fossils doubtfully referred to the Permian, and as fossils supposed to be of that age occur in local limestone beds near Thermopolis to within 150 feet of the top of the "Red Beds," apparently these beds are nearly all if not all of that age. Possibly their deposition extended into Triassic time, but there is no evidence on this point. At most localities there is evidence of uplift and erosion of the "Red Beds" in an interval prior to the deposition of the marine Jurassic beds of the Sundance formation.

Jurassic sea.—In the Bighorn Mountain 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. Some of the earliest deposits are fine-grained sandstones, or sandy shales, in part ripple-marked, evidently laid down in shallow water and probably the product of a time when sedimentation was in excess of subsidence, if not during an arrest of subsidence. An extensive marine fauna and limestone layers in the upper shales of the Sundance formation indicate that deeper water followed, but more sandy sediments appear near the top, indicating the resumption of shallower water conditions.

Cretaceous sea.—During the Cretaceous period deposits of various kinds, but generally uniform over wide areas, gathered in a great series, beginning with such as are characteristic of shallow seas and estuaries along a coastal plain, passing into sediments from deep marine waters, and changing toward the end to fresh-water sands and clays with marsh vegetation. The earliest deposits constitute the Morrison formation, a widespread mantle of fine-grained materials, mixtures of clay and fine sand, with thin, irregular bodies of coarser sand deposited by streams, or along shores, and with occasional thin beds of limy sediments. Huge saurians were abundant, as is shown by the frequent occurrence of their remains in the deposits, although it is possible that the abundance of such remains is due mainly to increased mortality, or to more favorable conditions of preservation, or both.

Morrison time was succeeded abruptly by a change to conditions under which the coarse-grained, cross-bedded, massive basal conglomerates and sandstones of the Cloverly formation were deposited. Although the deposits change abruptly and there is occasional local channeling of the surface of the soft Morrison deposits, the erosion appears to be of remarkably small amount—no more than would be expected to result from strong currents bearing coarse sands and pebbles. It is believed that there was no great uplift-erosion interval following Morrison deposition, for if there had been the soft deposits would have been widely removed. It is a significant fact, indicating regular succession, that some of the saurians of Morrison time apparently continued into the next epoch. The coarse deposits of the lower part of the Cloverly were derived from sources not fully located and spread by strong currents over an extensive area. In the earlier stages there were some coaly deposits, but apparently no such coal beds as are found in the Black Hills region. The coarser beds are usually less than 50 feet thick and give place to massive clays and sandy clays, mostly of light color, not unlike the Morrison beds, which usually have a thickness less than 100 feet and are supposed to represent the Fuson formation of the Black Hills. The Dakota sandstone is not recognizable, but, as there is no unconformity at the top of the Cloverly formation, the sediments of Dakota time are no doubt represented by deposits that are not characteristic. At the beginning of the Benton there was everywhere in the region a rapid change of sediments to material that formed dark-colored, fissile shales. These are the products of a later Cretaceous submergence, in which marine conditions prevailed and which continued until several thousand feet of clays were deposited during the Colorado (Benton and Niobrara) and the Pierre epochs. In Benton time there were occasional thin deposits of sand, especially at first and at the end, and in middle Benton time some fine-grained sandy beds, now known as the Mowry member, were laid down. The calcareous sediments of the Greenhorn limestone in the middle of the Benton are not represented in the Bighorn region, and the Niobrara sediments were clays lacking the chalky ingredient which characterizes them in other regions. The period of Pierre deposition was long, over 3000 feet of dark clays, deposited slowly under very uniform conditions, having accumulated in most of the region. The retreat of the sea during later Cretaceous time resulted in extensive bodies of brackish water, which spread sand over the clay beds; and then fresh waters deposited sands, clays, and marsh materials of the Laramie and later formations. In this region there was an uplift of moderate prominence in the early part of this time, in part at least, along a fault on the east slope of the Bighorn Mountains. It was of sufficient magnitude, however, to afford erosion products from beds down to the Cambrian, some of the materials of which appear in a long lens of Kingsbury conglomerate that extends from a point southwest of Sheridan southwestward for 40 miles, to Crazy Woman Creek. Deposition of finer grained materials progressed during and after this uplift, and several thousand feet of shales and sands of the De Smet formation accumulated, including scattered beds of carbonaceous materials which are now lignite coal, in some places 20 feet or more in thickness. It is believed that this epoch extended to and perhaps into early Eocene time.

Early Tertiary mountain growth.—There was extensive uplift in the Rocky Mountain province in early Tertiary time. This fact is clearly indicated in most of the mountain regions, where Oligocene deposits lie on an eroded surface having the general configuration of the present topography, a relation which indicates that the uplifts were truncated and the larger outlines of their topography established in earlier Eocene time. Where the great mass of eroded material was carried is not known, but a part of it was transported west and southwest of the Bighorn Range, where it constitutes the Bridger and Wasatch beds. Some idea of the extent of erosion in the Bighorn uplift is given in fig. 5, in which the approximate profile of the Pierre and underlying formation is continued over the uplift. Probably some of the formations later than Pierre extended over the dome.

Later Tertiary fresh-water deposits.—Oligocene and overlying deposits were laid down by streams and local lakes and finally covered much of the Northwest to a level now far up the flanks of the various mountain ranges. Erosion has removed them from most of the higher regions where they formerly existed, especially along the steeper slopes. Various deposits of supposed Tertiary age remain in the lower slopes of the granite area of the Bighorn Mountains at altitudes of 8000 to 9000 feet and along the higher slopes of the limestone front ridges at altitudes of 6000 to 7000 feet.

Quaternary conditions.—Several small glaciers remaining in the higher portions of the Bighorn Mountains are diminutive remnants of much more extensive bodies of ice which formerly occupied the principal valleys of the highlands. In this respect the history of the Bighorn Mountains is similar to the history of other similarly situated high ranges in the western part of the United States. The glacial history of these mountains is complex. The great glaciers which have left the most distinctive records of themselves were successors of earlier glaciers, the marks of which have been partly effaced by weathering and erosion. There is evidence that the Bighorn Mountains were occupied by glaciers during two widely separated epochs, and there is some suggestion that there may have been glaciers at a still earlier time. Some features of the glacial history are given in a preceding section in the account of the glacial geology.

In the plains area in Quaternary time gravels and sands were deposited by streams, at first at a higher level than the present valleys; later these valleys were cut at various depths and the bottoms of the larger ones have been covered with alluvium.

ECONOMIC GEOLOGY.

SOILS.

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

Distribution.—The arable soils of the Bald Mountain and Dayton quadrangles are found mainly on the Quaternary deposits. These occupy most of the larger valleys in the plains area and cap some of the divides and higher terraces extending eastward from the foot of the mountains. The materials have been washed from the mountains and are loamy mixtures of sand and clay of a high degree of fertility. Usually such tracts are level, well drained, and in every way adapted to agriculture. Their distribution is shown on the areal geology sheet. The widest alluvial deposits are along Tongue River and Wolf, Soldier, Smith, East Pass, Big Goose, Beaver, Little Goose, and Shell creeks, below the mouths of the canyons. Nearly all the land in these valleys is cultivated, mainly for the production of hay. The crops depend principally on irrigation, ditches for which extend along most of the valleys. The high terrace deposits have fertile soils, but they are usually coarser grained and more difficult to keep moist; besides, many of them lie above the ditch lines, so they can not be irrigated. If larger water supplies were available many of these terraces could be irrigated. A large area of this kind extends along the north side of the valley of Soldier Creek and there are others between Hanna and Hurlburt creeks, Big Goose and Beaver creeks, and on both sides of Tongue River Valley above Ranchester. The bottom lands in Shell Creek Valley average about 1 mile in width. Along Beaver Creek below Cloverly there is an alluvial flat, at most places about one-quarter of a mile wide, and a similar flat extends along Trapper Creek for some distance above its mouth, while narrower areas extend along Stockade, Alkali, and some of the smaller creeks in the shale areas.

In the extensive areas of granite much of the surface consists of rocky ledges and the region is at an altitude entirely too elevated for agriculture. In many of the valleys in the mountains there are extensive meadows, and more or less grass grows on the slopes, affording rich pasturage during the summer season. The formation whose outcrop area is next in extent to that of the granite is the De Smet, consisting of sandstones and shales with soils that might be serviceable when irrigated, but usually all the available water in the plains area is applied to the richer soils of the alluvial and other Quaternary deposits. The rocks of the front ridge are largely limestones and sandstones, which would have fertile soils if the slopes were not so steep, but the soil is washed away nearly as fast as it is formed and rocky ledges are the prevailing surface features. Along the Red Valley the land is mostly rough and the soil thin and barren. The Pierre shale and adjoining shale formations contain some good soils but ordinarily there is too much clay in them and they are frequently "acid" from decomposing pyrites.

WATER SUPPLY.

Surface waters.—In the mountain area of the Bald Mountain and Dayton quadrangles there are numerous large flowing streams, which also cross the adjoining plains. On the east slope the principal stream is Tongue River, which, with its branches, drains a wide area. Little Bighorn River and its branches drain the region north and east of Bald Mountain. In the extreme southeast corner of the Dayton quadrangle are two main branches of Piney Creek, a large tributary of Clear Creek, which empties into Powder River. Tongue River derives most of its water supply from the region of high ridges in the granite area, where large masses of snow continue to melt far into the summer. From gagings made at Dayton in 1903 its flow was found to vary from 109 to 845 second-feet, the latter rate occurring in the early floods of June, after which the flow gradually diminished to 115 second-feet, in August.

