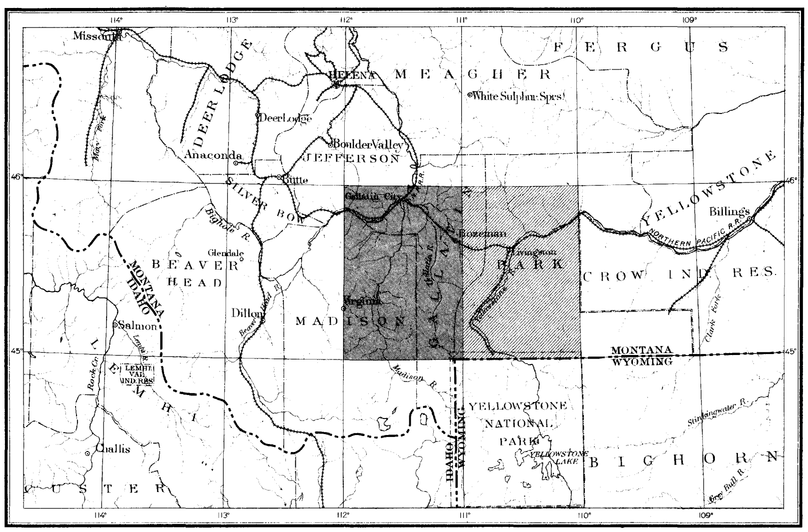
DEPARTMENT OF THE INTERIOR
UNITED STATES GEOLOGICAL SURVEY
CHARLES D. WALCOTT, DIRECTOR

GEOLOGIC ATLAS
OF THE
UNITED STATES

THREE FORKS FOLIO
MONTANA

INDEX MAP



SCALE: 40 MILES-1 INCH

AREA OF THE THREE FORKS FOLIO

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FOLIO 24 — LIBRARY EDITION — THREE FORKS

WASHINGTON, D. C.
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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 stated on the map by numbers. It is desirable to show also the elevation of any part of a hill, ridge, or valley; 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 constant 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:

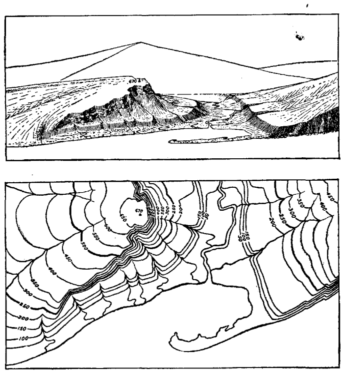

Fig. 1.—Ideal sketch and corresponding contour map.

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 to a precipice. Contrasted with this precipice is the gentle descent of the western 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 occur 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 so with any other contour. In the space between any two contours occur 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 240 feet long and 180 feet high this would cover, on a scale of 1 mile to the inch, 3,025,000 square inches. 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 special 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 fractional 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 of natural length to an inch of map length. 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 three scales are stated, 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.—The map is being published in atlas sheets of convenient size, which are bounded by parallels and meridians. Each sheet on the scale of $\frac{1}{250,000}$ contains one square degree; 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. These areas correspond nearly to 4,000, 1,000, 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. For convenience of reference and to suggest the district represented, each sheet 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 region 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 areal geologic map represents 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 maps show 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 very 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 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 made are carried as solid particles by the 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 rocks 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 a guide 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 and formed 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 one was deposited first.

Fossil remains found in the rocks of different areas, of different provinces, and of different 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 below. The names of certain subdivisions of the periods, frequently used in geologic writings, are bracketed against the appropriate period names.

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, with the exception of the Pleistocene, are distinguished from one another by different patterns, made of parallel straight lines. Two tints of the

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.

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. 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 of surficial formations of the Pleistocene is so great that, to distinguish its formations from those of other periods and from the igneous rocks, the entire series of colors is used in patterns of dots and circles.

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.

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.

Areal 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. The formations are arranged according to origin into surficial, sedimentary, and igneous, and within each class are placed in the order of age, so far as known, the youngest at the top.

Economic 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 areal 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 these 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:

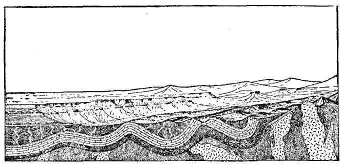

Fig. 2.—Sketch showing a vertical section in the front of the picture, with a landscape above.

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:

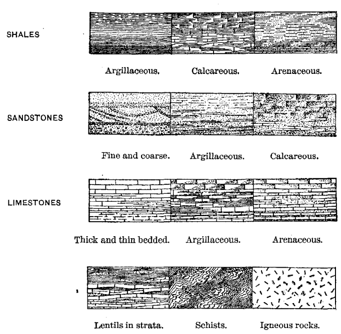

Fig. 3.—Symbols used to represent different kinds of rock.

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 position, 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 consist 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 constitute the local record of geologic history. 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 1,000 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.

DESCRIPTION OF THE THREE FORKS SHEET.

GEOGRAPHY AND TOPOGRAPHY.

The square degree represented on the Three Forks sheet lies between the meridians 111° and 112° and the parallels 45° and 46°. The district is in the southwestern mountainous portion of Montana, and includes 3,354 square miles, distributed mainly between three counties of the State. Nearly the whole of the eastern half is in Gallatin County. Toward the southeast a part of Park County appears, and in the extreme southeast corner the Yellowstone National Park barely encroaches upon the area. Two hundred square miles of the northwestern corner belong to Jefferson County, and the remainder of the western half lies within the limits of Madison County. The sheet derives its name from the fact that the three forks of the Missouri River—the Jefferson, Gallatin, and Madison—unite in its northern-central portion, in what is known as the "Three Forks" Valley. This valley is important as well from a historic as from a geographic standpoint, as being the first place within the limits of the sheet to be visited by white men. Lewis and Clark reached this point in their explorations in July, 1805, and named the three large rivers which there unite to form the head of the Missouri. The general elevation of the region is high, the lowest point not being below 4,000 feet. About one-half the area is occupied by high mountains. The highest elevation is attained by Lone Mountain, a sharp porphyritic peak which is 11,194 feet above sea-level and rises nearly 6,000 feet above the Madison Valley, which it overlooks. Most of the high peaks are found in the gneissic area that extends diagonally across the district, dividing it into a northeastern and a southwestern section. Although they range in height only from 9,000 to 11,000 feet, they are very sharp and rugged and rise in abrupt pine-clad walls that tower from 5,000 to 6,000 feet above the streams that cut deep canyons across this area. About three-quarters of the district is occupied by valleys, three of which—the Gallatin, Madison, and Three Forks—are of considerable extent within its limits, while a fourth—the Jefferson—expands widely west of the district.

The Gallatin Valley is 24 miles in length, and has an average width of 12 miles. Its average elevation is 4,700 feet. To the south it is bordered by gently rolling, grass-covered hills, back of which are the sharp, snow-covered peaks of the Gallatin Mountains. On the east, long, sloping terraces lead to the foot of the Bridger Range, whose rather rounded and bare summits stand out against the sky, culminating in Bridger Peak and Ross Peak. On the north a series of comparatively low ridges separates the valley from the upper Missouri Valley. A plateau of nearly horizontal lake beds on the west divides the valley from the Madison Valley. Next in size to the Gallatin Valley is the upper Madison Valley, which occupies a very considerable area in the southwestern section of the district. It is about 30 miles in length, with an average width of 7 miles. It ranges in elevation from 5,000 feet at the northern or lower end to about 6,000 feet at the southern end or head of the valley. A remarkable system of terraces occupies this valley. They are very persistent and uniform on both sides of the Madison River, forming three benches, the first of which is about 10 feet, the second 30 feet, and the third 100 feet above the river, which flows slowly through a nearly level alluvial plain dotted with numerous islands and adjacent marshy areas. The terraces end abruptly against the foothills on either side of the valley. On the east is the Madison Range, whose mountains are among the highest in the district, and the valley is overlooked from this side by three prominent peaks, each composed of rocks very different from either of the others.

Wedge Peak, toward the south, is a dark-gray, gneissic summit. Next, to the north, is the Sphinx, 10,800 feet high, carved out of a mass of red conglomerates. Still farther north is a group of sharp pinnacles of light-colored porphyritic rock, in which the central peak attains an elevation of nearly 11,000 feet. The terraces west of the Madison River are narrow, and soon end against the foothills or lower margin of a somewhat irregular mass which is partly mountainous and partly plateau-like. This is the Jefferson Range, and it can be divided into three sections. First is a southern hilly rather than mountainous mass, which rises gradually to a long, narrow, plateau-like ridge extending north and south, and is composed mainly of limestones. This ridge has an elevation of about 8,000 feet, and at its northern end culminates in Old Baldy Mountain, 9,672 feet high, at the edge of the area of gneisses in which lies the famous mining region of Alder Creek and Virginia City. This gneissic area is continuous to the northward with the area which forms the second section, surrounding Wards Peak, which has an elevation of 10,267 feet. Between the two sections thus outlined, and forming the divide between the Madison Valley and Alder Gulch, is the third section, a basaltic plateau, the elevation of which averages about 8,000 feet. This plateau is 12 miles long and 4 miles wide, and has a gradual slope to the eastward. The Madison River, to reach its lower valley, cuts across the northwestern end of the Madison Range, in a rough canyon which is about 16 miles in length and whose gneissic walls are from 2,000 to 3,000 feet high.

The third large valley of the district is the Three Forks Valley. It is about 5 by 8 miles in its immediate extent, but is continuous with the lower Madison Valley, which reaches to the canyon of the Madison, 18 miles south of the junction of the three rivers. It also merges with the Jefferson Valley, whose upper limit is 12 miles southwest of the "Three Forks."

The mountain ranges of this region are the Gallatin, the Madison, the Jefferson, and a part of the Bridger Range. Of these the Madison Range occupies the largest area. It lies in the southern-central portion, almost entirely in the southern half, between the Gallatin and Madison rivers. The Archean gneisses form the bulk of its northern part and also a small portion of the southern end, reaching beyond the limits of the map. The central portion of the range is composed of an immense laccolite, or mass of volcanic rock, which has pushed up through the strata and has carried portions of the sedimentary rocks almost to the summit of the range and has overturned, broken, and changed the strata along the western and northwestern edges of the range. Many of the peaks in this part of the range rise considerably above 10,000 feet.

The Gallatin Range occupies about 200 square miles east of the Gallatin River and south of the Gallatin Valley. The summit is, in general, plateau-like, and is composed largely of volcanic breccias, which dip steeply to the eastward, and along the western edge reach an elevation of about 10,000 feet. Above this level a number of peaks rise several hundred feet higher. The most prominent of these peaks lie at the northern end of the range; among them is Mount Blackmore, with an elevation of 10,196 feet.

