DEPARTMENT OF THE INTERIOR

UNITED STATES GEOLOGICAL SURVEY

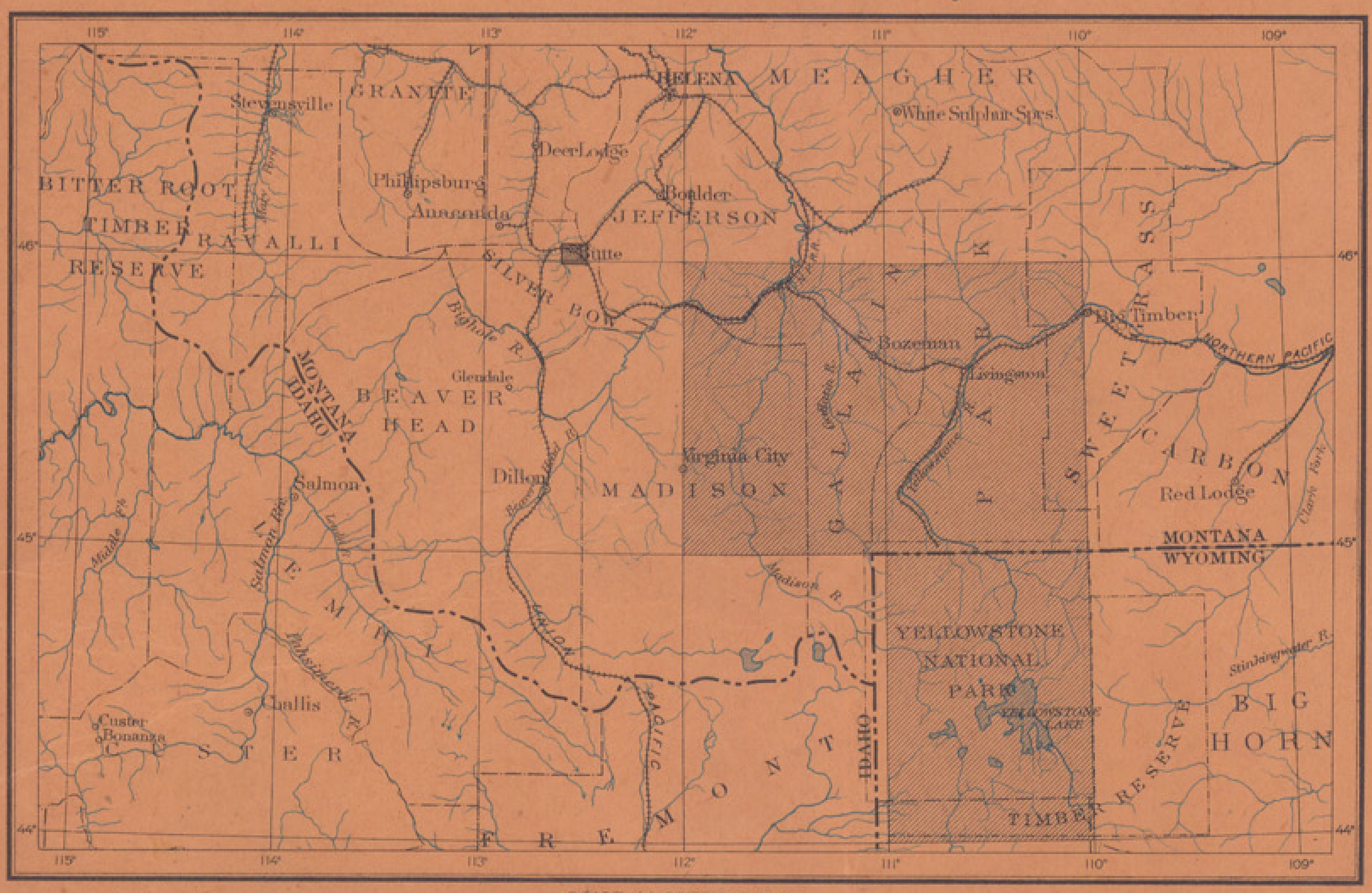
CHARLES D. WALCOTT, DIRECTOR

GEOLOGIC ATLAS OF THE UNITED STATES

BUTTE SPECIAL FOLIO

MONTANA

INDEX MAP



SCALE: 40 MILES=1 INCH

AREA OF THE BUTTE SPECIAL FOLIO

AREA OF OTHER PUBLISHED FOLIOS

LIST OF SHEETS

DESCRIPTION | TOPOGRAPHY | ECONOMIC GEOLOGY | STRUCTURE SECTIONS

FOLIO 38 | LIBRARY EDITION | BUTTE SPECIAL

WASHINGTON, D. C.

ENGRAVED AND PRINTED BY THE U.S. GEOLOGICAL SURVEY

EXPLANATION.

The Geological Survey is making a geologic map of the United States, which necessitates the preparation of a topographic base map. The two are being issued together in the form of an atlas, the parts of which are called folios. Each folio consists of a topographic base map and geologic maps of a small area of country, together with explanatory and descriptive texts.

THE TOPOGRAPHIC MAP.

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

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

The manner in which contours express elevation, form, and grade is shown in the following sketch and corresponding contour map:

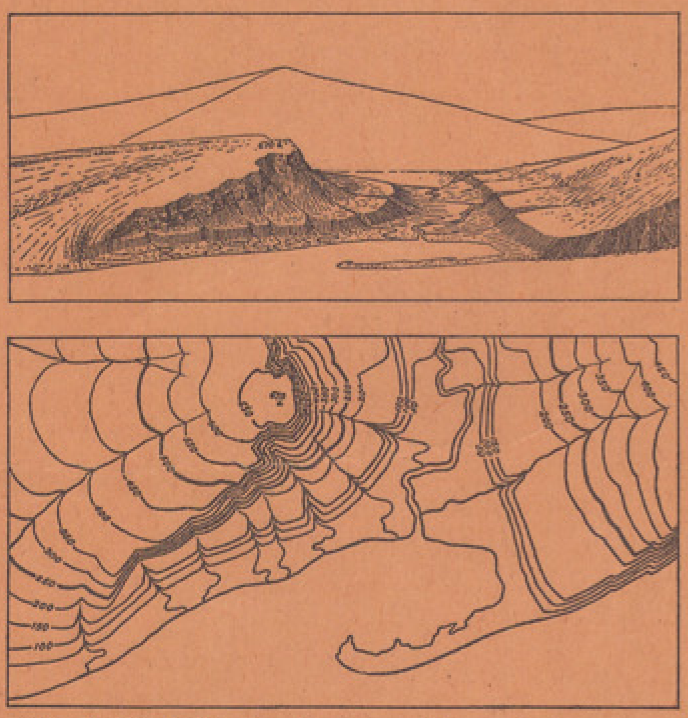


Fig. 1.—Ideal sketch and corresponding contour map.

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

1. A contour indicates approximately a certain height above sea-level. In this illustration the contour interval is 50 feet; therefore the contours are drawn at 50, 100, 150, 200 feet, and so on, above sea-level. Along the contour at 250 feet lie all points of the surface 250 feet above sea; and similarly with any other contour. In the space between any two contours are found all elevations above the lower and below the higher contour. Thus the contour at 150 feet falls just below the edge of the terrace, while that at 200 feet lies above the terrace; therefore all points on the terrace are shown to be more than 150 but less than 200 feet above sea. The summit of the higher hill is stated to be 670 feet above sea; accordingly the contour at 650 feet surrounds it. In this illustration nearly all the contours are numbered. Where this is not possible, certain contours—say every fifth one—are accentuated and numbered; the heights of others may then be ascertained by counting up or down from a numbered contour.

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

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

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

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

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

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

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

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

The atlas sheets, being only parts of one map of the United States, are laid out without regard to the boundary lines of the States, counties, or townships. To each sheet, and to the quadrangle it represents, is given the name of some well-known town or natural feature within its limits, and at the sides and corners of each sheet the names of adjacent sheets, if published, are printed.

Uses of the topographic sheet.—Within the limits of scale the topographic sheet is an accurate and characteristic delineation of the relief, drainage, and culture of the district represented. Viewing the landscape, map in hand, every characteristic feature of sufficient magnitude should be recognizable. It should guide the traveler; serve the investor or owner who desires to ascertain the position and surroundings of property to be bought or sold; save the engineer preliminary surveys in locating roads, railways, and irrigation ditches; provide educational material for schools and homes; and serve many of the purposes of a map for local reference.

THE GEOLOGIC MAP.

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

KINDS OF ROCKS.

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

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

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

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

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

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

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

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

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

The surface of the earth is not fixed, as it seems to be; it very slowly rises or sinks over wide expanses, and as it rises or subsides the shore-lines of the ocean are changed: areas of deposition may rise above the water and become land areas, and land areas may sink below the water and become areas of deposition. If North America were gradually to sink a thousand feet the sea would flow over the Atlantic coast and the Mississippi and Ohio valleys from the Gulf of Mexico to the Great Lakes; the Appalachian Mountains would become an archipelago, and the ocean's shore would traverse Wisconsin, Iowa, and Kansas, and extend thence to Texas. More extensive changes than this have repeatedly occurred in the past.

The character of the original sediments may be changed by chemical and dynamic action so as to produce metamorphic rocks. In the metamorphism of a sedimentary rock, just as in the metamorphism of an igneous rock, the substances of which it is composed may enter into new combinations, or new substances may be added. When these processes are complete the sedimentary rock becomes crystalline. Such changes transform sandstone to quarzite, 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

DESCRIPTION OF THE BUTTE SPECIAL DISTRICT.

GEOGRAPHY.

The maps of this folio represent, on a large scale, the detailed topography and geology of an area of about 23 square miles, known as the Butte district, a region made world-famous by its enormous copper and silver ore deposits.

The district is situated in southwestern Montana, Silver Bow County, in the central part of the Rocky Mountain region. The drainage is toward the Pacific, but the continental watershed is so near that streams tributary to the Missouri are diverted for the water supply of the city of Butte. The district described forms but a part of a broad intermontane depression 5500 feet above sea-level, and is surrounded on all sides by high mountain masses. Three miles east of Butte the continental divide rises 2000 feet above the valley; it is here a narrow granite ridge, locally known as East Ridge. Southward, 16 miles away, is the line of sharp peaks culminating, at 10,000 feet above the sea, in the Highland Mountains; 10 miles distant to the west is a lower range, while immediately north a broad summit region rises over 8000 feet above sea-level.

General geographic relations of Butte.

Butte, with its adjacent settlements, lies on the northern margin of this depression, and is reached by three trans-continental lines of railway and two local lines. To one approaching the city the general appearance is most desolate; bare, brown slopes, whose very rocks look burnt, rise from the almost equally barren valley, and scattered here and there through the city which lies toward the base of the slopes, and dotting all the hills about, are the red mine buildings, forming, with their great gray dump-heaps, the most conspicuous feature of the landscape. The discolored waters of Silver Bow Creek flow through the valley toward the west, encircling the base of the slopes, while west of the city is the sharply conical hill, The Butte, from which the city takes its name. Barring the total absence of vegetation, caused by the clouds of sulphur fumes coming constantly from the smelters in the valley, the city itself is a pleasant one, with its compact, well-built brick business blocks and many residences on the hills which command the magnificent mountain views of the district.

Barren aspect of the district.

GEOLOGY OF THE SURROUNDING REGION.

The distribution of the rocks of the district is shown on the accompanying geological map. The types represented are few, and they are closely related in mineral and chemical composition, though quite different in appearance. In order that the origin of these rocks, their relation to one another, and their connection with the economic geology of the district may be understood, it is necessary to give a brief sketch of the geological features and structure of the surrounding region.

THE GRANITE INTRUSION.

Extending from the peaks of the Highland Mountains on the south nearly to Helena on the north, and from the Deerlodge Valley on the west to the Elkhorn Range and Bull Mountain on the east, is a tract that differs markedly in both scenery and rock structure from the mountain ranges about it. This whole tract, 40 miles wide and 70 miles long from north to south, is underlain by granite (concealed in part by other igneous rocks, but constituting one great mass) in which are carved mountains, gorges, and valleys. The granite is traversed by varying, well-defined systems of joint planes, is extensively decomposed in some localities, and weathers into rugged crags and monoliths and great bowlder masses which form the picturesque scenery so frequently typical of granitic areas. The larger topographic features lack the rugged character of the sedimentary ranges, for the coarsely granular nature of the granite produces broad summits and smooth-surfaced valleys; the ruggedness of the tract is in the smaller topographic features.