Big Goose Creek, the principal affluent of Tongue River, carries a large volume of water in the early summer (400 to 600 second-feet), which diminishes greatly later in the dry season. Little Goose Creek also supplies a large volume of water in early summer.

Wolf Creek is a stream of moderate size, which heads in the high granite ridges, and Soldier, Columbus, and Smith creeks are flowing streams which gather waters from the eastern slopes of the mountains. The numerous small branches which head in the divides on the plains are dry throughout the greater portion of the year and flow only when there are heavy rains or when the snow is melting. West Pass, East Pass, Twin, East Twin, and Fool creeks are small streams which head on the limestone slopes in the northern portion of the mountain area.

On the west slope of the Bighorn Mountains there are numerous streams carrying large volumes of water, portions of which are derived from the snow that remains throughout the season on many of the higher areas. Shell Creek, the principal stream on the west slope in the Bald Mountain quadrangle, probably carries an average of about 50 second-feet. Its branches, Granite, Willitt, Cedar, and Beaver creeks, are small flowing streams. Trout, Deer, Porcupine, Five Springs, Alkali, Bear, North and South Beaver, Horse, White, Trapper, and Cedar creeks are all good streams which head in the mountain slopes and flow throughout the year. Their volume varies from 10 to 25 second-feet. Nearly all of the smaller mountain branches of the streams above mentioned are running, so that the entire highland district has abundant water supplies. In the wide areas of shale west of the mountains there are numerous local watercourses that run only in the rainy season or after a summer shower.

In portions of the high mountain area there are a number of small lakes which owe their origin to dams formed of glacial material, mostly morainal. The largest of these is Dome Lake; two others of moderate size are Adelaide and Last Chance lakes. There are numerous small lakes and ponds above Dome Lake, at the headwaters of West Fork of Goose Creek. The waters from the mountains are all of very fine quality for all uses, but on the plains the surface waters often are contaminated with minerals dissolved from the large bodies of shale.

Underground water.—The problem of underground water supply is of no special interest in the mountain area, and in the adjoining plains the surface waters are abundant for most needs. It is probable that the basin area west of the mountains is underlain by several horizons of water-bearing sandstones which might furnish artesian flows, especially in the lower portions of the valleys. In the region of Colorado and overlying shales west of the mountains the Cloverly sandstone lies at moderate depth, and this member is almost certain to contain water under moderate pressure. This source of supply might prove useful in the valley of Bear Creek near the western margin of the Bald Mountain quadrangle and possibly also in the slopes adjoining Shell Creek below the mouth of Beaver Creek. The Tensleep sandstone is undoubtedly a water bearer, but owing to the steep dips along the mountain slopes the water passes rapidly to a considerable depth. Along the contact of the Sundance and Chugwater formations it lies from 650 to 800 feet below the surface. On the Morrison-Sundance contact it would be from 200 to 300 feet deeper, and on the Cloverly-Morrison contact about 300 feet deeper still. Doubtless the Tensleep sandstone would yield flows in all of the lower lands east of the main mountain slope, except, perhaps, in the high ridges southwest of Cloverly.

The thick series of sedimentary rocks that underlie the plains region on the Dayton quadrangle contain numerous sandstone members which carry underground waters. Some of these are deeply buried; others are near the surface. Owing to the steep dips and faults along the front ridge the lower water-bearing beds sink rapidly to depths too great to be reached by ordinary well boring. This is particularly the case with the Deadwood, Tensleep, and Cloverly sandstones, which appear to receive and carry underground a considerable amount of surface water. The Parkman sandstone is doubtless a water bearer, although its texture is so fine that the volume of water in it can not be very large. The situation of this formation underground is shown in sections A–A to F–F on the structure section sheet. It will be seen that, owing to the steep dips, the formation passes rapidly to great depths beneath the surface. At no great distance east of its outcrop zone it lies at depths of over 2000 feet.

In the many sandstones in the De Smet, Kingsbury, and Piney formations there are probably water supplies which might be utilized in wells of moderate depth, but as most of the supplies lie at low levels it is not likely that flowing water could be obtained from them, except possibly along some of the valleys. Owing to the irregular stratigraphy of the formations it is not practicable to indicate any special beds of sandstone that are likely to yield water supplies, so that all information on this subject must be derived from experimental borings. It is probable that the Kingsbury conglomerates extend eastward under a portion of the region and that they contain water. Most of the shallow wells in the plains region have obtained water without difficulty, chiefly from sandstones in the De Smet formation or from the alluvium along the bottoms of the valleys. These waters vary greatly in quality and some of them contain a considerable amount of mineral matter.

MINERAL RESOURCES.

General statement. — The principal mineral resource of the area to which this folio relates is lignite coal, which underlies much of the northeastern portion of the Dayton quadrangle. Gypsum occurs throughout the Chugwater formation, small amounts of gold and copper have been found in the granite area of the mountains, and vast quantities of limestone are obtainable from the Bighorn, Madison, and Amsden formations. Building stones also are abundant in most portions of the quadrangle and clays suitable for brick making are available at many localities.

Coal.—Coal mines on Owl Creek 2 miles northeast of Beckton, owned and operated by R. S. Addleman, were opened in 1897. The coal deposit is 18 feet thick in its thickest portion, and 12 feet of this is good coal, but only 7 feet is worked, near the middle of the bed. The dip is about 4° to the northeast. About 4000 tons of coal are mined each year, which sells at $1 a ton at the mine. A half-mile farther east, in Goose Creek Valley, the same bed is opened at the Big Goose coal mine, operated by H. Timm. It was first developed in 1890. The mine is worked during only part of the year and has an output of 5 tons a day, valued at $1 a ton at the mine. It is used mainly in Sheridan and is entirely satisfactory for domestic purposes. About 2½ miles farther southeast, on the east side of Beaver Creek Valley, is the Nelson Brothers' coal mine, which has been in operation since 1899. The bed is the same one as in the other mines, but it is 21 feet thick without a parting. It dips northeastward at an angle of about 4°. The company is working only 9 feet of the bottom of the vein. There is an average output of 15 tons a day in winter, which sells at $1.25 a ton at the mine. Coal has been reported in some of the black shales of the Benton formation on both sides of the mountains, but on special examination none was found. At the base of the Cloverly sandstone in some places there are deposits of coaly shale, but they are very thin and at no point give promise of value.

Gold and copper.—The granite area of the Bighorn uplift has been extensively prospected for metallic minerals, but the results appear not to be encouraging. Small amounts of free gold occur in quartz veins connected with the diabase dikes in the granite, and some of the basal deposits of the Deadwood formation carry gold, but the values are low. Copper minerals have been found at some places in these veins, but no promising deposits have been observed.

At intervals during the last decade attempts have been made to develop gold mines in the vicinity of Bald Mountain, but the results have not been encouraging. The basal gravels of the Deadwood formation, especially where they are mixed with disintegrated portions of the underlying granite, contain fine-grained free gold, but the values are low and the distribution is irregular. The highest assays reported are $2 a ton, but the amount is usually so much less that the washings have not been profitable. At a point about 2 miles west of the abandoned Bald Mountain cabins a mill with a jig machine was in operation in 1903, working the disintegrated sandstone and granite at the base of the Deadwood formation, but it is stated that only small portions of the material yielded paying results. Some of the small intrusive dikes or chimneys about Fortunatus Mill are reported to contain gold, but the extent of mineralization is small and the value is low.

A mine on the ridge southwest of the mouth of South Fork of Tongue River, belonging to the Nickel and Copper Refining Company, has been worked at intervals since 1896 but is now abandoned. The mine consists of a shaft 180 feet deep, with buildings and extensive machinery. The shaft is sunk along the contact of a large dike of peridotite and a quartz vein, but apparently very little mineral was found. It is stated that the mining of platinum was one of the principal objects of the enterprise. Extensive prospecting was done at intervals along the dike, which has a length of about 3 miles.

There are several prospects on the headwaters of East Fork of Big Goose Creek near the southern margin of the Dayton quadrangle. Work was begun on these in 1898 but, although the results have appeared promising, no ore has been produced. The rock is a dark-gray granite, containing some pyrite and traces of copper. Assays of gold showing $4 a ton are reported. In one opening $12 of gold and $7 of silver a ton were found.

On a branch of South Fork of Wolf Creek, southwest of Walker Prairie, several efforts have been made to develop a copper mine in a 15-foot quartz vein in the granite. A shaft has been sunk 56 feet and crosscuts have been made. The ore is mainly malachite, occurring in irregular veins in the quartz. Some galena also occurs, and parts of the vein carry gold values ranging from $3.50 to $4 a ton. The quartz vein at this locality extends southwestward for about 3 miles and the same distance eastward, passing under Deadwood sandstone at Walker Prairie. Near its northeastern end, at Walker's mine, where it is about 25 feet wide, it has been prospected to some extent. A small amount of pyrites was obtained, carrying small values in gold.

Considerable prospecting has been done in two large dikes southeast of bench mark 9213, on the south side of Willitt Creek. The minerals are galena and pyrite, occurring in small streaks in quartz along the diabase contacts. A few small prospects have been made in a quartz vein about a mile north of Tongue River Cabin.