The Jefferson Range, already described, can be naturally divided into three parts. North of Wards Peak, which is only one of a number of similar high mountains still unnamed, there is a large area of granitic, gold-bearing rocks. The southern part of the range consists in reality of two high ridges, the first or more eastern of which, as already described, is plateau-like. The western ridge, which is the higher, extends southwest from Old Baldy Mountain, and is a monocline in which the sedimentary beds are overturned, the inversion being most marked near the southwest end of the ridge, where it passes out of the district.

Although the greater part of the Bridger Range lies within the area of the Livingston sheet, a small portion crosses the extreme northeastern edge of the Three Forks district, and farther south the larger part of the western foothills of the range come within its area. As seen from the Gallatin Valley, the range is very conspicuous. It divides naturally, from this point of view, into three sections which are quite distinct from one another. First is the section lying between the Bridger Canyon and Spring Hill Pass. This southern extension of the range is mainly an overturned monocline of stratified rocks, somewhat complicated by faulting. They rest upon Archean gneisses which form the western spurs or foothills and also a very considerable portion of the mountain mass. The overlying stratified beds, whose erosion has contributed to the fertility of the Gallatin Valley, are sometimes overturned, sometimes in normal position, and form a sharp crest with peaks whose forms are somewhat rounded as seen from the Gallatin Valley. Of the summits, Bridger Peak attains the greatest elevation, reaching 9,106 feet. The middle section of the range reaches from Spring Hill Pass to Flathead Pass. The general elevation of this portion of the range is somewhat greater than that of the southern section, and its peaks are more rugged in outline. Ross Peak, composed mainly of sharply eroded limestones, is the most prominent point, at the southern end of the section, and stands out conspicuously, as seen from all parts of the valley. Farther north are several other high peaks. The summit of the range is still made up of sedimentary rocks, but the dip is not so high as farther south, and here the gneisses are absent, the underlying beds that form the foothills being the dark-green and steel-gray sandstones, shales, and cherty limestones of the Algonkian, which attain a great thickness. The underlying gneisses do not come to the surface in any part of this section of the range. The northern section of the Bridger Range extends from Flathead Pass to where the hills gradually decrease in elevation and die out into the basin of Sixteenmile Creek. The Algonkian sandstones, shales, and limestones here also form the central core, but they do not appear so prominently as farther south, and the Paleozoic and overlying rocks which curve around the end of the range form the greater part of the mountain mass.

Taking out the valleys and mountain masses, the remainder of the area shown upon the Three Forks sheet is about equally divided between the plateaus or terrace-plains and high rolling country. The most noticeable plateau is the one extending northward between the Gallatin and Madison rivers. It is 12 miles in width and 16 miles long. With a gentle inclination it reaches northward from the gneissic foothills of the Madison Range to the Three Forks Valley. A similar but narrower plateau is seen west of the Madison River.

The drainage of the Three Forks district is mainly by the Gallatin and Madison rivers. Both streams come from beyond the area of the sheet, having their extreme sources in the Yellowstone National Park, the northwestern corner of which forms a small portion of the southeastern corner of the Three Forks area. The Gallatin drains nearly one-half of the country shown upon the Three Forks sheet. It enters the southeast corner of this area, emerging from a canyon, and for about 18 miles flows through comparatively open country, with two expansions, known as the Upper and Lower basins. In this part of its course the fall of the river is about 1,000 feet, or something over 50 feet to the mile. From the Lower Basin the Gallatin plunges into a canyon of extreme ruggedness. In the 20 miles of its canyon course the fall is about 80 feet per mile. From the time the river leaves this canyon it flows along the western side of the Gallatin Valley until it turns westward along the northern edge of the Gallatin-Madison plateau to join the Madison and Jefferson rivers in the Three Forks Valley.

The Madison River drains about 1,000 square miles of the territory included in the Three Forks quadrilateral, and has a course of nearly 70 miles within its limits. Its course has been described when referring to the valleys of the Madison. The Jefferson River drains about 700 square miles in the northwestern part of the district. Almost one-half of its course is in canyon through a region of complicated, folded, and faulted strata.

GENERAL GEOLOGY.

Crystalline schists and gneisses are the oldest rocks found in this region. They are designated Archean, which are generally regarded as among the earliest rocks entering into the composition of the earth's crust. Great variations are observed in both their mineral and their physical features. Movement and pressure have greatly changed them from their original character, and they are now highly metamorphosed and contorted. In pre-Cambrian time these rocks formed a land mass which comprised nearly all if not all the area included in the map, and which also doubtless extended far to the southward as well as to the east and west. The exact limits of this ancient land it is now impossible to determine. It was long subjected to erosive influences, and from the degradation of its surface came the sediments which formed the Belt formation, in which conglomerates predominate in this district. In the lower portion of the formation pebbles and large angular masses of gneiss are found, showing that the ancient shore was not far distant when they were laid down. The series, as measured, has a thickness of 6,000 to 10,000 feet, and may in some places reach even 12,000 feet. While its beds were being deposited a gradual subsidence of the region was going on, and just before the Flathead quartzite was formed the sea spread over a vast extent of country which prior to that time was a land area. The Flathead quartzites represent the beach and shore deposits of the advancing sea, and were deposited unconformably upon both the Archean gneisses to the southward and upon the Belt formation to the northward. Limestone, sandstone, and shale form the Paleozoic and Mesozoic beds, and the conditions under which they were deposited varied from time to time. Shallow seas prevailed sometimes, and at other times the waters were relatively deep. Many of the beds were coarse inshore deposits, while others may have been formed at a long distance from the shore in deep waters. During the Paleozoic age there were many minor oscillations of the surface, and they were probably more frequent during Cambrian time than during the Devonian and Carboniferous periods, the latter being represented almost entirely by limestones. In the Juratrias period sandstones and argillaceous and arenaceous limestones predominate. Near the lower part of the Cretaceous a persistent bed crowded with fresh-water shells is found wherever the Cretaceous strata are seen. Toward the close of the Cretaceous period a general elevation of the region began, and soon after the deposition of the Laramie formation there was an upward movement, during which the strata were folded and subjected to erosion coincident with considerable and widespread volcanic activity. It was then that the Livingston formation was laid down unconformably upon these eroded older beds. The Livingston beds are almost entirely made up of volcanic and igneous material. Volcanic activity continued throughout a large part of the Eocene and Neocene periods. The formation of the mountain ranges and their subsequent erosion resulted in many valleys, which became the basins of fresh-water lakes. These were eventually partly filled with deposits derived from the adjacent mountain areas. Finally the lakes were drained by the gradual cutting away of their outlets. Sphinx Mountain, in the Madison Range, is composed of a thick mass of conglomerates, probably the remnant of a once extensive formation of Eocene age. The fresh-water lakes attained their greatest extent in the Neocene period, lasting in all probability until the Pleistocene period was well advanced. During the earlier portion of the lake period there was a time of intense volcanic activity, or perhaps there were several such periods. Immense bodies of volcanic dust were carried by winds from eruptive centers lying to the southward, possibly in the Yellowstone Park. They were deposited in the waters of the lakes as white dust beds, and at the same time fell upon the surrounding land surfaces. From the latter they were afterwards washed into the lakes and deposited upon the pure white volcanic dust, from which they are easily distinguished by their yellowish and rusty colors. In the upper part of the lake beds the volcanic dust is mingled with débris from the shore rocks exposed later on, after erosion of the dust beds. The dust showers destroyed both animal and vegetable life, and their remains were carried into the lakes and buried in the upper part of their deposits. In the central portion of the Gallatin-Madison lake-basin, in some of the upper beds, large deposits of fossil bones and opalized and silicified wood are found. Both bones and wood present all the evidences of having been tossed about by the action of the waves for a considerable time after being washed into the lake and before being covered by the deposits. The streams that emptied into these lakes occupied about the same relative positions that they do to-day, and where they entered the lakes coarser beds and conglomerates are now found. As the barriers that held back the waters were worn away the lakes were gradually drained, and erosive agencies soon removed not only all vestiges of the dust that had been deposited upon the land, but also carried away a large part of the lake beds themselves. Later on, and possibly contemporaneously with the later stages of the lakes, occurred a period of glaciation which has left its evidence in morainal material found in many canyons of nearly all the mountain ranges of the district. The glaciers were local, and moraines are found in the Madison Range; in the Jefferson Range, both at the north near Ward Peak and in the south below Old Baldy Mountain; and also in the Gallatin and Bridger ranges. The drift deposits in the valleys are mainly of local origin, and on the map the drift has not been distinguished from the later alluvial deposits found along the courses of the principal streams. The thin covering of drift material found on the plateaus of the Bozeman lake beds and in other areas has not been indicated upon the map. The latest volcanic flows were of basalt. They were, however, shortly preceded by rhyolitic eruptions. These lava sheets, both basaltic and rhyolitic, now form the summits of tables or mesas found mainly in the southern portions of the district.

DESCRIPTION OF ROCK FORMATIONS.

More than half of the area included in the Three Forks sheet is covered, so far as the surface is concerned, with rocks of sedimentary origin, while the crystalline rocks occupy an area of approximately 1,000 square miles.

The remainder of the area is covered with igneous material, the most prominent of which is the andesitic breccia forming the main part of the Gallatin Range. The next in extent is the great porphyrite laccolite of the Madison Range, and then comes the basaltic plateau lying between the Madison Valley and Virginia City.

Various dikes and sheets occur scattered over the map in such small areas that it is impossible to differentiate them in mapping them.

ARCHEAN.

The Archean gneisses possibly include some beds that may eventually be referred to the Algonkian. The principal areas in which they occur are the foothills or western spurs of the Bridger Range and the mountain masses at the northern and southern ends of the Madison Range, especially in the central portion of the district, where a belt of gneissic rocks from 10 to 12 miles in width and nearly 30 miles in length extends from the western limits of the Three Forks sheet to near its southeastern edge. The Madison River, which cuts across this Archean belt a little west of its center, shows the best section of its beds, the canyon containing most beautiful exposures of the highly contorted rocks. Another gneissic area is found north of Virginia City and west of the Madison Valley, abutting against the eruptive granite of the Revenue mining region, just north of the Jefferson Range. South of Virginia City and southwest of Old Baldy Mountain, in the southern part of the Jefferson Range, gneissic rocks prevail, which here, as elsewhere in the district, are gold and silver bearing. The foothills of the Gallatin Range south of the Gallatin Valley are also gneissic, and similar rocks show beneath the Bozeman lake beds at the southern end of the plateau, between the Gallatin and Madison valleys. Wherever the sedimentary beds are found in contact with the Archean they are unconformable.

SEDIMENTARY ROCKS.

ALGONKIAN.

Cherry Creek beds.—The Cherry Creek beds consist of a series of marbles, or crystalline limestones, and interlaminated mica-schists, quartzites, and gneisses, well shown southwest of Madison Valley. They are all highly inclined and are perfectly conformable to one another, occupying an area of 30 to 40 square miles in the foothills immediately west of the Madison River, a few miles north of the southern boundary of the map. They are folded, but the folds are somewhat obscure, so that it is impossible to estimate accurately the total thickness, but it is certainly not less than several thousand feet. A limited area of these beds occurs on the east side of the Madison Valley at the western edge of the Madison Range. Between Cherry Creek and Wigwam Creek, on the west side of the Madison Valley, the unchanged beds of the Cambrian rest upon the upturned edges of this group.

