DEPARTMENT OF THE INTERIOR

UNITED STATES GEOLOGICAL SURVEY

CHARLES D. WALCOTT, DIRECTOR

GEOLOGIC ATLAS

OF THE

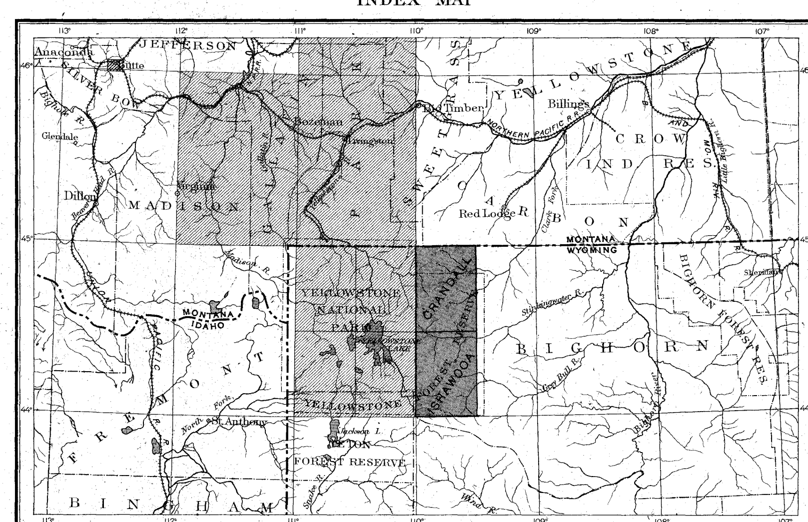
UNITED STATES

ABSAROKA FOLIO

CRANDALL AND ISHAWOOA QUADRANGLES

WYOMING

INDEX MAP



SCALE: 40 MILES-1 INCH

AREA OF THE ABSAROKA FOLIO

AREA OF OTHER PUBLISHED FOLIOS

LIST OF SHEETS

DESCRIPTION — TOPOGRAPHY — HISTORICAL GEOLOGY — COLUMNAR SECTIONS — SPECIAL ILLUSTRATIONS

FOLIO 52 — LIBRARY EDITION — ABSAROKA

WASHINGTON, D. C.

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

1899

EXPLANATION.

The Geological Survey is making a geologic map of the United States, which necessitates the preparation of a topographic base map. The two are being issued together in the form of an atlas, the parts of which are called folios. Each folio consists of a topographic base 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 horizontal outline, or contour, of all slopes, and to indicate their grade or degree of steepness. This is done by lines connecting points of equal elevation above mean sea-level, the lines being drawn at regular vertical intervals. These lines are called *contours*, and the uniform vertical 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:

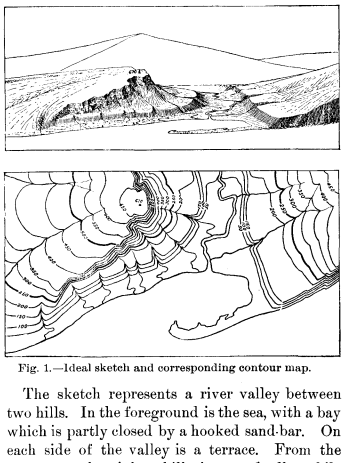


Fig. 1.—Ideal sketch and corresponding contour map.

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 in a precipice. Contrasted with this precipice is the gentle descent of the left-hand slope. 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 approximately a certain height above sea-level. In this illustration the contour interval is 50 feet; therefore the contours are drawn at 50, 100, 150, 200 feet, and so on, above sea-level. Along the contour at 250 feet lie all points of the surface 250 feet above sea; and similarly with any other contour. In the space between any two contours are found all 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 nearly all the contours are numbered. Where this is not possible, certain contours—say every fifth one—are accentuated and numbered; the heights of others may then be ascertained by counting up or down from a numbered contour.

2. Contours define the forms of slopes. Since contours are continuous horizontal lines conforming to the surface of the ground, they wind smoothly about smooth surfaces, recede into all reentrant angles of ravines, and project in passing about prominences. The 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 vertical 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 used 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 the stream flows the year round 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, and artificial details, are printed in black.

Scales.—The area of the United States (excluding Alaska) is about 3,025,000 square miles. On a map with the scale of 1 mile to the inch this would cover 3,025,000 square inches, and to accommodate it the paper dimensions would need to be 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 $\frac{1}{63,360}$. Both of these methods are used on the maps of the Geological Survey.

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 and corresponds nearly to 1 square mile; on the scale $\frac{1}{125,000}$, to about 4 square miles; and on the scale $\frac{1}{250,000}$, to about 16 square miles. At the bottom of each atlas sheet the scale is expressed in three different ways, one being a graduated line representing miles and parts of miles in English inches, another indicating distance in the metric system, and a third giving the fractional scale.

Atlas sheets and quadrangles.—The map is being published in atlas sheets of convenient size, which are bounded by parallels and meridians. The corresponding four-cornered portions of territory 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-quarter 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, respectively.

The atlas sheets, being only parts of one map of the United States, are laid out without regard to the boundary lines of the States, counties, or 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 sheet.—Within the limits of scale the topographic sheet is an accurate and characteristic delineation of the relief, drainage, and culture of the district represented. Viewing the landscape, map in hand, every characteristic feature of sufficient magnitude should be recognizable. It should guide the traveler; serve the investor or owner who desires to ascertain the position and surroundings of property to be bought or sold; save the engineer preliminary surveys in locating roads, railways, and irrigation ditches; provide educational material for schools and homes; and serve many of the purposes of a map for local reference.

THE GEOLOGIC MAP.

The maps representing areal geology show by colors and conventional signs, on the topographic base map, the distribution of rock formations on the surface of the earth, and the structure-section map shows their underground relations, as far as known, and in such detail as the scale permits.

KINDS OF ROCKS.

Rocks are of many kinds. The original crust of the earth was probably composed of *igneous rocks*, and all other rocks have been derived from them in one way or another.

Atmospheric agencies gradually break up igneous rocks, forming superficial, or *surficial*, deposits of clay, sand, and gravel. Deposits of this class have been formed on land surfaces since the earliest geologic time. Through the transporting agencies of streams the surficial materials of all ages and origins are carried to the sea, where, along with material derived from the land by the action of the waves on the coast, they form *sedimentary rocks*. These are usually hardened into conglomerate, sandstone, shale, and limestone, but they may remain unconsolidated and still be called "rocks" by the geologist, though popularly known as gravel, sand, and clay.

From time to time in geologic history igneous and sedimentary rocks have been deeply buried, consolidated, and raised again above the surface of the water. In these processes, through the agencies of pressure, movement, and chemical action, they are often greatly altered, and in this condition they are called *metamorphic rocks*.

Igneous rocks.—These are rocks which have cooled and consolidated from a liquid state. As has been explained, sedimentary rocks were deposited on the original igneous rocks. Through the igneous and sedimentary rocks of all ages molten material has from time to time been forced upward to or near the surface, and there consolidated. When the channels or vents into which this molten material is forced do not reach the surface, it either consolidates in cracks or fissures crossing the bedding planes, thus forming dikes, or else spreads out between the strata in large bodies, called sills or laccoliths. Such rocks are called *intrusive*. Within their rock enclosures they cool slowly, and hence are generally of crystalline texture. When the channels reach the surface the lavas often flow out and build up volcanoes. These lavas cool rapidly in the air, acquiring a glassy or, more often, a partially crystalline condition. They are usually more or less porous. The igneous rocks thus formed upon the surface are called *extrusive*. Explosive action often accompanies volcanic eruptions, causing ejections of dust or ash and larger fragments. These materials when consolidated constitute breccias, agglomerates, and tuffs. The ash when carried into lakes or seas may become stratified, so as to have the structure of sedimentary rocks.

The age of an igneous rock is often difficult or impossible to determine. When it cuts across a sedimentary rock, it is younger than that rock, and when a sedimentary rock is deposited over it, the igneous rock is the older.

Under the influence of dynamic and chemical forces an igneous rock may be metamorphosed. The alteration may involve only a rearrangement of its minute particles or it may be accompanied by a change in chemical and mineralogic composition. Further, the structure of the rock may be changed by the development of planes of division, so that it splits in one direction more easily than in others. Thus a granite may pass into a gneiss, and from that into a mica-schist.

Sedimentary rocks.—These comprise all rocks which have been deposited under water, whether in sea, lake, or stream. They form a very large part of the dry land.

When the materials of which sedimentary rocks are composed are carried as solid particles by water and deposited as gravel, sand, or mud, the deposit is called a mechanical sediment. These may become hardened into conglomerate, sandstone, or shale. When the material is carried in solution by the water and is deposited without the aid of life, it is called a chemical sediment; if deposited with the aid of life, it is called an organic sediment. The more important rocks formed from chemical and organic deposits are limestone, chert, gypsum, salt, iron ore, peat, lignite, and coal. Any one of the above sedimentary deposits may be separately formed, or the different materials may be intermingled in many ways, producing a great variety of rocks.

Sedimentary rocks are usually made up of layers or beds which can be easily separated. These layers are called *strata*. Rocks deposited in successive 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 over wide expanses, and as it rises or subsides the shore-lines of the ocean are changed: areas of deposition may rise above the water and become land areas, and land areas may sink below the water and become areas of deposition. If North America were gradually to sink a thousand feet the sea would flow over the Atlantic coast and the Mississippi and Ohio valleys from the Gulf of Mexico to the Great Lakes; the Appalachian Mountains would become an archipelago, and the ocean's shore would traverse Wisconsin, Iowa, and Kansas, and extend thence to Texas. More extensive changes than this have repeatedly occurred in the past.

The character of the original sediments may be changed by chemical and dynamic action so as to produce metamorphic rocks. In the metamorphism of a sedimentary rock, just as in the metamorphism of an igneous rock, the substances of which it is composed may enter into new combinations, or new substances may be added. When these processes are complete the sedimentary rock becomes crystalline. Such changes transform sandstone to quartzite, limestone to marble, and modify other rocks according to their composition. A system of parallel division planes is often produced, which may cross the original beds or strata at any angle. Rocks divided by such planes are called slates or schists.

Rocks of any period of the earth's history may be more or less altered, but the younger formations have generally escaped marked metamorphism, and the oldest sediments known, though generally the most altered, in some localities remain essentially unchanged.

Surficial rocks.—These embrace the soils, clays, sands, gravels, and bowlders that cover the surface, whether derived from the breaking up or disintegration of the underlying rocks by atmospheric agencies or from glacial action. Surficial rocks that are due to disintegration are produced chiefly by the action of air, water, frost, animals, and plants. They consist mainly of the least soluble parts of the rocks, which remain after the more soluble parts have been leached out, and hence are known as residual products. Soils and subsoils are the most important. Residual accumulations are often washed or blown into valleys or other depressions, where they lodge and form deposits that grade into the sedimentary class. Surficial rocks that are due to glacial action are formed of the products of disintegration, together with bowlders and fragments of rock rubbed from the surface and ground together. These are spread irregularly over the territory occupied by the ice, and form a mixture of clay, pebbles, and bowlders which is known as till. It may occur as a sheet or be bunched into hills and ridges, forming moraines, drumlins, and other special forms. Much of this mixed material was washed away from the ice, assorted by water, and redeposited as beds or trains of sand and clay, thus forming another gradation into sedimentary deposits. Some of this glacial wash was deposited in tunnels and channels in the ice, and forms characteristic ridges and mounds of sand and gravel, known as osars, or eskers, and kames. The material deposited by the ice is called glacial drift; that washed from the ice onto the adjacent land is called modified drift. It is usual also to class as surficial rocks the deposits of the sea and of lakes and rivers that were made at the same time as the ice deposit.

AGES OF ROCKS.

Rocks are further distinguished according to their relative ages, for they were not formed all at one time, but from age to age in the earth's history. Classification by age is independent of origin; igneous, sedimentary, and surficial rocks may be of the same age.

When the predominant material of a rock mass is essentially the same, and it is bounded by rocks of different materials, it is convenient to call the mass throughout its extent a *formation*, and such a formation is the unit of geologic mapping.

Several formations considered together are designated a *system*. The time taken for the deposition of a formation is called an *epoch*, and the time taken for that of a system, or some larger fraction of a system, a *period*. The rocks are mapped by formations, and the formations are classified into systems. The rocks composing a system and the time taken for its deposition are given the same name, as, for instance, Cambrian system, Cambrian period.

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

Strata often contain the remains of plants and animals which lived in the sea or were washed from the land into lakes or seas or were buried in surficial deposits on the land. Rocks that contain the remains of life are called fossiliferous. By studying these remains, or fossils, it has been found that the species of each period of the earth's history have to a great extent differed from those 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 formations are remote one from the 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 rocks of different areas, provinces, and continents, afford the most important means for combining local histories into a general earth history.

Colors and patterns.—To show the relative ages of strata, the history of the sedimentary rocks is divided into periods. The names of the periods in proper order (from new to old), with the color or colors and symbol assigned to each, are given in the table in the next column. The names of certain subdivisions of the periods, frequently used in geologic writings, are bracketed against the appropriate period name.

To distinguish the sedimentary formations of any one period from those of another the patterns for the formations of each period are printed in the appropriate period-color, with the exception of the first (Pleistocene) and the last (Archean). The formations of any one period, excepting the Pleistocene and the Archean, are distinguished from one another by different patterns, made of parallel straight lines. Two tints of the period-color are used: a pale tint (the underprint) is printed evenly over the whole surface representing the period; a dark tint (the overprint) brings out the different patterns representing formations.

PERIOD.	SYMBOL.	COLOR.
Pleistocene	P	Any colors.
Neocene { Pliocene / Miocene }	N	Buffs.
Eocene (including Oligocene)	E	Olive-browns.
Cretaceous	K	Olive-greens.
Juratrias { Jurassic / Triassic }	J	Blue-greens.
Carboniferous (including Permian)	C	Blues.
Devonian	D	Blue-purples.
Silurian (including Ordovician)	S	Red-purples.
Cambrian	Є	Pinks.
Algonkian	A	Orange-browns.
Archean	Æ	Any colors.

Each formation is furthermore given a letter-symbol of the period. In the case of a sedimentary formation of uncertain age the pattern is printed on white ground in the color of the period to which the formation is supposed to belong, the letter-symbol of the period being omitted.

The number and extent of surficial formations of the Pleistocene render them so important that, to distinguish them from those of other periods and from the igneous rocks, patterns of dots and circles, printed in any colors, are used.

The origin of the Archean rocks is not fully settled. Many of them are certainly igneous. Whether sedimentary rocks are also included is not determined. The Archean rocks, and all metamorphic rocks of unknown origin, of whatever age, are represented on the maps by patterns consisting of short dashes irregularly placed. These are printed in any color, and may be darker or lighter than the background. If the rock is a schist the dashes or hachures may be arranged in wavy parallel lines. If the rock is known to be of sedimentary origin the hachure patterns may be combined with the parallel-line patterns of sedimentary formations. If the metamorphic rock is recognized as having been originally igneous, the hachures may be combined with the igneous pattern.

Known igneous formations are represented by patterns of triangles or rhombs printed in any brilliant color. If the formation is of known age the letter-symbol of the formation is preceded by the capital letter-symbol of the proper period. If the age of the formation is unknown the letter-symbol consists of small letters which suggest the name of the rocks.

THE VARIOUS GEOLOGIC SHEETS.

Historical geology sheet.—This sheet 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 particular colored pattern and its letter-symbol on the map 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 symbols and names are arranged, in columnar form, according to the origin of the formations—surficial, sedimentary, and igneous—and within each group they are placed in the order of age, so far as known, the youngest at the top.

Economic geology sheet.—This sheet represents the distribution of useful minerals, the occurrence of artesian water, or other facts of economic interest, showing their relations to the features of topography and to the geologic formations. All the formations which appear on the historical geology sheet are shown on this sheet 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 symbol for mines is introduced at each occurrence, accompanied by the name of the principal mineral mined or of the stone quarried.

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 name 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 the formation of rocks, and having traced out the relations among beds on the surface, he can infer their relative positions after they pass beneath the surface, draw sections which represent the structure of the earth to a considerable depth, and construct a diagram exhibiting 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:

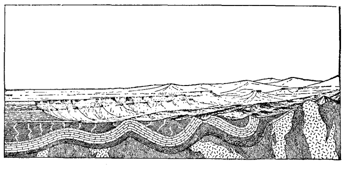


Fig. 2.—Sketch showing a vertical section in the front of the picture, with a landscape beyond.

The figure represents a landscape which is cut off sharply in the foreground by a vertical plane that cuts a section so as to show the underground relations of the rocks.

The kinds of rock are indicated in the section 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·

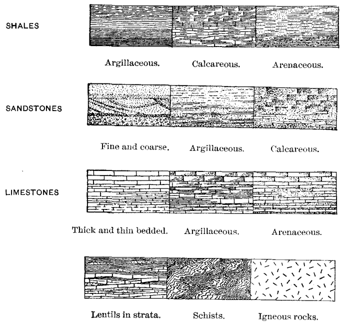


Fig. 3.—Symbols used to represent different kinds of rock.