Gypsum.—The gypsum deposits in the Chugwater formation are mostly pure and occur in beds sufficiently thick to be of value for the manufacture of plaster of Paris. The mineral is a hydrous sulphate of lime, which is converted into plaster by calcining the rock at a moderate heat to drive off most of the chemically combined water and grinding the product into a fine powder. Plaster of Paris has been produced at a number of places in Wyoming and adjacent States, but its selling price is so low that it can not bear the cost of shipment to distant markets. In the Dayton quadrangle the gypsum deposits in the Chugwater formation are somewhat variable in thickness. The principal bed is near the base of the formation and averages from 3 to 5 feet thick at most places. It outcrops almost continuously from Pass Creek to Little Goose Creek. On the west slope of the mountains the gypsum beds are from 10 to 15 feet thick at most localities.

Bentonite.—No bentonite has been observed in this area, but, as it occurs in adjoining areas and appears generally to be present in the Colorado shale, probably it will eventually be found. It occurs at two horizons, one below and the other above the Mowry member. The mineral is a pale greenish-buff clay of compact texture and of such porous structure that it will absorb several times its bulk of water. On account of this absorbent quality it has a moderate market value for several uses.

Building stones.—Many of the rocks in the mountainous portion of the area are more or less well suited for building stone. Some of the granites are massive, have a fine appearance when polished, are relatively free from minerals that cause stains on weathering, and may at some time be valuable for shipment for building. Some of the limestones in the Madison formation are of very satisfactory texture and appearance, and possibly some of them could be worked for marble, especially the upper member. Several years ago a small quarry was opened east of Sheep Mountain. The Tensleep sandstone is usually massive, even textured, and of white or light-buff color, so that, if nearer to markets, it might be profitably worked as a freestone. The red sandstones of the Chugwater formation are of pleasing color but are mostly too soft to be of value for building. Large supplies of rough stones suitable for foundations and similar uses are obtainable from the Parkman, Piney, De Smet, and Cloverly sandstones and from the hard ledges in the Sundance formation.

Phosphate.—The spherical concretions occurring in the lower portion of the Colorado formation consist mainly of phosphate of lime, and, as they could be obtained in large numbers by means of suitable excavating machinery, they may at some time be utilized as a source of phosphate.

Limestone.—The limestones of the mountain slopes are in large part sufficiently pure for lime burning, or for smelting flux, but there is very little demand for these products in the region. No analyses have been made to ascertain the chemical character of the rocks.

TIMBER.

The mountainous area in the Bald Mountain and Dayton quadrangles is irregularly forested and although there have been numerous fires considerable timber remains. The greater part of the high lands is included in the Bighorn Forest Reserve, the limits of which are shown on the maps in this folio. A description of the forests of this reserve is given by F. E. Town in the Nineteenth Annual Report of the United States Geological Survey, part 5, pages 165-190. Nearly all the trees on the reserve are pine, mainly of one species, *Pinus murrayana*, which is called "white pine," "yellow pine," "jack pine," and "lodgepole pine," the different names being applied in part on account of differences in development. The wood is coarse grained and knotty and few of the trees yield large logs, and as the lumber warps and cracks considerably it is not regarded as valuable. Trees of another species of pine, *Pinus flexilis*, are scattered among the other pines. The Engelmann spruce grows in some moist areas along the mountain slopes and in the higher portions of some of the canyons. The pine forests grow at altitudes ranging from 6000 to nearly 10,000 feet. The most extensive forested areas are in the Bald Mountain quadrangle on the northeastern slopes of the limestone ridges lying north and east of the main divide. There is also a large area of small mixed pine and spruce on the slopes adjoining Porcupine Creek. The greater portion of the Deadwood shales and Bighorn limestone and Chugwater areas bear but few trees. The largest areas of forest are on the ridges lying southwest of Dry Fork of Little Bighorn River and adjoining West Fork of Little Bighorn River and Lodgegrass Creek. Fires have destroyed large areas along Little Bighorn Canyon and West Fork, in the valley of Tongue River south of bench mark 7469, and on the ridges between Cedar and Granite creeks.

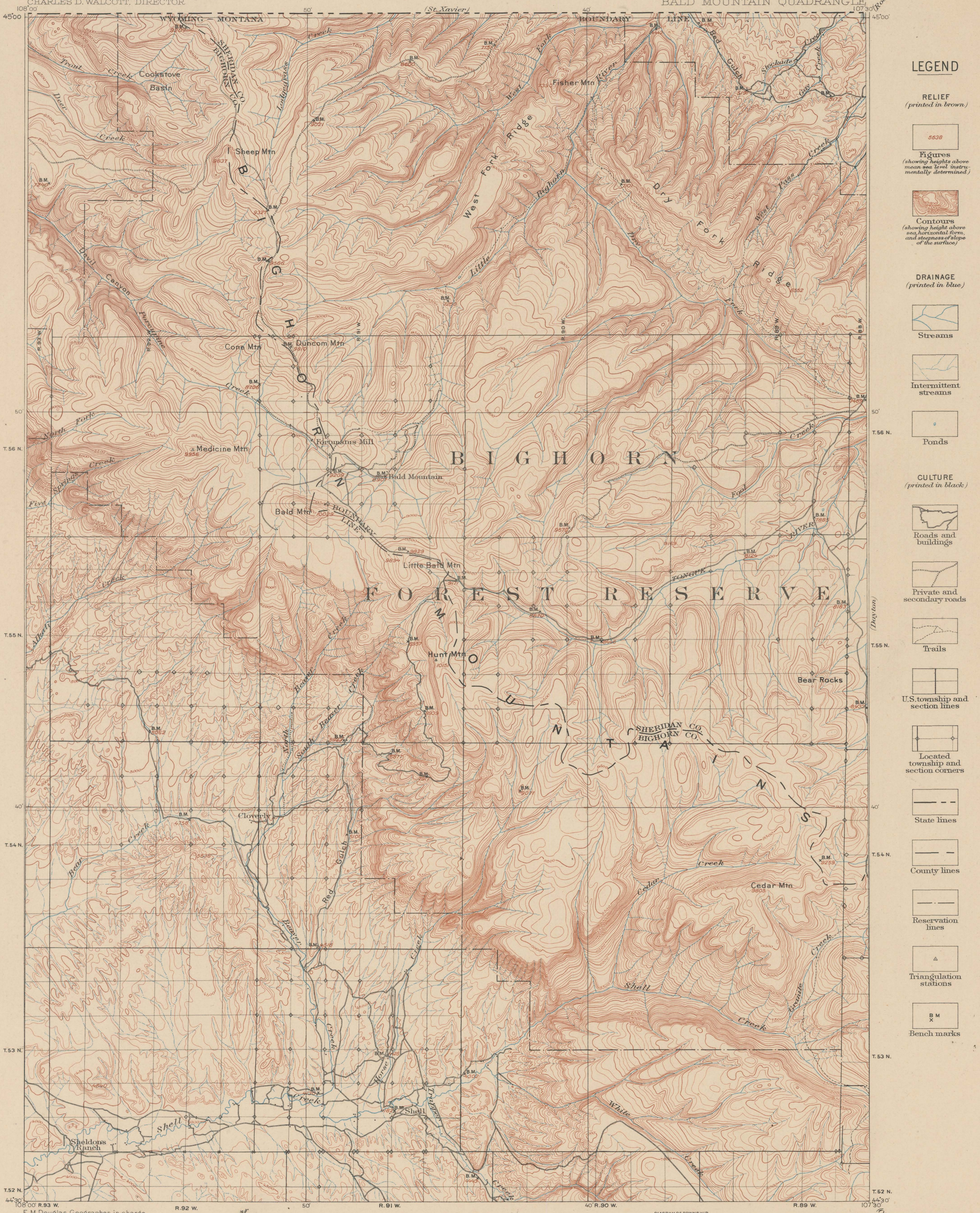
The most extensive forests in the Dayton quadrangle are about Black Mountain and in the area extending from that peak to the heads of South Fork of Tongue River and Wolf Creek, along Big and Little Goose valleys, especially south and southwest of Little Goose Peak, southwest of Finger Rock, and on Cross Creek. Much small timber occurs in scattered bodies along Shell Creek and Willitt Creek and on the limestone areas about Freeze Out Point, especially to the northwest. One of the finest forest areas in the mountains formerly extended up Tongue River Valley and over the adjoining ridges, but heavy fires and extensive tree cutting have depleted it. Large areas have also been burned on West Fork of Goose Creek, from Walker Prairie to timber line south of Dome Lake, and many other smaller areas have been obliterated by fire. The high ridges of the divide are above timber line, which is at an average altitude of about 9500 feet. The plains adjoining the Bighorn Mountains have timber only along some of the streams, which are generally bordered by cottonwoods and small willows.

June, 1905.

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

TOPOGRAPHY

WYOMING
BALD MOUNTAIN QUADRANGLE



E.M. Douglas, Geographer in charge.
Triangulation by W.S. Post.
Topography by Frank Tweedy.
Surveyed in 1898.

APPROXIMATE MEAN DECLINATION 1902.

Scale $\frac{1}{125000}$

Contour interval 100 feet.
Datum is mean sea level.