Belt formation.—The oldest unaltered sedimentary rocks mapped on the Three Forks sheet are found in the northern portion of the region; first in the foothills of the northern portion of the Bridger Range; then in the hills north of the Gallatin and East Gallatin rivers; and again in the rugged hills north of the Jefferson canyon, in the northwestern part of the district. They form a series of beds of littoral formation which, as exposed in the area just described, reach a measured thickness of from 2,300 to 6,000 feet. The lower portion of the formation consists of an alternation of coarse sandstones and conglomerates, whose arkose character is evident. They are of somber hue, dark-green and steel-gray colors predominating. In the central portion of the series argillites and siliceous limestones are frequently found, and in the upper part sandstones again seem to predominate. The formation, as far as examined, is non-fossiliferous. To the northward, beyond the limits of the district, these beds attain a thickness of from 10,000 to 12,000 feet. In the northern quarter of the area the Belt formation immediately underlies the Flathead quartzite, but to the southward it is absent and does not intervene between the Archean and the undoubted Cambrian, and the formation certainly was not laid down on the Archean except within a comparatively narrow strip of the northern edge of the area shown on the map, and even here the actual contact with the gneisses has not been seen, although the line of junction is probably not far below the base of the sections seen in the Bridger Range and near the Jefferson Canyon. It is possible that further investigation may result in the reference of this formation to the lower part of the Cambrian. At present, however, it is referred provisionally to the Algonkian.

CAMBRIAN.

The rocks of this period begin with a series of sandstones and shales, the lower member of which is sometimes known as the basal quartzite, which rests with marked unconformity upon the Archean throughout three-fourths of the area of the district. In the remainder it rests upon the Algonkian, where the unconformity, if it exists, is very slight, probably because the subsidence of the country was very gradual, allowing the beds to overlap with little, if any, discordance. The beds gradually become more and more calcareous as we ascend in the section, until limestones predominate in the upper part. The oldest fossils found are of Middle Cambrian age, but as none were discovered in the very lowest members of the section, there is a possibility that the latter may be of Lower Cambrian age. The total thickness of the section referable to the Cambrian is about 1,300 feet, as seen in the northern part of the district; in the southern sections the series is somewhat thinner. Everywhere the strata are conformable throughout.

Flathead formation.—The Flathead formation consists of the Flathead quartzite, a persistent quartzite or sandstone which lies at the base of the conformable section, with overlying beds of softer, shaly sandstone. Its total thickness is only 125 feet, and as it is usually steeply inclined, its outcrop is narrow and its area at the surface is relatively but little more than a line, as colored upon the map. It is non-fossiliferous and has been provisionally correlated with the quartzite that in other parts of the Rocky Mountain region has been referred to the lower Cambrian. The Flathead shales are frequently separated from the quartzite by a band of eruptive rock. They are arenaceous at the base, gradually becoming more and more calcareous toward the top, with interlaminated, thin bands of glauconitic limestone. The shales are 290 feet thick, and are so soft generally that they are concealed beneath their own débris in most places. However, they form characteristic ravines, which can be traced without difficulty. The beds are highly fossiliferous at several horizons, all the forms found being of middle Cambrian age.

Gallatin formation.—This formation consists essentially of limestones, which occur in three bluff-faced exposures, usually separated by beds of shales. The lower limit of the formation has been drawn at the base of the first well-defined limestone (trilobite limestone), which immediately follows the fine, green, sandy shales of the upper part of the Flathead formation. This limestone is 120 feet thick, massively bedded in the center, and somewhat laminated at the top, and is very persistent, forming a low bluff back of the sharp ridge of the Flathead quartzite, from which it is separated by the Flathead shales. The limestone is characteristically fossiliferous, especially at the base. Following the trilobite limestones, the Obolella shales occupy a space of about 280 feet. The outcrops are very obscure, owing to the soft character of the calcareous and sandy beds, the erosion of which has formed deep ravines parallel to the strike of the beds. An undetermined species of Obolella is the only fossil recognized as coming from this horizon. The limestones that come next are massively bedded, forming a characteristic topographic feature wherever noted, and derive their name of "mottled" limestones from the characteristic mottling of yellowish and dark spots seen in the central portion of the beds. They are 260 feet in thickness, and are followed by the Dry Creek shales, a series of brownish-yellow, red, and pink, saccharoidal shales and thin-bedded sandstones about 30 feet in thickness, which separate them from the pebbly limestones. The latter consist of about 145 feet of light-colored laminated limestones in bands of 4, 6, or 8 feet each in thickness. They are pebbly throughout, the lower bands being the coarsest, and containing also glauconite in abundance. The pebbles are of limestone. Fossils are found at the base, in the middle, and at the top, the forms being apparently the same throughout. Some of them are the same that in other regions occur in the Cambrian, passing into the base of the Ordovician.

DEVONO-SILURIAN.

The pebbly limestones pass imperceptibly into a series of black, magnesian limestones which for several hundred feet are, so far as examined, devoid of fossils. It is possible, as the pebbly limestones have every indication of being on or near the border line between the Cambrian and the Silurian, that their upper beds and a part of the overlying black limestones may eventually be referred to the Silurian. There is little doubt that the sedimentation was continuous, and we need not be surprised if sometime in the future this now barren interval should somewhere furnish a mingling of Silurian and Devonian forms.

DEVONIAN.

The black limestones referred to under the head of Devono-Silurian have been provisionally referred to the Jefferson formation, because the fragments of fossils found in the middle and upper part, although few and very indistinct, were recognized to be the same as those occurring in the Three Forks shales, which are, without much doubt, Devonian. The total thickness referred to the Devonian is about 870 feet.

Jefferson formation.—The Jefferson limestone forms the base of the formation, consisting of several hundred feet of black or mud-colored limestone, which is generally crystalline and magnesian from top to bottom. It is well exposed in all parts of the Three Forks region, and at most localities is non-fossiliferous, only a few forms having been obtained from near the top of the formation, and these only in the region north of the East Gallatin River.

The Three Forks shales, which rest conformably upon the Jefferson limestone, may be divided into three parts: the lower or orange-colored shales, about 50 feet in thickness; a band of grayish-brown, argillaceous limestone, 20 feet thick; and the upper green, black, and argillaceous shales, some 50 feet in thickness, which are crowded with Devonian fossils and capped by a band of yellow laminated sandstone 25 feet thick. These Devonian fossils were found both in the northern and in the southern portion of the district, and doubtless occur wherever the beds are found. A coal-black slate is seen near the upper part of the shales in the vicinity of the head of the Missouri River. In the Jefferson Canyon this has developed into a bed of coal, in which are found limestone nodules containing the same Devonian forms that are elsewhere found in the shales. The shales are near the border line of the Devonian and Carboniferous, and their organic remains contain a mingling of forms of both, but the preponderance of evidence is in favor of their Devonian age.

CARBONIFEROUS.

After the deposition of the shales and sandstones of the upper Devonian, there followed an epoch almost continuously favorable to the formation of calcareous deposits. Resting upon the Three Forks shales is a series of beds 1,600 feet in thickness, the lower 1,250 feet of which consist entirely of limestones and the upper 350 feet of an alternation of limestone and quartzites. The rocks, therefore, are easily divisible on lithological grounds into two formations, the Madison and Quadrant. The former probably represents the lower and middle Carboniferous—although the two can not be differentiated—and the latter is most likely upper Carboniferous.

The Madison formation.—This formation consists entirely of limestone beds, having a thickness of about 1,250 feet. These can be divided into three portions, the lower 325 feet consisting of laminated limestone, followed by 350 feet of massively bedded limestone, upon which rest 575 feet of limestone sometimes called the jaspery limestones, although the jasper which gives them their name is conspicuous only in the upper part of the series. As a whole, the paleontological aspect of the Madison limestones is that of the lower Carboniferous epoch, to which it must be at least provisionally referred.

Quadrant formation.—After the deposition of the Madison limestones there seems to have been a marked change in the character of the sediments, due possibly to the prevalence of much shallower seas or to more active erosion of land areas. The lower beds, to which the name of "red" limestone has been given, are everywhere arenaceous and argillaceous, and in many localities a conglomerate of limestone pebbles lies at the very base of the formation. Although no true dolomites are found, these lower limestones are all more or less magnesian. The section varies considerably at different points, but its thickness is between 300 and 400 feet. The red limestone is from 170 to 200 feet thick, and the brilliant red color of its débris makes it very conspicuous, while its soft character leads to the development of a ravine back of the outcrops of the Madison limestone. The fossils found in the red limestone are of upper Carboniferous age. Following the red limestone are from 150 to 180 feet of thin-bedded, cherty limestone, alternating with quartzitic layers, the latter predominating at the top and being capped by a prominent bed of quartzite or quartzitic sandstone, which has been taken as the base of the overlying Mesozoic.

JURATRIAS.

Just above the Carboniferous lies a prominent bed of quartzitic sandstone, which may belong to that period or may be the equivalent of the red sandstones which at more southern localities represent the base of the Juratrias. The latter is probably the more correct view, but in the absence of paleontologic evidence no attempt has been made to distinguish the quartzite from the overlying beds, all being included on the map under the head of the Ellis formation. This quartzite is from 40 to 60 feet thick, and is remarkably persistent throughout the district.

Ellis formation.—Above the basal quartzite this formation consists largely of argillaceous limestone, many of the beds being crowded with characteristic Jurassic fossils. These fossiliferous calcareous beds are near the base, the upper and middle beds being more arenaceous and devoid of fossils. The total thickness of the formation is between 300 and 400 feet, and it outcrops in all portions of the district with the overlying Cretaceous, never, however, occupying any great area.

Its occurrence is distinctly marked by the two quartzitic sandstones which lie, one at the base and the other just at the top, both being equally persistent.

CRETACEOUS.