Extent and relations of the granite mass.

Surrounding the granite area, broken and folded sedimentary rocks form higher peaks and ranges. These upturned sedimentary beds, many thousand feet in thickness, are of interest in this connection only because of the evidences they present of the age and nature of the granitic rocks. They consist of limestone, sandstone, shale, and slate. They contain fossils, and comprise strata of various ages from oldest Algonkian to late Cretaceous. The contact between the granite and these rocks shows unmistakable evidences of the eruptive nature of the granite. The stratified rocks exhibit striking effects of alteration at and near the contact, dark and dense limestone being altered to white, coarsely crystalline marble, contact minerals such as garnet and epidote occurring in abundance, and otherwise soft shales being baked to hard, brittle slates. These facts indicate that the granite, while a molten rock, broke up through sedimentary beds. The coarseness and evenness of the granite mass as a whole, and its undoubted unity, show that the liquid rock cooled under a cover. The granite varies but slightly in nature throughout the greater part of this area, the differences in appearance being due to jointing and weathering or to chemical alteration. Near the borders of the mass, however, the rock varies from a light-colored, typical granite to a darker variety approaching quartz-diorite in composition. These changes are often abrupt and pronounced in character near the contact with the sedimentary rocks. The nature and thickness of the rocks which once covered the granite can not be conjectured, as no trace of them now remains. The highest parts of the granite mass show no such irregularities of grain and composition as are observable at the borders of the intrusion, where cooling was rapid owing to the contact with the sedimentary rocks. It is therefore inferred that the upper contact is nowhere present.

Evidences of the intrusive character of the granite.

That this great granite mass is not Archean but a more recent intrusion of igneous rock is conclusively proved by the the exposures at several localities along the contact with the sedimentary rocks. Of the rocks actually cut and altered by the granite the youngest of those containing recognizable fossils are Carboniferous, but folded coal-bearing rocks of Laramie (Cretaceous) age occur near Anaconda, and the general mountain folding of the adjacent sedimentary formations is known to have occurred after the Laramie epoch. The granites are therefore younger than the Carboniferous rocks, and are possibly of post-Laramie date.

Date of the granite intrusion.

LATER ERUPTIONS.

A large part of the granite tract is now covered by later volcanic rocks, which have been cut through in the canyons of the region. A long period of erosion, however, must have intervened between the time of the granite intrusions and these later volcanic outbursts, for the rocks above the granite were entirely removed and the country was carved into a roughly hilly surface before the succeeding period of volcanic activity began.

Andesite eruptions.—The rocks found upon the granite are of two distinct kinds and represent two distinct periods of volcanic activity. The older rocks are andesites. They vary much in appearance, but are generally dark-colored and show a compact and dense groundmass commonly dotted with porphyritic crystals of feldspar, augite, or other minerals. They are readily distinguished from the granites from which they differ in color and texture and in character of outcrop. Though usually massive and dense, porous varieties and those with agate amygdaloids also occur. Owing to their superior hardness these rocks are conspicuous in the gravels of all the streams draining andesite localities.

Description of the andesites; their character, extent, and associated deposits.

The andesites are of volcanic origin. In part they are intrusive, breaking through the granite, and in part they are extrusive, forming accumulations of breccia resting upon it. They never covered the entire granite tract, and are not found near Butte, but they form the high mountain summits east of the granite region, extending from the valley of the Jefferson northward to the Missouri River. They also occur in numerous isolated areas throughout the central part of the mountain mass between Butte and Helena. Mineral deposits occur in the andesites as well as in the older granites, but the only productive veins thus far found in them have been those of the Zosel district, a few miles east of Deerlodge.

After the andesite eruption had ceased the region underwent erosion for a prolonged period, during which the mountain masses and intervening valleys of the present day were carved by the streams. The Jefferson and Missouri valleys on the east and the Deerlodge on the west were at that time deeper than and as broad as they are to-day. This long period of quiet was succeeded by a tilting of the region, which reversed the drainage of the greater valleys, whose waters accumulated in lakes, a phenomenon general throughout the region. The lake beds formed at this time may be seen about the borders of the granite tract, and in Silver Bow Valley they were deposited upon the granite.

Effects of erosion and tilting after the andesite eruptions.

Rhyolite eruptions.—Rhyolitic rocks form a prominent feature of a large part of the region surrounding the Butte district. The rocks are light-colored and present a wide variety of types. They occur as dikes, cutting both the granites and the andesites, and as both massive and fragmental rocks. They form the hills west of Butte and the summits of the continental divide north of the district. The fragmental rocks and lava flows rest upon granites and andesites whose surface was as uneven as is that of the present day. The rocks are of truly volcanic origin and came from a number of vents. They represent the product of the third and latest period of igneous activity, which occurred after the great disturbance that formed the Miocene lakes of the region.

Phenomena of the third and latest epoch of igneous activity.

This period of volcanic activity was a general one for this part of the Rocky Mountain region. Its results are most marked in the Yellowstone Park. The age of these eruptions is a matter of much interest, since the rocks are more recent than the ore deposits of Butte. The lake beds of the valleys are formed largely of rhyolitic dust which fell into the quiet waters of the lakes and of fine volcanic ash and débris washed from the surrounding slopes. In these lake beds vertebrate remains of late Miocene age have been found, furnishing positive evidence of the date of the rhyolite eruptions. The hot springs which occur at a number of localities in the region described are believed to be due to the lingering heat of this period of volcanic activity, and to furnish evidence of its comparative recency.

RECENT CHANGES.

Since the close of the volcanic epoch represented by the rhyolites no great changes have occurred in the geological features of the district. The Miocene lakes have been drained by streams flowing northward. During the later Glacial times only the higher summits were covered by local ice sheets. They formed the moraines now conspicuous in some localities, though none occur near Butte. The grander features of topography are the same to-day as they were at the close of Miocene time, modified by canyon cutting and valley filling, which have changed only the details of scenery.

THE ROCKS OF THE BUTTE DISTRICT.

The rocks of the Butte district are all of igneous origin, are of few types, and are of simple mineral composition. They are mostly members of the granite family, whose essential constituents are alkali feldspar and quartz, with varying but smaller amounts of other minerals. Granites are characterized by the presence of orthoclase (monoclinic) feldspar as an essential constituent, but in these rocks the proportion of plagioclase (triclinic) feldspar is occasionally so large that the rocks are intermediate in composition between those of the granite and of the quartz-diorite families, plagioclase feldspar being a distinguishing mineral of the diorites. The names of the predominant rock types have been used because the variations occur as part of a continuous rock mass.

The geological map shows that granite rocks cover the greater part of the district, two varieties being distinguished. One is a dark, grayish, coarse-grained granite, the other a white or cream-colored rock, variously called "white" or "Bluebird" granite. These two rocks are intimately associated, and together constitute a part of the great granitic intrusion already described, into which they may be traced almost uninterruptedly eastward and southward. They are the oldest rocks of the district, and the great mineral veins occur in them. They are cut by intrusions of the more recent rocks, whose surface varieties rest upon the granite, as is shown in the plate of geological cross sections. The dark-colored granite of the district differs in appearance and mineral composition from the rock commonly prevailing throughout the surrounding region, and as it is nearly constant in character and is characteristic of the district it has been given the distinctive name of Butte granite. The "white" granite is a typical aplite, or fine-grained, siliceous granite. The two rocks are not only unlike in color and appearance but are readily distinguished in outcrop, the aplite forming rocky exposures standing above the surface of the more crumbly Butte granite.

Nature of the granites in general.

THE BUTTE GRANITE.

This, the common and characteristic rock, covers the eastern half of the district, where the great producing mines occur, and underlies the city. Throughout the entire district the rock is very uniform in color and texture, and in the kind, amount, and distribution of the component minerals. To the unaided eye it is a dark-colored rock, of coarsely and evenly granular appearance, but so dark and basic looking as to resemble a coarse diorite. Dark-green or black hornblende occurs in abundant, irregular grains. Biotite-mica, of the usual dark-brown color, is but little less common, occurring rarely in grains with crystalline form. The light-colored constituents, forming about five-sixths of the bulk of the rock, consist of pink orthoclase and, but little less abundant, gray and faintly greenish plagioclase, together with clear but not conspicuous quartz. Occasional black grains of magnetite, brown zircon, and apatite are recognizable, and pyrite is occasionally seen in the fresh rocks. Isolated square or rectangular masses of pink feldspar, an inch across, with partly crystalline form, constitute a common feature of the rock.

Mineralogical composition of the Butte granite.

Thin sections of the rock studied under the microscope show that orthoclase is the most abundant mineral, and that the rock is therefore a granite, though the plagioclase is relatively more abundant than is usual in granite. Examination of numerous sections shows a slight variation in the relative amounts of plagioclase (oligoclase-albite). The extreme variations are from a typical hornblende-granite to a diorite-granite. The most basic form was found at the Poulin mine, the andesine-feldspar of this rock slightly exceeding the orthoclase in amount. In the rock quarried east of the Bell mine the acid plagioclase-feldspar equals the orthoclase in amount. No order of arrangement of such variations was found, and the chemical analyses of the extreme variations are nearly identical and show a remarkably uniform composition of the rock throughout the district. Four analyses show 63.88 to 64.34 per cent of silica; alumina, 15.38 to 15.84; iron (FeO, Fe_2O_3), 4.5 to 4.7; lime, 3.97 to 4.3; magnesia, 2.08 to 2.23; potash, 4.0 to 4.23; soda, 2.74 to 2.81. Small amounts of CO_2 show that carbonates are present, and that slight decomposition has occurred in spite of the fresh appearance of the rock. The analyses confirm the microscopic determination, and show that the rock is a basic granite approaching diorite in composition. The percentage of lime is so large that a slight excess of plagioclase-feldspar might readily form in some parts of the mass. The analyses closely resemble those of the granodiorites of the Gold Belt of California, the relatively greater amount of potash giving a relative abundance of acid feldspars.

Included fragments of a fine-grained, much

Inclusions of dioritic rock in the Butte granite.

darker-colored rock occur in the granite in a few localities. These inclusions weather less rapidly than the rock containing them and they project sharply above the weathered surfaces. Such fragments carry a much larger proportion of the dark-colored minerals and are finer-grained than the granite. They resemble the basic contact forms of the great granitic mass, and are believed to represent portions of a partly hardened basic, dioritic phase of the Butte granite, torn from deeper-seated parts of the rock mass and brought up while the granite was still molten.

Although this rock covers so much of the district, natural exposures are few over the greater part of the area. On the high summit above Walkerville, north of the mineral belt, are prominent "bowlder" outcrops, and the slopes immediately east of the summit afford very striking examples of this peculiar weathering of granite. At various places throughout the granite area occasional bowlders occur in situ, though it is seldom that the rock is covered by soil.

Effect of heating, chilling, and wind on the granite.

The fresh rock is found only in the railway cuttings and the mine workings. In all the natural exposures the rock is much altered. This is due to two causes, disintegration and true alteration. Disintegration produces a loosening of the grains of the rock, so that it may be easily crumbled between the fingers. This is very common throughout the district and often extends to a depth of 20 feet or more. Where rocky outcrops occur the surface scales off and the plates crumble to loose, angular sand, which is blown away by the heavy winds. The prevalence of extensive disintegration accounts also for the lack of outcrops. In the absence of protecting vegetation erosion of the loose rock is rapid, and the drainage channels are choked with sand. The porous crust of the granite absorbs water readily, which assists in the further disintegration of the rocks.

Chemical alteration of the granite.

True alteration, or decomposition of the granite, as distinguished from disintegration, has also occurred extensively throughout the district. It is most marked along fissures traversing the rocks or along the walls of mineral veins, where it has produced changes in the mineral, chemical, and physical composition of the rocks. In extreme cases the granites are altered to soft clays, and at many mines the hard waste rock thrown out on the dump-heaps slacks to a soft clay after short exposure to the air. This alteration is due to both surface and vein waters, and is most commonly marked by a rusty staining of the rock. When this alteration is more complete the hornblende disappears, the biotite is recognizable only by the silvery plates which occupy its place, and the feldspars are opaque white masses of clay-like material (generally sericite). The granite forming the Anaconda Hill has been so altered by the mineralizing agencies which produced the great ore deposits of the locality that it retains few traces of its original character. Owing to the presence of much secondary silica the rock does not disintegrate into the usual crumbly, sandy material, but breaks into sharp, angular fragments which cover the steep slopes of the hill.