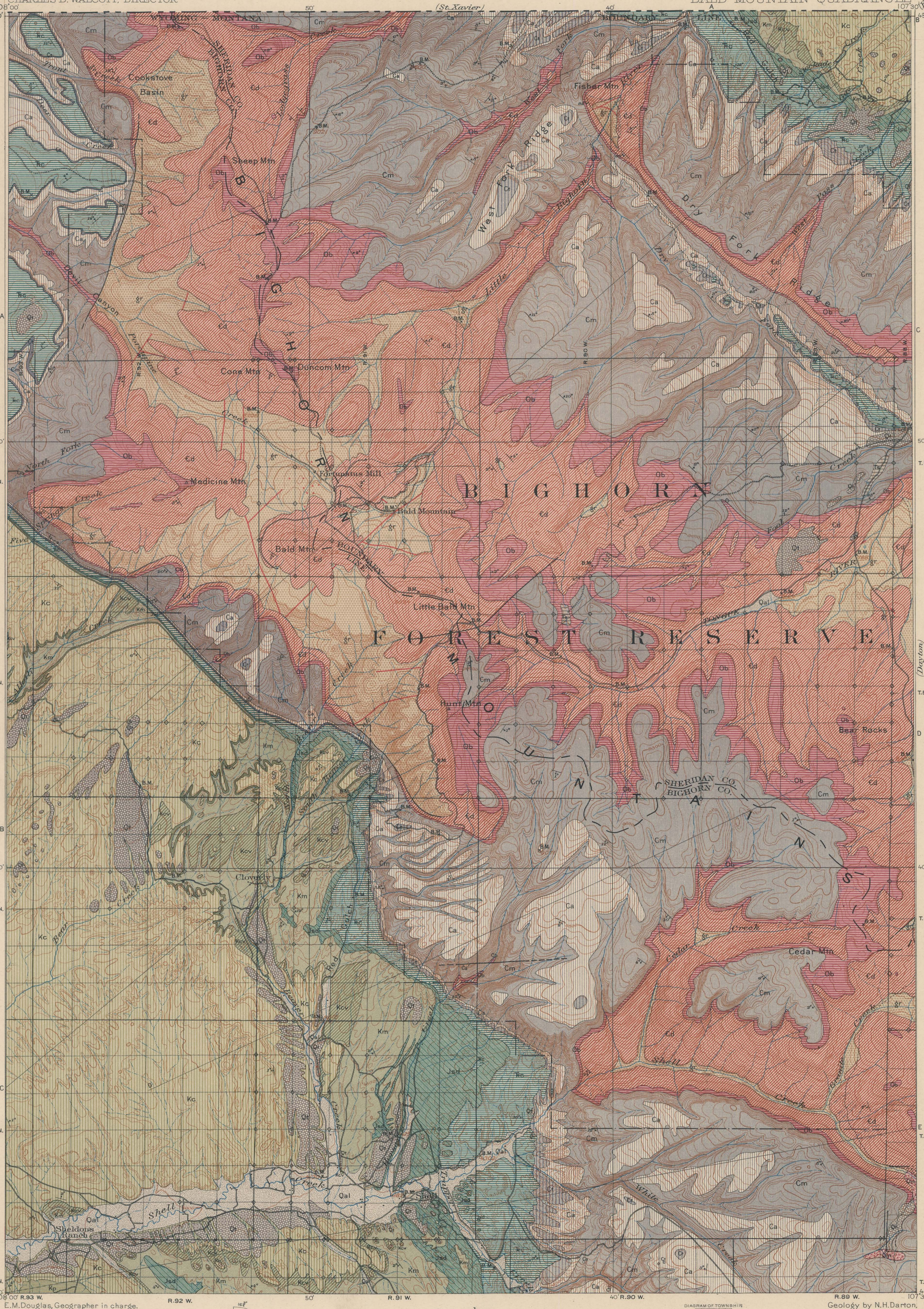
DIAGRAM OF TOWNSHIP.

Edition of Mar. 1901, reprinted Jan. 1906.

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

AREAL GEOLOGY

WYOMING
BALD MOUNTAIN QUADRANGLE



LEGEND

SEDIMENTARY ROCKS

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

QUATERNARY

- Qal — Alluvium (gravel, sand, and loam; only the larger areas are shown)
- Qt — Earlier terrace deposits
- Qm — Moraines (later drift)

TERTIARY ?

- Ts — Sand and gravel (on high divides)

CRETACEOUS (Upper Cretaceous)

- Kp — Pierre shale (dark-gray shale)
- Kc — Colorado formation (gray shale with thin, hard sandstones)
- Kcv — Cloverly formation (massive, buff sandstone overlain by gray to reddish clay)

CRETACEOUS OR JURASSIC

- Km — Morrison formation (gray, green, and maroon clays with thin limestone and sandstone beds)

JURASSIC

- Jsd — Sundance formation (green shale and buff sandstone)

UNCONFORMITY

TRIASSIC ?

- Trc — Chugwater formation (red sandstone and sandy shales, with gypsum and thin limestone beds)

CARBONIFEROUS (Pennsylvanian Permian ?; Mississippian)

- Ct — Tensleep sandstone (gray, white, and buff, massive sandstone)
- Ca — Amsden formation (limestone, in part cherty, and sandstone, with bright-red sandstone at base)
- Cm — Madison limestone (hard, massive limestone, gray and sandy below, light gray, brecciated, and cavernous above)

UNCONFORMITY

ORDOVICIAN

- Ob — Bighorn limestone (very massive, hard, cream-colored limestone overlain by softer beds)

UNCONFORMITY

CAMBRIAN (Acadian)

- Ꞓd — Deadwood formation (brown to buff sandstone, greenish-gray shale, and gray, greenish, and pinkish limestone and limestone breccia)

IGNEOUS ROCKS

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

PRE-CAMBRIAN

- Diabase (dikes and plugs; the smaller ones not represented)
- gr — Granite (mostly red, locally gray, massive, coarse-grained granite)

Faults

20° Strike and dip of stratified rocks

⚒ Gold mines
x Gold prospects

Sections

E.M. Douglas, Geographer in charge.
Triangulation by W.S. Post.
Topography by Frank Tweedy.
Surveyed in 1898.

APPROXIMATE MEAN DECLINATION 1902.

Scale $\frac{1}{125000}$

Contour interval 100 feet.
Datum is mean sea level.
Edition of Feb. 1906.

DIAGRAM OF TOWNSHIP

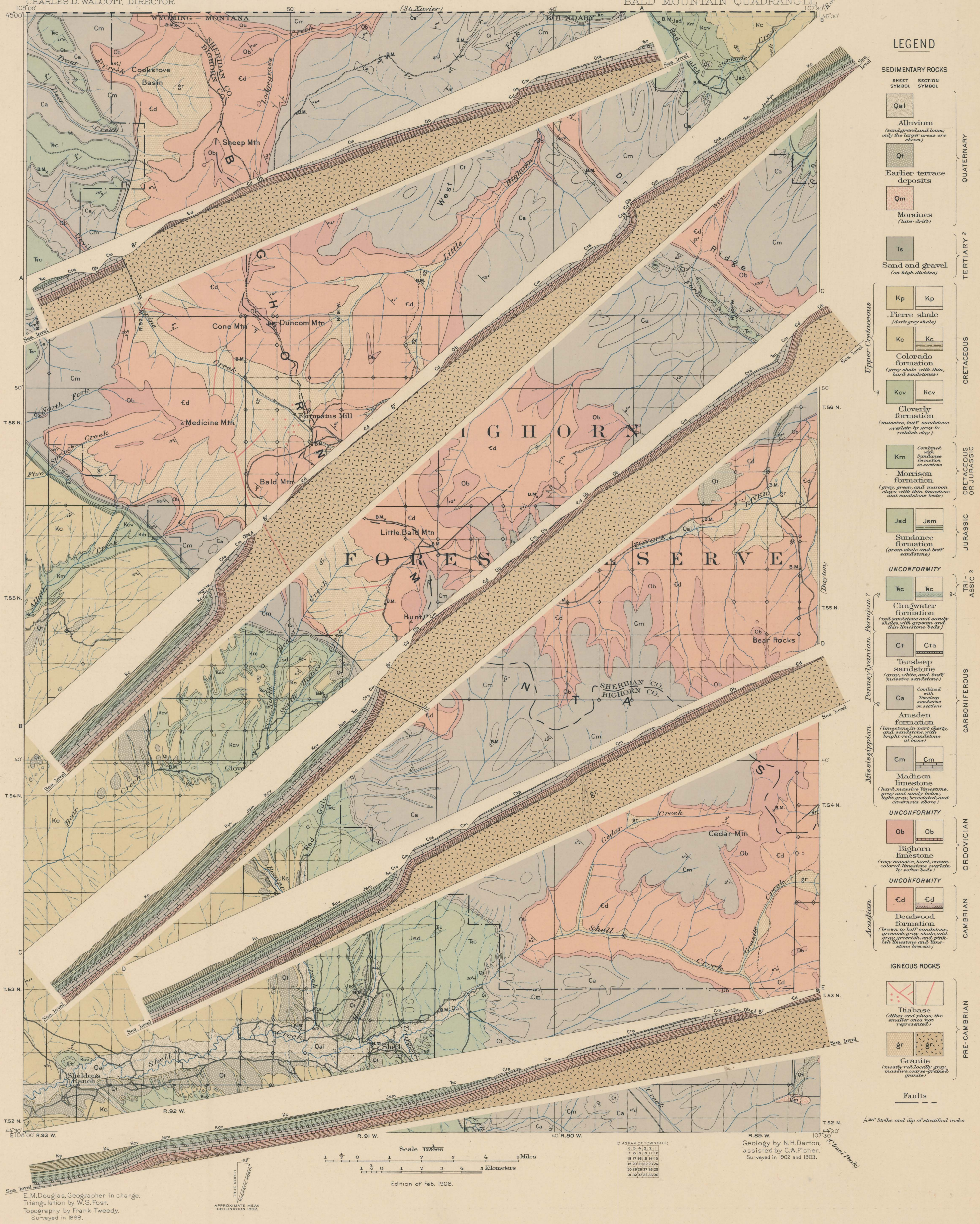
6	5	4	3	2	1
7	8	9	10	11	12
18	17	16	15	14	13
19	20	21	22	23	24
30	29	28	27	26	25
31	32	33	34	35	36

Geology by N.H. Darton, assisted by C.A. Fisher.
Surveyed in 1902 and 1903.