The Cretaceous rocks found in the northern and northwestern parts of the district occupy an erea of about 75 square miles, occurring in what may be described as five separate basins, two of which are connected across the top of the range that lies south of the Jefferson River. Nixon basin, the most eastern one, is connected to the northward with the basin of Sixteen-mile Creek, which is included in the Fort Logan sheet. The basin next to the westward is simply the prolongation of a basin lying immediately west of the Missouri River, just north of the limits of the sheet. Next is the basin lying between the north Boulder Creek and the Jefferson River. This is partially covered by Bozeman lake beds, although erosion in many places has reduced the covering to a very thin sheet. South of the last-named basin is a smaller one, on the Jefferson River, where the Cretaceous is faulted partly against a high ridge of Algonkian rocks and partly against a narrow strip of Devonian lying at the base of the ridge in the western portion of the basin. The Cretaceous rocks here are continuous across the mountain range on the south side of the Jefferson in a narrow, curving strip connecting with those of the small basin on the South Boulder and Antelope creeks. This is a region of considerable complicated folding and faulting. The section as shown in these basins does not attain the thickness seen elsewhere in the region, and in many places so much has been eroded and carried away that only the lower members of the section are seen. In the Nixon basin the Livingston formation does not show at all, and nearly all of the Laramie has been worn away, only its lower portion showing in the central part of the main basin. The lines between the different divisions of the Cretaceous are indistinct, and on the map the Colorado and Montana formations have been represented as one, separated from the Dakota below and from the Laramie above. The latter has been outlined because of its economic importance. The Livingston formation is usually distinctly unconformable to the rest of the Cretaceous, especially in the southern half of the district.

Dakota formation.—The lowest beds referred to the Dakota formation consist of sandstones, which in some places are quartzitic and conglomeritic and in one or two localities consist of true conglomerates. This conglomeritic quartzite is usually a very conspicuous topographical feature wherever the formation is seen. Its thickness is about 50 feet. Following it, and sometimes separated from it by an intrusive sheet, are shaly beds, generally reddish and greenish-gray in color. Next follows a light-bluish limestone, composed largely of the remains of a fresh-water gasteropod, seemingly of one species, although there are sometimes associated with it two or three other fresh-water forms.

Colorado and Montana formations.—These two formations consist of about 2,000 feet of beds that are generally very shaly, although near the top there are several conspicuous bands of sandstone. The beds in the lower portion consist of fine black shales and greenish-gray sands and a few beds of limestone. The upper beds are generally of a light-gray color. The shales become gradually more and more argillaceous in ascending order.

Laramie formation.—From an economic standpoint the Laramie formation is the most important division of the Cretaceous, as it usually contains two or three beds of coal, which, however, are not of equal importance in all localities. The formation consists essentially of light-gray or whitish sandstones, with interlaminated argillaceous beds, some of which are locally much indurated. The two areas in which the strata are best exposed are in the Nixon basin, north of the Gallatin Valley, and in the Gallatin basin lying between the Gallatin and Madison ranges. The total thickness of the formation is from 800 to 1,000 feet. In the Nixon basin unios and other fresh-water shells are found in connection with the coal. A fossil-plant horizon occurs just above the upper coal bed in nearly every exposure, especially in the southern portions of the district.

Livingston formation.—The Livingston formation occupies at the present time comparatively little area within the limits of the Three Forks sheet, and nowhere is it likely that the entire thickness of the formation is shown. The largest area is probably that in the vicinity of Sphinx Mountain, where the Sphinx conglomerate rests unconformably upon it. This area is about 15 to 20 square miles in extent, and the deposits are made up of a mass of volcanic materials indistinctly bedded, mostly andesitic in nature, and of a somber hue. At one or two places conglomerates made up of all sorts of volcanic pebbles are seen near the base. This generally black mass rests unconformably upon the eroded surfaces of the previously deposited Cretaceous formations, contrasting strongly in color with the Laramie sandstones and the Dakota conglomerates, with both of which it is in contact at different points. Dikes of porphyrite intersect these volcanic deposits, extending from the laccolitic mass that occupies the center of the range to the northward.

The Livingston beds, in the northwest corner of the district, present a somewhat different aspect from those just described, being not so dark in color and showing more distinct evidences of bedding; they are also more nearly conformable to the underlying Laramie beds with which they are in contact. In the vicinity of Jefferson Canyon they have a dark greenish-gray color and apparently contain interbedded hornblende-andesites, which seem to have been laid down as lava flows. Other beds are conglomerates composed of all sorts of volcanic material, andesites, however, as at other localities apparently predominating. The period during which they were deposited was undoubtedly one of great volcanic activity.

EOCENE.

Sphinx conglomerate.—In the Sphinx Mountain, which reaches an elevation of 10,840 feet in the central part of the Madison Range, is found a group of beds which once may have spread over an extensive area of country, although at present occupying only an area of about 2 square miles. This remnant is between 2,000 and 3,000 feet in thickness, made up of reddish sandstones and coarse conglomerates of limestone pebbles and bowlders cemented with a reddish sand. The entire mass of the peak is composed of these beds, which are horizontal in position and distinctly stratified, the rugged and steep slopes of the mountain rendering evident the gigantic scale of the erosion which has left it in this district the only monument of this group of beds. So far as observed the strata are nonfossiliferous, the character of the beds precluding the preservation of fossils. They are, therefore, somewhat arbitrarily referred to the Eocene, but they form a group certainly younger than the Bozeman lake beds and older than the Livingston formation.

NEOCENE.

The movements that began during the latter part of the Cretaceous period ultimately resulted not only in the folding of the strata but also in the formation of the numerous basins or valleys found throughout the mountainous portions of Montana. Some of these valleys were filled with water during the early part of the Tertiary period, while others did not become lakes until the Neocene. Toward the end of that period, however, a series of fresh-water lakes had been formed along the courses of nearly every stream in the western part of Montana. At first these lakes were probably more numerous and more distinct from one another than during their later stages. The deposits found in the lower part of the basins show by their character that they were derived from the land areas of closely adjacent shores. After their deposition there followed a period during which immense showers of fine volcanic dust, evidently wind-carried, fell upon the surfaces of the lakes and upon the land. In the former they quietly settled to the bottom as pure white sediments in which no traces of foreign material are found. These beds occur in the central portions of the large valleys, and upon them, spreading out over wider areas, rest undisturbed beds of a rusty color, although composed of the same pumiceous dust, which was evidently washed into the lakes from the surrounding country. The beds of pure white dust in the Gallatin-Madison lake have a total thickness of only about 20 feet, while above them the beds of rearranged dust attain a thickness of over 1,000 feet.

In the upper beds, especially near the edges of the basins, the dust deposits contain, mingled with the pure pumiceous glass, a small proportion of foreign fragments, derived undoubtedly from the adjacent shores by the erosion of the underlying rocks exposed after the removal of the dust deposits from the land surfaces. The erosion following the draining of the lakes at length carried away every vestige of the dusts from the land, and also an enormous mass of the lake deposits themselves. An effusion of basalt occurred subsequent to the deposition of the lake beds. Near Virginia City, lake beds outcrop beneath the basalt plateau, and basaltic flows are seen on the lake beds west of Salesville, in the vicinity of Red Bluff, and in the upper Madison Valley. In the latter locality rhyolite also seems to have flowed over a part of the valley after an interval of considerable erosion, and is now found in palisades along the course of the river just as it enters the southern boundary of the district.

Bozeman lake beds.—There were two principal lakes within the limits of the Three Forks sheet. The larger of these was the Gallatin Lake, which was undoubtedly connected with another large lake that occupied the Jefferson Valley, lying mainly within the area mapped on the Dillon sheet, directly west of the Three Forks sheet. It was also connected with the lake of the north Boulder Valley, which extends northward beyond the limits of the map, and which was itself connected with the Jefferson Lake. The Gallatin Lake also extended a short distance northward beyond the limits of the map, along the west side of the Bridger Range, and to the eastward, in the area of the Livingston sheet, west of Bozeman, the town from which the beds have been named on account of the good exposures in its vicinity.

The deposits of this lake occupy at present only about 700 square miles of the surface of the district, and yet at its greatest expansion the lake must have had an area nearly twice as great. Although it probably never connected with the Madison Lake to the southward, except by the river, it reached to within about 2 or 3 miles of it, as shown by the deposits left as remnants in Burnt Creek Valley, south of Norris. The small basin in Spanish Creek Valley was also continuous with it through the lower canyon of the Gallatin River.

The beds in the main basin have a dip of a few degrees to the eastward or northeastward, causing the slope noticeable in the surface of the plateau that lies between the Madison and Gallatin rivers. If continued this dip would carry the beds there visible below those exposed in the hills east of Bozeman, and make the total thickness of the deposits more than 2,000 feet. At no one place, however, can a complete or continuous section be obtained. The highest occurrence observed was at the contour of 5,700 or 5,800 feet, and at present the lowest exposure is at an elevation of about 4,000 feet. In the hills east of Bozeman the dip is from 5° to 8°, which would give there a thickness of at least 1,000 feet, and an artesian boring made at Bozeman is sunk 400 feet deeper, yet the pure dust beds are not reached in this section, and they probably occur about one-third of the distance from the base.

In the Madison Valley, 12 to 15 miles above Three Forks, a section 800 to 1,000 feet thick is shown, and if these beds are lower, as they apparently are, than those near Bozeman, from which they differ, the total thickness would be nearer 2,500 than 2,000 feet.

On the southern and western sides of the basin the lowest beds, whenever exposed, are conglomerates of Archean pebbles. There is little doubt that throughout the greater portion of their extent the lake beds rest upon an Archean base. However, at the northern end, where the shores were of limestones, white secondary limestones are the lowest beds of the lake formation. It is only in the central portions that the beds of pure volcanic dust are found, and the best exposures occur in the vicinity of Foster Creek, southeast of Hillsdale, although they were seen also in some of the ravines that cut into the plateau lying south and southwest of Manhattan or Moreland. In the latter region also, at one of the lowest horizons noted, old hot springs deposits—calcareous tufa—were seen. Many of the cones built up by the old springs, with the tubes through which the water flowed, are in perfect condition, although long after their formation they were buried beneath an immense accumulation of the lake deposits. The pumiceous dust occurs in beds 2 to 5 feet thick, separated by thin calcareous bands. The total thickness is about 20 feet. They consist of sharp, angular fragments of pumiceous glass, with occasional gas cavities, and show the peculiar curvilinear outlines characteristic of such deposits. The petrographic nature of the material is rhyolitic.

In the summit of the Madison Bluffs, in a layer of gray conglomerate sandstone, numerous fragments of fossil bones were found, which were identified as the same as those found at other localities in the Pliohippus beds of Marsh. In the sandstones below the fossil horizon immense quantities of opalized wood are found, the logs all presenting evidences of having been waterworn.

The lake that occupied the upper Madison Valley, although not all included within the limits of the Three Forks sheet, was less extensive than the one just described. Its deposits at present cover about 270 square miles; the outcrops are very obscure but are sufficient to show that the character of the beds is similar to that of those seen in the larger basin. Beds of very pure pumiceous dust were found near the southern edge of the map. The deposits of this lake must be from 1,000 to 1,500 feet in thickness. They have been cut into a beautiful series of terraces, covered with drift of local origin. This, at the upper or southern end of the valley, is very coarse, and interferes with the agricultural development of this portion of the valley.

At the northern edge of the district, in the vicinity of the Horseshoe Bend of the Missouri River, is a small area of lake beds, the southern end of a basin lying mainly on the east side of the Missouri. This basin was apparently distinct from the Three Forks basin, and also from the area on the Missouri around Townsend, some miles to the northward.