Fissure systems of the granite.

The granite is traversed by joints and shear planes, which are prominent where fresh exposures are seen. These fissure systems are of different ages and bear various relations to one another. The oldest joints are in part filled by aplite; these fracture planes were probably formed by contractional strains in the cooling granite. Later fractures which cross the aplite dikes were formed during several periods before and since the ore was deposited. In parts of the productive area these fissure planes are so close and so numerous that the rock is reduced almost to a breccia. In the northeastern part of the district, north of Meaderville, the jointing is less abundant but is more apparent in its effects. The parallel fissures which sheet the rock are from a few inches to many feet apart and furnish planes of ready weathering, separating the rock into rounded monoliths and bowlders which form the very striking scenery noticed from the Great Northern trains. The railroad cuttings there show a very marked sheeting of the rocks, the planes being sometimes occupied by veins, a few of which have been worked. Good examples of the sheeting of the granite in the productive area may be seen in many of the railroad cuts in the slopes above the city.

The Butte granite has already been stated to be of post-Carboniferous age, for it is a part of the great granitic intrusion of that date.

APLITE.

Mineralogical composition of the aplite.

Aplite occurs in unusual abundance, covering large areas in the western half of the district. It is a granular or finely granular, siliceous granite consisting of alkali-feldspar and quartz. At Butte it contains a very little plagioclase-feldspar and some small, scattered grains of biotite, and is white or cream-colored, medium-grained, of sugary texture, and bears a superficial resemblance to sandstone. Transition also occurs into the darker Butte granite. Under the microscope it is seen to consist of a mosaic of orthoclase and quartz grains, sometimes rounded, with a sprinkling of small biotite-mica plates. When slightly decomposed the rock is pale-green, becoming somewhat rusty from further alteration.

Distribution of the aplite.

The aplite occurs intrusively in the granite in a great variety of forms. It is most commonly seen in dikes and in irregular sheets of widely varying size and form. Both dikes and sheets are shown on the map when possible, but many small intrusions in the vicinity of the copper mines are too small to represent. Dikes often spread out into sheets, the form of the intrusion depending upon the position of the fracture plane of the granite. Some of the intrusions of the district are remarkable for their size. The largest of these covers an area extending from the west base of The Butte to the broad open valley on the western limit of the district, a distance of 1½ miles, and has an equal breadth. Branches of this intrusion penetrate the granite about its borders, and the mass also contains included fragments of granite; but the mass of aplite is relatively shallow, and the workings of the Bluebird mine show that it is underlain by granite at the depth of only a few hundred feet.

Weathering of the aplite.

The aplite weathers much less readily than the Butte granite, and the intrusions therefore form conspicuous outcrops—rocky reefs that rise sharply above the smooth granite slopes. The rock of the greater intrusions weathers into gentle slopes and bare, rounded surfaces, not unlike those of the Butte granite. Usually the aplite is covered by a weathered crust which is loosely granular and easily reduced to coarse sand. Though apparently fresh, this weathered rock has lost all traces of the biotite, and the feldspars are cracked and somewhat altered. Beneath the outer, weathered crust the rock is still somewhat altered, and for this reason is easily quarried and readily dressed, so that it is much used for building purposes in the city. The rock outcrops seldom show the prominent jointing and sheeting seen in the Butte granite, yet in quarries and railroad cuts the fracturing of the rock is readily recognized. In some cases the shearing movements have reduced the rock adjacent to the fissure planes to a fault breccia.

Relations of the aplite to the granite.

Aplite intrusions are of common occurrence in large masses of granitic or dioritic rocks, and are now generally regarded as contemporaneous in origin. They probably belong to the same general intrusion as the granite, but represent a differentiated, more siliceous material from the still molten rock below, filling fissures and contraction cracks in the upper and consolidated part of the granitic mass. This conclusion accords with the phenomena observed about the borders of several aplite masses, where the rock shows gradations between the two rock types. The larger intrusions, forming broad sheet-like masses resting upon the granite, may have been injected between the cooling, contracted granite and the overlying cover. The relation of the aplite to the mineral veins is the same as that of the Butte granite.

QUARTZ-PORPHYRY.

Quartz-porphyry; its mineralogical character and occurrence.

The granite forming Anaconda Hill is cut by several dikes of quartz-porphyry, a rock type not found in any other part of the district. The freshest rock has a pale-green color and is thickly dotted with small crystals of opaque white feldspar and with larger but less abundant, rounded grains of glassy quartz, which sometimes show pyramidal crystal outlines. Much larger phenocrysts, or well-defined crystals, of orthoclase occur, but are still less common; they are white or pale flesh-colored, with vitreous centers, and often measure a half-inch across. Square or rectangular light-colored masses—inclusions formed of these same minerals—are also seen, an inch in width. The dense groundmass shows a scanty peppering of mica plates and aggregates, and epidote is present, though very rarely. Thin sections examined under the microscope show that the rock is a typical quartz-porphyry of very uniform character. The feldspars are seen to be altered orthoclase, or rarely plagioclase, converted into sericite and clay. These occur in a finely crystalline groundmass, also altered to the same minerals. Along the dike walls a narrow band of denser-grained material is found. The weathered rock shows a rusty, iron-stained surface with small rectangular cavities due to the complete removal of the smaller feldspar crystals. The glassy quartz and the large orthoclase phenocrysts appear unaltered. The rock of the surface outcrop is always much decomposed and colored by iron oxides. Material from the mines also shows alteration along the fracture planes. The quartz-porphyry has a smoother fracture and is somewhat more highly colored by iron oxides than the granite about it, yet it would be difficult to distinguish the two rocks at times were it not for the presence of the well-defined quartz grains of the porphyry, which often weather in relief above the surface of the rock. The chief exposures of the quartz-porphyry occur on the sharp ridges forming the spur of Anaconda Hill on which the Modoc shaft-house stands. The crest of this ridge consists of dark-colored blocks, the outcrop of the Modoc dike. The intrusion of quartz-porphyry can be traced on the surface from the slopes immediately above Meaderville to a point above the Modoc mine, a vertical rise of 500 feet. Good exposures occur in the rock cuttings across the ridge along the various railroad lines. The main body of the dike is seen to have generally vertical walls, with branches and stringers penetrating the granite along fracture planes in at least two directions. The greatest width observed in these cuttings was 210 feet, below the Modoc shaft-house. In its lower occurrences the dike splits into two, as is shown on the map, and wedges out as it approaches the valley bottom. These exposures show that while the porphyry follows well-defined fracture planes in the granite, it has been sheeted with it by later fracturing, the planes dipping at 75° to 80° to the southeast, parallel to the dike walls. The dike is earlier than the ore formation, as the veins cut it in many instances. It is also brecciated and crushed by fault movements. Several other intrusions of this rock occur in the vicinity of the Modoc dike, but they can not be defined from surface exposures. They form wedge-shaped bodies, encountered in the various mine workings.

No definite age can be given for the intrusion of the quartz-porphyry. It apparently represents an independent period of rock fracturing and igneous intrusion occurring before the ore deposition of the district.

RHYOLITE.

About one-fifth of the surface of the Butte district is covered by rhyolite. It is the most variable rock of the district, occurring in many colors and forms representing the different phases which were produced from one molten rock magma under various conditions of consolidation. Two distinct varieties have been mapped, according to the manner of occurrence of the rock: intrusive rhyolite, forming the dikes and filling volcanic necks or conduits; and extrusive or surface rhyolite, forming the lava flows and surface breccias and other products of explosive volcanic action. Although this distinction is shown on the map, the boundary is indefinite and not always recognizable where the surface rocks overlap the intrusive forms. Both forms are of economic interest, since the dikes intercept and cut off the ore deposits, and the surface rocks cover and conceal them.

Types of rhyolite; its mineralogical composition.

The rocks are mostly typical rhyolites, but they contain an abundance of biotite-mica as a regional peculiarity. This is an indication of their affinities with the quartz-dacites, the corresponding plagioclase-feldspar rocks, into which the rhyolites do, in fact, pass in one place. They vary from the glassy forms to those dense varieties whose groundmass is not recognizably crystalline. They usually show conspicuous crystals (phenocrysts) of white feldspar, glassy quartz, and black mica. The color varies most commonly through different shades of gray, but red and lavender and, more rarely, bright-green tints occur.

The rock usually weathers with a reddish or rusty crust, on which slight differences of texture or structure are emphasized, because the denser forms resist weathering better than those of more open texture. On exposed surfaces it breaks up into small fragments, and no conspicuous outcrops are seen within the limits of the district, although the same rocks form very striking and picturesque exposures on the high hills to the northwest, and in Silver Bow Canyon and Brown's Gulch.

The intrusive rhyolite.—Under this head the rocks of The Butte are grouped with the intrusive dikes of rhyolite, but the former really constitute a complex of both intrusive and extrusive rocks.

General character of the rhyolite dikes.

The dike rocks are massive rocks of nearly uniform character. To the unaided eye they present the general characteristics noted as typical for all the rhyolites of the district. Studied under the microscope, both sanidine and plagioclase feldspars are distinguished, the former very greatly predominating. Near the dike walls the texture is denser and the porphyritic crystals are smaller and fewer. The dike rocks break readily into quite small, generally platy débris, and it is only the denser contact form of the dike walls that offers enough resistance to weathering agencies to appear in outcrops above the general surface of the ground.

Enumeration of the principal dikes.

The longest of these dikes is seen near the Nettie mine and is encountered in the mine workings. It forms but an obscure outcrop, traceable by the fine débris, or rarely by the platy contact band. The surface exposures range in width from 20 to 100 feet, and extend from the rhyolite area on the north to the detrital sands and clays south of the railway track near the Nettie mine.

The Germania dike trends nearly north and south, just west of the mine of this name. It is about 25 to 30 feet in width at the north end and near the Germania mine, but widens to 100 feet farther south. Near the north end the dike splits, and one of its branches extends nearly to the mine shaft. It is traceable by a few obscure outcrops and the débris, until lost in the detrital sands of the valley.

The Soudan dike, which cuts off the vein of the Soudan mine, is the widest of the intrusions, but like several others shown on the map, it offers no especial features for description.

Dikes of rhyolite, mostly decomposed to white clay, are exposed by the placer workings west of Missoula Gulch. East of this gulch, near the Travona mine, a dike averaging 100 feet across extends in a general, but not constant, north-south direction to the alluvial valley bottom. It does not cross the "Ancient" vein, but it is said to be 140 feet wide in the Travona workings. Good exposures are seen in the railroad cuttings and in the prospect pits to the south, where it wedges out.

In general, all the rhyolite dikes exposed have an approximately north-south trend. In a few instances they are directly traceable to The Butte as a center of eruptive activity, and all of them are believed to be offshoots from this vent.

Rock characters and associations in the volcanic vent at The Butte.

The rocks of the hill known as The Butte are extremely variable in nature and in their relations to one another. In part they probably represent the filling of a typical volcanic vent which was opened through the granite at this point and from which explosive outbreaks occurred. In part the rocks represent the remains of a former volcanic cone, consisting of both breccias and massive intrusive forms. There is therefore an intimate association of both surface and intrusive forms of the same rocks occurring in a great variety of colors and texture.

The massive rocks of The Butte are either dikes or surface flows. The light-gray rock capping it presents the characteristics of a lava flow. The rock has a rough, irregular fracture, and shows fine, pale-buff streakings emphasized by a ribbed surface on the weathered rock. Quartz, sanidine, and plagioclase form abundant but not very conspicuous phenocrysts in a groundmass peppered with biotite leaves.

The intrusive rocks are very like the dike rocks described. They are generally gray and of a type common also as fragments in the breccia of The Butte.