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

STRUCTURE SECTIONS

WYOMING
BALD MOUNTAIN QUADRANGLE



Scale 1/125000
1 ½ 0 1 2 3 4 5 Miles
1 ½ 0 1 2 3 4 5 Kilometers

Edition of Feb. 1906.

APPROXIMATE MEAN DECLINATION 1902.

DIAGRAM OF TOWNSHIP

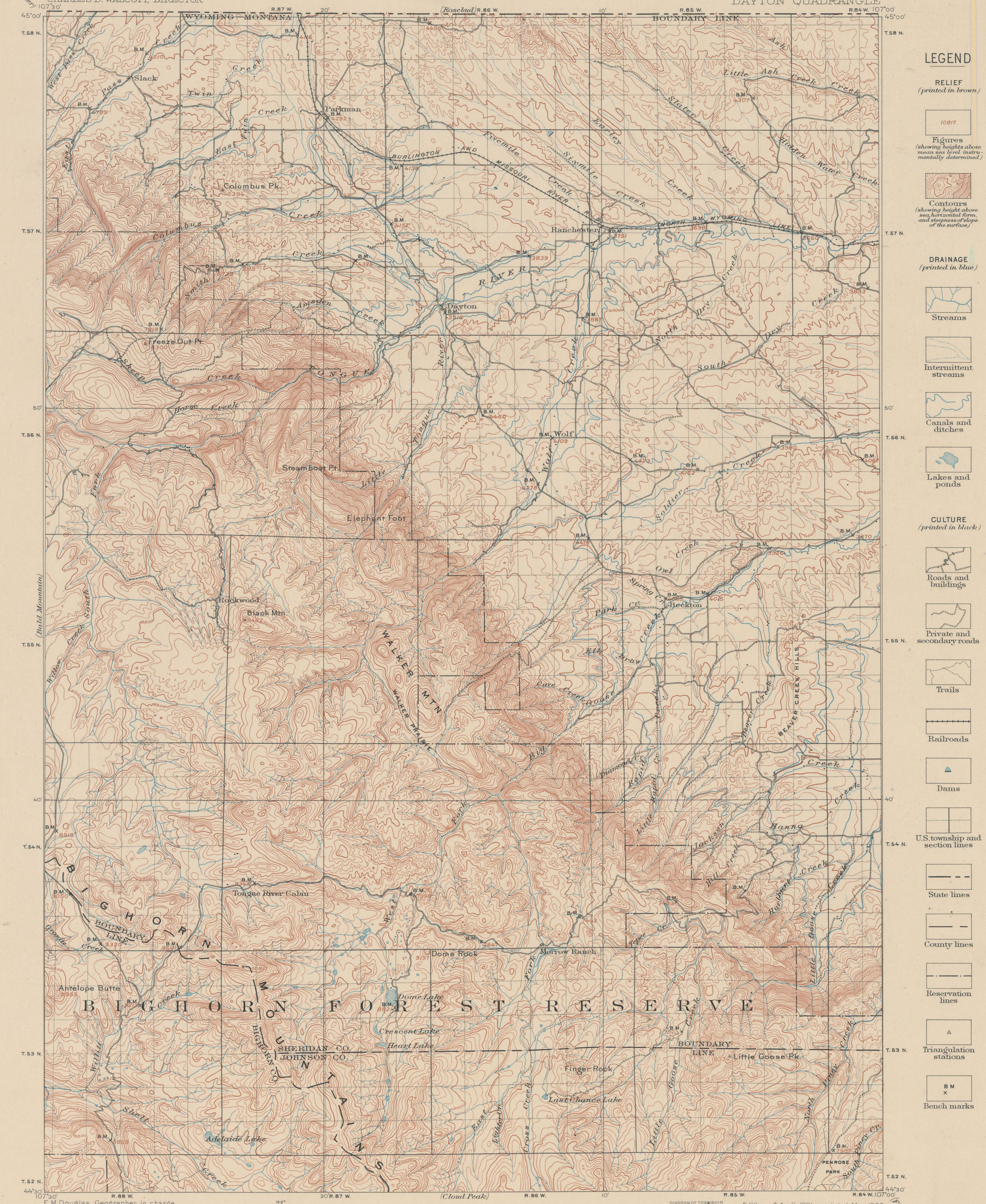
Geology by N. H. Darton, assisted by C. A. Fisher.
Surveyed in 1902 and 1903.

E. M. Douglas, Geographer in charge.
Triangulation by W. S. Post.
Topography by Frank Tweedy.
Surveyed in 1898.

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

TOPOGRAPHY

WYOMING
DAYTON QUADRANGLE



E.M. Douglas, Geographer in charge.
Triangulation by W.S. Post.
Topography by Frank Tweedy.
Surveyed in 1899.

APPROXIMATE MEAN DECLINATION 1902.

Scale $\frac{1}{125000}$

Contour interval 100 feet.
Datum is mean sea level.

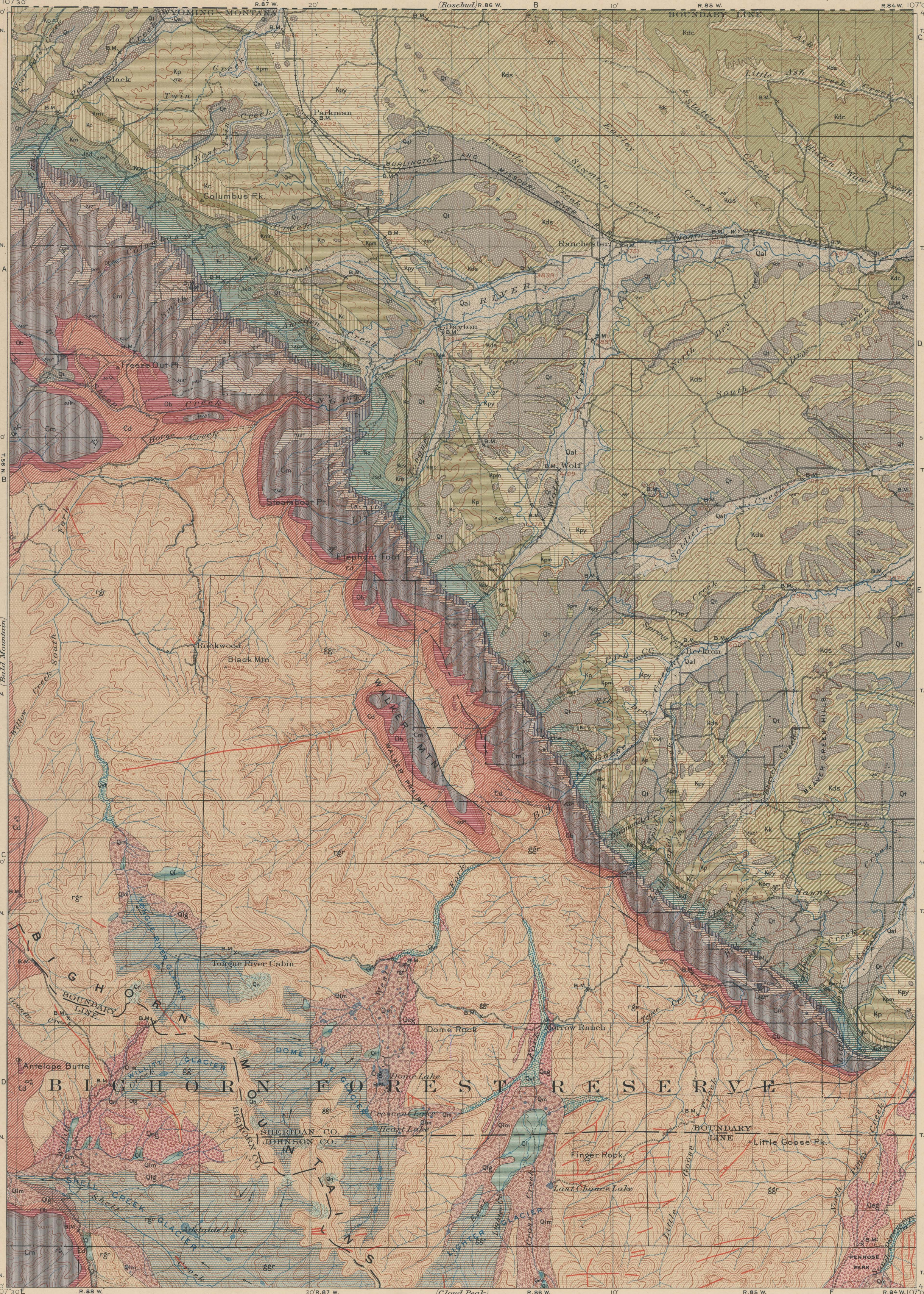
DIAGRAM OF TOWNSHIP

Edition of April 1901, reprinted May 1906.