PLEISTOCENE.

Glacial drift and moraines.—Evidences of glaciation can be seen in all the mountainous portions of the district, and well-defined moraines occur in the vicinity of Wards Peak, in the Gallatin Canyon in the Madison Range, and south of Old Baldy Mountain. The best-defined moraine is found on the west side of the south branch of Indian Creek, north of the Wedge Peak. It is 4 miles in length and rises from 400 to 500 feet above the valley of the stream. It is composed of gneissic débris from the mountains at the head of the stream. Along the west side of the foothills of the Bridger Range, north of Reese Creek, there is a considerable area of drift that might be of glacial origin.

Alluvium and drift.—In the areas along the principal streams very recent fluviatile deposits have been distinguished. The three principal areas are in the Gallatin Valley, the upper Madison Valley, and the Three Forks Valley, including the prolongation up the valleys of the Jefferson and the Madison. A small area occurs on upper Willow Creek, and there is an alluvial area on the Jefferson above the canyon extending westward from the mouth of the North and South Boulder creeks, and narrow belts along the Jefferson River both in the canyon and below it, as well as a very small area in the Gallatin River above the canyon. The larger areas described are undoubtedly underlain by Bozeman lake beds.

IGNEOUS ROCKS.

A very considerable part of the area mapped in the Three Forks sheet consists of igneous rocks. They form some of the highest and most rugged peaks of two of the principal mountain chains of the region, and occur as well in other tracts of less topographic prominence. Although varying widely in geological occurrence and mineralogical character, they can be readily divided into two groups: intrusive, and extrusive or volcanic. The *intrusive* rocks occur either as great bodies of massive material which has broken through the Archean and later stratified formations, or as sheets and dikes penetrating various formations. The *effusive* rocks, or surface volcanics, consist of tuffs, agglomerates, and breccias, the fragmental deposits of explosive volcanic activity, together with various lava flows.

INTRUSIVE ROCKS.

Granite.—In the western part of the district, just north of the central line, there is a mass of granite 16 miles long and 4 or 5 miles in width, into which the northerly ridges, spurs, and foothills of the Jefferson Range extend. This rock breaks up through crystalline schists, but the age of its intrusion is not known. It is a very massive, coarsely crystalline rock, of uniform composition throughout the entire mass, and is of economic interest, as the ore deposits of Revenue and Pony occur in it.

Porphyrite (andesite-porphyry).—The most common form of intrusive rock occurring in the region is a porphyrite, the name indicating a porphyry in which the feldspars are plagioclase. The different masses shown upon the map under this name vary somewhat in mode of occurrence, although there is little difference in mineral composition. One body occurs in the extreme southeastern corner of the district, where it is in part included within the limits of the Yellowstone Park, and others also occur in its vicinity, a little to the westward. Near the Jefferson River, in the northwestern corner of the district, there is another mass, which is noticeable as an intrusion occurring in the Cambrian formation and splitting apart its beds. By far the largest body of this rock is the "laccolite" in the central part of the Madison Range, forming there an extremely rugged region of sharp and high peaks, only one of which, however, Lone Mountain (11,194 feet), is named. The porphyry breaks irregularly through sedimentary formations of Cretaceous age, which are broken, crumpled, and overturned about its western borders, the soft shales being frequently altered by the heat and vapors of the intrusion into dense and hard, flinty rocks. Areas of these Cretaceous rocks shown upon the map as surrounded by the igneous rock are fragments and masses broken from the sedimentary beds and carried upward with the porphyrite. Many of the metamorphosed shaly masses are imbedded in the porphyrite, and dikes extend from the main mass intersecting the adjacent sedimentary beds.

In petrographic characters the rocks composing the various porphyrites of the region are acidic (siliceous) rocks, of a normal andesite-porphyry type. The rock presents a remarkable uniformity of character, its most noticeable mineral being the black hornblende crystals scattered abundantly through its mass. Near the line of lower contact with the shales, however, the rock becomes somewhat micaceous and carries free quartz. At the immediate contact it is a dense or aphanitic rock, with the appearance of porcelain, and breaking with a marked conchoidal fracture.

Diorite.—Near the extreme northern limit of the map an area of diorite and diorite-porphyry is shown. These rocks, differing from each other only in coarseness of grain, constitute what is probably one body. The diorite is a coarsely granular rock in which black hornblendes and pinkish or gray feldspar crystals are seen with the unaided eye. The porphyry phase of this same rock, mapped as diorite-porphyry, is a dark-gray, holocrystalline rock thickly sprinkled with dark hornblende crystals, some of which are over a half inch in length and which often occur in stellate clusters of radiating crystals.

Dike rocks.—The intrusive rocks which are found in the form of dikes or sheets are common features in many parts of the region and present unusual and quite interesting rock types. Upon the map they are shown by two shades of intense red, the distinction corresponding to two groups—one of newer and the other of older rocks—the first representing dikes of augite-porphyrite, syenite, and allied rocks; the second embracing similar intrusions of diabase and peridotite. The rocks of the first class are seen to occur mainly as intruded sheets in the folded sedimentary rocks, while the basic diabase and peridotites occur as dikes cutting the crystalline schists. The latter are seen in greatest abundance in the ranges about the northern end of the Madison Valley.

Diabase and peridotite.—The diabase is of the ordinary tpye, sufficiently unaltered to be readily recognizable in the field.

The rocks embraced under peridotite include those rare rock types known as hornblende-picrites, saxonites, wehrlites, and, in one instance at least, pyroxenite. (They are described in a paper by Dr. G. P. Merrill, in Proceedings United States National Museum, Vol. XVII (1894), pp. 637–673, 1895). The picrites are sometimes extremely altered into serpentine, especially in the region west of Meadow Creek.

Augite-porphyrite, syenite, etc. — The rocks included under this head are found mainly in the area between the Gallatin River and the Horse Shoe Bend of the Missouri, and in the vicinity of the South Boulder Creek, one of the southern branches of the Jefferson River. The most interesting occurrence is found in connection with the dip faults noted in the basal quartzite of the Flathead formation north of the East Gallatin River, about 8 miles east of Logan. Under the one color upon the map are included two rocks, which in most places are closely associated; the first is a granular syenitic rock with an upper, more basic facies, and the other an augite-porphyrite, best displayed in the deep cuts of Cottonwood Creek north of Logan, and also near the Horse Shoe Bend of the Missouri River. The exact relationship of this porphyritic type with the syenitic rock has not as yet been definitely ascertained. Of all the rocks within the area of the sheet, the syenitic rock and its basic phase are of the greatest interest in the present state of petrographic science. The syenite is a holocrystalline, granular, feldspathic rock with accessory black mica and greatly elongated, green augites and sporadic sodalite. With it is always associated a black basic rock consisting of a feldspathic base and abundant phenocrysts of olivine and augite. As first studied in the obscure outcrops of the Flathead shales north of the East Gallatin River, the rocks, as described in Bulletin 110 of the Survey, were so decomposed as to greatly obscure their true lithological nature, but the rock as it occurs on Antelope Creek is much fresher, and the conditions for study are there more favorable, although the relationship between the two types is less apparent at the latter locality. There can, however, be no doubt that the syenitic and the black basic overlying rock, although entirely distinct from a lithological standpoint, are parts of one and the same geological body. The lithological peculiarities of the rocks can not be dwelt upon in detail here, and reference must be made to the paper in the Proceedings of the National Museum above noted.

EFFUSIVE ROCKS.

The effusive rocks of the region not only cover considerable areas, but, by reason of their geological relations, afford evidence of the succession of volcanic events which have transpired since the post-Cretaceous uplifting of the region.

The earliest of the volcanic rocks are those which now form the Livingston beds. Though a stratified, water-laid formation, it should be mentioned here, as the pebbles are chiefly volcanic and constitute the only evidence we have of the beginning of a period of volcanic activity which with varying intermissions has probably lasted up to the present epoch. We have no evidence to show the location of the vent in which these rocks had their origin.

After the uplift and the epoch of erosion which succeeded this early period of volcanic activity came a time of prolonged and intense volcanic outbursts. The remains of the material ejected at this period now constitute the Gallatin Range, where the andesite breccias cover an area of 150 square miles and form many of the high peaks so conspicuous immediately to the southward of the city of Bozeman. In the area of the Three Forks sheet these rocks are from 1,500 to 2,000 feet thick, and are seen to rest upon eroded older sedimentary beds.

These basic breccias and agglomerates, with other associated lava flows, constitute a geological unit, because of their mechanical constitution and common origin. They are aerial, fragmentary, volcanic accumulations, and present in many localities no evidence of having been laid down by water action. The rocks are for the most part, however, rudely bedded and dip eastward at low angles. The bedding is sometimes quite prominent in large exposures. The rocks vary in texture from fine-grained tuffs resembling sandstones to irregular, chaotic mixtures of large and small rock fragments. The greater part of the formation consists of thickly bedded agglomerates in which large and small fragments are promiscously mingled. These fragments represent compact, vesicular, and, rarely, scoriaceous rocks of very closely allied types of andesite. The formation is generally hard, weathers into picturesque crags, and affords but scanty foothold for vegetation. In color it varies from brown and black exposures through various shades of dull-red, brown, and, rarely, green. In petrographic character the breccia is made up of black or dark-gray, more rarely light-colored, rocks, which are classed as andesites. The groundmass is dense and compact and contains crystals of plagioclase and augite, and more rarely of mica and hornblende, which are visible to the naked eye.

The andesite flows are associated with the breccias just described. In the area of this sheet they occur at many localities as intercalated lava flows in the breccia, but are discriminated only in the northern part of the Gallatin Range, where the outcrops occur capping some of the hills west of the Gallatin River and where they are secn also beneath the western edges of the breccia-capped summit of Mount Blackmore and neighboring peaks. On the eastern side of Boulder Creek are other limited areas of andesite lava flows, occurring in successive sheets, the oldest and lower rock here being a compact hornblende-andesite, overlain in turn by a semi-glassy hypersthene-andesite, and this in turn by basalt, followed by a small sheet of rhyolite.

Rhyolite.—Rhyolite occurs in numerous small remnants of lava flows which rest upon various rocks and show that a long period of erosion elapsed after the formation of the volcanic breccias. The rhyolite is the same rock which covers so large a portion of the Yellowstone Park, and in the Middle Basin and Lower Basin of the Gallatin River the mesa-like hills are possibly the remnants of a former extension of the rhyolite flow from the park. In general the rhyolite appears to have filled the old valleys, but the diversion of the drainage has not been marked, and the present remnants are thus left as tables by the cutting of narrower valleys below the surface of the older and broader valley. Similar areas are found along the upper course of the Madison River, one of which forms palisades on the river as it enters the district. The rocks vary from glassy to felsitic forms. They are light-colored, sometimes are banded, and show clear glassy crystals of sanidine and quartz, and more rarely glistening flakes of mica.