In the bench on which the School of Mines building is located the massive rock exhibits, in places, a decided fluxion structure in the arrangement of the feldspar and mica crystals. The rocks are noticeably sheeted, but this may be due to shrinkage or to fracture planes developed in the solidification and cooling of the rock, as is indicated by bands of denser rock along such planes. These rocks are noticeably altered, tinted a pale green on joint surfaces, and are often soft and break like chalk while freshly quarried and moist. The rocks are probably, in part at least, intrusions injected between the underlying granite and the former covering of extrusive rhyolite breccias. Massive rhyolite, whose red color has frequently tempted prospectors, occurs in several places about the flanks of The Butte, but its exact relations are doubtful, as it weathers readily to a soft, clayey material and no contacts are seen.

Description of the rhyolitic lava flows.

The breccias compose the greater part of The Butte. They consist of angular and in part of rounded fragments, held together in a matrix of fine rhyolitic débris. Very commonly the fragments and matrix are alike in color and appearance, especially in the breccias forming part of the old volcanic cone. In other cases the fragments and the matrix are dissimilar and are strongly contrasted in color and texture; this is especially true where the rocks forming the filling of the volcanic conduit are exposed.

The commoner gray breccias are seen on many parts of the slopes of The Butte. The brecciated structure is not always apparent on a fresh fracture, but is brought out by weathering. The fragments are always sharply angular and, like the matrix, resemble the massive rocks described. The breccias can not be distinguished from the extrusive breccias forming the hills to the northwest.

The vent breccias, as they may be called to distinguish them from those last noted, are well exposed in the gully scoring the south side of The Butte, where the granite walls of the old vent may be seen. The fragments are so large in places that the material might be called an agglomerate. No order or arrangement of any kind is apparent. The fragments vary in size up to 3 feet or more in diameter, and include granite and aplite, besides a great variety of rhyolitic rocks. The granite and aplite are fresh, like the rocks found about The Butte.

A dark-colored, glassy rock is the most prominent of the rhyolite fragments. It is itself a breccia composed of pieces of black glass cemented by a steely or brownish-gray matrix. The black glass is a rhyolite-porphyry, showing abundant quartz and glassy sanidine-feldspar crystals in a black, glassy groundmass; the pieces are sometimes crowded or occur in shreds, but are commonly sharply angular and well defined. The brownish or gray paste, when examined in thin section under the microscope, is seen to contain so much plagioclase that it must be termed a dacite. This is confirmed by chemical analysis, which shows it to be a dacite pitchstone. Where the rocks are exposed the black glass weathers in relief.

Besides these fragments of glassy rock other varieties occur. One form is banded rhyolite of a steely-gray color, dense, but showing slight variations in texture along prominent flow lines, and stippled with abundant minute phenocrysts of white feldspar. This type is common in the drift on the sides of The Butte. Fragments of rhyolites, red and gray, and more rarely green, are seen.

The cement or matrix of the vent breccias is a pale-gray or brown, dense rock which, when studied under the microscope, is seen to be merely a very fine breccia or tuff formed by explosive action and consisting of the same rocks as the fragments.

On the east flank of The Butte a green breccia has been quarried. It contains granite and aplite fragments, as well as those of rhyolite, in a bright-green matrix. It has been assayed for copper but has proved barren.

The distribution of the two kinds of breccias forming The Butte can not be shown on the map, and it is difficult to distinguish them in the field. The commoner forms, probably really extrusive, cover vein-bearing aplite rocks which outcrop and have been prospected on the southern flanks of The Butte. The contact between the granite and both the massive intrusive rock and the intrusive breccias is very irregular, and the granite itself is in part a fault breccia, but shows no recent alteration.

Extrusive rhyolites.—Extrusive rhyolites are the common form of the rock in the northwestern part of the district. They are usually recognized by the unaided eye as fragmental in character. They consist of angular fragments of lithoidal rhyolite firmly cemented together with fine particles of similar material. The rocks are of rather uniform types and appearance. Vesicular forms rarely occur, and although remnants of massive flows exist they are small in amount as compared with the breccias. The fragments are seldom over a few inches in diameter and are very uniform in size; neither tuff beds nor coarse breccias are noticeable parts of the formation. Under the microscope the rocks are seen to be rhyolites of the ordinary types, and are clearly recognizable as tuff or breccia due to explosive volcanic outbursts.

The extrusive rhyolites cover large areas but vary in thickness. Near the Nettie mine and other mines of the western part of the district they are often but a few feet thick—a mere veneer upon the granite surface. In the Oro Fino Hills they are several hundred feet thick, but they rest upon a very uneven, hilly surface of granite and the thickness varies accordingly. Prominent outcrops are rare, as the rock breaks into irregularly platy or angular fragments, seldom a foot across. It generally forms well-rounded slopes tufted with grass. Exposures near the Nettie mines are typical; the rocks are a light rusty red, and form low, rough masses not unlike débris piles. Occasional buttress outcrops occur on the slopes north of Oro Fino Gulch.

LAKE BEDS.

Deposits of sediment which accumulated on lake bottoms are found only in the extreme western part of the district. They consist of compact but generally unconsolidated sands, gravels, tuffs, and stony clays. The beds are horizontal, but show local cross-bedding, and vary from place to place both in general character and in the nature of the material composing them. The gravel is composed of granite and aplite. The tuff beds are formed of fine rhyolitic ash, which also enters into the composition of some of the beds of sand. The stony clays show no bedding, or only such as is too rude to be recognizable in prospect shafts. The true nature of the material forming the tuff beds is discernible only under the microscope. It is a volcanic dust, the product of an ash shower from an explosion of a volcanic vent. It is composed of minute angular particles and threads of glass which chemical analysis shows to be rhyolitic in nature.

Sands, gravels, tuffs, and clays deposited in Miocene lakes.

These deposits form the level benches and almost flat slopes west of the district, only a small part of them occurring within its limits. Topographically the area differs markedly from the rest of the district. The country covered by these deposits is the typical valley bench land, so common in the State, devoid of timber, but covered by sagebrush and from a distance looking like a burnt stubble field. Natural outcrops are poor and are seen only in the cut banks of dry channels. The material weathers down and often is recognizable only by the bare, light-colored spots seen on the slopes. Near the hills the deposits form benches resting on the steep slopes. Prospect shafts sunk in these benches to depths of over 60 feet show only stony clays. The slopes of the benches show horizontally stratified gravels and sands. The gravels are generally rounded, not flat like beach shingle. The pebbles show a slightly altered surface and are sometimes lime-encrusted. Locally the beds have been cemented by percolating waters carrying iron, lime, or silica in solution.

These deposits represent the material washed into a lake which covered the Silver Bow Valley west of Rocker, extending south across what is now the continental divide. Only the extreme eastern margin and shore of this lake were within the district described, but the deposits were continuous westward and southward to places where vertebrate bones have been found. These fossils were of upper Miocene types. The evidence is of importance, as the lake beds were contemporaneous with the rhyolite eruptions, and these latter took place after the period of ore deposition, so that the age of the ores must be pre-Miocene.

ALLUVIUM.

The areas shown on the map as covered by alluvium include those parts of the district where the rock-bed is concealed by a mantle of recent detritus. This includes, therefore, the alluvium of stream bottoms, the sands which cover the valley-flat, whether wind-blown or water-laid, and the unassorted, angular débris from the mountain slopes often significantly called "wash." Areas covered by tailings and other débris from the smelters are also included. These deposits are wholly detrital, are unconsolidated, and conceal the nature of the underlying rock. They vary greatly in thickness, but in general simply fill the valley bottoms, as is indicated in the map showing cross sections. In the valley east of Meaderville alluvium fills an old drainage channel to a depth of 400 feet, or about 350 feet below the present channel of Silver Bow Creek. The placer grounds of Missoula Gulch and South Butte have not been mapped as alluvium because the gravels are never over a few (rarely 10) feet deep, and the workings afford numerous exposures of the underlying rocks.

Material recently spread by streams and winds.

VEIN OUTCROPPINGS.

An account of the areal geology of the district is not complete without reference to the vein outcroppings which form such prominent features of the region. They resemble somewhat the bold reefs of aplite, but are generally stained with manganese. They are fully described in this text under the heading "Economic Geology," following.

WALTER HARVEY WEED,
Geologist.

ECONOMIC GEOLOGY OF THE BUTTE SPECIAL DISTRICT.

GEOGRAPHY.

The Butte Special map, which represents the surface features of the Butte mining district, covers an area a little less than 4 by 6 miles in extent, or about 23¾ square miles, which is included between 45° 59′ 28″ and 46° 02′ 54″ of north latitude and 112° 29′ 30″ and 112° 36′ 42″ of longitude west from Greenwich.

As contrasted with the surrounding regions the area is distinguished by gently rounded topographical forms and a general barrenness of aspect. The former peculiarity results from the ready disintegration of the surface rocks, which is most marked in the mineralized areas, while The Butte, in the center of the district, which is formed of rock ejected since the period of mineralization, is a sharp cone, almost precipitous on its northern side. The sparse growth of timber which once flourished on the hills was early cut down for use in the mines, and the fumes from the smelting works prevent any renewal of the growth of natural grasses, which was never abundant. Water is not plentiful, the main stream being Silver Bow Creek, which flows first south, then west, along the eastern and southern limits of the district, while a small tributary fed by springs in the hills to the north reaches it through Missoula Gulch.

Details of topography of the Butte district.

Missoula Gulch is a north-south depression at the eastern foot of The Butte (locally known as the Big Butte), and the city of Butte is situated on the hill-slopes east of this gulch, for the most part between it and a minor depression known as Dublin (formerly Town) Gulch.

Around the head of Dublin Gulch are most of the copper mines, which at present constitute the principal wealth of the district. The mountain spur between the head of Dublin Gulch and Silver Bow Valley is here called Anaconda Hill, the richest copper mine of the district, which belongs to the company of that name, being situated on it.

DEVELOPMENT.

As has been the case with most of the important mining districts of the West, Butte was originally a gold-placer camp. The first practical discovery of gold-bearing gravels was made in 1864 along Missoula Gulch. Two causes combined to turn the attention of the miners unusually early to deep mining. One was the limited supply of water, which sufficed only for part of each season and thus stopped work on the placer claims. The other was the prominence of many outcrops of mineral veins which seamed the surface of the hills, often standing up in ridges 15 or more feet in height. Locations were early made on both copper- and silver-bearing lodes, and various fruitless attempts to reduce their ores followed. After the exhaustion of the richer placers the camp was in a quiescent state for many years, and for a time became nearly deserted. New interest was, however, excited by the discovery of rich silver ore in the Travona lode in 1875, and most of the claims were relocated under the new mining law. Silver ore shipped to the smelters at Salt Lake attracted the attention of miners and capitalists in that region, and resulted in the purchase by the Walker Brothers in 1877 of the Alice mine at the head of Missoula Gulch. This mine proved so rich and profitable that in a few years the town of Walkerville was built up by the miners employed in it, and the Lexington mine, next south of this town, was bought by a French Company for a million dollars. After some experiments a modification of the so-called Washoe process was successfully adopted for the treatment of the silver ores, consisting in dry crushing by stamps, roasting with salt, and pan amalgamation. The Lexington, Alice, and Moulton mills, with 70, 60, and 40 stamps respectively, were erected near the hoisting works of the mines so named, and their output soon gave the district a high rank among the silver producers of the West. A host of other silver mines were opened and more or less successfully worked along the high ground north of the Lexington mine and between Oro Fino Gulch and Silver Bow Creek, also down Missoula Gulch and westward along the southern flanks of The Butte. The only silver mine besides the three named above which had a special mill for the treatment of its ores was the Bluebird. This mine was opened in 1885–86 in ground west of The Butte, hitherto considered most unpromising, and its 90-stamp mill produced nearly 2,000,000 ounces of silver before it was closed down in 1892. Another important mine in the same portion of the district is the Nettie, whose ore goes to the smelting works of its owner, the Colorado Smelting and Mining Company. The decrease in the price of silver has been mainly responsible for the abandonment of the silver mines, though in many cases there has been a decrease in quality of ore with depth. At the present day the few mines that are active are to a large extent worked by lessees.

Placer mining and early attempts to reduce the ores.

Development of the silver mines.

The copper mines at the west end of the Parrott lode were worked to a limited extent in the earlier days, and various unsuccessful attempts were made to smelt the ores, but it was not until the plant of the Colorado Smelting Company was erected in

Development of the copper mines.