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 beds of sandstone that rise to the surface. The upturned edges of these beds form the ridges, and the intermediate valleys follow the outcrops of limestone and calcareous shales.

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.

When strata which are thus inclined are traced underground in mining, or by inference, it is frequently observed that they form troughs or arches, such as the section shows. But these sandstones, shales, and limestones were deposited beneath the sea in nearly flat sheets. That they are now bent and folded is regarded as proof that forces exist which have from time to time caused the earth's surface to wrinkle along certain zones.

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

In fig. 2 there are three sets of formations, distinguished by their underground relations. The first of these, seen at the left of the section, is the 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 swelled upward 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 strata thus rest upon an eroded surface of older strata 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 this pressure and intrusion of igneous rocks have not affected the overlying strata of the second set. Thus it is evident that an interval of considerable duration 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, marking a time interval between two periods of rock formation, is another unconformity.

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

Columnar-section sheet.—This sheet contains a concise description of the rock formations which occur in the quadrangle. The diagrams and verbal statements form a summary of the facts relating to the character of the rocks, to the thicknesses of the formations, and to the order of accumulation of successive deposits.

The rocks are described under the corresponding heading, and their characters are indicated in the columnar diagrams by appropriate symbols. The thicknesses of formations are given under the heading "Thickness in feet," in figures which state the least and greatest measurements. The average thickness of each formation 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 is placed at the bottom of the column, the youngest at the top, and igneous rocks or other formations, when present, are indicated in their proper relations.

The formations are combined into systems which correspond with the periods of geologic history. Thus the ages of the rocks are shown, and also the total thickness of each system.

The intervals of time which correspond to events of uplift and degradation and constitute interruptions of deposition of sediments may be indicated graphically or by the word "unconformity," printed in the columnar section.

Each formation shown in the columnar section is accompanied by its name, a description of its character, and its letter-symbol as used in the maps and their legends.

CHARLES D. WALCOTT,
Director.

Revised June, 1897.

DESCRIPTION OF THE ABSAROKA QUADRANGLE.

GEOGRAPHY AND TOPOGRAPHY.

Location and extent of district.

The area of country mapped and described in this folio includes the Ishawooa and Crandall quadrangles, each 30′ by 30′ in extent, and is situated in the northwestern part of the State of Wyoming, the northern line of the Crandall quadrangle coinciding with the boundary between Wyoming and Montana. The Ishawooa quadrangle lies between parallels 109° 30′ and 110° and meridians 44° and 44° 30′, the Crandall quadrangle lying directly to the north of it. Their combined area comprises 1706 square miles. The eastern boundary of the Yellowstone National Park, as defined in the statute establishing the Park, lies 10 miles east of Yellowstone Lake, a line nearly coincident with the meridian of 110°. Along this line the Park adjoins for its entire length the country described in this folio.

Yellowstone Timber Reservation.

The Absaroka district derives its name from the Absaroka Mountains, the prominent physical feature of the region. Beyond the Park limits the Yellowstone Park Forest Reservation embraces most of the range, having been set aside by President Harrison under the act of March 3, 1891, as the first forest reserve established by the General Government in the Rocky Mountains. As this reserve surrounds the Park on the east and south, and stands so closely identified with it, the Secretary of the Interior has placed it under the supervision of the Park Superintendent, the Park rules applying to the entire area. The boundaries of the reservation, as defined in the proclamation of the President, are laid down upon the folio sheets.

Absaroka Range.

With the exception of a relatively small area in the northeast corner of the Crandall quadrangle, this entire region of country may be considered as belonging to the Absaroka Range. The Absarokas, so called from the Indian name of the Crow nation, extend in a north-south direction for over 80 miles. With an average width of nearly 50 miles, they stretch eastward beyond the limits of the area mapped, while westward long, rugged ridges fall away toward Yellowstone River and Lake. At the southern end the range, which is made up of enormous outflows of volcanic material, is structurally so closely connected with the Wind River Plateau and Owl Mountains that no well-defined line of demarcation can be drawn. On the other hand, at the northern end the broad valley of Clark Fork of the Yellowstone sharply separates the range from the Beartooth Mountains, the river flowing closely under the cliffs that mark the northern escarpments of this vast pile of lavas.

The Absarokas present a broad, deeply eroded plateau rather than a sharply outlined ridge, with irregular lateral spurs putting out from the crest of a high well-defined watershed. Along the east side this mass of lava rises out of the plain from an elevation of about 5000 feet, while on the west slope the adjacent level is clearly indicated by Yellowstone Lake and the wide bottom of the Upper Yellowstone, which may be taken as 8000 feet. Along the northern portion of the Absarokas the western base is defined by the valley of Lamar River, with an approximate elevation of 7000 feet above sea level.

Peaks and remnants of table-lands.

Excessive denudation has carved this broad plateau-like body into a complex mass of rough and rugged peaks and of jagged and broken pinnacled mountains interspersed between long, crenulated buttresses with bold escarpments rising above the general level of the surrounding country. Gently inclined tables, in many instances inaccessible by reason of their abrupt encircling walls, everywhere characterize the larger physical features of the range. The higher peaks and castellated remnants of table-lands do not follow in definite trend, but lie scattered over the entire region. Needle Mountain, situated in the southeast corner of this dissected plateau, and Trout and Dead Indian peaks, near the eastern boundary, attain elevations of over 12,000 feet above sea level. Numerous peaks with commanding outlooks reach altitudes of more than 11,000 feet. Several of the more prominent points lie within the Park, presenting an imposing panorama of high sierras dotted over with snow fields, rising 3000 feet above the level of Yellowstone Lake. Index Peak, the highest point in the northern Absarokas, attains 11,740 feet and stands out conspicuously as a slender pinnacle, seen far and wide and easily recognized by its graceful outlines. A few mountain trails, seldom used, lead over into the Park, but until recent years the Absarokas presented an unbroken barrier to travel along the entire eastern side of the Park. For railway or wagon traffic the best natural route across the crest of the mountains from the Yellowstone follows Soda Butte Creek to Cook City in Montana, just beyond the boundaries of the area mapped, and thence down Clark Fork Valley to the open plain. A striking feature of this region is the many deeply trenched canyons, which in some instances have penetrated the lavas to a depth of 4000 and 5000 feet, presenting narrow defiles with somber, rugged cliffs of varied form and outline.

Watershed.

The main watershed of the plateau follows a sinuous course with sweeping curves, maintaining, in general, a north-south direction. At the northern end of the range the divide lies wholly east of the Park, Index Peak and Hurricane Ridge draining toward Clark Fork. Continuing southward the watershed sweeps far to the west, and, entering the Park, curves in and out along the crowning crest of the ridge that rises abruptly above Yellowstone Lake. It again curves eastward, encircling in its winding course a large area of country which sends its waters through Thorofare Creek into the Upper Yellowstone. Above the junction of the two streams the Thorofare drains more country than the Yellowstone, while the amount of water carried by each is about the same.

Drainage.

Three main streams—Clark Fork, Stinkingwater, and Shoshone rivers—carry off the waters from the east side. Clark Fork and its two principal tributaries, Sunlight and Crandall creeks, drain all the northeastern portion of the country, being fed by numerous mountain torrents both from the high plateaus of the Absarokas and from the southern slopes of the Beartooth Range. All the central portion of the Absarokas drains eastward by the Stinkingwater, a clear, sparkling river flowing through a picturesque valley hemmed in by rugged walls. Stinkingwater is one of the oldest geographical names in the State of Wyoming, dating back to the days of those gallant explorers, Lewis and Clark. In those days it was designated by the fur trappers the River by the Stinkingwater—a hot sulphurous spring well known as a landmark near where the river leaves the high mountain for the open plain. The trappers are said to have taken the name from the Indians. The Shoshone River drains all the southern portion of the Absarokas represented on the map. It rises on the Wind River Plateau close by Younts Peak, near the sources of the Yellowstone. It enters the Ishawooa quadrangle at the southwest corner and flows northeasterly through the most imposing and profound gorge in the mountains, the summit of Needle Mountain rising with precipitous slopes over 5000 feet above the bed of the stream. After leaving the rugged canyon, the river meanders through a broad plain, dotted with meadows and patches of agricultural lands. Sheer cliffs of basalt and breccia, in places exposing nearly 3000 feet of vertical section, border both sides of the valley for many miles. Finally, just beyond the eastern limit of the area mapped, the Shoshone joins the Stinkingwater, and thence, through the Bighorn, pours into the broad Yellowstone in Montana.

Beartooth Mountains.

Only a small portion of the Beartooth Mountains, which form one of the most prominent physical features of this part of the country, comes within the Absaroka district. The entire crest of this range and all the higher summits are situated in Montana, and some of them stand among the loftiest peaks to be found in the State. Beartooth Butte, with an altitude of 10,500 feet above sea level, is the highest point of the mountains in Wyoming. The slopes of the range fall away in broken, accidented hills and ridges toward Clark Fork. Numerous streams, fed from the snow fields and lakes of the higher alpine ridges, flow southward and empty into the main stream.

Forests.

Coniferous forests cloth the greater part of the Absaroka Range, at least that portion included within the Yellowstone Park and Yellowstone Park Forest Reservation. Interspersed through these denser areas of forest occur numerous gently inclined lava slopes, barren of arborescent growth, while open glades abound everywhere. Isolated peaks and broken crests of the main elevated ridges stand out above timber line, with only here and there a scattered and stunted growth of weather-beaten trees. Along the western side of the range, toward the Park, the slopes are generally forest clad, but eastward the timber becomes less and less dense and bare ridges are more and more apparent, with the lower slopes covered by luxuriant grasses. If the lower eastern slopes are excluded, together with the barren area around Sunlight Basin, about 80 per cent of the forest reserve is forest covered. The somber, black *Pinus murrayana* is the prevailing tree of the Absaroka Range. Associated with it, but generally found at higher altitudes, occur considerable bodies of *Pinus flexilis*, and upon still higher ridges and exposed slopes the variety *P. albicaulis*, with its smooth white bark. The balsam, *Abies subalpina*, and spruce, *Picea engelmanni*, occur over all parts of the range, but nowhere grow to any great height or size, although many of the trees appear uncommonly graceful in the more open basins and sheltered park-like areas. Of all trees the Douglas fir, *Pseudotsuga taxifolia*, is the most stately and vigorous in its growth, developing a dark, rugged bark and towering above all its companions of the forest, but it is found only in small numbers scattered over widely separated areas. Nowhere in the Absarokas can timber be said to be of superior quality, but at some future time, if judiciously cut, it may meet all the requirements for local consumption. For maintaining and regulating the water supply of the Absarokas these forests are of incalculable value. But little land in the Absarokas is available for the purposes of agriculture. The canyon bottoms consist for the most part of narrow, rocky defiles piled up with bowlders and without any covering of soil. In broad, open valleys patches of rich meadow lands border the streams, but, owing to the elevation of the country and the consequent severity of the climate, only isolated areas are suitable for the cultivation of cereals. Many of the intermontane valleys and gently inclined lava slopes, notably Shoshone Valley and Sunlight Basin, afford excellent grazing lands capable of furnishing pasturage for thousands of cattle and horses.

Meadow and grazing lands.

GEOLOGY.

Crystalline granite, schist, and gneiss.

Archean rocks.—Crystalline granites, schists, and gneisses represent the oldest rock masses in this region. They are regarded as constituting a part of the earliest rock formations of the crust of the earth, and, like similar crystalline masses elsewhere in Montana and Wyoming, are supposed to be of Archean age. In the area of country described in this folio these Archean rocks are found only in the northeastern portion of the Crandall quadrangle, where they constitute the massive body of the Beartooth Mountains. They are entirely unknown in the Absaroka Range, although other exposures of the Archean occur at short distances to the eastward, notably at Cedar Mountain, and to the southward they come to the surface, occupying large areas in the Owl Mountains. The Beartooth Mountains, at least so much of them as comes within the Crandall quadrangle, consist almost wholly of mica-gneiss, amphibolites, and schists, distinctly light in color, well shown in the sheer cliffs exposed along the mountain slopes and in the polished glaciated hills rising above the valley of Clark Fork.

Composition and structure of the Archean rocks.

In mineral composition, texture, and physical features the Archean rocks exhibit constant variations and modifications. Much of the rock structure consists of a mingling of both coarse and fine quartz and feldspar, with varying proportions of ferromagnesian minerals, chiefly hornblende and mica. Over large areas some of the rock masses are distinctly bedded, while in others indications of structure appear to be wanting. Evidences of movement in the material and of the rearrangement of the constituent minerals abound, such as the distortion of the individual crystals and the gnarled and twisted appearance of the segregated patches of quartz, feldspar, and mica. Frequently the effect of lateral compression is clearly brought out by minute faulting and folding. Evidences of metamorphism, caused by movement accompanied by pressure, may be seen all along the southern slopes and in the walls of the lateral canyons. The stream bed of Clark Fork, which flows easterly along the base of the range and serves as a well-defined line of demarcation between the Beartooth Mountains and the Absarokas, lies wholly in Archean rocks. Just below the mouth of Crandall Creek the river falls away rapidly and enters an imposing gorge known as Clark Fork Canyon. A partial view of the canyon is shown in fig. 4 of the page of illustrations, a reproduction of a photograph taken from a commanding knoll, looking westward up the valley. It represents a narrow defile, with nearly perpendicular walls rising in places over 1200 feet above the stream. Occasionally benches and shelves carved in hard gneisses parallel with the canyon break the abrupt rock face. The canyon walls stand out in buttresses of grand ruggedness, piled one above another in a most impressive manner. The canyon affords an exceptionally fine opportunity for a study of the Archean rocks and their forms of erosion in recent canyon cutting, the gorge being of much later origin than the Archean platform of the broad valley above.

SEDIMENTARY ROCKS.

Paleozoic sandstones, limestones, and clays.

Back from the brink of Clark Fork Canyon the Archean rocks stretch away in rounded hills and mounds, dotted over with lakes and ponds of glacial origin. Upon the uneven and deeply eroded surface of this Archean continental land mass there was deposited unconformably a series of sediments consisting of sandstones, limestones, and clays, which were laid down partly as coarse material in shallow waters as inshore deposits and partly as finer sediments, mainly clays and muds, accumulated as offshore deposits in more tranquil and deeper seas. These overlying sediments represent, so far as known, a great thickness of conformable Paleozoic rocks, extending from the basal beds of middle Cambrian age through the Silurian and Devonian and well on into limestones of the Carboniferous period. On the south side of Clark Fork Valley these Paleozoic rocks are well shown in a long line of cliffs which border the valley for its entire length, extending from Pilot Peak far to the east of Russell Peak. It is this line of cliffs which defines the northern mural face of the Absaroka Range, its present configuration being in great part due to the action of glacial ice in its movement down the valley. The sedimentary beds lie inclined to the southward at slight angles, varying from 1° to 5°, dipping away from the Archean mass of the Beartooth Mountains and passing beneath the accumulation of Tertiary lavas of the Absaroka Range.

Erosion, followed by lava flows.

After these Paleozoic rocks were lifted above the sea, erosion, cutting very irregularly upon the sediments, carried away varying thicknesses of strata, leaving rocks of very different ages exposed at the surface. These in turn were again protected from atmospheric agencies by the pouring out of the more recent breccias and lavas, which in places rest directly upon the Cambrian rocks and in others rest upon the Silurian, Devonian, or Carboniferous. The most complete exposure of the Paleozoic beds is shown at Hunter Peak, lying in the angle between Crandall Creek and Clark Fork Valley. They attain a thickness of about 2000 feet. Here the beds rise boldly above the stream, with the Cambrian sandstones at the base and the Carboniferous limestones forming the summit of the mountain. At numerous places along this northern escarpment deep lateral canyons, carrying streams coming down from the Absarokas, break through the lavas and cut into the underlying sedimentary rocks, in which case the strata are frequently seen exposed for several miles up the valley, notably along the different tributaries of Crandall Creek.

Sedimentary cliffs.

In fig. 5 of the page of illustrations will be found a reproduction from a photograph of a characteristic view of the sedimentary cliffs. Along the base of the cliffs the contact between the crystalline and sedimentary rocks is largely concealed by forest growth, but the irregular broken line between the light-colored limestone strata and the somber lavas is sharply defined. Persistency in the continuity of certain beds is also well shown in the illustration by the conspicuous bluffs of Cambrian limestones, and by the inclined benches carved out of the interbedded clays and shales. This line of cliffs is maintained for over 25 miles, stretching from the Snowy Range eastward to the outlet of Sunlight Basin, beyond the limits of the area mapped.

Paleozoic rocks north of Clark Fork.