Succeeding the outflows of rhyolitic lavas was a period of volcanic activity, of which the only representative deposit found within the limits of the district appears to be the tuffs and beds of volcanic glass which now constitute the Neocene lake beds.

Basalt.—The basalt outflows were the last of the lavas of the district, and now form conspicuous if but limited areas, resting upon older rocks. The most extensive exposure is that west of the Gallatin Valley in the vicinity of Virginia City, where there is a basalt plateau occupying an area of about 50 square miles. The rocks vary in color from dull-gray to nearly black, and in structure from coarsely vesicular rocks to dense, compact forms, which often show yellow crystals of olivine large enough to be recognized by the eye. In many places the basalt plateau near Virginia City is underlain by light-colored tuffs and breccias, and at the southern end of the plateau these tuffs rest upon Archean gneisses and sedimentary rocks, the latter mainly of Carboniferous age. Small isolated areas of basalt, the remnants of former extensive flows, occur at a number of localities, in several instances resting upon the Neocene lake beds. In a few instances varieties of the basalt are found carrying porphyritical quartz crystals, which show zonal bands of green augite similar to those of the well-known California and New Mexico quartz-basalts.

STRUCTURAL GEOLOGY.*

General consideration.—The complex arrangement of rock masses apparent in the Three Forks map is the result of movements which have disturbed the regular successions of strata, resulting in the present structure of the district, which is delineated in both the areal and the structure section sheet.

The movements of the earth's crust have occurred in two directions—vertically, both upward and downward, and horizontally. Vertical movements are recognized in the evidences of uplift and subsidence of various areas, and horizontal movements in the folding and overthrusting of the sedimentary beds.

The structure is complicated by eruptions of igneous rocks, which occur in the forms of laccolites, dikes, and surface flows.

The beginnings of disturbances in the earth's crust antedate the earliest records, and the movements have continued down to very recent times, or perhaps to the present.

Vertical movements.—The thickness of the sedimentary rocks deposited in this region during pre-Cambrian, Paleozoic, and Mesozoic time was many thousand feet. The materials for the deposits were worn from land areas, which must have been raised either somewhat steadily or at times separated by quiet intervals, the altitudes favorable to erosion being thus restored. The seas which received the sediments must therefore have deepened by more or less regular subsidence, or the vast volume of débris would have filled them.

Unconformities exist which show that areas previously raised to land surfaces and worn down have subsided, have been crossed by an advancing shore, and later have passed beneath the sea.

The movements of the Algonkian period are obscurely, though not doubtfully recorded. Their sequence was certainly prolonged. At the base of the Algonkian, between the Cherry Creek formation and the Archean, is a probable unconformity, the significance of which is not yet worked out. The complex structure of the Cherry Creek formation, which is indicated in the southern part of Section D, is the record of a prolonged series of events, its highly disturbed and metamorphosed condition marking a great epoch of folding and deep erosion prior to the deposition of the Belt formation.

At the base of the Cambrian is the unconformity marked by the overlapping of the Flathead formation. The subsidence was extensive and gradual. It was one of a series of gentle vertical oscillations which, continuing during Paleozoic time, became more energetic in the Mesozoic. These conditions are apparent in the generally calcareous character of the Cambrian, Devonian, and Carboniferous formations and in their moderate thickness. The coarser mechanical character of the Cretaceous sediments, and their great thickness also, indicate the more rapid subsidence of the sea bottom and the energetic erosion dependent upon a more vigorous uplift of the land. From the Flathead to the Laramie the formations dip conformably, a proof that, whatever the irregularities of vertical movement may have been, they did not involve marked tilting of the beds.

Horizontal movements.—The great series of conformable strata topped by the Laramie formation is closely folded. The strata have been pushed up in arches, many of which have been overturned. This is the effect of horizontal thrust, which began to act about the close of the Cretaceous period. The area mapped on the Three Forks sheet does not afford sufficient data for generalizing with reference to forces which affected the whole Rocky Mountain province, but these facts are apparent in the map and the structure-section sheet.

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*The structure sections were redrawn in the office of the Geological Survey from diagrams furnished by the author. The geologic map being taken as a standard, the sections were adjusted to it and the dips of strata were modified. In the original diagrams the hades of all faults are drawn in a vertical position. In redrawing, these were changed to hades in the direction of the upthrow, characteristic of overthrusts. The author did not see the proof, and in justice to him this explanation and the following corrections are inserted at his request.

At the northeastern end of Section C there is no flattening of the dip in the Belt formation next to the valley. The section line cuts the beds obliquely and therefore shows a greater thickness. Where the section line crosses the fault west of Salesville the hade should be vertical or nearly so, and the ends of the sedimentary beds should not be so much turned up against the Archean. In Section D, where the line crosses the mountain ridge between the Sphinx Mountain and Indian Creek, the fault line should not cut the Cherry Creek formation, but should lie between it and the sedimentaries, and the Flathead formation should not come so close to the surface.—EDITOR.

The simple as well as the overturned synclines are marked by the areas of Laramie (Cretaceous) beds, which at the time of the folding were the latest and highest of the formations. But the arches between the troughs, having been exposed by their elevation to excessive erosion, have been worn down to the older and even to the oldest rocks, the Archean.

The Archean areas shown are the axes of extensive uplifts, modified by faulting, and largely denuded of their former covering of sedimentary rocks and are the greater, while the folds, which form such conspicuous features of the map, are the lesser features.

Unlike the Appalachian folds, which are strikingly parallel and continuous, the central lines or axes of the synclines in the Three Forks region lie in various directions, trending south in the southwestern corner, southeast in the body of the area, northeast in the northern part, and east near the western margin. This is apparently the result of several independent centers of uplift. To the north the great anticline of the Belt Range has probably affected the structure in the vicinity of the "Three Forks," while to the south the laccolite of the Madison Range, and eastward that of the Snowy Mountains, have, perhaps, influenced the great folds of the region. The anticlines are limited in longitudinal extent, rising usually from a low arch, often to an overturned fold, and sinking again on the opposite pitch within short distances. In general the steeper dips are on the western, northwestern, and northern limbs of the synclines. In the vicinity of "Three Forks" the strata are markedly overturned southeastward; and similar effects are seen in the Bridger, Madison, and southern Jefferson ranges.

There principal faults cross the Gallatin Range, and two of them extend across the Madison Range to the western part of the area of this sheet. Their course is about 50° to 55° west of north. The hade or dip of the fault planes is not determined, but is drawn on the structure sections as though the Archean had been overthrust southwestward, which is probably not the case. The northernmost of these faults springs from the northern limb of a syncline, 10 miles south of Bozeman, and extends parallel to the axis of the fold, crossing the Gallatin Valley where it is covered by the lake beds, and reappearing for a few miles west of the valley. In consequence of this break the Archean is brought into contact with Cambrian, Devonian, and Carboniferous strata. The hade of this fault is vertical, or nearly so. A more extensive fault occurs 6 miles farther south, and is parallel to the first. It also traverses the northern limb of a syncline parallel to the axis, and brings the Archean in contact with Paleozoic strata up to the Carboniferous. Its southeastern end is buried beneath the great mass of andesitic breccias of the Gallatin Range, and northwestward it passes beneath the Bozeman lake beds west of Madison River. The third fault of the system lies south of Gallatin Peak; crossing the Gallatin River at the head of Gallatin Canyon, it extends almost parallel to the strike of Devonian and Carboniferous beds, but soon cuts across their ends, and still farther west crosses a broad syncline of Cretaceous strata, after which it cuts across the northern end of the overturned sedimentaries of the west side of Madison Range. Northwest of Madison River this fault is more obscure, but it is probably indicated by the line between the Archean gneisses and the granite of the Revenue region. It constitutes a well-defined feature of the topographic map.

In the vicinity of the Jefferson River, in the northwest corner of the area of this sheet, are two other interesting faults, although neither is of very great extent within the limits of the district. The first, or most northern, with a general direction of about south 60° or 70° west, crosses the Jefferson River about a mile or two below the mouth of South Boulder Creek and continues southwestward into at least the eastern portion of the area of the Dillon sheet. East of the Jefferson River this fault involves Carboniferous and Juratrias beds, which are faulted against the Belt beds of the Algonkian. West of the South Boulder, for 5 or 6 miles, the fault is obscured by lake beds, and when it is seen again is somewhat changed in direction, involving Carboniferous, Juratrias, and Cretaceous strata, which are now faulted against the Carboniferous, Devonian, and Cambrian rocks. The next fault is only a few miles to the southeast of the one just described, and begins with the Livingston formation faulted against the Algonkian. This fault is profound and soon develops into a double fault. The Livingston formation dips sharply to the northward against a very narrow strip of Devonian shales and limestones, which themselves dip at about the same angle in the same direction, being faulted against the Algonkian conglomerates that form the lower foothills of the rugged area north of the Jefferson River. This double fault may be traced in a curving line to the summit of the range south of the Jefferson River, which it crosses at right angles to its trend. From the range westward and southwestward into the area included in the Dillon sheet the fault involves only the Cretaceous and Carboniferous strata, the former being faulted against the latter.

In the area north of the East Gallatin River, west of Dry Creek, several interesting transverse faults are seen, where the Flathead quartzite is apparently thrown down in blocks, and wherever these blocks occur an intrusive sheet of igneous rock is found above the quartzite. These faults are at right angles to the strike of the beds, showing a horizontal displacement of 300 feet and a throw of about 100 feet. They seem in most cases to involve only the Flathead quartzite, although one of them was traced through the Cambrian as far as the upper part of the Carboniferous.

The folding of the Cretaceous and pre-Cretaceous strata was accompanied or succeeded by an uplifting of the region, which provided conditions favorable to extensive erosion. The resulting detritus was deposited unconformably upon the Laramie and earlier strata, constituting part of the Livingston formation, which also contains large amounts of volcanic material erupted during this epoch. In the area about Sphinx Mountain the Livingston beds are twisted and bent, and along Jefferson River, as already noted, they are faulted. Compressive movements were, therefore, renewed after the deposition of the Livingston.

Development of the lake basins.—The Bozeman lake beds occupy basins which extend across other structural features of the area in a manner so irregular that the development of the basins appears to belong not only to a later but to a different movement. Westward from Bozeman these Neocene beds rest upon the Archean, and north of the Gallatin and Jefferson rivers they extend in undisturbed attitude across the various upturned formations from Algonkian to Cretaceous. The basin of the Madison Lake covers a broad anticline in the older rocks. Thus the unconformity between the Neocene and the earlier formations is very strongly marked.

The Bozeman lake beds are now the floors of extensive valleys separating the detached mountain ranges, which rise about 6,000 feet above their bases. As the lake deposits are about 2,000 feet deep, the difference of elevation between the bottoms of the lake basins and the summits of the peaks is probably 8,000 feet. The relations of the relatively undisturbed lacustrine strata to the ranges show that the region was a mountainous one before the development of the lakes. It can not now be stated how high the mountains were before the lakes were formed, nor what part of the existing difference of 8,000 feet is due to the subsidence of the valleys and what part to the relative uplift of the mountains. In the evolution of the existing relief, movements and erosion have both operated to accent the topographic differences.