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

AREAL GEOLOGY

WYOMING
DAYTON QUADRANGLE



E.M. Douglas, Geographer in charge.
Triangulation by W.S. Post.
Topography by Frank Tweedy.
Surveyed in 1899.

TRUE NORTH — MAGNETIC NORTH $16\frac{1}{2}°$
APPROXIMATE MEAN DECLINATION 1902.

Scale $\frac{1}{125000}$

Contour interval 100 feet.
Datum is mean sea level.
Edition of May 1906.

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

General Geology by N.H. Darton, assisted by C.A. Fisher.
Glacial Geology by E. Blackwelder.
Surveyed in 1901-1904.

LEGEND

SEDIMENTARY ROCKS

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

QUATERNARY

- Qal — Alluvium *(gravel, sand, and loam; only the larger areas shown)*
- Qt — Earlier terrace deposits *(gravel and loam)*
- *Later glacial epoch:*
  - Ql — Lake deposits *(mainly silt)*
  - Qn — Névé deposits *(rock débris accumulated under former snow fields)*
  - Qvt — Valley trains *(stream gravels)*
  - Areas occupied by ice *(during later glacial epoch)*
  - Qlm — Lateral moraines
  - Qm — Terminal moraines
  - Qlg — Later glacial drift *(only the larger areas shown)*
- Qeg — Earlier glacial drift *(bowlders and sand; deposits in part discontinuous)*

CRETACEOUS — *Upper Cretaceous*

- Kds, Kdc — De Smet formation *(carbonaceous shale, sandstone, and coal beds, with burned-out coal or clinker beds, Kdc, in upper portion)*
- Kk — Kingsbury conglomerate *(local conglomerate composed largely of limestone)*
- Kpy — Piney formation *(brown sandstone and shale)*
- Kpm — Parkman sandstone *(light-buff, fine-grained, massive sandstone)*
- Kp — Pierre shale *(dark-gray shale or clay with concretions)*
- Kc, Kmr — Colorado formation *(dark-gray shale with thin brown sandstone near base, and Mowry member, Kmr, of hard shale and sandstone)*
- ? Kcv — Cloverly formation *(coarse buff sandstone overlain by light-colored clay)*

CRETACEOUS OR JURASSIC

- Km — Morrison formation *(massive sandy shale, gray, greenish, and maroon, with several gray sandstone layers)*

JURASSIC

- Jsd — Sundance formation *(soft buff sandstone and greenish shale with local limestone layers)*

UNCONFORMITY

TRIASSIC ? — *Permian ?*

- ? Ꞓc — Chugwater formation *(soft red sandstone and red shale with thin limestone near top and base, and local gypsum deposits)* ?

CARBONIFEROUS

- *Pennsylvanian:*
  - Ct — Tensleep sandstone *(hard, massive, white sandstone)*
  - ? Ca — Amsden formation *(cherty and fine limestone, with sandstone layers; red shale at base)*
- *Mississippian:*
  - Cm — Madison limestone *(gray limestone, upper part massive and lighter colored)*

Legend is continued on the left margin.

LEGEND

SEDIMENTARY ROCKS *(continued)*

UNCONFORMITY

ORDOVICIAN

- Ob — Bighorn limestone *(massive, buff, siliceous limestone, overlain by thin-bedded limestone; gray sandstone at base)*

UNCONFORMITY

CAMBRIAN — *Acadian*

- Ꞓd — Deadwood formation *(buff sandstone, green shale, limestone, and limestone conglomerate)*

IGNEOUS ROCKS

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

PRE-CAMBRIAN

- Diabase *(dikes cutting granite; only the larger dikes shown)*
- Peridotite *(dikes cutting granite)*
- rgr — Red granite *(mostly of reddish color; merges into gray)*
- ggr — Gray granite *(mostly of gray color; merges into red)*

Faults

20° *Strike and dip of stratified rocks*
Glacial striae

Sections

A B C D E F

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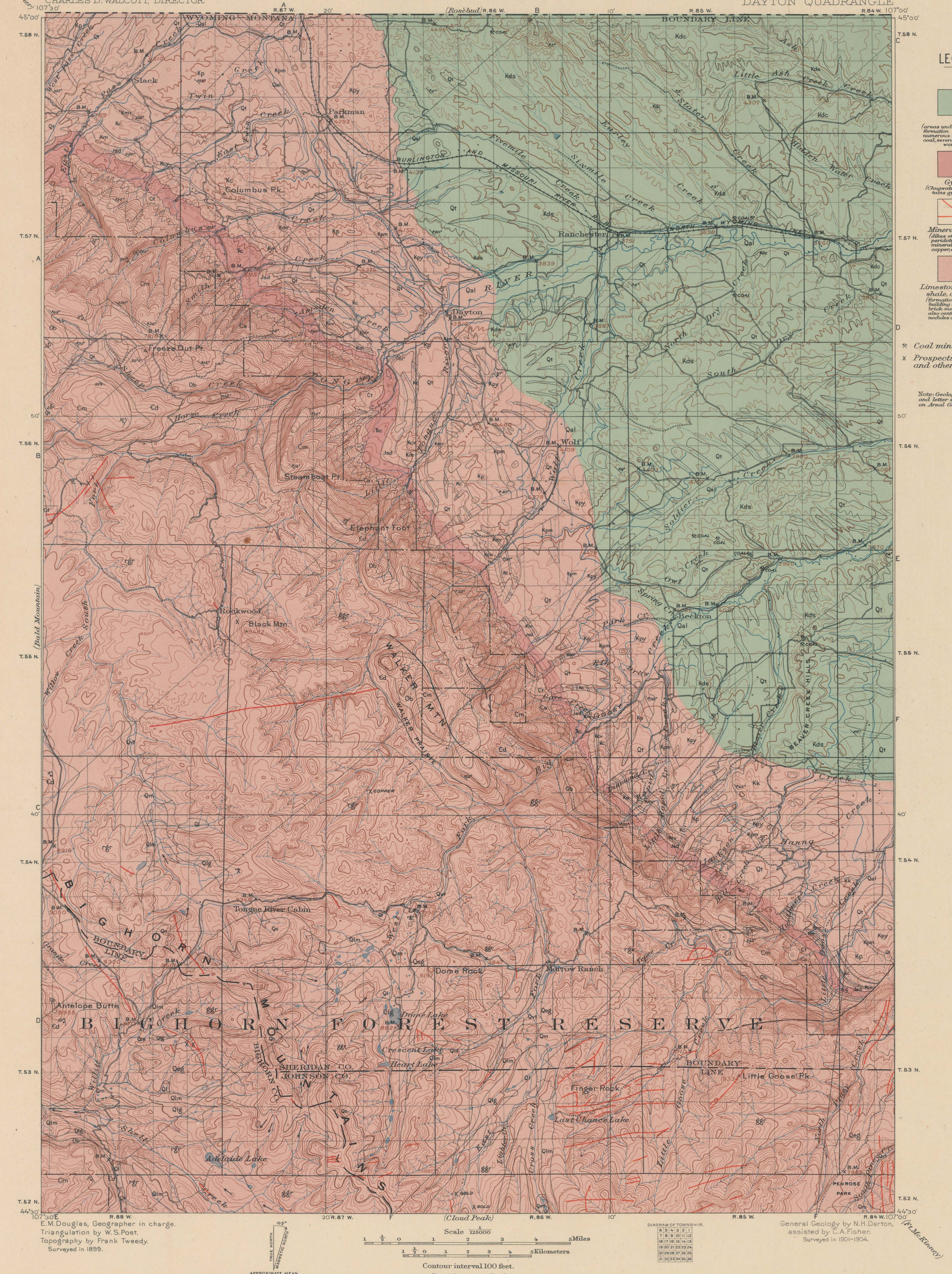
CHARLES D. WALCOTT, DIRECTOR

ECONOMIC GEOLOGY

WYOMING
DAYTON QUADRANGLE



LEGEND

Coal (areas underlain by De Smet formation which contains numerous beds of lignite coal, several of which are workable)

Gypsum (Chugwater formation contains gypsum deposits)

Mineralized dikes (dikes of diabase and peridotite more or less mineralized with gold, copper, and other metals)

Limestone, sandstone, shale, and granite (formations available for building stone and lime and brick making; certain beds also contain bentonite and nodules of lime phosphate)

⚒ Coal mines

x Prospects of copper, gold, and other metals

Note: *Geologic boundary lines and letter symbols explained on Areal Geology map.*

E. M. Douglas, Geographer in charge.
Triangulation by W. S. Post.
Topography by Frank Tweedy.
Surveyed in 1899.

APPROXIMATE MEAN DECLINATION 1902.

Scale $\frac{1}{125000}$

Contour interval 100 feet.
Datum is mean sea level.
Edition of May 1906.

General Geology by N. H. Darton,
assisted by C. A. Fisher.
Surveyed in 1901-1904.

U.S. GEOLOGICAL SURVEY
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STRUCTURE SECTIONS

WYOMING
DAYTON QUADRANGLE

Scale 1/125000
Miles
Kilometers
Edition of May 1906.
APPROXIMATE MEAN DECLINATION 1902.
DIAGRAM OF TOWNSHIP

E.M. Douglas, Geographer in charge.
Triangulation by W.S. Post.
Topography by Frank Tweedy.
Surveyed in 1899.