North of the river Paleozoic rocks are known in only two localities, resting upon the Archean slopes of Beartooth Mountain, and of these the picturesque mass of Beartooth Butte is the more prominent. The second locality is the angle between Beartooth Creek and Clark Fork Canyon, where a slightly inclined limestone table is found. In both these areas the uppermost rocks consist of Cambrian strata, all later beds having been removed by erosion. The only other locality in the Absaroka district where Paleozoic rocks occur is Sunlight Basin. Here there is a broad, plateau-like mass of nearly horizontal rocks, consisting of Devonian and Carboniferous strata. The underlying rocks are, so far as known, nowhere exposed. The relation between the sedimentary rocks and the Tertiary lavas is well shown, the latter filling up all the uneven surfaces in the sedimentary beds and in places rising high above the level of the limestone plateau. The Paleozoic cliffs of the Absaroka continue westward into Yellowstone Park, where they present much the same physical features of sedimentation, and where they have been studied and compared with other localities of similar rocks in the Park. Identical geological horizons have been correlated, and in consequence the same nomenclature has been adopted for the Absaroka country.

Character of the sedimentary rocks.

The basal sediments are mainly siliceous, passing gradually up through transition beds into nearly pure limestones. From this point to the top of the series of beds exposed limestones form the great block of sediments. Some beds are highly arenaceous, others carry a large amount of argillaceous material, while still others hold enough ferruginous matter to impart a distinct character to the strata. Brecciated, nodular, and cherty deposits, persistent variations in color, and the tendency of impure argillaceous beds to take on a shaly structure over large areas, make it possible to divide this great development of sediments into a series of formations recognized solely by their physical features. In many instances the geological position of these formations may be determined without the aid of paleontological evidence.

CAMBRIAN.

Basal member of the Cambrian.

Resting directly upon the uneven surface of the Archean mass comes a series of beds made up of coarse and fine material consisting of both angular and rounded grains of quartz, mingled with fragmentary pieces of the underlying crystalline rock. This detrital material was all derived from the disintegration, under atmospheric agencies, of the granites, schists, and gneisses, and everywhere represents a beach accumulation deposited on a steadily but slowly receding land surface. It represents the basal member of the Cambrian period, so far as it is exposed in this part of the country. The beds pass upward into fine-grained sandstone carrying more and more calcareous material, until they become nearly pure limestones, retaining this character to the summit of the beds assigned to this period.

Two sharply defined series of Cambrian beds.

Rocks of the Cambrian period have been divided into two sharply defined series, based primarily upon their organic remains. The underlying series of beds, recognized as representing a single epoch, has been designated the Flathead formation, while the overlying terrane is known as the Gallatin limestone. Each is distinguished by its own peculiar fossil fauna; at the same time each is equally well defined by lithological characters. The Flathead and the Gallatin are usually found associated, but with varying thicknesses of the basal beds. In this way they are exposed all along the northern escarpment of the Absarokas from Soda Butte to Sunlight Creek. Just east of the limit of the area mapped they stand out in a most imposing manner, appearing as isolated limestone tables resting upon an Archean platform. The total thickness assigned to the Cambrian rocks is 1100 feet; at least that seems to be their broadest development where best exposed and where their summit is most clearly defined. Upon paleontological evidence the Flathead formation corresponds to and has been correlated with the middle Cambrian, while the Gallatin has been assigned to the upper Cambrian. Excellent localities for the study of these rocks may be found near the entrance of Republic Creek, on the ridge between Crandall and Closed creeks, and at Beartooth Butte.

Quartzite and sandstone.

Flathead formation.—This formation, which is exposed in a number of localities throughout northern Wyoming and central Montana, derives its name from Flathead Pass, in the Bridger Range, in the latter State. The Flathead formation in the Absarokas has been divided into three series dependent upon lithological distinctions persistent over wide areas: (1) quartzite and sandstone, (2) shales, and (3) limestones. It can not be affirmed positively that the lowest members of the Flathead are exposed along the Absaroka escarpment, for there is no evidence as to the thickness of the quartzites and sandstones, but it is certain that wherever they occur next to the gneiss and schist they consist, as already mentioned, of detrital material derived from the ancient Archean land mass. For the most part the lowest beds consist of coarse quartz grains compacted into sandstone or quartzite, the degree of hardness being dependent mainly upon the amount of pressure they have undergone. Beds which in places consist of loose and friable material, disintegrating readily, are continued elsewhere as firm and dense rocks weathering in solid blocks. Varying amounts of oxide of iron tinge the beds either red or yellow, the iron frequently serving as the cementing agent for the more compact beds. In some instances this produces a banded structure, which not only affords an excellent means of determining the slight angle of inclination of the strata but serves as a base line for the measurement of the thickness of deposits.

Shale.

Passing upward the siliceous material becomes finer and is mingled with more and more micaceous and argillaceous material, the latter derived from the decomposition of feldspars in the crystalline rocks. It is the alteration of these latter sediments under pressure that has caused the shale formation. Gradually the beds become more and more calcareous, until they pass over into nearly pure limestones, forming the third division already enumerated.

Limestones.

From the coming in of the first limestone to the top of the Flathead formation the sediments consist mainly of limestone, separable into beds of varying condition of sedimentation or mode of weathering. In some instances they are divided by narrow shale beds. Grains of glauconite not infrequently impart a greenish tinge to limestone belts, which may be traced for long distances. At a number of localities along the northern escarpment of the Absarokas the Flathead formation affords a few characteristic fossils. The widely distributed species *Ptychoparia antiquata* occurs on the broad Cambrian tables 700 feet above the Archean platform of Clark Fork Canyon. Near the same horizon at several localities in the neighborhood of Sunlight Creek gray limestones carry *Hyolithes primordialis.* Both these species characterize the middle Cambrian strata in the Yellowstone Park.

Mottled limestone.

Gallatin limestone.—Directly overlying the thinly bedded limestone of the Flathead comes the Gallatin limestone, the name for the terrane being appropriately derived from the range of mountains where it occurs especially well developed. In the Absaroka Range the Gallatin limestone may be divided into two distinct broad beds separated by calcareous shale, the lower known as the mottled limestone and the upper generally designated the fossiliferous belt. The mottled limestone presents one of the most characteristic topographic features to be found in the entire Paleozoic series, and nowhere is it better displayed than along Clark Fork Valley, extending for miles as a bold escarpment difficult to scale. It is massively bedded, and its prominence is in great part due to the crumbling away of fissile beds beneath the escarpment and the erosion of shaly ones above, exposing the hard, resistant surface that forms the top of the mottled limestone. It occurs as a dark-brown crystalline ledge, its mottled appearance being due to the cherty character of the dark-gray and brown lenticular patches scattered through it. The weathered surfaces are invariably rough and rugged, with narrow seams of indurated clays and flinty aggregations disseminated through the beds and standing out from the main mass of the limestone. No well-preserved fossils have been obtained from the mottled limestone, consequently no evidence based upon paleontological facts determines the precise age of the bed. Provisionally it has been placed at the base of the Gallatin formation, the few trilobitic fragments found indicating a facies more closely allied to the Gallatin than to the Flathead fauna.

Fossiliferous belt.

Immediately above the mottled limestone the fossiliferous belt of the formation is foreshadowed by the fissile nature of the argillaceous and calcareous shales, passing upward into more and more massive limestone and holding interstratified shaly layers and beds of brecciated material. These limestones are usually highly crystalline, varying in color, but with a prevailing yellowish-brown tint, becoming decidedly darker toward the top. Fragmentary remains of fossils are occasionally found throughout the limestone beds, although well-preserved species are only found either immediately over the mottled limestone or in bluish-gray limestone at the summit of the strata. Such species as have been determined clearly show the existence of a characteristic upper Cambrian life, the non-fossiliferous mottled limestone lying between two sharply defined faunas and separating the middle from the upper Cambrian. The thickness of the Gallatin formation has been estimated approximately at 400 feet, with a development of the mottled limestone varying from 100 to 150 feet.

SILURIAN.

Rocks assigned to this period in the Absarokas consist mainly of limestones, showing, as regards angle of deposition, conformity of sedimentation with the underlying Cambrian strata. Viewed in in a broad way, they present similar physical conditions in lithological habit across the entire width of the Absaroka Range from Lamar River to Sunlight Creek, but in detail they show considerable variation in bedding, crystallization, and position. No divisions of the Silurian into epochs has yet been made, the entire formation being designated the Jefferson limestone, a name derived from the mountain range in Montana where the beds are well exposed. Along Clark Fork Valley the Jefferson limestone stands out conspicuously as one of the sedimentary walls that make up the grand escarpment rising above the river. As already mentioned, the broad bench usually found above the mottled limestone is carved in shaly beds, but the next cliff back from the valley presents a fairly continuous wall of Silurian rocks.

Highly crystalline bluish-black or gray limestone.

Jefferson limestone.—In general the ledges consist of massive beds of highly crystalline, bluish-black or gray limestone, but not infrequently all traces of bedding are obliterated until the coming in of interstratified bands of yellowish-brown arenaceous deposits. The beds near the base are for the most part dark and somber in color, growing lighter toward the top of the series, becoming occasionally almost creamy white in the bright glare of the sun. Seams of white calcite often traverse the Jefferson beds. Under the blows of the hammer the dark-colored beds frequently give off a strong fetid odor, which is rather characteristic of this horizon. It is difficult to give even a rough estimate of the thickness of these Silurian beds, owing to the lack of recognized lithological limits and the absence of well-preserved fossils to define its boundaries. From our present knowledge the thickness is estimated at about 300 feet.

Absence of characteristic fossils.

No positive evidence based upon paleontological data has been obtained which determines the geological position of the Jefferson beds. Throughout this entire series not a fossil was procured that could be called characteristic of the Silurian period. Nothing indicating even a possible grouping of forms was obtained. In fact, with the upper beds of the Gallatin formation, which carry organic remains regarded as belonging to the top of the Cambrian series, the fossiliferous strata suddenly cease. In the Jefferson formation only partial and most fragmentary proof of the existence of a fauna remains. This is true for the entire region of the Absarokas. Such partially preserved fossils as were obtained in the lower beds assigned to the Jefferson indicate the existence of species that possess a wide vertical range and might occur high in the Cambrian or near the base of the Silurian. In the same way, at other localities the species procured from near the summit of the terrane are such as possess a wide vertical range and might be found as low as the Silurian, but at the same time are known to occur elsewhere with typical Devonian species. For these reasons it is frequently impossible to determine either the base or the summit of the formation with any degree of precision.

DEVONIAN.

Rocks of the Devonian period in the Absarokas consist mainly of limestone, and may usually be readily identified wherever the overlying Carboniferous strata are exposed. As yet no subdivisions of the Devonian have been worked out upon lithological grounds, and the organic remains, while characteristic, are meager in species, with an apparent vertical range throughout the entire thickness of 250 feet assigned to them. They have been correlated with the Three Forks formation, the designation given to the Devonian strata exposed at the three forks of the Missouri River in Montana, where they carry a small and varied typical Devonian fauna. Without any apparent interruption in the continuity of oceanic sediments, the brown and dark-gray limestones of the Silurian pass upward into bluish-gray beds holding Devonian fossils, which are regarded as representing the base of the Three Forks terrane.

Bluish-gray limestones, shaly beds, and fine clays.

Three Forks limestone.—The bluish-gray limestones at the base alternate with shaly beds and fine clays, the latter also occasionally carrying organic remains. These pass upward into bedded limestones, generally of light tints of purple and blue, with intercalated thin layers of indurated earthy sandy material. Recurring alternations abound, but with limestone as the prevailing rock. In places near the top of the formation the shaly beds exhibit bright red and orange tints, but this is by no means a safe guide in tracing the strata, as in many other places these highly colored layers appear to be wanting. Over wide areas there are slight evidences of organic remains, consisting mainly of coralline fragments too poor for specific identification. Such typical Devonian fossils as *Atrypa reticularis* and *Spirifera engelmanni* determine with certainty the geological horizon of the Three Forks formation. Localities yielding small groupings of a Devonian marine fauna may be found at Abiathar Peak near the eastern boundary of the Yellowstone Park, at Mount Miller just north of the Park, and again on Little Sunlight Creek in bright-colored shales below Carboniferous beds.

CARBONIFEROUS.

Sub-divisions of the Carboniferous rocks.

Rocks of the Carboniferous period fall readily into two sharply defined formations based upon lithological distinctions indicating marked changes in conditions of sedimentation, the lower formation being calcareous, the upper one siliceous. They have been designated the Madison limestone and the Quadrant quartzite. Nowhere within the Absaroka district are the Quadrant quartzites exposed, although only a short distance eastward they are shown on Dead Indian Ridge in strong force, several hundred feet in thickness. In the Absaroka Range the sediments of the Paleozoic ocean have undergone so much erosion that not only has the Quadrant quartzite been removed but with it also a very considerable thickness of the Madison limestone. Along the northern face of the range Carboniferous rocks are for the most part wanting, but are well shown capping Hunter Peak and along the bottoms of several of the deeply trenched lateral canyons. The most impressive exposure of the Carboniferous occurs in Sunlight Basin, where there is a broad body of Madison limestone nearly 1000 feet in thickness. The narrow defile of the main Sunlight Creek presents nearly vertical walls of similar strata on both sides of the stream.

Finely crystalline, gray, cherty limestone.

Madison limestone.—The Madison limestone takes its name from a prominent range of mountains in central Montana, just west of Yellowstone Park. Within the Park the Madison maintains a thickness of quite 1600 feet, but the Absarokas offer no point where the summit of the formation can be determined. By gradual transition the Three Forks formation passes into a finely crystalline gray limestone, in places more or less cherty, which in certain localities consists of irregular nodular bands, but this latter feature is not maintained over any wide area. Viewed in a broad way, this great development of limestone is dark bluish gray at the base, coarsely crystalline, and thinly bedded. It passes gradually upward into light colored masses, rough and rugged in texture and less finely bedded. The upper portions consist of light bluish-gray beds, in places nearly white. The characteristic weathering with a tendency to produce rounded forms, together with the light coloring, renders it possible to recognize the upper members of the Madison limestone upon far-away ridges, all the more readily as it not infrequently forms the summit of prominent peaks and the capping rock of long lines of cliffs. In detail it is by no means easy to correlate or compare individual beds from widely separated areas, in spite of the marked uniformity of sedimentation when the limestone formation is considered as a unit.

Madison fauna.

As previously pointed out, the line of demarcation between the Devonian and Carboniferous is drawn upon paleontological evidence based upon the earliest appearance of organic remains usually assigned to the latter period. A study of these fossils shows that the Madison limestone throughout its entire development belongs to the lower Carboniferous, without any distinct foreshadowing of a higher or coal-measure fauna. About 80 species have been determined and described from this terrane. All the fossil collections obtained from the Carboniferous were submitted to Mr. George H. Girty, who regards the Madison limestone as a paleontological unit corresponding closely to the Choteau-Waverly division of the Mississippi Basin. Nearly one-half of the fossils have been specifically identified with forms occurring in the Waverly limestone, and about one-quarter of them are described for the first time from the Madison limestone. Fourteen species are found throughout the entire 1600 feet of beds assigned to the Madison, and are for the most part characteristic of the lower Carboniferous elsewhere. In the Absarokas all evidence of life in the Paleozoic sea ends with the limestone-making epoch of the Madison.

The entire series of Paleozoic sediments exposed in the range is shown in the columnar section, which represents a thickness of 3200 feet. At the base of the section 700 feet is assigned to the Flathead, which is about the average thickness of the formation. At the top 1600 feet is given to the Madison limestone. Nowhere within the limits of the area mapped does the Madison attain so broad a development, but only a short distance beyond the borders of the Crandall quadrangle it is estimated to measure that amount.

CRETACEOUS.

Juratrias and larger part of Cretaceous not represented.

Rocks of Mesozoic age occupy but limited spaces in the Absaroka district. All sediments of the Juratrias and of the larger part of the Cretaceous period are unknown. Only beds assigned to the Montana formation of the upper Cretaceous are exposed, all intermediate sediments, if ever present in this region, being submerged beneath accumulations of breccias and basaltic flows. Such exposures of the Montana as occur are found along the eastern base of the range, where they come to the surface from beneath the volcanic lavas, or in the deeply trenched canyons of the Stinkingwater and Shoshone rivers. Along the Stinkingwater Canyon the stream has cut its way through breccias and agglomerate, but where it leaves the narrow defile and enters the more open country, sandstones of the Cretaceous period come to the surface upon both sides of the river, on the north side extending back in bluffs and benches to a height of nearly 600 feet. These sandstones are everywhere capped by breccias. The region presents a depressed area occupied by sedimentary beds encircled by lavas rising for 2000 feet above the lowland. A small area of sandstone lies higher up the river, near the junction of the Stinkingwater with Wapiti River. In Shoshone Valley the Montana stretches along the stream bottom, only here and there exposed beneath the coarse gravels of the flood plain and the still higher detrital material upon the hill slopes. Neither valley affords suitable opportunity for a study of these sandstones, no good vertical sections being exposed. Either the beds are dislocated and disturbed by intrusions of igneous rocks or the surface of the country is covered by Pleistocene deposits.