The structure of the region has been modified by the late eruptions of volcanic rock, especially by the basaltic lava flows near Virginia City and the rhyolites that are part of the great volcanic flow of the Yellowstone Park. These are described under "Igneous Rocks."

ECONOMIC GEOLOGY.

The mineral resources of the district may be enumerated under the head of gold, silver, iron ore, limestone, copper, coal, brick clays, building stone, polishing materials, and mineral springs.

Auriferous gravels.—Gold-bearing gravels in the district are found in the famous Alder Gulch above Virginia City, which is said to have yielded nearly one-half of all the gold produced in Montana since the first discovery in the Territory. The placers are still worked there, as well as in some of the adjacent gulches, although the yield seems to be gradually declining. Other placers are worked at Washington Bar, on Meadow Creek, on Norwegian Creek, on Cherry Creek, and in the Jefferson Canyon between the mouth of the South Boulder Creek and the mouth of Antelope Creek.

In some gravels of probable glacial origin, which are more or less consolidated, and form what has been called the Gravel Range, lying on the west side of the divide between Warm Spring Creek and the Madison Valley, southeast of Virginia City, gold is said to exist in considerable quantity, although little has been done to develop any mining operations.

Gold veins.—The principal gold-bearing quartz districts are found in the vicinity of Virginia City, around Wards Peak, in the Revenue District, near Red Bluff, and in the mountains adjacent to Pony. In all of these, quartz mines are worked, gold being the principal product.

Silver.—Silver is found in connection with gold at most of the localities enumerated above, especially in the Red Bluff and Pony districts. Free silver occurs in the vicinity of Cherry Creek, 8 or 10 miles northeast of Red Bluff, but at present little or no mining is done there.

Iron ore.—Iron ore, mostly hematite, so far as seen, is found at numerous localities throughout the district, especially in the foothills and mountains south of the Gallatin Valley, and in the vicinity of Three Forks, although it is nowhere mined at present.

Limestone.—The supply of limestone for the burning of lime is abundant in all sections of the district. Limekilns have been built in the canyons south of Bozeman and at many other localities near that city, and they furnish a fair quantity of lime for building purposes.

Copper.—Copper is found in connection with silver throughout the Archean area extending from Sterling to Pony and between Cherry and Elk creeks, east of the Madison River. At present its economic importance in the district is not very great.

Coal.—Wherever the Laramie formation is exposed, from one to three beds of coal may be looked for. It seems to be best developed and occupies larger areas in Nixon Basin and in the Gallatin basins above the lower canyon of the Gallatin River. At no place in either are any extensive mining operations carried on at present, and careful detailed exploration will be necessary before the value of the individual beds can be determined. Coal is also found in the vicinity of the Jefferson Canyon, in the valleys of Ruby and Warm Spring creeks, in the southwest corner of the district; also in the basin of Jackass Creek, east of the Madison Valley, and east of Flathead Pass, in the extreme northeastern corner of the map. However, the basin of the upper Gallatin is the largest coal field of the district, as it includes a very considerable portion of the area lying between the Madison Mountains and the Gallatin River, south of the mountains in which Gallatin Peak is the center. There is a possibility that careful and detailed exploration may sometime result in the finding of anthracite or semi-anthracite coal in the vicinity of the great porphyritic laccolite of the Madison Range. The occurrence of Devonian coal on the north side of the Jefferson canyon, several miles above Sappington, is of geologic interest, though not of very great economic importance. The coal is of poor quality, owing to its containing many nodules of limestone, and the area in which it is likely to be found is of rather limited extent.

Brick clays.—Brick clays are found in the alluvium of a number of the streams and in some of the beds of the Bozeman lake beds, although the latter are apt to be somewhat sandy. Bricks are burned at present only in the vicinity of Bozeman.

Polishing materials.—In the Bozeman lake beds, at many localities throughout the Gallatin and Madison valleys, beds of fine pumiceous volcanic dust occur which could readily be utilized as polishing material, as similar deposits have been utilized in other localities, particularly in the States of Kansas and Nebraska. The finer portions might be separated from the coarser by a process of washing.

Building stone.—Although good building stone may be obtained from rocks in various localities, such as the granite of the Revenue region and the sandstones of the Flathead formation, in nearly every place where the formation is exposed little quarrying has been done, mainly on account of the lack of a sufficient demand. The Flathead formation west of Salesville has been quarried and yields a reddish sandstone that has been utilized to a limited extent in Bozeman. There are many localities, among which one in the vicinity of Antelope Creek, near the Jefferson, may be mentioned, where a quartzite or quartzitic sandstone occurs in this formation that can scarcely be distinguished in color or texture from the Potsdam sandstone (quartzite) of New York State, and which will probably furnish an equally good building stone. The Laramie formation also furnishes at many localities a light-gray sandstone which resembles the Berea sandstone of Ohio. It has been utilized to some extent in Bozeman, where blocks of large dimensions have been used in a number of buildings. It works readily when first quarried, but hardens upon exposure. As the State becomes more thickly settled there will be greater demand for building stone, and the demand will undoubtly be met from an abundance of material, of which not a small portion will be found within the area of the Three Forks sheet.

Mineral springs.—The mineral springs of the district may all be properly placed under the head of warm springs, and include those at the following localities: Ferris Hot Springs on the west Gallatin River, which at present is the only one that is developed and utilized as a resort; the springs east of Red Bluff, which have a temperature of 112° F.; and the springs 5 miles south of Pony on the south branch of Willow Creek, which cover an area of several acres and have temperatures of 80°, 90°, 100°, 116°, and 122° F. There is a small warm spring in the lower canyon of the Jefferson above Willow Creek. The temperature of the water is about 90° F.

The Ferris Hot Springs were formerly known as the Mathews Warm Springs. They are situated about 7 miles west of Bozeman, and have been improved by the erection of a hotel and bath houses. There are two principal springs, with temperatures of 114° and 122° F. The water may be classified as sulphated alkaline-saline; that is, it contains both alkaline carbonates and sulphates as the predominating constituents. It resembles somewhat the water of the Carlsbad Sprudel Springs, although the proportion of solid contents is less and the temperature is not quite so high.

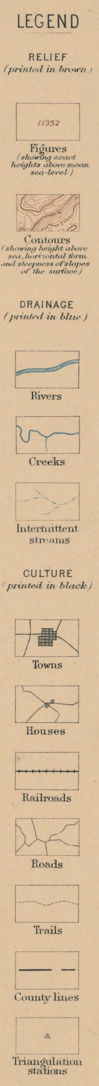
A. C. PEALE,
Geologist.

April, 1896.

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

TOPOGRAPHY

MONTANA
THREE FORKS SHEET



Henry Gannett, Chief Geographer.
A.H. Thompson, Geographer in charge.
Triangulation by J.H. Renshawe and E.M. Douglas.
Topography by the Northern Transcontinental Survey and Frank Tweedy.
Surveyed in 1886.

N.T. Survey
F. Tweedy

Scale $\frac{1}{250000}$

2 0 2 4 6 8 10 Miles

2 0 2 4 6 8 10 Kilometers

Contour Interval 200 feet

Datum is mean Sea level

Edition of Aug. 1895.

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AREAL GEOLOGY

MONTANA
THREE FORKS SHEET

LEGEND (continued)

IGNEOUS ROCKS

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

- b — Basalt
- rh — Rhyolite
- pt — Porphyrite
- dp — Diorite-porphyrite
- di — Diorite
- an — Andesite
- bbr — Basic, andesitic breccia and flows
- gr — Granite
- Dikes of augite-porphyrite, syenite, etc.
- Dikes of diabase and peridotite

Faults

Sections

LEGEND

SURFICIAL ROCKS

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

PLEISTOCENE
- Pald — Alluvium and drift
- Pgd — Glacial drift and moraines

SEDIMENTARY ROCKS

(Areas of Sedimentary rocks are shown by patterns of parallel lines. Metamorphism is indicated by short dashes combined with the parallel lines.)

NEOCENE
- Nb — Bozeman lake-beds *(sand, conglomerate, limestone, clay and volcanic dust)*

EOCENE
- Es — Sphynx conglomerate

?
- lv — Livingston formation *(conglomerate, sandstone, and andesitic tuff)*

CRETACEOUS
- Kl — Laramie formation *(sandstone and clay with seams of coal)*
- Kmc — Montana and Colorado formations *(sandstone, limestone, and shale)*
- Kd — Dakota formation *(conglomerate, quartzite, sandstone, and shale)*

JURATRIAS
- Je — Ellis formation *(sandy and clayey limestones, and quartzite)*

CARBONIFEROUS
- Cq — Quadrant formation *(cherty and magnesian limestones)*
- Cm — Madison limestone

DEVONIAN
- Dt — Three Forks formation *(shale and magnesian limestone)*
- Dj — Jefferson limestone *(possibly including Silurian at base)*

CAMBRIAN
- Єg — Gallatin formation *(limestone and shale)*
- Єf — Flathead formation *(limestone, shale, and quartzite)*

ALGONKIAN ?
- bt — Belt formation *(conglomerate, sandstone and arenaceous limestone)*

ALGONKIAN
- Ac — Cherry Creek formation *(marble, mica-schist and gneiss)*

(Areas of ancient, crystalline rocks and of metamorphic rocks of unknown origin are shown by patterns of short dashes.)

ARCHEAN
- Agn — Gneiss and schist

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Geology by A.C. Peale.
Surveyed in 1883-89.