General Geology by N.H. Darton, assisted by C.A. Fisher.
Glacial Geology by E. Blackwelder, under the direction of R.D. Salisbury.
Surveyed in 1901-1904

LEGEND

SEDIMENTARY ROCKS

SHEET SYMBOL / SECTION SYMBOL

QUATERNARY

- Qal — **Alluvium** *(gravel sand, and loam; only the larger areas shown)*
- Qt — **Earlier terrace deposits** *(gravel and loam)*

Later glacial epoch

- Ql — **Lake deposits** *(mainly silt)*
- Qn — **Névé deposits** *(rock débris accumulated under former snow fields)*
- Qvt — **Valley trains** *(stream gravels)*
- Qlm — **Lateral moraines**
- Qm — **Terminal moraines**
- Qlg — **Later glacial drift** *(only the larger areas shown)*
- Qeg — **Earlier glacial drift** *(bowlders and sand; deposits in part discontinuous)*

CRETACEOUS

Upper Cretaceous

- Kdc, Kds / Kds — **De Smet formation** *(carbonaceous shale, sandstone, and coal beds, with burned-out coal or clinker beds, Kdc, in upper portion)*
- Kk — **Kingsbury conglomerate** *(local conglomerate composed largely of limestone)*
- Kpy / Kpy — **Piney formation** *(brown sandstone and shale)*
- Kpm / Kpm — **Parkman sandstone** *(light-buff, fine-grained, massive sandstone)*
- Kp / Kp — **Pierre shale** *(dark-gray shale or clay with concretions)*
- Kmr, Kc / Kc — **Colorado formation** *(dark-gray shale with thin brown sandstone near base, and Mowry member, Kmr, of hard shale and sandstone)*
- Kcv / Kcv — **Cloverly formation** *(coarse buff sandstone overlain by light-colored clay)*

CRETACEOUS OR JURASSIC

- Km — *Combined with Sundance formation on sections* — **Morrison formation** *(massive sandy shale, gray, greenish, and maroon, with several gray sandstone layers)*

JURASSIC

- Jsd / Jsm — **Sundance formation** *(soft buff sandstone and greenish shale with local limestone layers)*

UNCONFORMITY

TRIASSIC?

Permian?

- Ꞧc / Ꞧc — **Chugwater formation** *(soft red sandstone and red shale with thin limestone near top and base, and local gypsum deposits)*

CARBONIFEROUS

Pennsylvanian

- Ct / Cta — **Tensleep sandstone** *(hard, massive, white sandstone)*
- Ca — *Combined with Tensleep sandstone on sections* — **Amsden formation** *(cherty and fine limestone, with sandstone layers; red shale at base)*

Mississippian

- Cm / Cm — **Madison limestone** *(gray limestone, upper part massive and lighter colored)*

Legend is continued on the left margin.

LEGEND

SEDIMENTARY ROCKS *(continued)*

SHEET SYMBOL / SECTION SYMBOL

UNCONFORMITY

ORDOVICIAN

- Ob / Ob — **Bighorn limestone** *(massive, buff, siliceous limestone, overlain by thin-bedded limestone, gray sandstone at base)*

UNCONFORMITY

CAMBRIAN

Acadian

- Ꞓd / Ꞓd — **Deadwood formation** *(buff sandstone, green shale, limestone, and limestone conglomerate)*

IGNEOUS ROCKS

PRE-CAMBRIAN

- **Diabase** *(dikes cutting granite; only the larger dikes shown)*
- **Peridotite** *(dikes cutting granite)*
- rgr / gr — **Red granite** *(mostly of reddish color; merges into gray)*
- ggr — *Combined with red granite on sections* — **Gray granite** *(mostly of gray color; merges into red)*

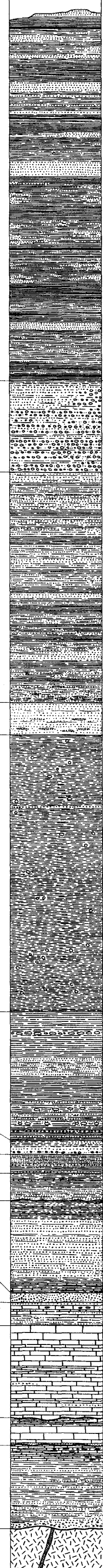
Faults

20° *Strike and dip of stratified rocks*
Glacial striae

COLUMNAR SECTION

GENERALIZED SECTION FOR THE BALD MOUNTAIN AND DAYTON QUADRANGLES.

SCALE: 1 INCH=1000 FEET.

System	Series	Formation Name.	Symbol.	Columnar Section.	Thickness in Feet.	Character of Rocks.	Character of Topography and Soils.
CRETACEOUS	UPPER CRETACEOUS	De Smet formation.	Kds		4000+	Gray to buff sandstones, mostly massive, and shale, partly carbonaceous, with numerous beds of lignite, in some areas more than 20 feet thick. Over wide areas the lignite near the surface has burned and converted the associated shale into clinker beds. Most of the clinker is red and resembles slag.	Low hills and ridges and wide valleys. The clinker beds often give rise to flat-topped buttes of moderate prominence. Sandy and loamy soil of moderate fertility, covered by sod.
		Kingsbury conglomerate.	Kk		0–1500	Conglomerate, composed largely of pebbles and bowlders of Madison, Bighorn, and Deadwood limestone and Deadwood limestone conglomerate with intercalated sand and clay. Thick in east-central portion of Dayton quadrangle and thins out to north.	Ridges of considerable prominence. Partly covered by sod.
		Piney formation.	Kpy		2500	Sandstones and carbonaceous shale with hard sandstone concretions. Sandstones vary from buff to dark gray and brown.	Slopes and ridges of moderate elevation. Sandy soil covered by sod.
		Parkman sandstone.	Kpm		350	Fine-grained, soft, massive, buff sandstone, with darker, hard concretions.	Low ridges. Thin, sandy soil.
		Pierre shale.	Kp		1500–3500	Gray shale with fossiliferous concretions and a few local sandstone layers.	Low hills and slopes. Clay soil, usually covered by sod.
		(Mowry shale member.) Colorado formation.	(Km) Kc		1050–1700	Gray shale. Dark-gray shale with lens-shaped concretions containing *Prionocyclus* and other ammonites. Fine-grained, slabby, gray sandstone and hard shale with many fish scales. Weathers light gray. Black and gray shales with oval iron-carbonate concretions and local bodies of sandstone. Dark, fissile shale, thin sandstones, and small spherical concretions.	Shale slopes, partly eroded into "badlands." Steep, narrow ridges, nearly bare of soil. Shale slopes and low buttes, often bare and partly eroded into "badlands."
	L. C.	Cloverly formation.	Kcv		30–300	Massive, coarse, gray sandstone, in part conglomeratic; variegated clay.	Low hogback ridges, wooded buttes, and cliffs. Scanty soil.
CRETACEOUS OR JURASSIC		Morrison formation.	Km		100–300	Massive green to maroon shale with thin beds of gray to buff sandstone.	Slopes and low hills. Scanty barren soil.
JURASSIC		Sundance formation. UNCONFORMITY	Jsd		250–350	Green shale and soft greenish gray sandstone with hard layers, often highly fossiliferous.	Low ridges and slopes with prominent ledges. Scanty but fertile soil.
TRIASSIC?	PERMIAN?	Chugwater formation.	Ʀc		750–1200	Red shale with several thin limestones. Soft, red sandstone, in part massive, with red shale partings. Red shale with two persistent limestone beds and gypsum deposits.	Ridges, slopes, buttes, and canyons at foot of the mountains. Scanty sterile soil.
CARBONIFEROUS	PENNSYLVANIAN	Tensleep sandstone.	Ct		30–150	Massive, cross-bedded white to buff sandstone.	Cliffs, buttes, rocky slopes, and canyon walls. Very sandy soil.
		Amsden formation.	Ca		150–350	White limestone, cherty above; red sandy shale at base.	Rocky slopes, canyon walls, and rounded ridges. Soil sandy.
	MISSISSIPPIAN	Madison limestone. UNCONFORMITY	Cm		1000	Massive light-colored limestone; weathers into pinnacles and caverns. Gray limestone, mostly hard and massive but in part slabby.	Castellated canyon walls and rocky slopes. Thin, rich soil. High rocky ridges and precipitous canyon walls. Soils thin but rich.
ORDOVICIAN		Bighorn limestone. UNCONFORMITY	Ob		300	White limestone, in part shaly, with corals of Richmond age. Massive, buff limestone of Trenton age, lying on white sandstone.	Canyon walls and rocky buttes. Little soil.
CAMBRIAN	ACADIAN	Deadwood formation.	€d		900	Gray slabby limestone with flat-pebble limestone conglomerate. Greenish shales and sandstones. Brown sandstone, mostly coarse.	Long slopes and high rounded hills. Clay soils, usually covered by sod, but treeless. Low cliffs and rocky surfaces. Scanty sandy soil.
PRE-CAMBRIAN		Granite.	gr			Red and gray granite, intersected by dikes, mostly diabase.	Rocky ridges and slopes with little soil.

N. H. DARTON,
Geologist.

ILLUSTRATIONS I

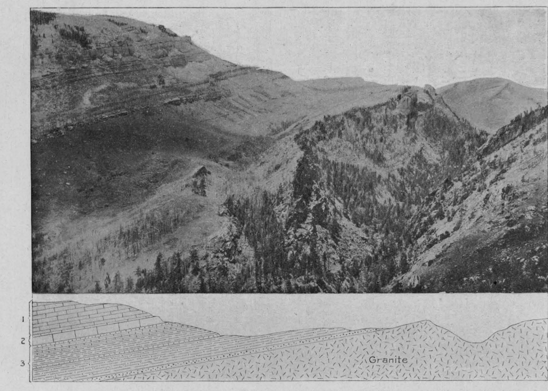


FIG. 1.—LOWER PALEOZOIC ROCKS ON GRANITE, EAST SLOPE OF BIGHORN MOUNTAINS. LOOKING SOUTH UP WOLF CREEK.