Pierre shale and Fox Hills sandstone.

Montana formation.—This formation embraces both the Pierre shale and the Fox Hills sandstone, it being impossible in northeastern Wyoming to distinguish between the two subdivisions frequently so well defined elsewhere. Here the Montana was essentially a sandstone-making epoch, although by no means uniform in its sedimentation and varying greatly in its mode of bedding. The sandstones are usually white or yellowish gray and occasionally brown, due to varying amounts of iron deposited with the quartzitic material. They are more or less impure, with recurring alternations of interbedded dark clays and shales, the latter occurring as lenticular bodies far more strongly developed in certain localities than in others. Good exposures of such black and gray shales are seen on Bobcat Creek, where it leaves the mountains and enters the valley of Shoshone River.

In the absence of a fossil flora and fauna the beds are only provisionally assigned to the Montana. Black argillaceous shales carrying organic matter accompanied by fragmentary plant remains, such as stems, twigs, and partial impressions of leaves, have been found, but all too poor for specific identification. Marine Cretaceous invertebrate fossils also occur sparingly, but their specific characters could not be made out. It is possible that some of these higher sandstones should be assigned more properly to the Laramie formation.

Laramie formation.—Sandstones of this epoch are not definitely known in the Absaroka district, but a short distance east of the southern half—the Ishawooa quadrangle—they occur over large areas, conformably overlying the Montana. It is not always easy to discriminate between the two formations. The Laramie is far less uniform in its sedimentation and the beds are less pure sandstones. It is characterized by terrestrial vegetation found also elsewhere in the Rocky Mountains and known as the Laramie flora. It is a formation of great economic importance, as nearly all marketable coals found in northern Wyoming and Montana occur in the Laramie sandstone. Near the close of the epoch evidences of shallow water, cross bedding, and frequent fluctuations of sea level foreshadow marked changes in the geological development of the pre-existing continental area.

POST-LARAMIE MOVEMENT.

Elevation, with dislocation.

With the close of the Laramie formation the deposition of conformable Paleozoic and Mesozoic sediments ceased. Oscillations of sea level took place, the accumulating sediments being laid down partly in shallow and partly in deep waters. In this region no unconformity of beds by deposition has been recognized, and in this sense they may be said to be conformable throughout from middle Cambrian time to the summit of the Laramie, although evidence of this continuity is wanting in the immediate country represented by the Absaroka folio. The entire region was again elevated above the sea. In the Absaroka Range the great Paleozoic sedimentary beds were tilted up at low angles, with more or less dislocation, but the region is so submerged beneath more recent volcanic outflows that very little of the structural features can be made out. Profound orogenic movements took place, and the entire region became one of mountain building accompanied by folding and faulting. All evidence tends to show that this uplifting was contemporaneous in all the ranges. For this reason, and on account of its great geological importance, this uplift has been named the post-Laramie movement. With this elevation a greatly enlarged continental land mass was raised above the sea, and coincident with it a denudation of the new continental area took place, accompanied by deposition of fresh sediments, unconformable to the uplifted Laramie. In this connection it may be stated that the Laramie, with its marine and brackish faunas, along the east base of the Absarokas attains an elevation of about 6000 feet. On Big Game Ridge, to the west of the volcanic plateau, the sandstones have been uplifted to nearly 10,000 feet above sea level.

Rounded smoothly worn pebbles mingled with sand and gravel.

Pinyon conglomerate.—Between the blocking out of the mountains composed of sedimentary rocks at the close of the Laramie and the pouring out of enormous masses of igneous rocks, there were deposited at a number of localities beds of coarse conglomerate. They are not exposed within the Absarokas, but are found just west of the range high up on the mountains, resting unconformably upon the tilted and eroded Laramie sandstones. They consist of nearly horizontal beds designated the Pinyon conglomerate, the name being derived from the mountain where they occur admirably exposed, on the divide between Wolverine and Gravel creeks, in the Yellowstone Park. Nearly all of this material consists of rounded, smoothly worn pebbles mingled with sand and gravel. It has accumulated to a thickness of nearly 600 feet, and indicates clearly the shallow water inshore deposit. The Pinyon conglomerates stretch southward in patches in the Wind River Mountains, and under the breccias of the Wind River Plateau. This formation, while unrepresented in the Absarokas, is mentioned here on account of its importance in the geological history of the region. It was laid down after a very considerable erosion of the Laramie, and probably before the eruption of the greater part of the volcanic material, since it contains no fragments of the Absaroka breccias. On the other hand, the basic breccias cap the conglomerates of Pinyon Peak and have served as a protection against the wearing away of the more easily eroded beds. Provisionally they have been assigned to the Eocene period, being subsequent to the Laramie movement. Possibly they were synchronous with some portion of the uptilted Livingston formation in Montana, which, from its somewhat meager fossil flora, is supposed to be more closely allied to Cretaceous than to Tertiary time. In any case they represent the latest sediments laid down in this region before the pouring out of the breccias. Their geological position and relations to both the uplifted Laramie sandstone and the overlying breccias may be seen in the generalized section of the igneous rocks of the Yellowstone Park given in folio 30 of this series.

IGNEOUS ROCKS.

POST-LARAMIE VOLCANIC EPOCH.

Volcanic eruptions.

Closely associated with the post-Laramie movement, but followed by a long period of erosion of the Mesozoic land area, there occurred the first of those volcanic eruptions along the Absaroka Range which subsequently, in Tertiary time, submerged all the surrounding country. This eruptive material, forcing its way upward, followed lines of least resistance along or near planes of faulting, or wherever strain had been greatest upon the weakened or crumpled strata. It continued to pour forth during a long period, lasting, with intervals of comparative rest, throughout Eocene and a great part of Neocene time. Evidence of partial cessation of activities is seen at one or two places in the erosion of lavas before the pouring out of fresh masses. In other localities seasons of volcanic inactivity are recorded by fossil flora representing vigorous growths of forest trees and plants which were repeatedly submerged by renewed outbursts of muds and tuffs.

The building of the Absaroka Range.

The Absaroka Range was built up by the slow accumulation of volcanic breccias with interbedded basaltic flows, which buried everything beneath them to a depth of several thousand feet. Volcanic agglomerates, silts, and tuffs, and extrusive lavas, or those that have poured out and cooled near the surface, make up by far the greater part of the range. Other rocks playing any part in the building up of the mountains have already been described under the head of Paleozoic and Mesozoic sediments. In close proximity to the lavas these latter rocks have been more or less altered by heat and pressure; the limestones have been changed to marble, the clays baked to argillites, and the Montana sandstones compressed to compact indurated quartzites.

Breccias and lava flows.

The breccias and lava flows were thrown out from numerous vents and centers of volcanic activity, now for the most part obliterated by the piling up of successive layers of later material. Gradual transitions in mineral composition, texture, and mode of occurrence of the ejected lavas may be found, but, taken as a whole, the Absaroka Range presents an elevated volcanic region showing from north to south great uniformity in its geological features. It consists essentially of a broad dissected plateau, greatly eroded and deeply trenched by a system of canyons exposing from 2000 to 5000 feet of nearly horizontal or only slightly inclined breccias and basalt sheets. Above the canyon walls the bare, rough ridges frequently rise beyond timber line for 1000 or 2000 feet more, offering additional sections across the accumulated material. It has been found possible to divide this enormous bulk of breccias and lavas ejected from many widely distributed fissures and orifices into six well-defined groups, dependent upon the relative age of eruption. They represent as many distinct periods or volcanic chapters in the long geological history of the range. Beginning with the earliest in order of eruption, they have been designated as follows: early acid breccia, early basic breccia, early basalt sheets, late acid breccia, late basic breccia, late basalt sheets.

Six groups of breccias and lavas.

The acid and basic breccias pass into each other by gradual transition products of intermediate mineral and chemical composition. The acid rocks are so designated because they contain a relatively large amount of silicic acid, together with a high percentage of alkalies. When there is an excess of silicic acid and the rock is completely crystallized, it is usually accompanied by free quartz. Basic rocks, in distinction from acid ones, carry less silicic acid, but contain a correspondingly large amount of the bases iron, magnesia, and lime. With this increase of the bases there is usually a development of what is called ferromagnesian minerals—hornblende, pyroxene, and mica. Under the discussion of each type of breccia there will be found a detailed account of its mineral composition.

Agglomerates, silts, muds, and tuffs.

Hornblende-andesites and hornblende-mica-andesites.

Early acid breccias.—The oldest volcanic lavas found in the Absaroka Range comprise a series of eruptive rocks made up almost entirely of fragmental material consisting of agglomerates, silts, muds, and tuffs, designated early acid breccia. In color they present usually light tints, varying from grayish white to lavender. Occasionally they are greenish brown, due in part to the decomposition of the ferromagnesian minerals. The color is constantly changing, dependent upon the texture of the material and the degree of decomposition of the included minerals. In mineral composition they vary considerably, but consist mainly of hornblende-andesites and hornblende-mica-andesites. Flakes of dark-brown biotite abound through the greater part of these breccias. Some of the most siliceous varieties carry phenocrysts of quartz, and in sufficient quantity to place the rock under the head of dacite or quartz-bearing andesite. Occasionally the more basic varieties carry a larger amount of ferromagnesian minerals, when some form of pyroxene is usually found accompanying the hornblende. These latter rocks show transitions into the overlying basic breccia, but in most cases the contrast between the two forms of acid and basic rocks is sharply drawn, by topographic configuration as well as by color.

A characteristic feature of these early acid breccias, but one by no means confined to them, is the occurrence at several localities of numerous angular fragments of gneisses and schists, evidently brought up from below at the time the breccia was thrown out by explosive action.

In the country embraced within the Absaroka Range the early acid breccias are known only in the northwest corner of the Crandall quadrangle. They are found all along the west wall of Republic Creek, in the bottom of the deep canyon formed by the junction of Timber and Closed creeks, and again at the head of Cache Creek Valley. In the first two localities they rest directly upon the Paleozoic limestones, and are clearly shown to be the earliest eruptions of a vast pile of lava. In the valley of Republic

Creek they present a mass of rudely bedded, coarse breccias, dipping to the south, away from the slightly inclined limestones.

In the Absaroka Range, but within the Park, the early acid breccias are shown for several miles along the bottom of Cache Creek Valley, the result of the deep trenching of the canyon. Above them lie the basic breccias, capping the high ridges on both sides of the stream. To the east rocks resembling the acid breccias are exposed at one or two localities. They are shown near the head of Lodge Pole Creek and on Dry Creek, but they are basic in character and are so intermingled with the undoubted basic breccias that they have not been discriminated from them upon the map. Similar rocks occur in Sunlight Basin beneath a great accumulation of basic breccia. In general where both series of breccias occur together they are easily recognized by their strong contrast of color, by differences in their forms of erosion, and by their marked unconformity, the earlier breccias showing evidences of extensive erosion before the pouring out of the later and more basic rocks. In some instances there appear to be transition rocks, passing over from one series to the other without any marked physical or mineralogical break.

Transition rocks.

In a few localities the finer beds seem to be made up of the mingling of material from both types of rock, as if the beds had been formed of the finer material from areas both of acid and of basic rock washed down into depressions and irregular basins.

As shown in the Absaroka Range and westward along the Yellowstone Valley, the acid breccia appears to have been thrown out from numerous and independent centers of eruption, none of which heaped up any very great mass of lava. But from all of such centers they were the earliest eruptions forced to the surface. Early acid breccias are exposed only in limited areas, due mainly to vast accumulations of still later lavas. In no instance do they attain any great elevation, the exposures being due to extensive erosion and characteristic trenching of narrow gorges. Induration of these breccias may be seen in several localities, but it is by no means a characteristic feature. Occasionally dikes of pyroxene-andesite have been observed cutting acid breccias, presenting additional evidence as to the relative age of the two types of rocks.

Volcanic material with interbedded flows of basalt.

Early basic breccias.—Overlying the early acid breccias occurs a vast accumulation of volcanic material with occasional interbedded flows of basalt, the entire mass near the orifices of ejection being piled up to a height of nearly 5000 feet. They cover a far more extensive area than any other group into which the lavas have been divided, stretching from the northern limit of the range southward beyond the boundaries of the Ishawooa quadrangle. All the northern portion of the Absaroka Range is made up of these breccias, which extend westward over the northeast corner of the Park. Like the early acid breccias, they consist of both coarse and fine material, showing marked differences in physical characters, dependent upon the nature of the material erupted and upon the distance from its source of eruption. In strong contrast to the early acid breccias, they are usually dark colored, owing to the amount of ferromagnesian minerals in the rocks. The lighter beds carry the same mineral constituents, but are made up of fine muds and silts. The material consists largely of hornblende-pyroxene-andesites, pyroxene-andesites, and basalts, both with and without olivine, the latter seldom occuring as an abundant mineral. Gradual transitions and slight variations may be found throughout the early basic breccias, but from one end of the range to the other the prevailing rock is a pyroxene-andesite, on the one hand passing into slightly more acid breccias with a development of hornblende, and on the other hand into more basic rock with characteristic basaltic form. The greater part of this erupted material is made up of coarse agglomerates, firmly held together by varying amounts of cementing ash and silts of the same mineral composition. The prevailing colors of the coarse material are black and brownish gray; the finer silts and mud flows free from bowlders are light brown, and stand out in sharp contrast to the mass of the breccia. In some localities the breccias show a decidedly reddish tinge. A characteristic feature is that over wide areas they present a rough and ropy surface, like recent volcanic scoria, piled up in a most irregular way. The cementing material was thrown out in a liquid state, carrying with it angular and subangular fragments of the earlier lava. The great bulk of the breccia shows indistinct bedding. A tumultuous piling up of large masses of agglomerate, the result of violent explosive action, from widely distributed fissures and vents, forms a characteristic feature of these breccias. Not infrequently they contain enormous andesitic and basaltic bowlders measuring 5 or 6 feet in length, and occasionally double that size. The interbedded sheets are usually fine-grained, dark rocks, like normal basalts elsewhere. Some of them are highly feldspathic and carry phenocrysts of hornblende, pyroxene, and orthoclase feldspar.

Hornblende-pyroxene-andesites, pyroxene-andesites, and basalts.

Through the central portion of the Absarokas these early basic breccias stretch across the entire width of the range, from the broad open valley on the east to the shores of Yellowstone Lake on the west. They may be well studied by following up the valley of the Stinkingwater from the entrance of the canyon, thence up Middle Creek and across Signal Hills to the terrace bluffs known as Signal Point, near the southeast corner of the lake. Along this line the continuity of the early basic breccias is broken only at one or two points by overlying basalts and by flows of rhyolite which skirt the foothills above the lake shore. The red, ropy, irregular breccias are well shown along the Stinkingwater River from the entrance of the canyon to its junction with Fishhawk Creek. Impressive mural faces are displayed in the south face of Saddle Mountain and on the south walls of Castor and Pollux peaks, towering above Little Lamar Valley. One of the most accessible places for the study of these breccias is along Clark Fork Valley, where they rest directly upon the Paleozoic sedimentary rocks, as shown in fig. 5 of the accompanying page of illustrations.

Rock sculpture.

Fantastic and ever-changing forms of rock sculpture, the results of erosion upon volcanic tuffs and loose agglomerate, characterize the early basic breccia, but are by no means confined to eruptions of any one period. They abound high up on canyon walls wherever layers of more or less indurated rock or basaltic bowlders rest upon friable material. They are usually carved out of the rock along edges of cliff furrowed by frequent shallow drainage channels. Many of these slender vertical rock columns stand closely packed together, recalling in some ways the so-called "fossil forests" found in this region. The famous Hoodoo Basin at the head of the Lamar River, frequently visited by tourists to the Yellowstone Park, is the most notable locality for these grotesque figures. They are also admirably shown in the lower portion of Stinkingwater Canyon and along the west side of Wapiti River.

Succession of basalt flows.

Early basalt sheets.—Next in order, and directly resting upon the uneven surfaces of the early basic breccias, comes a succession of basalt flows which in places near their vents have attained a thickness of 1500 feet, although over large areas they measure about 1000 feet, thinning out to a few hundred, while in certain places they appear to be wanting. They stand out in strong contrast to the less coherent breccias, due to differences in their mode of weathering and the great uniformity and monotony of individual flows. The separate sheets range in thickness from 5 to 50 feet, without showing any material evidence of change in the physical features of successive flows. Occasionally these lava streams develop layers of vesicular basalt at the top of the flows, showing evidences of the rapid cooling of the surfaces before the pouring out of fresh lava. Not infrequently they carry interbedded thin layers of silt and fine breccias, and in places show evidences of atmospheric agencies acting upon surface flows before the pouring out of fresh lavas.