1879–80 for making copper matte or regulus that the copper industry may be said to have been established on a permanent basis. In the following years the Parrott and Colusa smelters were erected, to treat the ore of the respective mines, and the Anaconda lode, which was first worked for silver, began to develop its enormous bodies of rich copper ore, as the workings passed below the zone of oxidation.

In 1881 the first railroad reached the district. The expense of building the last link, from the town of Silver Bow up, was borne by the citizens of Butte. From that time to the present the development of the copper industry has been steady and rapid. The town of Butte has become a city which, including the suburbs, has over 40,000 inhabitants. Several large smelting plants are busy reducing its copper ores, five within the district and two outside, at Anaconda and Great Falls, while another is building at Gaylord. The present productive capacity may be estimated at 275 to 350 tons of copper daily. Bessemer converters are used for reducing the matte directly to the metallic state, and electrolysis for refining the copper. An interest in the largest company, the Anaconda, which produces one-half of the total copper product of the district, has recently been sold to English capitalists at a rate which is said to represent a value of 35 millions of dollars for the whole property. This company has enormous reduction works at Anaconda, around which a town of over 7000 inhabitants has been built, and a railroad connecting the ore houses of its principal mines with these works. The principal copper mines of this company are the Anaconda, St. Lawrence, Neversweat, Mountain Con., Green Mountain, Wake-up-Jim, Diamond, Bell, High Ore, Modoc, Ramsdell-Parrott, and Ground Squirrel. The next largest company is the Boston and Montana, whose most important mines are the Mountain View, Colusa, and Pennsylvania. It has a large new smelting plant at Great Falls, on the Missouri River, 150 miles distant. Other important companies are the Parrott, with the Parrott and Moscow mines, a smelting plant within the district, and a new one building at Gaylord in the Jefferson Valley, 30 miles distant; the Butte and Boston, with the Silver Bow, Gray Rock, Blue Jay, and other mines; the Montana Ore Purchasing Company, with a large smelting plant in the district and another at Trail Creek, British Columbia, and the Rarus, Glengarry, and other mines; the Colorado Smelting and Mining Company, with its own smelting plant and the Original Butte, Gagnon, Nettie, and other mines; the Clark Brothers, owning the smelting plant known as the Butte Reduction Works and the Original, Stewart, Colusa-Parrott, and a number of other mines. Each of these companies has concentration works connected with its smelting plants. There are a number of other companies and private owners working copper mines, the most important of which is the Washoe Company, owning the Buffalo, Estella, Poulin, Washoe, Moonlight, and other mines. Four separate lines of railroad now enter the district, the Montana Union and the Butte, Anaconda and Pacific from the west, the Montana Central from the north, and the Northern Pacific from the east.

PRODUCTION.

In the value of its metallic product the Butte district ranks among the most important in the United States, and hence also in the world. Up to the close of the year 1896 the commercial value of its total product may be roughly estimated at three hundred millions of dollars, which is considerably in excess of that of Leadville, and probably not very much below that of the Comstock lode.

The total product valued at $300,000,000.

It is not possible to obtain strictly accurate data with regard to the product of such a district, since in the early days no records were made and in later years the larger companies for business reasons are not always willing to disclose their exact product. Fairly close approximations have, however, been presented in various publications, from which it may be deduced that in round numbers there have been mined in this district, up to January 1, 1897, 500,000 ounces of gold, 100,000,000 ounces of silver, and 1,600,000,000 pounds of copper.

The placer-gold product has been comparatively unimportant, being not only small in amount but also of low bullion value on account of the large alloy of silver. In the present mining gold furnishes about 3 per cent in value of the total product. Silver is now largely a by-product of copper mining. In the copper ores as a whole the average proportion is about 1 ounce of silver to 20 pounds (1 per cent) of copper, and 23 per cent of silver to 74 per cent of copper in value of the total product of the district.

The annual copper product is now (1897) about 200,000,000 pounds, thus constituting the predominant value in the yield of the district. Its increase, both absolute and relative, in the last decade has been most remarkable.

Absolute and relative values of the copper product.

In 1888 41 per cent of the total copper product of the world came from the North American continent, of which over 92 per cent was furnished by the United States. In 1895 the North American proportion of the world's product had increased to 56½ per cent.

Previous to 1880 the Lake Superior region produced on the average more than 80 per cent of the total copper product of the United States. In 1883 of this total product Lake Superior's proportion was 51.6 per cent, Butte's 21.4 per cent, and Arizona's 20 per cent. In 1887 Butte passed Lake Superior, and in 1895 the relative percentages were: Montana (Butte), 50 per cent; Lake Superior, 34 per cent; Arizona, 12½ per cent.

It thus appears that Butte is furnishing at present about 28 per cent of the copper product of the world, and of this over one-half is produced by a single mining company, the Anaconda.

FISSURE SYSTEM.

There have been many distinct periods of fracturing of the rocks of this district, which have produced a multiple system of fissures so complex that it is not possible in all cases to distinguish whether a given fracture system results from movements in one or more of these periods.

Relative age of fissures.—As stated in the preceding description of the areal geology, it is assumed that fissures and openings of varying form were produced in the cooling granite mass before its final consolidation, and that these were filled from the same general magma by a more acid material that formed the rock called aplite. When both granite and aplite had been thoroughly consolidated there developed another series of joints and fractures that must have been produced by some dynamic movement either previous to or contemporaneous with the intrusion of igneous rock material which formed quartz-porphyry. The resulting quartz-porphyry is seen to-day to fill not only irregular fissures but also small joint planes, horizontal as well as nearly vertical. In highly altered regions it is not always possible to distinguish what was once quartz-porphyry from decomposed granite; hence one can not form a very clear idea of the extent and character of this first fissuring. That there was some such earlier dynamic movement is proved not only by the intrusive bodies of quartz-porphyry but also by certain seams of fine-grained breccia or fault material, of earlier age than any mineral or ore deposit, which have been observed at a few points in the mines.

Fracturing which antedated the mineral deposits.

The main fracturing, from which resulted the fissures that admitted the mineral-bearing solutions, occurred subsequent to the intrusion of both aplite and quartz-porphyry, since the mineral-bearing fissures, or *vein fissures*, as they will be here called, cut indifferently through both of these rocks as well as the granite. Subsequent to the original deposition of mineral along the vein fissures there has been repeated movement and fracturing among rocks and already-formed mineral deposits, which will here be designated the secondary or post-mineral movement or fracturing. The rhyolitic intrusion occurred subsequent to the original vein fissuring, since the mineral veins are sharply cut off and discontinued when they come in contact with the intrusive bodies. As to the relative age of the rhyolite intrusion and the secondary fracturing it has not been possible to obtain definite evidence. There may have been more than one post-mineral movement, for there has been some fracturing of the rhyolite, and it is probable that a certain amount of fracturing of the adjoining rocks accompanied the rhyolitic intrusion; it is also quite possible that there was some secondary movement in the ore-bearing region previous to this intrusion.

Fracturing which admitted the mineral solutions.

Fracturing which succeeded the mineral deposits.

Vein fissures.—As this district is situated in the midst of a great area of igneous rock, and isolated from sedimentary formations in every direction, it is not possible to determine the date of the orogenic movement. The nature and direction of the dynamic forces which produced the vein fissures also remain indeterminate. It can only be said that their great number in the limited area represented testifies to the unusual magnitude and intensity of these forces, and that their comparative regularity and uniformity of direction indicate a simultaneity in the action of the forces. The relative homogeneity of the rock mass in which they have been formed has doubtless been an important factor in determining both their uniformity of direction and their persistence and continuity.

The tracings of the fissures on the map are those of their outcrops on the present surface, and hence depart somewhat from the theoretically true representation of their relations that would be afforded by their intersection with a horizontal plane. Inasmuch, however, as but few of the veins depart in dip more than 15° or 20° from the vertical, the distortion produced by the inequalities of the surface is generally very slight. Where no actual outcrop could be traced its probable position was ascertained by projecting upward the known plane of the vein as determined in underground workings. It must be borne in mind, therefore, in studying the map, that where breaks are shown in the continuity of what appears to be one and the same vein, it is possible that an underground continuity might have been demonstrated had the necessary underground drifts been driven, or those that actually exist been accessible. It has not been possible, owing to the small scale of the map, to represent the relative importance of the different veins as ore carriers. In a geological sense a fissure does not necessarily cease to be a mineral vein when it no longer contains ore in paying quantity or quality. Hence many of the veins represented are not now, and may never be, productive veins. This is especially true of those at considerable distance from the center of production, or on the outer limit of the district.

The most striking feature in the vein-fissure system of Butte is its uniformity of direction. All the fissures observed are included in the quadrant of the circle between northeast and southeast, and in only two individual instances does their strike depart as much as 45° to the north or south of an east-west line. In most systems of rock fracture there are observed to be one major direction of fracture planes and one or more minor directions, the fissures of the latter class being generally in the nature of cross-fractures connecting two or more master fracture planes or fissures. In the Butte district, while in individual mines or groups of veins it is generally possible to distinguish two prevailing directions of strike, the one to the north of east, the other to the south of east, it is not possible to say that in all cases the fissuring in one of these directions is so much stronger than that in the other as to be called the major direction. The rule seems rather to be—if indeed there is a sufficient uniformity in such matters to constitute a rule—that the strongest and most persistent fissure systems are those which appear to be a resultant of these two directions. In a general way it may be observed that in different portions of the region the veins as a whole, in each general group, tend to have a direction north of east at the west end and to assume the southern divergence at their eastern extremities; furthermore, that the divergence to the south is more general and greater in degree. The average divergence between these two may be taken at 30°, and the maximum in one and the same vein system or lode at 45°.

Direction of trend of the vein fissures.

The direction of veins in vertical planes, or their dip, is even more uniform than their strike. The veins to the north of the Alice mine, including the north vein of the Rainbow lode, stand either vertical or with a dip of 80° to 85° to the north. South of this line, with but one or two exceptions, the divergence from the vertical is to the south, and not more than 25° (dip of 65°), except in the region to the west of The Butte. The angle between the two directions of dip, then, may be taken at an average of 25° and a maximum of 35°. These are the average dips of the veins as a whole; in detail the profile or cross-section of a vein is generally a wavy line showing varying angles of dip at different points, whose maximum divergence may equal the above. When a vein sends off spurs, i. e., smaller veins branching off at an appreciable and fairly constant angle from the main vein and not returning to it, a similar divergence of 25° to 30° may often be noted between the dip of the spur and the average dip of the main lode.

Uniformity of dip of the vein fissures.

The term *lode* is used in this text to denote a coordinated system of mineralized fissures, nearly parallel, and generally separated by bands of more or less barren country rock. A lode may be about 100 feet wide and it may be not over 10. When more widely spaced veins are spoken of, which yet need to be coordinated, the term *vein system* is used. The individual veins, on the other hand, may be, and in this district generally are, made up of a number of closely spaced fractures. The space between the outer fracture planes may be occupied by alternating bands of country rock and of vein material, or by more or less altered country rock through which run many small cross-fractures or joints filled with vein material, or it may be entirely occupied by vein material. In the latter case it is impossible to determine how many fracture planes may have been originally developed. In a few instances the space is filled by a breccia, or broken fragments of country rock cemented by vein material.

Lodes and vein systems defined. Complexity of fractures.

Although it is probable, therefore, that there has been some slight movement in the fracture planes, sufficient to break the continuity of the adjoining walls so as to admit waters freely, and in some parts to leave open spaces in the fissures that have since been filled with vein material, the amount of this movement has evidently been very slight as compared with that in other fissure-vein districts. This is proved by the small amount of brecciation noted above, by the absence of evidence of microscopic fracturing in the country rock, and also by the character of the vein filling. The fact that the fissuring or shearing is so intense in this small area, and extends to such a limited distance from the center of mineralization, is evidence, so far as it goes, that the force which produced it, though intense and accompanied by enormous pressure, was local in its action and not in the nature of widespread orogenic movement.

Limited amount of relative movement.

Local development of intense action.

There is observable in the tracing of the veins a tendency to wrap around the copper-bearing area, which is also that of most abundant ore deposition and may be regarded in a broad way as the center of mineralization. It is more noticeable on the north side of this center than on the south, which may be due to the fact that the veins are not so extensively traced in the latter direction, as the rock surface is for the most part buried under the alluvium of Silver Bow Valley, and existing mineral developments have not encouraged underground exploration. This tendency was remarked early in the history of the district, and gave rise to the designation "Rainbow" lode, applied to the system of veins running through the Moulton and Alice claims.