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ECONOMIC GEOLOGY

MONTANA
THREE FORKS SHEET

LEGEND
(continued)

IGNEOUS ROCKS

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- Dikes of augite-porphyrite, syenite, etc.
- Dikes of diabase and peridotite

Faults

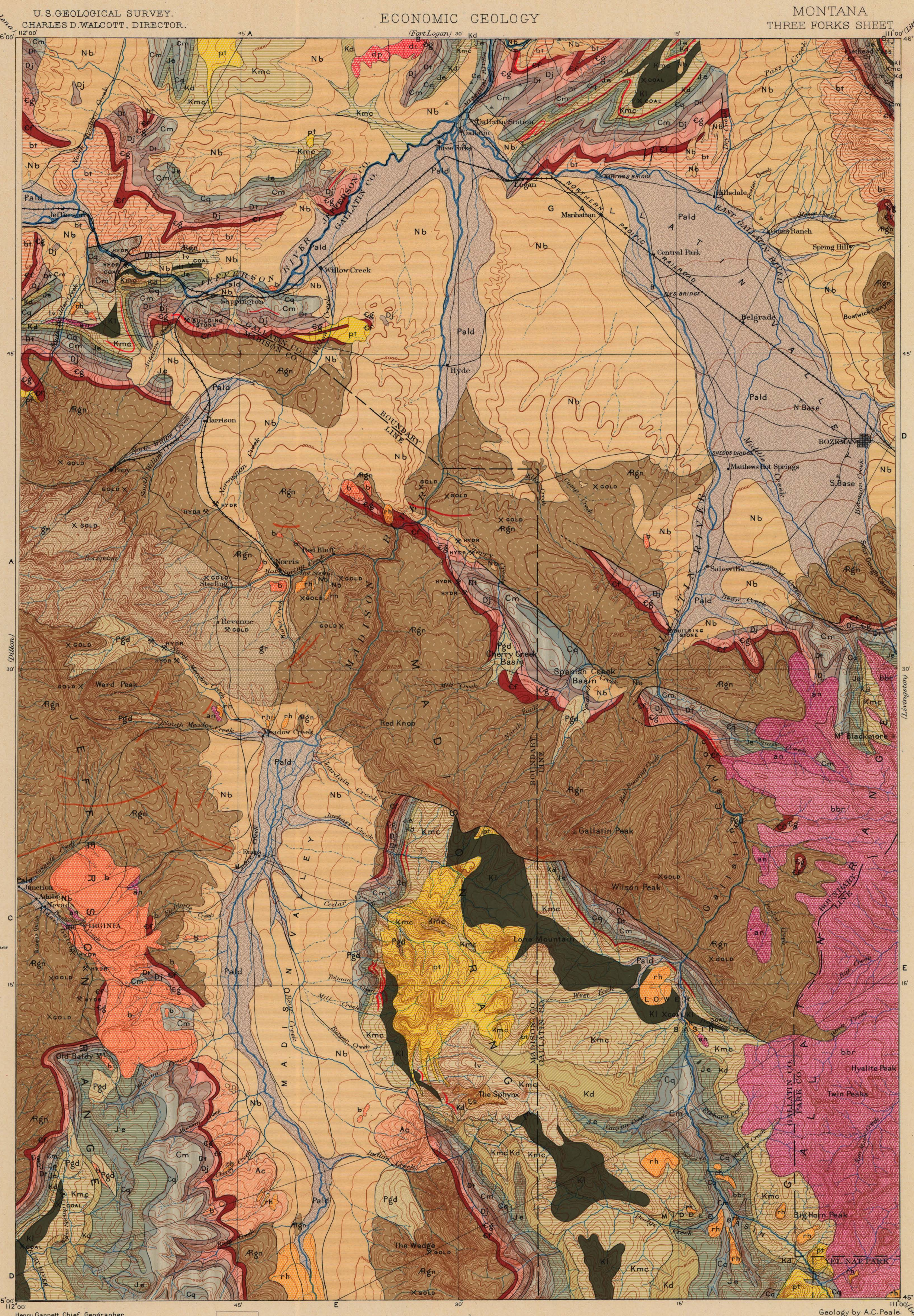
Sections

Known productive formations

- Coal
- Quartzite (building stone)

SPECIAL SYMBOLS

- Mines and quarries
- × Prospects
- HYDR Hydraulic gold mines



LEGEND

SURFICIAL ROCKS

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- Ac — Cherry Creek formation (marble, mica-schist and gneiss)

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ARCHEAN
- Rgn — Gneiss and schist

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Contour Interval 200 feet
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STRUCTURE SECTIONS

MONTANA
THREE FORKS SHEET

LEGEND
(continued)

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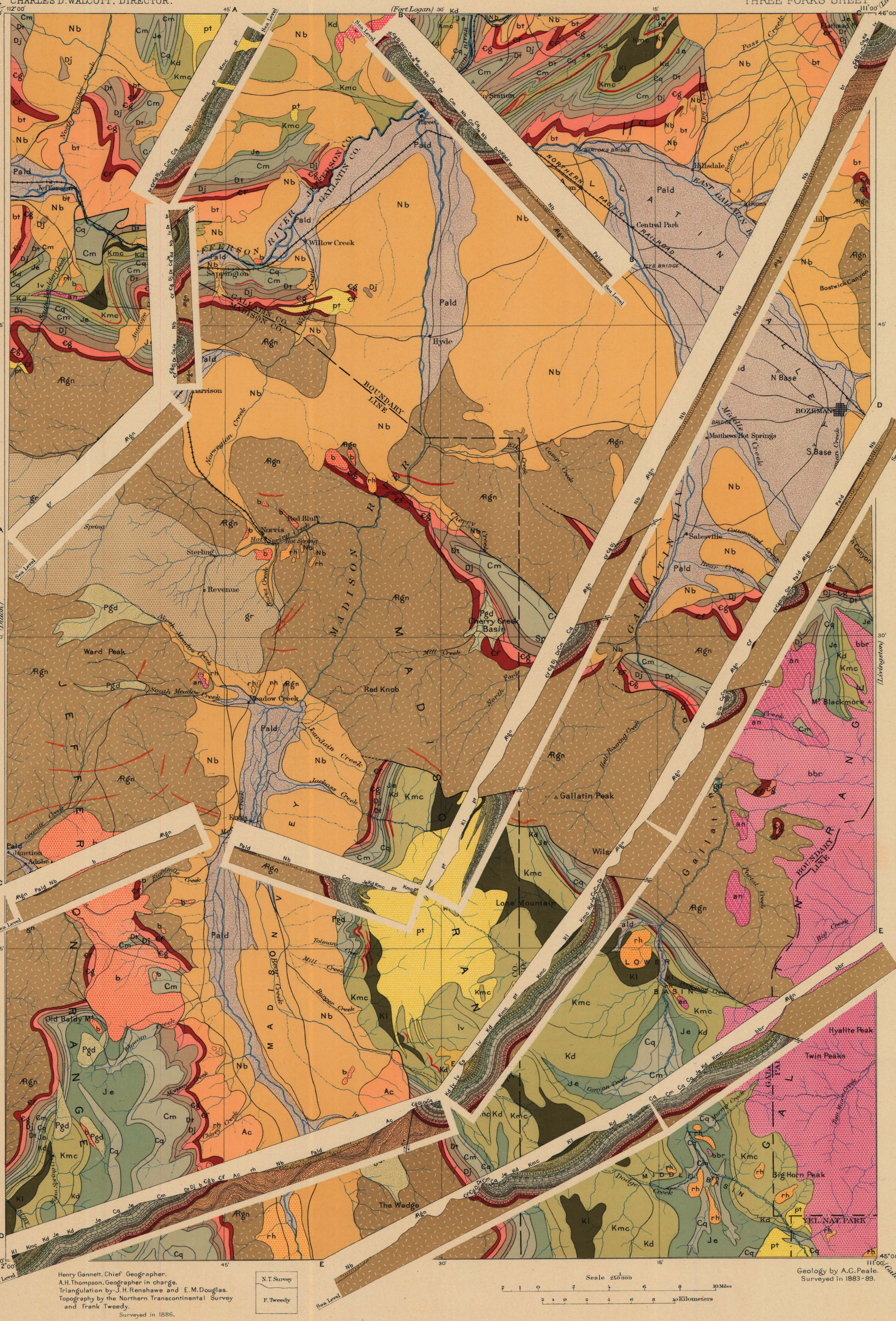
- Dikes of augite-porphyrite syenite, etc.
- Dikes of diabase and peridotite
- Faults

Known productive formations

- Coal
- Quartzite *(building stone)*



LEGEND

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

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- Rgn — Gneiss and schist

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Scale $\frac{1}{250000}$
Miles
Kilometers

Geology by A.C. Peale.
Surveyed in 1883-89.

Edition of Aug. 1895.

COLUMNAR SECTION

U. S. GEOLOGICAL SURVEY
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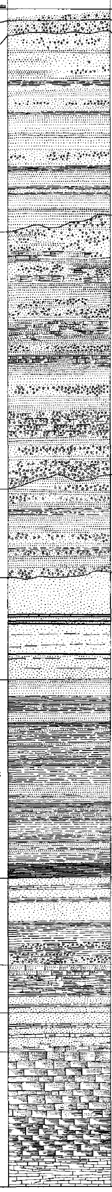
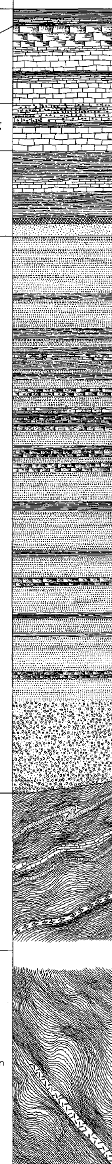
MONTANA
THREE FORKS SHEET

GENERALIZED SECTION FOR THE THREE FORKS SHEET.
SCALE: 1000 FEET = 1 INCH.

Period.	Formation Name.	Symbol.	Columnar Section.	Thickness in Feet.	Character of Rocks.
PLEISTOCENE	Alluvium and drift.	Pald		50+	Sand, gravel, and clay.
	Glacial drift and moraines.	Pgd		100+	Sand, bowlders, and unassorted material.
NEOCENE	Bozeman lake-beds.	Nb		1800–2500	Sand, conglomerate, limestone, clay, and volcanic dust.
EOCENE	Sphinx conglomerate.	Es		2000–3000	Conglomerate of limestone pebbles cemented by reddish sand.
CRETACEOUS ?	Livingston formation.	lv		1000+	Conglomerate, sandstone, and andesitic tuff.
CRETACEOUS	Laramie formation.	Kl		800–1000	Sandstone and clay, with coal beds.
	Montana and Colorado formations.	Kmc		1800–2000	Sandstone and shale.
	Dakota formation.	Kd		800–1000	Conglomerate, quartzite, sandstone, and shale.
JURATRIAS	Ellis formation.	Je		300–500	Arenaceous and argillaceous limestones, and quartzite.
CARBONIFEROUS	Quadrant formation.	Cq		300–500	Cherty and red magnesian limestones.
	Madison limestone.	Cm		1200–1500	Jaspery limestone. Massive limestone. Laminated limestone.

Period.	Formation Name.	Symbol.	Columnar Section.	Thickness in Feet.	Character of Rocks.
DEVONIAN	Three Forks formation.	Dt		150–200	Orange shale and magnesian limestone.
	Jefferson limestone.	Dj		700–1000	Massive black limestone with bands of laminated magnesian limestone.
CAMBRIAN	Gallatin formation.	€g		400–500	Pebbly limestone and shale. Mottled limestone.
	Flathead formation.	€f		800–1000	Greenish shale. Massive limestone. Shale, quartzite, and sandstone.
ALGONKIAN ?	Belt formation.	bt		6000–10000	Argillite, arenaceous limestone, and micaceous sandstone. Conglomerate.
ALGONKIAN	Cherry Creek formation.	Ac		7000 or more	Gneiss, mica-schist, crystalline limestone, and quartzite.
ARCHEAN		Agn			Gneiss and schist.

A. C. PEALE,
Geologist.