The designation "early basalt sheets" has been applied to these basalts, and they are considered as a unit, since they mark a distinct period in the geological history of the volcanic eruption. In studying the general sequence of lavas the early basalt sheets play an important part, as they overlie the early series of acid and basic breccias and underlie a similar series of erupted material known as late acid breccia and late basic breccia and flows.

Composition of the early basalt sheets.

In mineral composition they are usually fine grained, with but few well-developed megascopic constituents, mainly augite, olivine, and plagioclase. In chemical composition they show within certain limits considerable variation, with corresponding change in mineral development. Many of these flows covering large areas are decidedly feldspar basalt, being rich in alkalies and carrying both leucite and orthoclase, and are the extrusive members of the absarokite group described later under the heading "Intrusive rocks." Leucite has been determined from a number of localities in sufficient amount to form a characteristic feature of several basaltic outflows. Phenocrysts of plagioclase and pyroxene are frequently well developed in the feldspar basalts. Basalts cap many of the higher peaks and ridges, presenting to the eye for long distances broad, plateau-like summits with precipitous walls on all sides. These basalt tables are remnants of much broader fields. Many of them in cooling have developed fine examples of columnar structure, the pillars of basalt extending across the entire thickness of the flow and standing out in the canyon walls in a most impressive manner. Perhaps the grandest display of this structure is shown at the head of Mole Creek in the bold escarpment under Sheep Mesa, where the smooth jet-black basaltic columns spread out with a radial, fan-like structure. Here the columns and surrounding basalts are glassy and show abundant evidence of being part of a surface outflow.

Columnar structure of the basalt.

Over large areas the basaltic flows are wanting. They do not occur capping the breccias in the northeastern portion of the Absarokas, nor on the southwestern slopes of the range draining toward Yellowstone Lake. Within the Yellowstone Park these basalts are well shown in the abrupt precipices of Mirror Plateau, facing Lamar Valley. From here they stretch southeastward across the crest of the range between Lamar and Stinkingwater rivers, and are admirably exposed on Wapiti Ridge and in the massive walls on both sides of Shoshone River. They extend over a broad belt of country, with a general northwest-southeast trend.

Hornblende-mica-andesite, and hornblende-andesite, with pyroxene-andesite.

Late acid breccia.—These breccias do not play an important part in that portion of the range lying within the Absaroka district, but westward, inside the Park line, they present an imposing appearance. Unlike the early acid breccias, they are not so deeply buried beneath later erupted masses, but form the summits of several peaks and elevated ridges, and are spread out in thin sheets over the earlier basalt tables. They are found only along the western borders of both the Crandall and the Ishawooa quadrangles, occurring as the eastern extension of more massive bodies. They may be seen high up on the ridges near the sources of Middle Creek, in the bottom of the broad basin of Mountain Creek, and on the slopes of Overlook Mountain. They closely resemble the early acid breccia, consisting of hornblende-mica-andesite and hornblende-andesite, in places carrying considerable pyroxene-andesite, together with fragmental material similar in mineral composition to the Ishawooa intrusive masses. Both augite and hypersthene are recognized in these breccias. In color they vary considerably from light brown and gray to purple, the cementing material being a friable, easily disintegrating tuff. Nearly all the brecciated material is angular, and the fragments for the most part are only a few inches in length, but the beds show great variation in structure and composition.

Contact between acid and basic breccias.

Occasionally the line of contact between the acid breccias and the later basic breccia is strongly shown, the latter filling up depressions and leveling off the uneven and rugged outline of an earlier topography. In the accompanying illustration (fig. 1) the dark breccia of pyroxene-andesite and basalt is seen to rest upon an abrupt hill slope of light-colored hornblende-andesite breccia. Over a large part of the area the line of contact is by no means so sharply defined, and in some localities the light-colored acid breccia carries considerable pyroxene-andesite. In some cases the transition products are so mingled together as to render any classification of the material difficult. Occasionally decidedly acid breccias from apparently many local centers of eruption rest upon well-defined basic breccia rich in angular basaltic fragments and basic cementing tuff. Broad bands of light-colored tuff occur in the dark breccia along the escarpment of Trident Plateau and on the east slope of Overlook Mountain.

Late basic breccia.—Overlying the late acid breccias comes a second series of basic breccias,

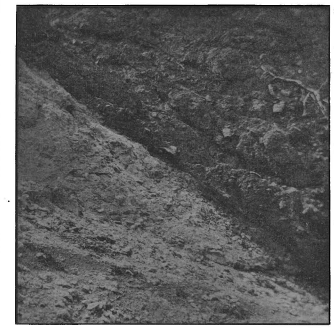


FIG. 1.—DARK BRECCIA OF PYROXENE-ANDESITE AND BASALT RESTING UPON AN ABRUPT HILL SLOPE OF LIGHT-COLORED HORNBLENDE-ANDESITE BRECCIA.

agglomerates, and andesitic sheets, closely resembling the earlier deposits of erupted material. In mineral composition this second series of basic rocks is nearly identical with the early basic breccia, consisting of hornblende-pyroxene-andesite and pyroxene-andesite free from hornblende and basalts. Hornblende-bearing rocks do not appear to characterize large areas, but at certain outflows at widely separated localities they abound with many well-developed individual crystals. Pyroxene-andesite, with both augite and hypersthene, is evidently the predominating rock, although normal olivine-bearing basalts occur in both the coarse and the fine volcanic ejectamenta. The two basic breccias are singularly alike in their mode of occurrence. Apparently the conditions governing their eruptions were much the same. In the early breccias the outflows are more frequently ropy and scoriaceous, without bedding. In the later the material thrown out ordinarily consists of coarse angular fragmental material near the sources of eruption, diminishing in size with distance from the vent. Nowhere can the contact between the late acid and basic breccias be better studied than in the open basin of Mountain Creek, along the eastern slopes of Overlook and Chaos mountains. The bottom of the basin and lower slopes are formed of acid breccia, while the ridges jutting out from the main crest of the range consist of dark-brown breccia superimposed upon the early flows. The overlying rocks weather in rounded, dome-like forms, the erupted material being firmly cemented in a compact mass, but furrowed at frequent intervals by shallow drainage channels.

Hornblende-pyroxene-andesite, and pyroxene-andesite free from hornblende and basalts.

Breccias of Wapiti Ridge and of Thorofare and Trident plateaus.

Wherever the late acid breccias are wanting the basic breccias have spread out upon the basalt sheets and over wide areas form the summits of many high ridges and elevated plateaus. In some instances, where the basaltic sheets themselves are wanting, the two basic breccias apparently come together, rendering it impossible to distinguish between them. Wapiti Ridge, one of the most prominent features of the range, presents a fine example of both basic breccias, with the early basalt beds spread out between them in long, monotonous flows. Both Thorofare and Trident plateaus present impressive masses of nearly horizontal beds of breccia with vertical walls over 2000 feet in height. In the accompanying illustration (fig. 2) the coarseness of the breccia, the lack of cohesion of much of the erupted material, and the angular character of the fragments are clearly brought out. The largest bowlder shown in the picture measures 15 feet in length, and nearly all the fragmental blocks, both large and small, look as if some parent stock had been shattered into innumerable pieces. It seems evident that the piled-up mass was the product of violent explosive action, deposited near the source of eruption. In fig. 6 (a photographic reproduction on the accompanying page of illustrations) a typical mass of basic breccia from one of the canyon walls is represented. It is a breccia of medium texture, without flow structure, showing characteristic forms of erosion. The nature of the cementing tuff and its power compactly to combine the coarser fragments is well brought out in the cliff.

At this particular locality there is little fine silt to serve as a cementing material and the mass is loosely held together. A good example of a narrow dike or fine stringer from some adjacent stock penetrating the breccia comes out in the illustration.

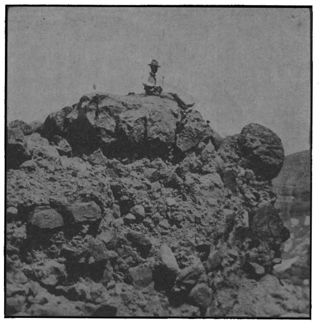


Fig. 2.—Late basic breccia, showing coarseness and angularity of the material.

It appears as a vertical intrusion near the left-hand edge of the ridge, but before reaching the top it falls away to the right and then again assumes a nearly vertical position.

Late basalt sheets.—Basalt flows overlying the late basic breccia occupy only limited areas. They are found capping the crest of the main ridge along the southern portion of the range in bold table-like masses with precipitous walls, probably remnants of one continuous flow. In broken patches they extend from Pinnacle Peak southward to Thorofare Buttes. They are best seen from Mountain Basin, looking eastward toward the ridge, where in panoramic view they present a castellated appearance, resting upon the fragmental and lighter-colored rocks. In general habit they resemble the earlier basalt sheets, and except for their geological position have little to distinguish them from the earlier flows. They are characterized by megascopic crystals of quartz. They all occur as black fine-grained rocks with few phenocrysts, and are found only near the central part of the range. These late basalts complete the cycle of eruptions which built up the Absaroka Range by the slow accumulation of successive flows of extrusive lavas, and with them the last phase in the volcanic history of this region came to an end.

Black fine-grained rocks with crystals of quartz.

A generalized section across the breccias and basalt flows of the Absaroka Range will be found in the sheet of columnar sections accompanying this folio. The combined accumulation of the breccias and extrusive flows is estimated at 11,000 feet, although from the very nature of the conditions under which the lavas were thrown out, this can be only a rough approximation. The section however, serves to present in tabular form the relative amounts of the different types of breccias, the varying nature of the materials, and their position with regard to the basaltic flows.

Fossil forests.—In the indurated tuffs, silts, and water-laid deposits, and not infrequently in coarse breccias, there occur, under favorable conditions, evidences of a luxuriant plant growth in both Eocene and Neocene times. Much of this fossil-plant material is found in a good state of preservation, and many silicified trees are still standing firmly embedded in the volcanic ejectamenta that poured over them. In many localities, on cliffs and in lateral canyons tributary to main drainage streams, erosion has laid bare great numbers of such trees. Some of them are standing, but others lie prostrate on the ground, having been thrown down by the force of the lava flows. Such groups have been designated "fossil forests." They occur scattered over the Absaroka Range, although the most remarkable of them are situated on the northwestern slopes of the range, beyond the limits of the Crandall quadrangle. In many of these localities there flourished a rich and abundant flora, as shown by well-preserved leaf impressions of various species.

Age of the breccias.—As already pointed out, the eruption of the great body of volcanic material began after the post-Laramie movement and the blocking out of the mountain ranges. On structural grounds the evidence shows that an outpouring of the breccias took place in post-Cretaceous time. The fossil trees and plant remains afford ample proof of the post-Cretaceous age of this entire body of extrusive lavas, from the early acid breccia to the latest basalt flows. Moreover, the long-continued activity of volcanic forces, accompanied by intervals of rest and quiet, is clearly brought out by the buried fossil flora. At Fossil Forest, near Chalcedony Creek, in the Park, there is a section nearly 2000 feet in thickness across a series of lava flows well exposed in the mural faces of a ravine. At frequent intervals throughout the section from base to summit there exists evidence of plant growth, and upon the surface of many mud flows forests have grown and flourished. These have in turn been killed by the pouring out of fresh material. In time new forests sprang up, only to be again buried by renewed lava streams. This is more fully stated in the Yellowstone National Park folio, No. 30 of the Geologic Atlas.

Age of lavas determined by fossil trees and plants.

A section across the basic breccias, silts, and mud flows exposed in the escarpment of Specimen Ridge at Fossil Forest will be found on the sheet of columnar sections. In an exposure of 2000 feet there is shown a series of beds carrying plant remains, leaves, stems, and rootlets, more or less well preserved, and at a number of localities fossil trees are still standing embedded in the finer silts and muds, which form an excellent soil for plant life. These trees may be found at different elevations all the way from Lamar Valley nearly to the summit of Specimen Ridge.

Similar growths, although on a much smaller scale, lie scattered over the Absarokas. They have been found on both the east and west slopes of the mountains, in lowlands of the valleys, and at high altitudes on prominent peaks and ridges. Large collections of fossil plants have been made at numerous localities, and all the material has been investigated by Prof. F. H. Knowlton. From this varied flora no fewer than 150 species have been determined, nearly one-half of which are new to science. Those which were previously known from distant fields serve to establish with considerable accuracy the geological horizons of the different groups. Each series of breccias into which the extrusive lavas have been divided yielded something to our knowledge of this extinct flora. A classification of the plants separates them into three fairly well-defined groups, which is in accord with the geological position of successive eruptions.

Fossil plants new to science.

The early acid breccias are characterized by a flora supposed to be of earlier age than that found in the overlying rocks. This grouping of species is so closely related to the flora found in the Fort Union sandstones near the junction of the Yellowstone and Missouri rivers, that the two floras are regarded as of the same age and are referred to the Eocene period. From these acid rocks about 80 species have been determined, and no fewer than 12 of them were previously known only at Fort Union. Among interesting species obtained from the limited exposures of these acid breccias are *Populus speciosa*, *Sapindus affinis*, *S. grandifolius*, *Cornus acuminata*, *Sequoia couttsiæ*.

Eocene flora.

A second group of fossil plants, provisionally known as the intermediate flora, occurs near the close of the period of early acid breccias and at the base of the early basic breccias. It is frequently found on hill slopes embedded in a soil made up of both types of rock and in shallow basins filled with coarse detrital material derived from both acid and basic lavas. In all probability it represents a flora which flourished during a transition period from one series of eruptions to another. This intermediate flora has not been recognized in either the Crandall or the Ishawooa quadrangle, but is found near the northwest corner of the Park, on cliffs bordering the Lamar River. It is, however, of much geological importance, as showing the great duration of volcanic activity in the Absaroka Range. This intermediate flora embraces about 30 species, of which only 2 or 3 are as yet known in the acid breccias. About the same number of species have been identified as belonging to the basic breccias, but the biological affinities of the group show that the flora as a whole is more closely allied to the overlying than to the underlying lavas. This flora is regarded as belonging to the base of the Neocene period, but as being older than the Auriferous gravels of California. Among the characteristic species may be mentioned *Platanus montana* and *Quercus yanceyi*.

Early Neocene, or intermediate flora.

The flora of the early basic breccia, late acid breccia, and late basic breccia appears to have been much the same wherever conditions were favorable for development of vegetation. As regards variety of species and profusion of material, the famous Fossil Forest locality on Specimen Ridge, in the Park, offers the most impressive display. Here petrified standing trees and trunks are so thickly grouped together as readily to suggest the idea of an ancient forest. Similar vegetation occurs throughout the early basic breccias at a number of localities scattered over the range, and recently some of the most characteristic species found on Specimen Ridge have been unearthed near the entrance to Stinkingwater Canyon, on the east side of the range.

The late acid breccias on Pyramid Peak and in Mountain Creek Basin have yielded fragmentary remains of a related flora. Here the species *Populus zaddachi*, widely distributed over America and Europe, occurs, but as far as yet known, it is limited in the Absaroka Range to the late acid breccia.

The late basic breccia, covering much larger areas than the late acid breccia, shows evidences of conditions favorable to plant life, although the lava ejected from the vents is usually coarser and less suitable either to develop or to preserve a luxuriant vegetable growth. Such fragmentary material as has been obtained agrees specifically with similar plant remains of the early basic breccia. In the accompanying illustration (fig. 3) there is shown a portion of a large fallen tree well preserved by silicification. It is 8 feet long and about 2 feet in circumference at the base. Its interest consists largely in the fact that it lies on the steep slope of Overlook Mountain, nearly 11,000 feet above sea level, far above the present timber line, in a region of rough and rugged aspect. Other trunks of trees similar to this one occur, and abundant leaf impressions show that as recently as late Neocene time a very considerable plant life flourished in the Absarokas. The high altitude at which this subtropical Neocene flora is found furnishes strong evidence as to the great uplifting of the mountains within comparatively recent time. The picture affords a good illustration of the usual character of the fine brecciated material upon which the vegetation flourished. A short distance northward, on Chaos Mountain, the finer beds carry leaves and twigs similar to those found in the lower breccias elsewhere.

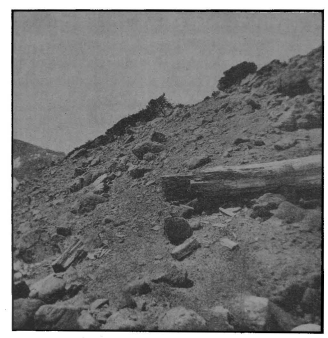


Fig. 3.—A portion of a large petrified tree on Overlook Mountain, far above the present timber line.

The flora has been referred to a higher horizon than the intermediate flora already described, and is regarded by Professor Knowlton as belonging to the upper Neocene, and as of about the same age as the flora of the Auriferous gravels of California, several of the species being identical. It has been designated the Lamar flora. Large collections have been made from different localities, and about 70 species have been recognized. Many of them are known only in the Absaroka Range, but others are identical with well-known species characteristic of geological horizons elsewhere. Among them may be mentioned such species as *Laurus californica*, *Magnolia californica*, *Aralia whitneyi*, and *Planera longifolia*.