Center of mineralization in the copper-bearing area.

It should be remarked that the map tracing can not adequately express the actual amount of fissuring that has taken place in this area, for many of the veins do not reach the surface in such a way as to be recognizable as such. Thus in the cross-cut tunnel driven south from the Alice shaft to the Blue Wing lode at the 1000-foot level (5300),[1] eight mineral-bearing veins were cut, only three of which appear at the surface, and in a similar cross-cut between the Anaconda and Bell shaft (5000) twenty such veins were crossed where only two or three have been recognized at the surface.

Secondary or post-mineral fissures or faults.—Two principal kinds of secondary faults have been recognized: *strike faults*, or those which are for the most part parallel to, and sometimes for considerable distance actually coincident with, the vein fissures;

Description of strike and dip faults.

[1] Figures in parenthesis denote elevation above sea-level.

and *cross* or *dip faults*, which are nearly at right angles to the vein fissures.

The strike faults are generally seen as fissures or zones of triturated material containing well-rounded fragments of country rock and of vein material, from a few inches up to many feet in width. It very frequently happens, especially in the upper parts of the mines, that they contain so much moisture that their filling becomes a soft, white pebbly mud, which runs when the fissures are opened. They are of very widespread occurrence, having been noticed at some point, either on foot or hanging wall, of every well-exposed vein. They generally have the same average dip as the vein, sometimes depart very slightly from it, and in one instance produce a marked step-faulting of the vein. In the Gagnon mine one of these fault planes in the foot-wall country, but near the vein, is called the Foot-wall vein. Its course is generally more direct than that of the vein itself, and in places it comes actually in contact with the foot-wall. It contains in this case a certain amount of secondary material. Where these strike faults cross the vein, as they sometimes do at a low azimuth angle, a slight amount of displacement of the vein is sometimes perceptible, and in others movement is indicated by striated surfaces, but it has not been possible to determine the amount of this displacement, and no attempt has been made to indicate these faults on the map.

The cross faults are less frequent but more noticeable, because they generally cause a slight displacement of the veins. As far as observed they are always normal to the direction of the vein, and their plane lies rather flat, the dip being generally between 65° and 45°. The inclination has been observed to be in some cases to the east, in others to the west. Under the conditions existing at the time of the examination, but few of these faults could be detected, and doubtless they exist in much greater proportion than is indicated by those represented on the map.

As will be shown later, there is evidence that both these systems of fissures have been channels for the entrance of solutions, probably descending from the surface, which have produced a certain amount of secondary ore deposition and transposition of vein material.

DISTRIBUTION OF ORES.

The economically valuable ores of the Butte district are found exclusively in the older rocks—granite, aplite, or quartz-porphyry. A few prospecting shafts have been sunk on what appeared to be veins within the area of the more recent rhyolite intrusion, but these in most cases have been proved to be vein-bearing ridges of the older rocks, from which the overlying rhyolite has been more or less completely denuded. A slight secondary mineralization has apparently taken place on some joint planes of the rhyolite, but it has thus far proved valueless.

General relations of both copper- and silver-bearing minerals.

The copper ores are found only in the granite, which is a very basic variety but of remarkably uniform chemical composition. The silver ores, on the other hand, occur indifferently in the basic granite or the very acid aplite, but are less extensively developed in the areas of the latter rock. There is no distinctive feature in the ores of either area that can be with certainty ascribed to the influence of the enclosing wall rock. Quartz-porphyry, which is of relatively subordinate geological importance, is found only in the copper area, and in dike-like bodies which preserve a general parallelism with the veins. It is, however, sometimes cut by them, thus proving its earlier injection. It is generally on the foot-wall, but so far as observed has had no direct influence on ore deposition. It is with difficulty traced in the underground workings, owing to the universal alteration of the country rock near the veins, and still more so on the surface, owing to disintegration. Hence its occurrence may be more widespread than is indicated on the map.

From a commercial point of view the deposits are divisible into two distinct classes, the silver deposits and the copper deposits, both of which contain a small proportion of gold values, which locally are so concentrated in certain silver deposits as to constitute an important part of the product.

Mineralogically the distinction between these two classes of deposits is less sharply defined, for the copper veins always carry silver, and many were originally opened as silver mines, while toward the west in most of the veins there is a gradual decrease in copper-bearing minerals, so that the ores finally become more valuable for silver and gold than for copper. Yet the typical ores of either class are characterized by distinctive and well-marked associations of minerals, and each includes certain combinations that are not found in the other class.

The areal distribution of the silver-bearing and copper-bearing veins is graphically represented by the distinctive colors of their respective tracings on the map, which shows that the latter occupy rather a central position in the eastern half of the district. No copper-bearing minerals whatever are known to occur in the areas west and directly south of The Butte.

Vertical distribution of the ores.

As regards the vertical distribution of the ores, their limits in depth have not been determined. The Alice and Lexington mines have been opened to a depth below the surface of 1500 and 1450 feet (4800) respectively, the Moulton to 800 feet, the Bluebird and the Nettie to 600 feet (5000). The other silver mines have not, as far as known, passed a depth of 400 feet. It is said by some that the silver tenor of the ore in these veins has decreased with depth. It has not been possible to verify this statement, which is, in all probability, not true as a general statement applicable to all the veins.

Most of the large copper mines, on the other hand, have gone to depths of 1000 to 1500 feet in their shafts. The average elevation of the lowest workings in the principal copper lodes is from 4400 feet (in the Gagnon) to 5000 feet, the bottom levels of the Anaconda, Neversweat, St. Lawrence, Parrott, Mountain View, Leonard, Modoc, Bell, East Gray Rock, Green Mountain, Mountain Con., Silver Bow, and Ground Squirrel being all below the latter level.

Enumeration of the copper-bearing veins.

Copper deposits.—In the western part of the copper-bearing areas on the line of Main street, the copper veins separate into two distinct belts or groups, between which lies an intermediate group of silver-bearing veins, and a little farther east a series of barren veins. The northern belt consists of the Syndicate lode, on which are situated, commencing from the west, the Moscow, Poulin, Buffalo, Mountain Con., Green Mountain, and Wake-up-Jim mines. Farther east it is a multiple system of veins, consisting of the Speculator, Bell, and High Ore veins in the East Gray Rock and Bell mines. On the east slope of the hill it consists of the Modoc vein alone, in the mine of the same name.

The southern belt commences on the west with the Gagnon-Parrott lode, which has been traced eastward through the grounds of the Original, Parrott, Anaconda, and Pennsylvania mines. To the north of this is the Anaconda lode, which eastward traverses the Mountain View and Rarus grounds. Still farther north are veins of the Mountain View lode, the northern of which, in the Colusa ground, crosses the line of the Modoc vein extended. South of the Parrott the Moonlight lode runs from the Blue Jay through the Moonlight, Pennsylvania, and Silver Bow mines; and still farther south, at the base of Anaconda Hill, the Ground Squirrel lode has been traced in the Belmont, Ground Squirrel, Glengarry, and Harrington mines; and a few other small copper-bearing veins have been opened.

None of these lodes have been continuously traced east of Silver Bow Creek, but a number of veins in the granite on East Ridge have been explored in the Six O'Clock, Atlantic, Homestake, Clinton, Altona, and other mines, which are on the same general line of strike; they have, however, a different association of minerals in their ores from that which prevails in the central copper area.

Outside of this central copper area, with unimportant exceptions, the commercial value of the ore deposits has been principally in silver, and the veins may be classed as silver veins.

Ores carrying a few per cent of copper have been found locally in veins along the northern edge of the copper area, notably in the south veins of the Lexington and Magna Charta mines, in the Old Glory, Flag, Sisters, West Gray Rock, Gem, Tuolumne, Mat, and possibly other mines; but as a rule their tenor in this metal has proved too uncertain to render them of permanent economic value. It is possible that an amount of copper too small to have been regularly determined in ore assays may be present in veins still farther away from the central area, for chalcopyrite was observed in the Alice mine, and its bullion contains a constant though small percentage of this metal.

Enumeration of the silver-bearing veins.

Silver deposits.—The most important silver deposits have been developed immediately to the north of the west end of the copper area. The Alice, Moulton, and Lexington have been the largest mines. Very rich silver ores have also been obtained from the mines along the east bank of Missoula Gulch, especially in the intermediate belt included between the western wings of the copper belt, of which the Late Acquisition and Clear Grit lodes are the most important. Several rich veins have also been worked directly south of The Butte, and the system of veins running through the Nettie, Bluebird, and Independence grounds, in the aplite area west of The Butte, have been important silver producers. In the northern tier of veins, north of the line of the Rainbow lode, are a very large number of silver-bearing lodes, all now abandoned. Of the mines which flourished on these lodes in earlier days many are said to have yielded large amounts of silver, individual products running up into the hundred thousands of ounces.

Ratios of gold to silver and copper.

Gold and other associated metals.—Gold is quite universally distributed throughout the ores, but in such small quantities that it is not determined in commercial assays. In the mines along the east bank of upper Missoula Gulch it has proved an important part of the value, and it was probably from these veins that the gold in the placer deposits was mainly derived, since both silver and copper have been found in the placers. In these mines the proportion of gold to silver by weight has run as high as 1 to 40 in mill lots. An average of five months' run in the Alice mill yielded 0.06 ounce gold to 21 ounces silver per ton treated. In the copper bullion produced from the ores of the copper area about 3 per cent of the value is in gold, and the average proportion of gold to silver, by weight, is $\frac{1}{200}$ to $\frac{1}{300}$. Small amounts of the metals arsenic, antimony, bismuth, tellurium, selenium, and nickel are also found in this bullion, the mineral combinations of which in the ores, except for the first two named, are not known.

Manganese.

With regard to the distribution of the other metals which do not as a rule constitute economically valuable ores, manganese is widespread in the silver veins and wanting in all the copper veins except those that form a transition phase between copper and silver veins. It occurs in varying amounts, from 1 up to 20 or 30 per cent of the metal. It is especially abundant in the aplite area west of The Butte, where the outcrops of the veins were primarily worked for the manganese oxides, which were useful as flux in smelting.

Zinc.

Zinc is also very widespread, and in greater amount in the silver than in the copper ores. In the latter, except in certain veins on the outskirts of the central area and in the west ends of the vein, it is not usually distinguished in the ore. In some second-class ores it averages 2 per cent, and in an average of analyses of matte from a certain group of mines, extending over several months' production, it was in the proportion of about 2½ per cent to 60 per cent of copper. In the silver veins it may be in considerable amount, smelters' assays of lots of ore that contain appreciable quantities showing from 2 up to 40 per cent. Its distribution is by no means uniform.

Lead.

Lead is in relatively small amount and is not usually taken account of by ore purchasers, nor is it generally visible in the ores; yet, in the average copper matte above mentioned, its proportion was about one-quarter that of zinc, with which metal it is generally associated. It is said that considerable amounts of galena were found in the Humboldt and other veins, in the zone of northwest strikes which include the Clear Grit lode.

ORE DEPOSITION.

Immediate source of the metals.

Ore deposition in this region has taken place through the agency of aqueous solutions, evidently alkaline in their nature, which probably gathered into this particular place because its intensely fissured condition rendered it peculiarly easy of access to circulating waters. As to the source from which the metallic minerals were derived, no direct evidence has been obtained, but as the granite at present forming the surface generally contains small amounts of the metals, it may be inferred that somewhere in depth within reach of the circulating waters there were parts of the great granite mass sufficiently rich in the metals to have furnished the deposits now found nearer the surface.

Circulation of solutions, vein filling, replacement, and impregnation.

The original mineral-bearing solutions evidently ascended along the fissure planes, and were probably at high temperature, though not necessarily under great pressure. On the other hand, secondary deposition or transposition of the copper minerals may have been produced by waters descending from the surface. Where the fissures presented continuous open spaces the materials brought in by the original mineral-bearing solutions filled these spaces, thus producing the ordinary type of fissure-vein deposit; but a large proportion of the fissures were mere cracks in the rock, only large enough to admit the passage of the solutions, and from these the solutions penetrated and attacked the adjoining wall rocks, removing part or all of their original constituents and replacing them by vein material, thus constituting the type of replacement vein. Between these two extreme types are many intermediate gradations, among which may be mentioned the filling of small cross fractures and joint cracks between main fissure planes, and the impregnation of the intermediate or adjoining country rock by vein materials. By the term impregnation is understood primarily a filling of minute spaces between constituent minerals, but this may pass into a partial replacement of some of these minerals, and it thus forms a stage toward total replacement.