Granite ledges in center and to right. Deadwood formation (3), overlying the granite, is capped by characteristic cliffs of Bighorn limestone (2), and this by Madison limestone (1).

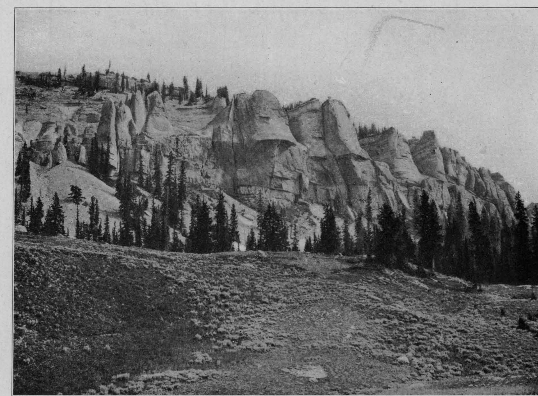


FIG. 2.—CLIFFS OF BIGHORN LIMESTONE ON NORTH SIDE OF TONGUE RIVER, EAST OF LITTLE BALD MOUNTAIN.

Shows unusual castellated form of weathering.

FIG. 3.—FLAT-PEBBLE LIMESTONE CONGLOMERATE FROM NEAR THE TOP OF THE DEADWOOD FORMATION.

FIG. 4.—CHARACTERISTIC WEATHERED SURFACE OF BIGHORN LIMESTONE.

The reticulated ridges are silica, the limestone between having been leached out. The area represented in the plate is about 4 by 5 feet.

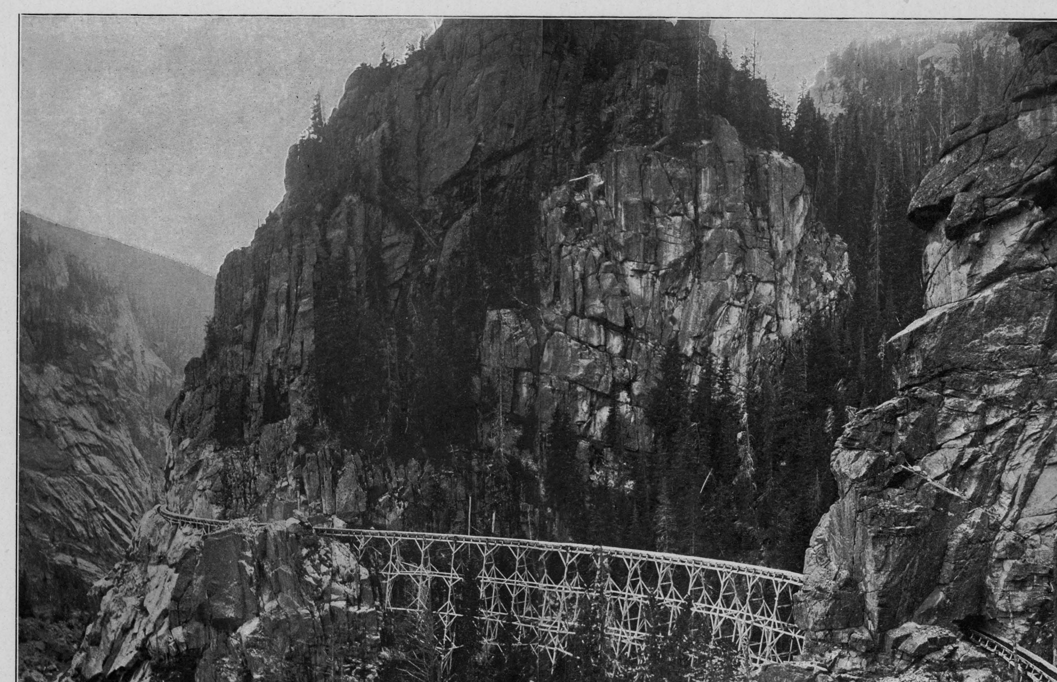


FIG. 5.—CANYON OF TONGUE RIVER CUT IN GRANITE, SOUTHWEST OF DAYTON, WYO.

Shows extensive jointing in the gray granite and method of taking out railroad ties by flume.

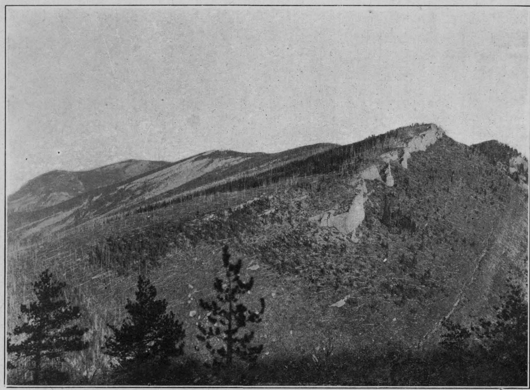


FIG. 6.—LOOKING SOUTH ALONG THE LIMESTONE FRONT RIDGE FROM NORTH SIDE OF CANYON OF LITTLE TONGUE RIVER.

Characteristic cliffs of Bighorn limestone, underlain by Deadwood beds to the right and overlain by Madison limestone to the left. Also shows extensive area of timber killed by forest fires.

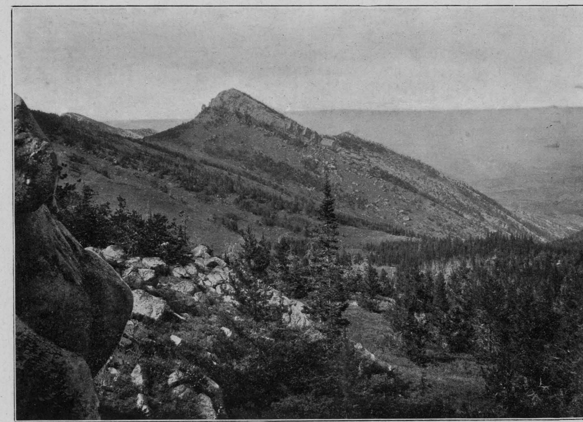


FIG. 7.—LOOKING NORTH ALONG THE LIMESTONE FRONT RIDGE OF THE BIGHORN MOUNTAINS AT HEAD OF LITTLE RAPID CREEK.

Bighorn limestone caps the prominent ridge; Deadwood formation occupies the depression to the left, extending to the granite in the foreground. Great Plains in the distance.

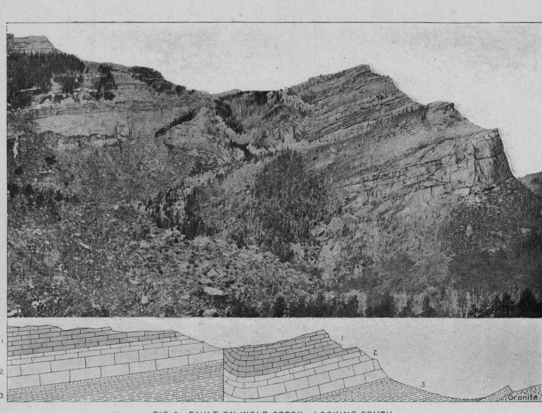


FIG. 8.—FAULT ON WOLF CREEK. LOOKING SOUTH.

The lower cliff to the right and that at the left (2) is Bighorn limestone, and the overlying ledges (1) are Madison limestone. Lower slopes (3), Deadwood formation. The fault in the middle of the view is about 300 feet. Beds on right of fault are somewhat upturned in the displacement.

FIG. 9.—PARTIAL CROSS SECTION OF LIMESTONE FRONT RIDGE, AT WOLF CREEK. LOOKING NORTH.

The prominent ledge of Bighorn limestone, on the left, is displaced by the sharp upward flexure near the middle of the view. Below is the Deadwood formation with a prominent medial sandstone member extending to the cliff in the foreground. In the lower slopes, to the left, is the granite.

FIG. 10.—BALD MOUNTAIN FROM THE SOUTH SIDE OF NORTH BEAVER CREEK.

The mountain is Deadwood formation lying on a broad shelf of granite, ledges of which appear in the canyon in the foreground. The granite shelf is the uncovered peneplain on which the Cambrian sediments were deposited.

FIG. 11.—CROSS SECTION OF ANTICLINE ON LITTLE BIGHORN RIVER. LOOKING NORTH.

The massive white ledges of Bighorn limestone (BB), rise nearly vertically in the center of picture and then, arching over the anticline, dip gently eastward. The slopes below are Deadwood formation, and beneath these appear granite ledges, which are prominent in foreground. The Bighorn limestone is overlain by Madison limestone and in the distance the overlying Amsden formation appears above.

FIG. 12.—SHARP FOLD EXPOSED IN CANYON OF NORTH BEAVER CREEK, NORTH OF CLOVERLY, WYO. LOOKING NORTH.

Flexed beds of Bighorn and Madison limestones are exposed in the canyon, and the Madison limestone again appears in the middle distance and on the slope at the extreme left, forming a syncline. The sharp knob near the middle of the view is composed of overlying Amsden formation in the syncline.

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84	Ditney	Indiana	25
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