Late Neocene, or Lamar, flora.

Rhyolite.—Before considering the intrusive rocks mention should be made of the extrusive flows of rhyolite, which are of much later age than the breccias and basalts. They are found only along the western border of the Crandall quadrangle, where, so far as the Absaroka Range is concerned, they play an insignificant part, representing in most instances only outlying bodies of the massive rhyolite plateau of the Yellowstone Park. The later age of the rhyolite is well determined by its position in the bottoms and along the sides of deeply trenched valleys cut in breccias. Examples of such occurrences are seen in both the Upper Lamar and the Little Lamar valleys, and at the base of Saddle Mountain and of Castor and Pollux peaks. It is also found filling the depression in the bottom of Cache Creek Valley. Isolated patches of rhyolite, probably remnants of erosion, rest upon the breccias high up on the slopes of Saddle Mountain and eastward toward Hoodoo Basin, but are unknown on the east side of the range. In mineralogical composition the different bodies closely resemble one another and are typical of the great flows which constitute the mass of the Park Plateau. Phenocrysts of sanidine and quartz abound, but those of other minerals are rare. Purplish-gray tints predominate wherever the rhyolite is fresh. It is a lithoidal rock, and, in sharp contrast with the breccias of the range, carries but little if any fragmental material.

Composition of the rhyolite.

INTRUSIVE ROCKS.

Intrusive rocks are those that in penetrating older rocks by means of fissures and vents of various kinds have cooled and consolidated before reaching the surface. Such rocks play a highly important part in the volcanic history of this region, and occur widely distributed over the greater part of the Absaroka Range. (See fig. 7 of accompanying page of illustrations.)

They occur as stocks, sheets, and dikes, varying in form from massive bodies 2 and 3 miles in width and several thousand feet in height to narrow offshoots a few feet in width, traceable at the surface for only a short distance from the parent body. Occasionally some of the larger bodies may rise for a short distance above the general level of the plateau, but most of them fail to attain so high an elevation, and none of them tower in massive proportions above the slightly inclined ridges. The top of the most impressive of them all lies buried beneath a thousand feet of breccia. Many of the interbedded sills may be traced to some one of the larger stock masses, but not infrequently they penetrate the breccias apparently independent of them. Some of them are long, narrow bodies, others spread out with very indefinite outline, still others are dome-shaped, developing laccolithic forms. Where they cross the interbedded breccias it is by no means easy to differentiate them from normal dikes, and the larger irregular masses closely resemble stocks. Although intrusive bodies probably penetrated the breccias from time to time during the building up of the range, it seems evident that the larger intrusions, together with most of the dikes, were forced upward and into the breccias at two fairly well-defined periods during the successive accumulations of the lavas. One of these periods was in part contemporaneous with the early basalt flows and in part followed them. The other followed the late basic breccia and flows and, so far as can be told, completed the final chapter in the volcanic history of the immediate region. All the more important intrusive masses have been regarded as belonging to one or the other of these periods. It does not follow that the intrusions of either period were necessarily contemporaneous in age, but simply that they belong to a certain phase of the eruptive energy.

Stocks, sheets, and dikes.

The stocks are cut by bodies and dikes of later age, intersecting those of earlier eruption found in many parts of the mountains. The intrusions which followed the early basic breccia have been designated the Sunlight intrusives, while those which followed the late basic breccia have been designated the Ishawooa intrusives. On the maps of the folio the two series of intrusive stocks have been discriminated by differences of color easily recognized.

Sunlight intrusives.—Rocks of this type derive their name from Sunlight Basin, where they are characteristically shown at a number of localities. The greatest body is found at the head of the valley on the divide between Sunlight Creek and the Stinkingwater. It measures nearly 3 miles in length, and may be traced across the deep amphitheaters of Copper, Fall, and Sulphur creeks, the high intervening ridges stretching northward being formed of indurated breccia. All three amphitheaters culminate in Stinkingwater Peak, the summit of which is made up of early basic breccia more or less indurated. The Sunlight group of intrusive rocks varies from a quartz-augite-syenite, through various forms of syenite and diorite, to gabbro. The Stinkingwater Peak body is essentially a syenite, accompanied by smaller bodies of monzonites and diorites. On the other hand, the Crandall Basin intrusive body on the north side of Hurricane Mesa is composed largely of diorites and orthoclase gabbros. The series as a whole contains a development of the minerals augite and orthoclase, with quartz and biotite in its more siliceous members, and olivine, plagioclase feldspar and hypersthene in its more basic types. Broadly stated the Sunlight intrusives are more varied in mineral composition than those of the Ishawooa group.

Mineral composition of Sunlight intrusives.

A remarkable array of sheets and dikes closely related geologically to the Sunlight intrusives occurs distributed over both the Crandall and the Ishawooa quadrangles. Many of them are directly connected with the larger intrusions, and radiate from them into the surrounding breccias as offshoots and apophyses from the central magma. They vary considerably in width, continuity of exposure, and mode of occurrence, and exhibit a wide range in texture and mineral composition. They include diorite, diorite-porphyry, andesite-porphyry, hornblende-andesite, and pyroxene-andesite. Many of them are quartz-bearing varieties. Basaltic dikes cut these early basic breccias, but their relations to the large intrusions are not always easy to determine, since a large proportion of them are related to the early basalt flows, while certain normal basalts appear to be of later age.

Absarokite group of sheets and dikes.

Associated with the Sunlight intrusives occurs a series of basaltic rocks known as the absarokite group, which show considerable variation in chemical composition, with corresponding development of mineral components. Large collections of these rocks made in the field have been studied under the microscope by Prof. J. P. Iddings and Dr. T. A. Jaggar, with the aid of numerous chemical analyses. Professor Iddings has classed these absarokite rocks under three heads—absarokites, shoshonites, and banakites—depending upon their varying chemical and mineral relations, and the reader is referred to The Geology of the Yellowstone National Park, Monograph XXXII, Part II, for a detailed study of these rocks. For the purposes of this folio they are here classed together under one head, designated the absarokite group. As a group the absarokite rocks represent phases of chemical differentiation from a basaltic magma. Chemically the group is characterized by a low percentage of alumina and high alkalies, with variable silica. In mineral composition they differ from normal basalt chiefly in the presence of orthoclase feldspar or its chemical equivalent in the groundmass, developed by reason of the excess of potash present. In color they vary from brown to black and gray, and are usually noticeable for their resinous luster. The most basic members develop olivine and augite as prominent phenocrysts, while the siliceous types carry mainly labradorite with subordinate biotite and augite. The groundmass varies from a somewhat glassy to a granular structure, showing alkali feldspar with magnetite, augite, and biotite. Exceptional rocks carry quartz, leucite, and hornblende.

Character of absarokite basalts.

The absarokite group of flows and dike rocks stand genetically related to the Sunlight intrusives, but, while they are found in close proximity to the larger and more prominent bodies it is equally true that they cut the early breccias at localities remote from any known exposure at the surface of a stock rock. Persistent dikes of the absarokite group are seen as far south as Shoshone River. One of the most striking of the leucite-absarokite rocks, carrying large phenocrysts of olivine and augite, with both leucite and orthoclase in the groundmass, occurs in Ishawooa Canyon. Nowhere can this group of rocks in the form of bold vertical dikes be better observed than along Stinkingwater Canyon between Clocktower and Fishhawk creeks. The bare hill slopes along the Wapiti Valley a short distance above its junction with the Stinkingwater afford excellent opportunities for a study of geological phenomena connected with dike rocks. It has been impossible to differentiate these dikes from others, and on the map they are printed in the same color as all other dikes regarded as belonging to the Sunlight intrusives.

Needle Mountain, an imposing intrusive mass.

Ishawooa intrusives.—As already mentioned, rocks of this type hold essentially the same relative position to the late acid and basic breccias that the Sunlight intrusives do to the early series of breccias. They take their name from Ishawooa Canyon, where in the narrow walls of the somber gorge they stand out in a remarkable manner, from the stream bed to the plateau summit—a light-colored rock set in dark breccia. Here they exhibit extremely complex manifestations of eruptive energy. The most imposing single occurrence of any intrusive mass in the Absaroka Range is Needle Mountain, near the southern boundary of the Ishawooa quadrangle. The gorge of the Shoshone River presents one of the most profound and at the same time picturesque canyons in Wyoming, with Needle Mountain standing out as its most prominent topographic feature. This intrusive mass, which stretches along the valley for nearly 4 miles, rises in abrupt and rugged walls for 4000 feet and is then capped with 1000 feet of more or less indurated breccia. It is penetrated by numerous small bodies, and from it have gone out into the surrounding breccia, tearing and ripping it up in all directions, innumerable dikes and sheets. Dikes also intersect the overlying breccia. Many of these offshoots occur as granite-porphyry. From Needle Mountain northward there occur at frequent intervals intrusive bodies with abundant evidence of their penetrating the later breccias as sheets and dikes from a parent stock. One of the most instructive of these is the granite-porphyry mass on the west side of Shoshone Canyon just south of Cabin Creek. All the rock face exposed consists of a light-colored, coarsely crystalline mass, carrying well-developed quartz and but little groundmass material. Similar intrusions may be followed along Shoshone Canyon, across Cabin and Deer canyons, and over the plateau ridge to the phenomenal display of intrusions in Ishawooa Canyon, where they reached the summit of the plateau at the point known as Clouds Home. From here they continue on across Wapiti and Fishhawk canyons, thence on to the head of Eagle Creek, where they are again well exposed by the incisive and deep trenching of the canyon, and thence into the Park, finally dying out a short distance north of Sylvan Peak in a group of well-defined dikes. By reference to the map it will be seen that these intrusive masses have a north-west-southeast trend for over 50 miles.

Mineral composition of Ishawooa intrusives.

The Ishawooa group of intrusives varies from a true granite associated with granite-porphyry through a series of increasingly basic rocks—diorite, diorite-porphyry, hornblende-andesite, hornblende-pyroxene-andesite, and pyroxene-andesite. In the granite and granite-porphyry orthoclase, quartz, and biotite are predominant. The diorites have hornblende and plagioclase, with a subordinate amount of quartz and biotite. The diorite-porphyries grade into andesites of finer groundmass, some of which appear to be surface flows. Needle Mountain consists mainly of fine-grained diorite with true granular structure. Many of the diorite-porphyries carry but a small amount of groundmass. The stock exposed on Dell Creek is essentially a granite-porphyry, penetrating the slightly inclined rocks of Thorofare Plateau, and is similar to the broad sheets observed near Yellow Mountain.

Dikes of the Ishawooa series.

Intervals between the larger stocks are for the most part occupied by indurated breccia, cut here and there by a marvelous network of dikes and irregularly shaped bodies. They extend all the way from Needle Mountain to Sylvan Pass, following the trend of the large intrusive bodies, and do not radiate from any central stock in so striking a manner as seen in the case of the Sunlight intrusives. By the induration of the breccias caused by the intrusion of dikes the topographic forms of the mountain are frequently rough and rugged and furrowed by ridges in a way quite different from the unaltered late breccias elsewhere. Like the larger intrusive bodies, the dikes vary greatly in mineral composition. They range from granite, granite-porphyry, and diorite-porphyry to andesite-porphyry and andesite. Associated with them are dikes of normal basalt, but their connection with the other dikes is not always easily made out. A study of these dikes shows a close relationship to the massive stock rocks of the Ishawooa group of intrusives, and they are regarded as having emanated and solidified from one and the same deep-seated magma. Owing to their great variability in composition and the small scale of the map, all dikes regarded as belonging to the period of the Ishawooa intrusives are printed in one color, similar to that adopted for the larger masses.

Mineral composition of Ishawooa dikes.

There is no evidence of volcanic action after the intrusion of the Ishawooa stocks and the accompanying sheets and dikes other than a few small patches of rhyolite extending over from the Park Plateau and possibly breaking out in a few isolated areas along the slopes of the range. The centers of volcanic energy moved westward, and eruptions were active over the area which is now the Yellowstone National Park. There remains no evidence of eruptions in the Absarokas during Pliocene time.

PLEISTOCENE DEPOSITS.

The Absarokas and the Park a local glacial center.

Glacial epoch.—After the cessation of volcanic activity in the Absarokas degradation of the plateau slowly took place, but no events of geological interest are recorded until the entire region was covered by glacial ice in Pleistocene time. The Absaroka Range and the Yellowstone National Park present such a broad area of elevated country favorable to the precipitation of moisture that the entire region was during Glacial time covered by a heavy capping of ice, forming one of the largest of the local glacial centers known in the Rocky Mountains south of the great northern continental ice sheet. From the Absaroka Range glaciers moved westward down the Lamar and Upper Yellowstone valleys in the direction of the Park, the former fed by the snows of the greater part of the northern Absarokas and the latter supplied from the Wind River Plateau, Thorofare Plateau, and the elevated country drained by Thorofare Creek. On the east side of the mountains all the upper valleys have been sculptured by ice action, and large amounts of glacial débris have been swept away, the loosely compacted breccias and fine silts yielding readily to ice movement. Such evidences of glacial phenomena as lateral and terminal moraines abound everywhere, and many of the walls of the narrow canyons are broadly benched for a thousand feet or more above the stream beds. The valley of Clark Fork was occupied by a profound glacier, and the rounded and polished forms of the gneisses and granites not only are characteristic features of the scenery, but stand out in marked contrast to glaciated valleys carved out of the breccias. In figs. 4 and 5, on the accompanying sheet of illustrations, the outlines of the valleys and the glaciated forms are clearly brought out.

Glacial phenomena.

Glaciers and snow fields.

In the deep basins of several of the higher valleys facing northeast long snow fields are still to be found, and in some instances the broad amphitheaters are occupied by small glaciers, which are in great measure protected from the direct rays of the sun by the high walls of breccia, but which receive vast accumulations of snow, driven northeastward by the prevailing southwest winds. Such glaciers and snow fields are found at the head of Hidden Creek, on Overlook Mountain, along the north side of Sheep Mesa, and at the head of Sulphur Creek, one of the tributaries of Sunlight Basin. In fig. 8, on the page of illustrations, is shown the glacier of Sulphur Creek, lying at the base of both Stinkingwater and Sunlight peaks. It has been named the Sunlight glacier. One of the crevasses across it is clearly brought out in the illustration, as well as a good example of a lateral moraine piled up at the base of a steep cliff. The mountain slopes are distinctly ice worn, and the canyons have the characteristic outlines of glacial valleys.

On the map the glacial drift is indicated only where it is spread out over large areas or is heaped up in intermontane valleys in such accumulations as to present a marked feature of the region.

Deposits of Shoshone River and Sunlight Creek.

Alluvium.—The areas indicated on the map as alluvium are restricted to the broader valleys along stream beds and flood plains. Such deposits are well shown along Shoshone River and Sunlight Creek, where they attain considerable thickness and conceal the underlying rocks. These valleys where the soil is cultivated have yielded good crops of hay and cereals. In most of the mountain valleys the alluvial deposits occupy limited areas and form but a light mantle over the breccia. In such instances they do not conceal the igneous rocks, and as they are of slight economic interest they have not been mapped, although patches of alluvial meadow lands may be found scattered over the mountains.

Alluvial fans.

Several of the larger valleys are characterized by alluvial fans, which are made up of coarse material brought down from the mountains by tributary streams and spread out over the country. The fan-shaped areas of detritus are narrow near the mouth of the canyons, but are frequently more than a mile in width in the open valley. A remarkable example of such alluvial fans is seen in Shoshone Valley at the mouth of Boulder Creek. The fan is ribbed by a number of narrow channels cut in the loose material by spring torrents. Here a large amount of material has been brought down from the plateau and spread out, extending entirely across the valley, nearly to the entrance of Ishawooa Canyon, on the opposite side. Still more remarkable are the fan cones that have been built up upon the steep hill slopes in Shoshone Canyon, where they rise for nearly 1200 feet above the stream bed.

Hot-spring areas.

Solfataric action.—Extinct areas of solfataric action are recognized only in one or two places in the Absaroka Range, the largest being Sulphur Lake, on the east side of Sulphur Creek, a short distance above Breccia Creek. The rocks in the immediate region are decomposed and whitened by extinct thermal agencies, and the fissures and seams in the breccia are permeated with sulphur. The water of the small lake is cold and sulphurous. Other areas of solfataric vents probably existed, but evidences of thermal action have for the most part long since been obliterated. On the west slopes of the Absarokas there are a number of hot-spring areas, but they lie within the Yellowstone Park just beyond the limits of both the Crandall and the Ishawooa quadrangles, and in most instances in the neighborhood of areas of rhyolite. On the west slopes of Saddle Mountain there are a number of localities marked by either active or extinct thermal-spring areas.

ECONOMIC RESOURCES.