In a general way it may be said that in the granite the copper veins are more commonly replacement deposits, while the fissure vein deposit is more common among the silver veins. In the aplite both types are observed, but, owing to the very siliceous nature of the rock, it is less easy to distinguish alteration products from fillings introduced from without.

Characteristics of the typical fissure veins.

Striated surfaces and clay selvages, which are common on the walls of most fissure-vein deposits, are here very rare, and where observed are apparently the result of secondary or post-mineral movement. The typical fissure vein or open-fissure filling is characterized by sharp definition between its walls and the adjoining country rock, and by a more or less symmetrical arrangement in bands of the contained minerals, with occasional vug cavities in the center, quartz being the predominant mineral in the vein fillings. The country rock outside the vein walls is barren of valuable minerals. Such typical fissure veins are well seen in the Alice and Lexington silver mines, also in the Mat copper mine. The vein filling may be a breccia of country rock cemented by vein materials; this is relatively rare in the Butte district. An instance in the Amy mine shows a subsequent fracturing of this vein filling and a healing of the fractures by quartz. In some cases the interstices of earlier fissures filled with breccia are impregnated with pyrite and quartz, as in the Lexington and Blue Wing mines. The vein material may occur in narrow, closely spaced, parallel fissures, or in short lens-shaped bodies, in either case sharply defined from the adjoining country rock.

In secondary veins instances are observed of breccias of vein materials cemented by quartz (Lexington mine) or by manganese minerals (Magna Charta mine), and again of breccias of quartz and country rock cemented by quartz.

Characteristics of typical replacement veins.

The typical replacement vein is, as a rule, the result of the action of ore-bearing solutions along a series of closely spaced parallel fissures. Under existing conditions the original fissures are often not distinguishable, especially when the mineralizing action has been very effective and the ore body is a very wide mass mostly or entirely made up of metallic minerals. The prominent characteristics of this type of deposition are: (1) Absence of symmetrical banding or comb structure in the vein material and of breccias of country rock cemented by vein material (both included under Pošepný's general term "crustification"). (2) Great irregularity in the width of the ore body, which sometimes reaches enormous dimensions in the copper lodes; the range is from 1 to 100 feet; an average in the prominent veins may be taken at 8 to 40 feet. (3) General lack of definition between ore body and wall rock; this is observed not only in the ore body as a whole but in individual bands of country rock and vein material.

In the vicinity of the vein the country rock is impregnated with vein material, generally pyrite and quartz; in the Rarus mine an impregnation with enargite was observed. The country rock is also altered, resulting in a development of sericite, and later of kaolin. The extent of the impregnation or alteration is in general proportionate to the intensity of the mineralization or size of the ore bodies, and may extend to a distance of 100 feet from the vein. In the copper mines the material intermediate between the outer fissure planes of a vein or lode often shows small joints and cross-fissures which have been filled by metallic minerals or quartz. According to the greater or less proportion of copper in such a mass it may constitute pay ore or simply a barren "horse." In impregnated or partially replaced material the separation of kaolin during the process of decomposition produces a characteristic crumbly condition of the ore. Such veins, as already stated, are characteristically developed in the copper area, where, however, the veins sometimes show a fairly distinct definition between vein material and wall rock, generally on the foot or north side. Among the silver veins in the aplite the replacement vein is a well-defined fracture zone, irregularly impregnated and replaced by vein material and accompanied by impregnation and alteration of the wall. In both types of veins clay selvages produced by secondary movement are likely to be mistaken for walls, in the sense of forming a boundary of the vein material, whereas they very frequently occur in the midst of vein material.

Effects of secondary deposition by transposition of ores.

Secondary deposition, or transposition of already deposited minerals, has played an unusually important rôle. In the case of the copper veins it has not been confined to the oxidizing action of surface waters, which has resulted in an impoverishment of the ore bodies, but below the zone of oxidation it has resulted in the formation of the richer copper minerals bornite, chalcocite, and covellite, in part at least by the breaking up of original chalcopyrite. Unusual enrichment of the middle depths of the lodes has thus been caused. Whether the two processes of impoverishment and enrichment have been differing phases of the action of descending waters, or whether the latter may have been a later result of the rhyolite intrusion, has not yet been definitely decided. It is, however, fairly well determined that the enrichment of the copper deposits is so closely associated with the secondary faulting that it may be considered to be a genetic result of it.

In the silver veins surface oxidation has resulted in general in the enrichment of the ore bodies. No certain evidence of secondary enrichment in the sulphide zone of these ore bodies was obtained.

THE ORE MINERALS.

Names and compositions of the ore minerals.

The commonest of the metallic minerals in the Butte ores are pyrite (FeS_2), chalcopyrite ($CuFeS_2$), bornite (Cu_3FeS_3), chalcocite (Cu_2S), enargite (Cu_3AsS_4), sphalerite (ZnS), galena (PbS), rhodonite ($MnSiO_3$), and rhodochrosite ($MnCO_3$), with quartz (SiO_2) as gangue. Less abundant are the metallic minerals tetrahedrite ($Cu_8Sb_2S_7$), tennantite ($Cu_8As_2S_7$), covellite (CuS), argentite (AgS), native silver (Ag), pyrargyrite (Ag_3SbS_3), wurtzite (ZnS), hübnerite ($MnWO_4$), and some gold mineral, and the earthy minerals calcite ($CaCO_3$), gypsum ($CaSO_4$), barite ($BaSO_4$), fluorite (CaF), and sericite ($[HK]\,AlSiO_4$).

The oxidation products are hematite (Fe_2O_3), limonite ($Fe_2O_3+3H_2O$), vivianite ($Fe_2P_2O_8$), cuprite (Cu_2O), melaconite (CuO), native copper (Cu), chrysocolla ($CuSiO_3+2H_2O$), malachite ($Cu_2CO_4+H_2O$), azurite ($Cu_3C_2O_7+H_2O$), chalcanthite ($CuSO_4+5H_2O$), goslarite ($ZnSO_4+7H_2O$), cerussite ($PbCO_3$), pyrolusite (MnO_2), manganite ($Mn_2O_3+H_2O$), psilomelane (H_4MnO_5), and wad (impure, H_4MnO_5).

PARAGENESIS.

In crystallizing from the ore-depositing solutions the minerals followed an order which can in general be determined from their relative positions. Under the heading of paragenesis are described those facts of association which relate to the sequence of mineral formation.

Pyrite most abundant and earliest of the minerals.

Pyrite.—This is the most widely distributed mineral. It is found (1) disseminated through the veins, (2) in bands of varying purity in the veins, (3) disseminated through the country rock next the veins, and (4) in many of the joint planes of the country rock. It was one of the earliest minerals to form, being preceded only by a bluish sulphide and a limited amount of quartz. The pyrite, whether in masses resembling bands in the vein or in isolated crystals through the vein, is with scarcely an exception enclosed by all of the other minerals save argentite.

This mineral has undergone much dynamical and chemical change, so that it appears when seen in the thin sections greatly broken and corroded, the cracks and irregular crystal outlines being filled with quartz and some of the sulphides.

When well crystallized the pyrite is usually quite pale and hard, but much of it occurs without definite crystal form and is softer than the crystallized mineral. Such masses are usually deeper in color, so that it is difficult to distinguish them from chalcopyrite. When the pyrite occurs in bands in the vein it is cemented either by quartz or by metallic minerals. When associated with quartz it forms from 20 to 90 per cent of the vein material.

In the country rock the pyrite is either widely disseminated in crystals and irregular masses in decomposed zones, sometimes associated with remnants of the darker silicates, or it occurs in the joint planes.

There is generally an increase of pyrite over the other minerals in depth.

Hematite and limonite occur only as an oxidation product from pyrite. They belong properly to the oxidation zone, but have been seen along fractures below this zone and in the form of stalactites on the walls of mine workings 1150 feet below the surface.

Vivianite results from the decomposition of pyrite and the country rock. It occurs, so far as observed, only as a white incrustation upon stalactites of iron oxide.

Sequence of various minerals after the pyrite, chalcopyrite, and quartz.

Sphalerite (zincblende) occurs in all the veins, but is more uniformly distributed in the silver veins than in the copper veins. In the copper veins it is most abundant in the Bellona, the west end of the Syndicate lode, and the upper levels of the Gagnon mine. It is closely associated with galena. It is always crystalline, but rarely with crystal outline. It varies in color; when it departs from the resinous yellow to a deeper hue it contains what seems to be a finely divided impurity; in other cases it loses its color through decomposition. Its association with galena shows that these minerals formed at the same time, but its relations to the other minerals show it to be later in origin than the pyrite, chalcopyrite, and some of the quartz, but earlier than any of the other minerals.

Wurtzite is reported only from the Gagnon mine, where it was recognized by Pearce in crystals of peculiar composition.

Goslarite results from the oxidation of sphalerite and wurtzite. It occurs in crystals 3 or 4 inches long, white or colorless, and resembles spun glass. It grows indifferently upon mine timbers and wall rocks.

Galena.—The association and distribution of galena are identical with those of sphalerite.

Cerussite has been found but sparingly, and in the oxide zone.

Argentite was recognized only in the silver veins, where it occurred as microscopic inclusions in pyrite and, rarely, apart from the pyrite. It is the earliest mineral to form, and is of the same age as the inclusions of quartz in pyrite.

Native silver has been found in both the copper and the silver veins. It is the only silver mineral that it has been possible to recognize in the copper veins. It always occurs in fractures of vein rock or vein crystals, and is without doubt the result of oxidation of some silver mineral, presumably argentite.

Pyrargyrite was observed only in the Springfield mine. It occurred in crystals along the fractures of the country rock.

Tetrahedrite.—Silver-bearing tetrahedrite was only found in the northeast silver belt.

Gold minerals.—No gold mineral was found, and its presence is known only through the constant presence of the metal shown by the assays and in bullion returns. In the copper veins tellurium is a constant constituent, and in such amount as to render it probable that the gold occurs as a telluride. It is not known whether tellurium occurs in the silver veins.

Manganese minerals, except hübnerite, occur but sparingly outside of the silver veins. They form a most striking mineral contrast between the two sets of veins. They are distributed with remarkable uniformity through the silver veins. In the copper veins they are seen only in outlying veins which form the boundary between the two.

Rhodonite is fine in texture and resembles massive white quartz, except for its pink color, which is somewhat paler than that of rhodochrosite. Microscopic studies show that its masses are made up of minute rhombs. It occurs in bands, but occasionally is seen distributed through the vein. It has formed synchronously with or later than much of the quartz, but prior to some of it. It is a distinctly earlier mineral than rhodochrosite, but post-dates all of the metallic minerals.

Rhodochrosite is not so uniformly distributed as rhodonite. It seems to decrease from the center of the silver belts outward, and in the case of individual veins toward the extremities. It occurs in bands cementing all the other vein minerals and distributed through the vein zone, binding brecciated vein material. It is always later than the other original vein minerals, except a very small percentage of the quartz, and seems to originate through the decomposition of rhodonite.

Hübnerite was found in the Gagnon mine. It occurs in perfect monoclinic crystals of considerable size and deeply striated. It is an original vein mineral and occurs in bands of quartz enclosed by sphalerite and the copper sulphides.

Manganese oxides.—These minerals occur in the oxide zone only, and as the result of normal decomposition of the silicate and carbonate of manganese. Wad is the commonest of the oxides. It is generally disseminated through the quartz of the veins, and usually as an extremely finely divided powder which arranges itself in curly, grotesque forms around crystals and along cracks. The other oxides of manganese are sometimes crystalline, but they usually occur in botryoidal, reniform, and massive forms, so that it is hard to distinguish the separate minerals.

Chalcopyrite is seen throughout the copper veins and sparingly in the silver veins. It is rarely pure or in distinct crystals, but is associated with pyrite so as to indicate that these minerals are indefinite mixtures, every stage of hardness and variation of color between the two having been observed. Microscopic studies show that the chalcopyrite is synchronous with pyrite except where it results from the separation of the mixtures of pyrite and chalcopyrite. It is an earlier mineral than bornite, into which it grades in such way as to indicate that the latter mineral is derived from the chalcopyrite.