No economic sheet is published in connection with the Absaroka folio, partly because by far the larger part of the Crandall and Ishawooa quadrangles is included within the Yellowstone Park Forest Reservation, which stands on a somewhat different basis from other Government forest reserves, as it adjoins the Park on the east and south and has been placed, by order of the Secretary of the Interior, under the protection of the Acting Superintendent of the Park, and partly because the mineral resources discovered in the Absaroka Range are as yet of slight importance.

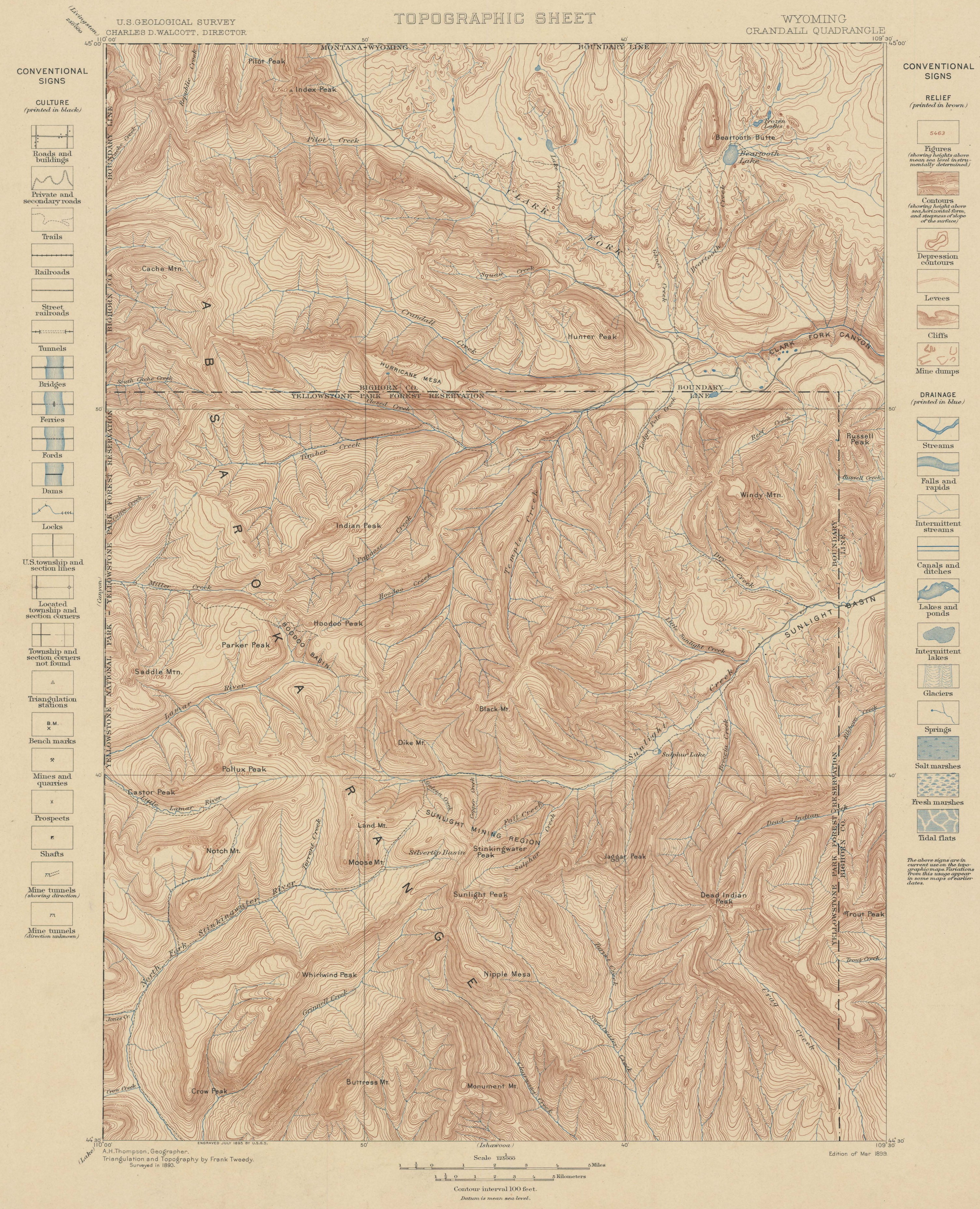
Mining districts.

Two mining districts have been located within the two quadrangles here mapped. One of them, known as the Sunlight mining district, is situated in the Crandall quadrangle and is geologically related to the massive body of Sunlight intrusives exposed in the deep amphitheaters of Galena, Copper, and Sulphur creeks and on the head of the Stinkingwater River in Silvertip Basin. The ores usually occur along lines of contact between syenite and syenite-porphyries and intrusive dikes. These dikes frequently penetrate the surrounding breccia, in which case the ores are also found along the contact between the dikes and breccia. The ores are mainly sulphides of copper and lead carrying silver. The mines that have been located are situated between 10,000 and 11,000 feet above sea level.

The other mining district, known as the Stinkingwater, is situated in Shoshone Canyon near Needle Mountain, the largest mass of the Ishawooa intrusive diorites and diorite-porphyries. In their geological occurrence these ore bodies closely resemble those found in the Sunlight district. Mining properties have been located near the base of Needle Mountain, on Crater Mountain and Ash Mountain, and on the west side of the valley. Less exploitation has been carried on here than in the Sunlight district, and none of the tunnels are as long. Neither in 1893 nor in 1897, when this district was visited, was there any one living permanently at the mines.

ARNOLD HAGUE,
Geologist.

December, 1898.


U.S. GEOLOGICAL SURVEY
CHARLES D. WALCOTT, DIRECTOR
TOPOGRAPHIC SHEET
WYOMING
CRANDALL QUADRANGLE
(Livingston)
110°00'
45°00'
50'
40'
109°30'
CONVENTIONAL SIGNS
CULTURE
(printed in black)
Roads and buildings
Private and secondary roads
Trails
Railroads
Street railroads
Tunnels
Bridges
Ferries
Fords
Dams
Locks
U.S. township and section lines
Located township and section corners
Township and section corners not found
Triangulation stations
Bench marks
Mines and quarries
Prospects
Shafts
Mine tunnels (showing direction)
Mine tunnels (direction unknown)
RELIEF
(printed in brown)
Figures (showing heights above mean sea level in instrumentally determined)
Contours (showing height above sea, horizontal form, and steepness of slope of the surface)
Depression contours
Levees
Cliffs
Mine dumps
DRAINAGE
(printed in blue)
Streams
Falls and rapids
Intermittent streams
Canals and ditches
Lakes and ponds
Intermittent lakes
Glaciers
Springs
Salt marshes
Fresh marshes
Tidal flats
The above signs are in current use on the topographic maps. Variations from this usage appear in some maps of earlier dates.
MONTANA-WYOMING BOUNDARY LINE
Pilot Peak
Index Peak
Pilot Creek
Beartooth Butte
Frozen Lakes
Beartooth Lake
CLARK FORK
Cache Mtn.
Squaw Creek
Crandall Creek
Hunter Peak
CLARK FORK CANYON
HURRICANE MESA
BIGHORN CO.
YELLOWSTONE PARK FOREST RESERVATION
BOUNDARY LINE
South Cache Creek
Hazel Creek
Timber Creek
Russell Peak
Russell Creek
Windy Mtn.
Indian Peak
Papoose Creek
Hoodoo Creek
Temple Creek
Dry Creek
A B S A R O K A R A N G E
YELLOWSTONE NATIONAL PARK
YELLOWSTONE PARK FOREST RESERVATION
BIGHORN CO.
BOUNDARY LINE
Miller Creek
Hoodoo Peak
HOODOO BASIN
Parker Peak
Saddle Mtn.
Lamar River
Little Sunlight Creek
SUNLIGHT BASIN
Sunlight Creek
Black Mt.
Dike Mt.
Sulphur Lake
Pollux Peak
Castor Peak
Little Lamar River
SUNLIGHT MINING REGION
Land Mt.
Stinkingwater Peak
Silvertip Basin
Jaggar Peak
Dead Indian Creek
Notch Mt.
Moose Mt.
Sulphur Creek
Sunlight Peak
Dead Indian Peak
Trout Peak
Trout Creek
North Fork Stinkingwater River
Whirlwind Peak
Nipple Mesa
Grinnell Creek
Crag Creek
Crow Peak
Buttress Mt.
Monument Mt.
(Lake)
(Ishawooa)
44°30'
ENGRAVED JULY 1895 BY U.S.G.S.
A.H. Thompson, Geographer.
Triangulation and Topography by Frank Tweedy.
Surveyed in 1893.
Scale 1/125000
5 Miles
5 Kilometers
Contour interval 100 feet.
Datum is mean sea level.
Edition of Mar. 1899.

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

HISTORICAL GEOLOGY SHEET

WYOMING
CRANDALL QUADRANGLE

A.H. Thompson, Geographer.
Triangulation and Topography by Frank Tweedy.
Surveyed in 1893.

Scale $\frac{1}{125000}$
Miles
Kilometers
Contour interval 100 feet.
Datum is mean sea level.
Edition of May 1899.

Geology by Arnold Hague.
Assisted by Joseph P. Iddings and Thomas A. Jaggar, Jr.
Surveyed in 1893 and 1897.

LEGEND

SURFICIAL ROCKS

(Areas of Surficial rocks are shown by patterns of dots and circles.)

PLEISTOCENE

- Pal — Alluvium *(gravel and clay forming the stream bottoms and terraces along the valleys)*
- Pgd — Glacial drift *(gravels, clays, and sands, distributed by glaciers of local origin)*

SEDIMENTARY ROCKS

(Areas of Sedimentary rocks are shown by patterns of parallel lines.)

CARBONIFEROUS

- Cm — Madison limestone *(massive cream-colored limestone above, thinly bedded blue-gray limestone below)*

DEVONIAN

- Dtf — Threeforks limestone *(massive gray limestone, frequently shaly and argillaceous)*

SILURIAN

- Sj — Jefferson limestone *(light-colored limestone, forming a persistent cliff, with black or brown limestone above)*

CAMBRIAN

- Cg — Gallatin limestone *(massive, mottled limestone overlain by thin-bedded limestone)*
- Cf — Flathead formation *(limestone, shale, and quartzite)*

IGNEOUS ROCKS

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

NEOCENE

- Nrh — Rhyolite *(massive flows of acid lava, carrying crystals of quartz and sanidine)*
- Ishawooa dikes *(basic and acid dikes cutting the late basic breccia)*
- Nlbb — Late basic breccia *(rocks of similar mineral composition to the early basic breccia, but of later age)*
- Nlab — Late acid breccia *(similar in composition to the early acid breccia and containing fragments similar to the Ishawooa intrusives of the Ishawooa quadrangle)*
- Sunlight dikes *(pyroxene-andesite, basalt, absarokite, and related rocks cutting the early basic breccia)*
- Nsl — Sunlight intrusives *(massive gabbro-diorite and syenite bodies cutting the early basic breccia)*
- Nebs — Early basalt flows *(dark-gray or black rocks separating the earlier series of breccias from the later series)*
- Nebb — Early basic breccia *(fragments of pyroxene-andesite, hornblende-pyroxene-andesite, and basalt associated with basic lava flows)*

EOCENE

- Eab — Early acid breccia *(fragments of hornblende-andesite and hornblende-mica andesite; light-colored)*

UNCLASSIFIED CRYSTALLINE ROCKS

(Areas of metamorphic rocks of unknown origin are shown by patterns of short dashes)

ARCHEAN

- Agn — Granite and gneiss

⚒ *Silver and copper mines*

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

TOPOGRAPHIC SHEET

WYOMING
ISHAWOOA QUADRANGLE

CONVENTIONAL SIGNS

CULTURE
(printed in black)

- Roads and buildings
- Private and secondary roads
- Trails
- Railroads
- Street railroads
- Tunnels
- Bridges
- Ferries
- Fords
- Dams
- Locks
- U.S. township and section lines
- Located township and section corners
- Township and section corners not found
- Triangulation stations
- Bench marks B.M. ×
- Mines and quarries
- Prospects
- Shafts
- Mine tunnels *(showing direction)*
- Mine tunnels *(direction unknown)*

RELIEF
(printed in brown)

- Figures *(showing heights above mean sea level instrumentally determined)* 5463
- Contours *(showing height above sea, horizontal form, and steepness of slope of the surface)*
- Depression contours
- Levees
- Cliffs
- Mine dumps

DRAINAGE
(printed in blue)

- Streams
- Falls and rapids
- Intermittent streams
- Canals and ditches
- Lakes and ponds
- Intermittent lakes
- Glaciers
- Springs
- Salt marshes
- Fresh marshes
- Tidal flats

The above signs are in current use on the topographic maps. Variations from this usage appear in some maps of earlier dates.

ENGRAVED AUG. 1895 BY U.S.G.S.

A.H. Thompson, Geographer.
Triangulation and Topography by Frank Tweedy.
Surveyed in 1893.

Scale $\frac{1}{125000}$
Miles
Kilometers

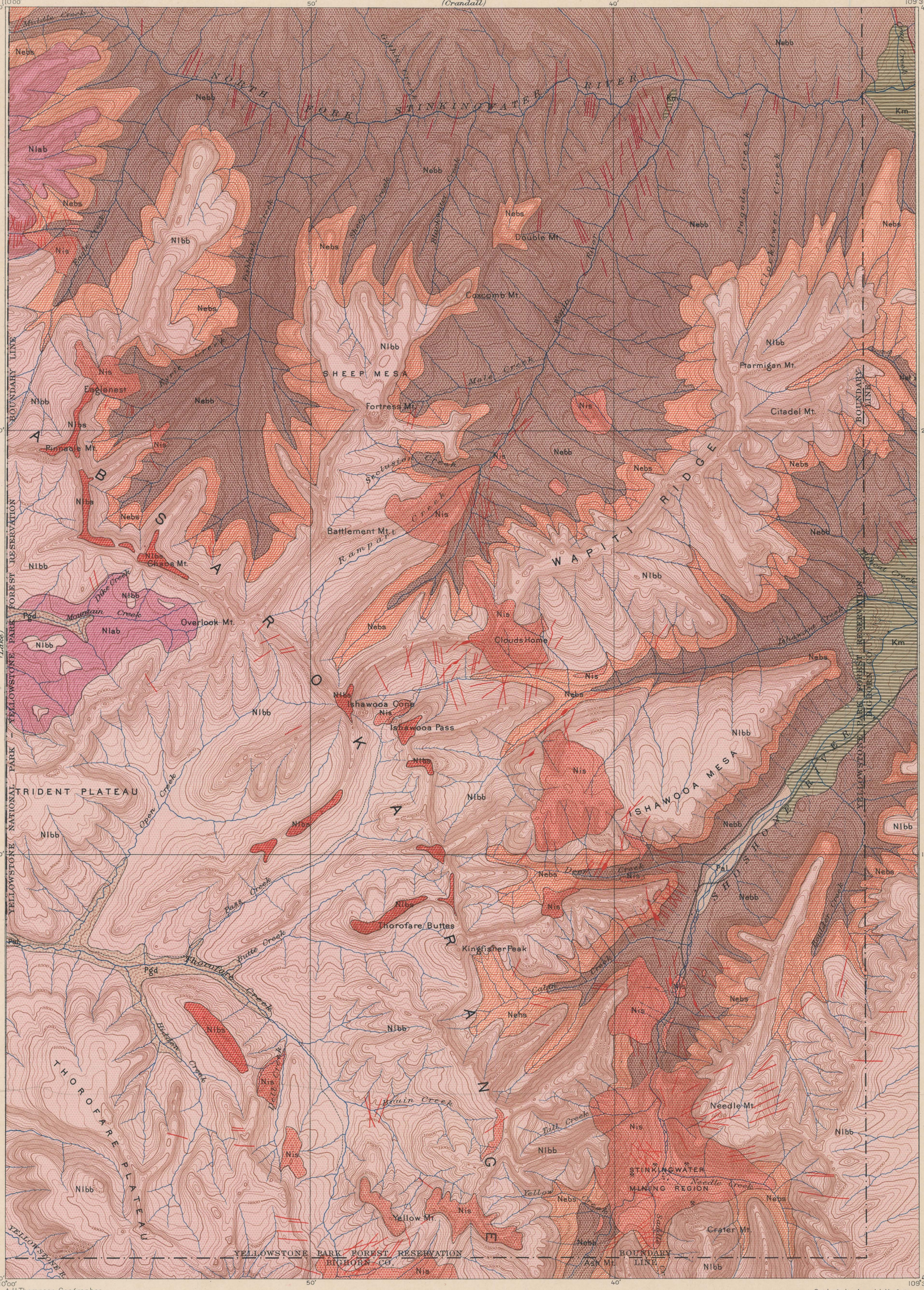
Contour interval 100 feet.
Datum is mean sea level.

Edition of Mar. 1899.

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

HISTORICAL GEOLOGY SHEET

WYOMING
ISHAWOOA QUADRANGLE



A. H. Thompson, Geographer.
Triangulation and Topography by Frank Tweedy.
Surveyed in 1893.

Scale $\frac{1}{125000}$
Miles
Kilometers
Contour interval 100 feet.
Datum is mean sea level.
Edition of May 1899.

Geology by Arnold Hague.
Assisted by Thomas A. Jaggar, Jr.
Surveyed in 1893 and 1897.

LEGEND

SURFICIAL ROCKS

(Areas of Surficial rocks are shown by patterns of dots and circles.)

PLEISTOCENE

Pal — Alluvium *(gravel and clay forming the stream bottoms and terraces along the valleys)*

Pgd — Glacial drift *(gravels, clays, and sands, distributed by glaciers of local origin)*

SEDIMENTARY ROCKS

(Areas of Sedimentary rocks are shown by patterns of parallel lines.)

CRETACEOUS

Km — Montana formation *(including the Fox Hills sandstone and Pierre shale, not generally distinguishable)*

IGNEOUS ROCKS

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

NEOCENE

Ishawooa dikes *(varying from diorite-porphyry to granite-porphyry and cutting the late basic breccia)*

Nis — Ishawooa intrusives *(massive andesite, diorite, and granite-porphyry bodies penetrating the late basic breccia)*

Nlbs — Late basalt flows *(black basalt capping the late basic breccia)*

Nlbb — Late basic breccia *(rocks of similar mineral composition to the early basic breccia, but of later age)*

Nlab — Late acid breccia *(similar in composition to the early acid breccia and containing fragments similar to the Ishawooa intrusives)*

Sunlight dikes *(pyroxene-andesite, basalt, absarokite, and related rocks cutting the early basic breccia and basalt flows)*

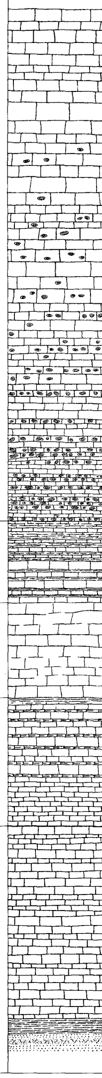
Nebs — Early basalt flows *(dark-gray or black rocks separating the earlier series of breccias from the later series)*

Nebb — Early basic breccia *(fragments of pyroxene-andesite, hornblende-pyroxene-andesite, and basalt associated with basic lava flows)*

⚒ *Silver, copper, and lead mines*

GENERALIZED SECTION OF THE PALEOZOIC SEDIMENTS OF THE ABSAROKA RANGE.

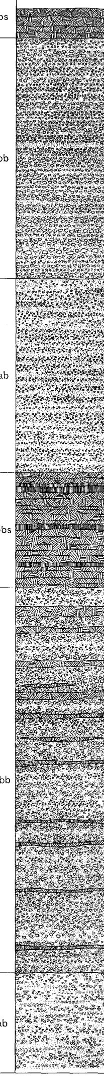
SCALE: 300 FEET = 1 INCH.



Period.	Formation Name.	Symbol.	Columnar Section.	Thickness in Feet.	Character of Rocks.
CARBONIFEROUS	Madison limestone.	Cm		1600	Limestone throughout. Beds finely bedded, carrying cherty and nodular layers, most numerous near the base. Upper beds massively bedded, near the top showing almost no bedding. Light gray in color.
DEVONIAN	Threeforks limestone.	Dtf		250	Alternating beds of limestone and calcareous shales. Beds become more massive toward the base, with thin layers of intercalated shales. Shaly layers more characteristic of the top than the base.
SILURIAN	Jefferson limestone.	Sj		300	Beds massive, frequently all traces of bedding having been obliterated. Limestone dark colored near the base, gradually changing to light blue near the summit.
CAMBRIAN	Gallatin limestone.	€g		400	Dark-blue limestone with frequent layers of calcareous shales. Beds near both base and summit are shaly. The shaly beds are characterized by fossils. Mottled limestone 150 feet thick, which shows in steep escarpments. Carries very few fossils.
	Flathead formation.	€f		700	Limestone. Shale, arenaceous at base, calcareous at summit. Sandstone, varying in thickness, averaging 50 feet.

GENERALIZED SECTION OF THE BRECCIAS AND BASALT FLOWS OF THE ABSAROKA RANGE.

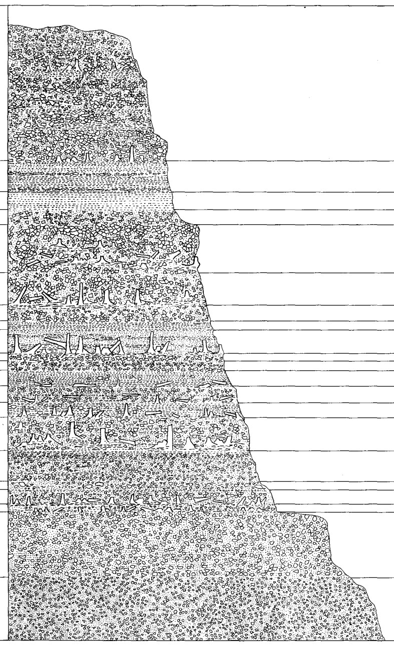
SCALE: 1000 FEET = 1 INCH.



Period.	Formation Name.	Symbol.	Columnar Section.	Thickness in Feet.	Character of Rocks.
NEOCENE	Late basalt flows.	Nlbs		300	Basalt flows well bedded, uniform in character. Beds somewhat thicker at the top than at the base.
	Late basic breccia.	Nlbb		2500	Material both coarse and fine, very similar to early basic breccia in physical character. The coarse material is generally more abundant near the base than at the summit, although there are marked exceptions. At the base there are frequent transitions in bedding, many of the beds being almost wholly made up of fine material.
	Late acid breccia.	Nlab		2000	In mineral composition much the same as the early acid breccia, mainly hornblende-andesite and hornblende-mica-andesite. Material all angular and for the most part finer than the early acid breccia. Beds of exceptionally fine material occasionally occur. Beds vary in thickness and overlap one another.
	Early basalt flows.	Nebs		1200	Basalts in beds from 5 to 50 feet in thickness. Beds thicken and thin out in different directions, and frequently overlap. Occasional flows of columnar basalt, more frequent near the top than at the base. Some of the flows are of feldspar-basalt (absarokite, shononite, and banakite).
	Early basic breccia.	Nebb		4000	Beds of coarse and fine breccia. Fragments for the most part are angular. Most beds are of medium-grained material; others are of fine material and more uniform in appearance. The latter are interbedded in the former. There is evidence of overlapping of the beds. Basalt sheets occur throughout these breccias, thin near the base, but increasing in frequency and thickness toward the summit. Lenticular beds of basalt occur, indicating numerous local sources of outflow.
EOCENE	Early acid breccia.	Eab		1000	Coarse and fine material, indistinctly bedded and irregularly heaped up. Much of the material shows no bedding. There are some thin beds of fine silts and muds, of the same material as the coarser beds. The mud flows thicken and thin out in different directions.

GENERALIZED SECTION OF BRECCIAS, ASHES, AND SILTS AT THE FOSSIL FOREST.

SCALE: 300 FEET = 1 INCH.



Feet.	Character of Rocks
400	Compact basic breccias of varying degrees of fineness, with interbedded bands of ash holding plant remains, but imperfect and fragmentary.
100	Interstratified beds of indurated green and gray ash, with layers of fine breccia, carrying small angular fragments.
50	Lead-colored, friable ash, crumbling readily into a loose soil. Leaf beds imperfectly preserved.
50	Yellowish-brown breccia, disintegrating more easily than the underlying bed.
150	Compact breccia presenting a well-defined ledge, withstanding erosion and projecting out beyond the slope of the cliff. Fragmentary tree and plant remains.
100	Dark basic breccia, changing rapidly according to conditions of deposition. Carries fossil trees.
50	Greenish breccia, mainly hornblende-pyroxene-andesite. Shows rapid deposition. Plant remains.
35	Fine silt, indurated and green below and carrying fragments of andesite in upper portion. Rich in plant remains.
75	Interbedded layers of ash and silts, varying slightly in color and compactness. Some layers crumble readily. Material mainly fine grained, but frequently contains large angular fragments. These beds carry standing and prostrate trees.
20	Dark breccia, both coarse and fine; fossiliferous.
30	Fine-grained breccias, with indurated green tuffs and ash beds. Upper beds fossiliferous.
50	Light-brown and gray indurated ash, with some bowlders. Intercalated stratified beds. Fossil leaves and stems.
50	Medium-grained-breccia, carrying fossil wood, with interbedded layers of fine volcanic muds.
50	Coarse ash, silt and mud flows, with every appearance of submerging of forests. Breccia bowlders scattered through it.
100	Andesitic breccia of angular and subangular material mingled with varying proportion of fine ash and indurated muds. Standing fossil trees.
95	Fine-grained basaltic breccia, with interbedded layers of ash and silt. Thin layer of compact drab-colored ash at the top.
25	Breccia varying in coarseness, with lenticular bodies of ash, carrying evidences of plant life. Occasional large bowlders.
45	Coarse breccia with angular bowlders of pyroxene-andesite, some of them 3 feet in diameter. Overlain by stratum of fine ash.
25	Two thin layers of fine-grained hornblende-pyroxene-andesite ash, carrying fragmentary fossil wood and standing trees.
200	Coarse breccia, subangular and rounded, firmly cemented by fine volcanic mud, and carrying fragmentary impressions of plant remains.
200	Andesitic and basaltic breccias characteristic of the early basic breccia of the Absaroka Range, with cementing ash and fine breccia more or less decomposed, the rock usually showing a greenish tinge. The beds more or less covered by soil and detritus.

ARNOLD HAGUE,
Geologist.

SPECIAL ILLUSTRATIONS

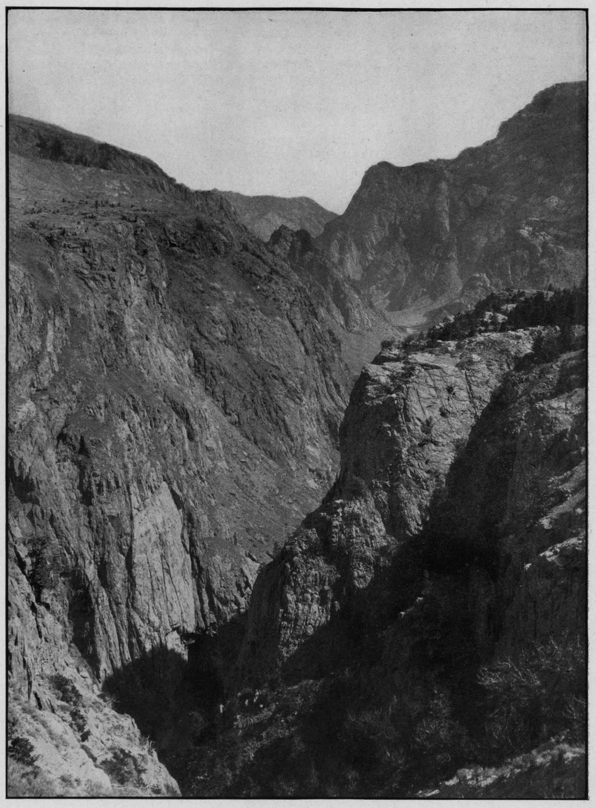


FIG. 4.—CANYON OF CLARK FORK.

A deep, narrow gorge, with abrupt walls, cut in Archean rocks, which drains the greater part of the northern end of the Absaroka Range.

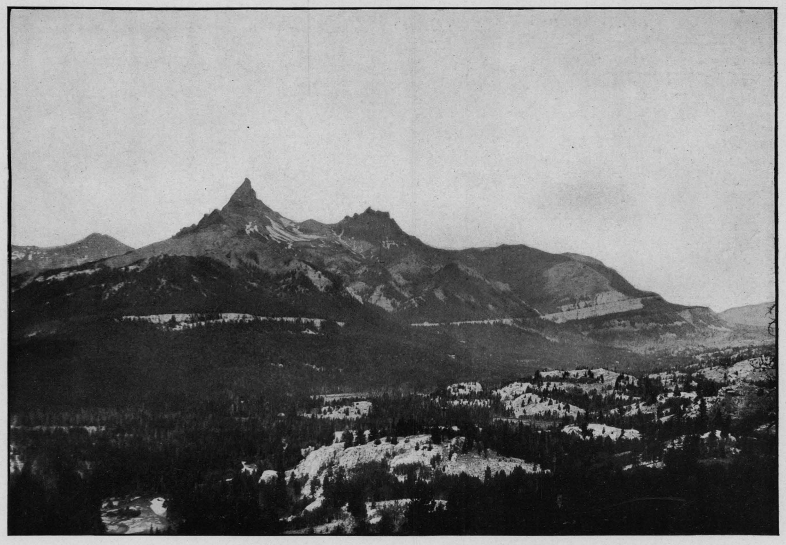


FIG. 5.—CLARK FORK VALLEY AND INDEX PEAK.

This view represents the valley of Clark Fork above the canyon. The foreground shows a rough, glaciated surface of Archean granites and schists. On the further side of the valley cliffs of Paleozoic limestone are well brought out, and overlying them are the breccias and basalt flows which form the Absaroka Range.

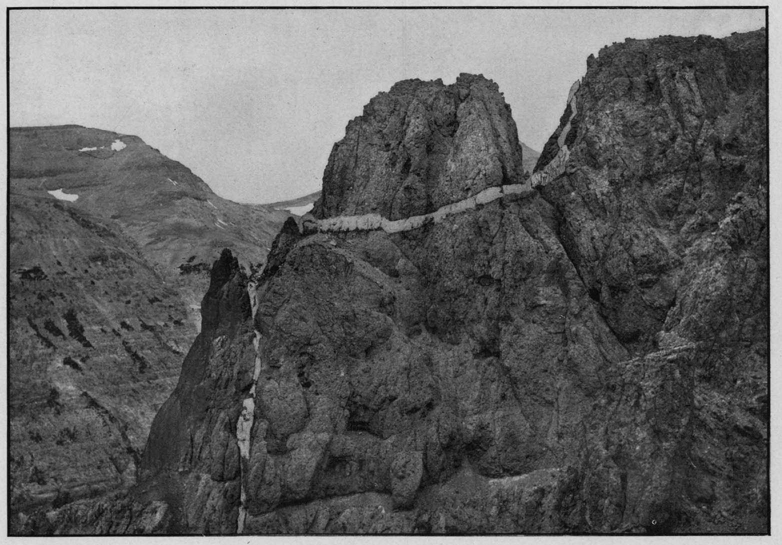


FIG. 6.—BASIC BRECCIA.

A typical mass of medium breccia near the source of Shoshone River. It is without any flow structure, and shows characteristic forms of erosion. On the left a narrow vertical dike may be seen, which near the top lies inclined at a low angle.

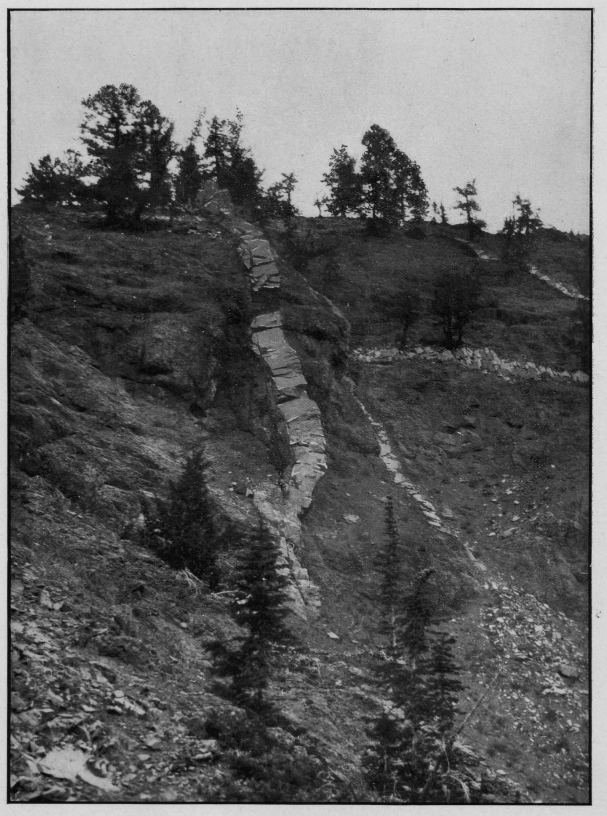


FIG. 7.—A COMPLEX OF DIKES.

This view represents several varieties of dikes cutting basic breccia, at head of Sunlight Creek, Absaroka Range.

FIG. 8.—SUNLIGHT GLACIER.

This glacier occupies the amphitheater of Sulphur Creek. A lateral moraine and a deep crevasse across the glacier are shown in the view.