Bornite ("horse-flesh ore" or "peacock ore") occurs in the copper veins, but has been found sparingly in the silver veins. It is a massive mineral without internal structure and has a characteristic silvery color in fresh fracture, which speedily tarnishes to a dull red and from this to a deep indigo-blue. It occurs in fractures in vein minerals and in small veins cutting vein and country rock. It is formed through the decomposition of chalcopyrite and is therefore later than chalcopyrite and the minerals which formed originally in the veins, pyrite, sphalerite, galena, and quartz.

Chalcocite (copper glance) has not been observed outside of the copper veins. It is distinctly the copper-bearing mineral of these veins. It is in steel-gray masses which have a most pronounced conchoidal fracture. It is almost invariably dotted with crystals of pyrite, and native silver is occasionally found coating its fractures. It occurs filling fractures in pyrite and chalcopyrite, and from its relations with these minerals and bornite it is certain that it is derived from the two latter minerals by decomposition, and is therefore later than these minerals.

Covellite ("indigo copper").—Particular interest attaches to this mineral because of its relatively greater abundance here than elsewhere in the world. The covellite from Butte occurs only in the copper veins. It is always massive, of a deep indigo-blue color, and has one perfect cleavage. It occurs in bowlders of vein material which have been dragged from their normal position by secondary fault movement. It is derived from chalcocite, and is the most recent of the copper sulphides.

Enargite has been found only in the copper veins. It occurs in crystalline masses which show a well-developed cleavage but no crystal outlines. In color it is brownish-black. It is widely distributed through the copper veins, but is particularly abundant in the Rarus and the lower levels of the Gagnon mine. It appears to have formed as an original vein mineral subsequent to the pyrite but earlier than the copper sulphides.

Tennantite has been found in the copper veins. It is a secondary mineral, and seems to result through the decomposition of enargite, with which it is always associated.

Tetrahedrite ("gray copper") has been found in both the copper and the silver veins, but is limited to the northeast silver belts and to the copper belts east of the Butte district. The mineral is usually massive, but has been found in crystals. It is an original mineral which occupies a position in the sequence of the vein minerals corresponding to enargite.

Cuprite (red oxide of copper) is found only sparingly. Through it native copper is found in irregular masses, the line of demarcation between the two minerals being always vague.

Melaconite (black oxide of copper), though sparingly found, is usually associated with cuprite or native copper, and occurs as a darker rim about the masses of cuprite, or forming a small proportion of the black powder immediately under the zone of complete oxidation.

Native copper is either closely associated with cuprite and melaconite or is in joint planes in the comparatively fresh granite adjoining the vein. In the former case it has an indefinite outline, but when found in the joint planes of the country rock it is in dendritic crystals.

Chrysocolla is green in color and has a gelatinous appearance. It is usually found in the altered country rock.

Malachite and azurite.—Both the green and the blue carbonates of copper, malachite and azurite, have been found, but they are no longer abundant because the outcrops of the veins have been worn away or covered up.

Chalcanthite (bluestone) is by far the most important of the recently formed minerals of the oxide zone. It grows in all the old mine workings, forming either on the mine timbers or on the wall rocks. It has been observed coating the fragments of waste rock in old stopes, and in some of the mines it is found so extensively that it has been profitable from time to time to employ men to collect it. The waters of the various mines have yielded many tons of metallic copper, which has been precipitated by contact with metallic iron, the copper of these waters being in the form of a sulphate. This mineral is in the waters of all the mines of the copper belts.

Molybdenite has been found only in the Gagnon and Neversweat mines. It occurs in plates in altered granite or as a thin greasy film in joint planes of fresh granite.

Quartz is the most abundant mineral of the veins. In the copper veins it is found in amounts varying from 1 to 80 per cent. It has both preceded and succeeded pyrite and chalcopyrite, but seems not to have formed to any extent after the rich copper sulphides. In the silver veins quartz is even more abundant than in the copper veins. It has formed several stages in the growth of these veins, and with the exception of argentite is found enclosing and enclosed by all of the minerals—even, though rarely, by the oxides of manganese. It has formed most abundantly, however, just before and after sphalerite and galena.

Barite (heavy spar) occurs sparingly, and in the majority of cases in the copper mines. So far as known it occurs only in small tabular crystals, transparent, and tinged yellow, these crystals forming in fractures of the vein and coating surfaces that have been or are distinct water channels.

Fluorite was not found by the writers. It has been reported from a number of mines, and several specimens were seen. It is associated with altered granite rather than with the veins proper.

Calcite appears but sparingly and has been observed in but one small vein as a gangue mineral. It usually occurs in small fractures in the vein or country rock, and has formed subsequent to the original vein as the result of decomposition of the granite.

Gypsum has been noted frequently. It occurs as incrustations on the walls of old mine workings or in mine dumps. It results, without doubt, from the decomposition of lime feldspar and pyrite in the granite, which have been subjected to the oxidizing influence of water and the atmosphere, and in the case of mine dumps to the sun's heat.

Sericite occurs in both the silver and the copper veins. Megascopically it usually is found coating fracture surface and is detected by the whitish tinge and greasy feel of these surfaces. Under the microscope it is seen to replace the silicates. It is a product of the vein solutions, but whether it is the result of decomposition of the country rock or is due to precipitation from the vein solution can not be determined.

DESCRIPTION OF LODES.

COPPER LODES.

Parrott: 1000 to 1450 feet deep. A complex fracture zone with secondary faulting and impregnation.

Parrott lode.—It was upon this lode that the first discoveries and earliest developments of copper ore were made. It has now been traced almost continuously from Missoula Gulch to Silver Bow Creek, a distance of over 2 miles, and in the greater part of this length has been actually developed by underground workings. The deepest levels of the principal mines working on this lode are from 1000 to 1450 feet below the surface, or at an absolute elevation of 4400 to 4800 feet above sea.

Its general course is nearly east and west, with a slight divergence to the south of this line at either end, amounting at the east to about 10°. The dip is to the south, usually at a steep angle.

It has been most extensively developed in the Gagnon-Original ground, where the association of minerals in its vein materials is unusual and varied. The average dip of the lode here may be taken at 84°. At 400 feet from the surface a spur makes off into the hanging wall with an average dip of 55°, and there is a second one parallel to this at the 900-foot level, both of which become barren within a few hundred feet of the main vein. The latter has a dip of 57° at the surface, but steepens below the 400-foot level, and between the 800-foot and 1000-foot levels is vertical or slightly overturned. In depth the fracture zone becomes multiple, there being two or three nearly parallel mineralized fissures connected by cross-fractures, which make up the main vein. Of secondary movement planes the most noticeable is one to the north of and generally parallel with the vein, which contains breccias of vein and country rock, together with secondarily deposited bornite; there is also a system of north-south cross-fractures which displace the vein a few feet.

In the grounds of the Original and Parrott mines, next adjoining on the east, the lode consists of two distinct veins, in places as much as 100 feet apart. The average dip is uniform, varying only from 75° to 85° to the south. In the Original ground and at the east end of the Parrott the veins converge upward, so that they come to the surface practically in a single outcrop. In the Parrott ground the north vein is the more uniform and persistent, the south vein not having been found below 600 feet, and in places diverging so much from the normal dip that it might be considered a spur vein. The secondary movement has been parallel to the vein and mostly on one of the walls; at the north end of the Parrott it crosses the vein diagonally and causes a slight displacement.

In the Colusa-Parrott there is a single steep vein of varying width, with spurs going off into hanging or foot-wall at a lower angle. Secondary strike faulting along the foot-wall displaces the foot-wall spur. In the Ramsdell-Parrott the lode, as far as explored (400 feet), is double, the two veins being 50 to 100 feet apart and having a uniform dip of 65°. In places the intermediate country rock has been so thoroughly impregnated with vein material that the entire zone is mined. In the Cuerpo Bazzo, Anaconda, and St. Lawrence grounds the lode is apparently a single vein whose dip is more irregular and in depth becomes quite flat, being but 35° in the 1000-foot level of the St. Lawrence. In the Lloyd, Pennsylvania, and Silver Bow grounds the lode has been cut and shows a nearly uniform width of 20 feet, the vein material consisting mainly of quartz and pyrite.

Anaconda: width of main vein 5 to 50 feet; minor parallel veins. Quartz-porphyry.

The *Anaconda lode* has been traced through the Neversweat, Anaconda, St. Lawrence, Mountain View, and Rarus grounds, a length of about a mile. There is a break in the continuity of the underground workings east of the St. Lawrence ground, beyond which there is a change in strike from a few degrees north, to almost 15° south of east. This is the most important ore producer of the Rarus and of the Anaconda Company's mines. Through the latter the lode consists of one broad vein or ore-bearing zone with minor small parallel veins, which sometimes join the main vein at one end, thus constituting a sort of spur vein. Through the western part of the ground the dip is steep, being nearly vertical down to 400 feet, when it changes to about 70°, and varies from 60° to 70° in the St. Lawrence. The width of the lode varies. At the west end, where it consists of a number of parallel veins, it rarely exceeds 15 feet in width, and the spur veins are about 5 feet wide. In the Anaconda ground the main vein aggregates 25 to 40 feet in width, decreasing to 5 feet in the east end of the St. Lawrence; on the 1300-foot level (4600) of the St. Lawrence it is 50 feet wide in places. In the eastern part of the Mountain View ground the lode consists of a single vein, known as the Johnstown, which stands at 75° to 85° S. and is 5 to 8 feet wide, carrying much enargite. Quartz-porphyry forms the north wall for considerable distances. In the Rarus ground it consists of three distinct veins with quartz-porphyry on the foot-wall of the northernmost. Two cross-faults displace the veins, and between them the ground is much broken and impregnated with ore, so that in places a width of 100 feet has been mined. The veins opened in the Snohomish ground are supposed to be the extension of this lode; a 40-foot dike of quartz-porphyry is cut in the workings.

Mountain View-Colusa: veins overlapping or én echelon.

Mountain View-Colusa lode.—This lode consists of a group of overlapping veing in which the "en échelon" structure is more noticeable because of its being on a larger scale than in the other lodes. Apparent curves or changes in direction of the vein are often to be accounted for by the development of this structure on a small scale among the fissures which go to make it up, and in which the ore filling will cease on one to be taken up on an adjoining one. Several cross-faults with northwest strike have been observed in the vicinity of the Mountain View, which form part of a zone of disturbance whose effects are also seen in the lodes to the south. Three veins are recognized in the Mountain View ground, which are mainly developed in workings below the 500-foot level. Their surface outcrops are not readily traceable. The south vein has been followed underground 1600 feet, but is not distinguished west of the cross-fault. It is a pyritous, siliceous vein, with good definition between ore and country rock on the foot-wall. Its dip is to the south at varying angles. The middle vein is thought by some to be a faulted portion of the north vein. It is thinner and its ore-bearing ground less extensive than the other two. There has been strongly marked secondary movement on its plane, which is traceable beyond where it ceases to be ore-bearing. The north vein is the most important. It has a steep southerly dip, being often vertical, and in places overturned. Its main copper-bearing mineral in the lower levels is enargite. A cross-fault cuts it off on the west, a little northeast of the shaft. To the east of this, underground workings extend continuously through this and the Colusa vein for 3500 feet, the ore-bearing zone being from 10 to 40 feet in width, and with remarkably little barren ground. It is a mineralized zone of closely spaced parallel and overlapping fractures. The Colusa vein, which is often considered to be the same fissure, is an overlapping system, diverging somewhat to the north at its west end, while the Mountain view system is taken up to the east in a series of veins south of the Leonard shaft. The overlapping of the two veins is noticeable on the dip as well as on the strike, and in the region of overlap the ore body is nearly 100 feet wide. The lower workings on either vein have reached the level of 4900 feet.

Moonlight: extent; influence of cross-faults.

The *Moonlight lode* has been proved underground from the Blue Jay ground on the west to Silver Bow Creek in the Silver Bow ground. In the former it sends off a spur to the south at an angle of 15° from the main vein, which has been proved downward for 200 feet. It has an east-west course and a width at various points of 20 to 25 feet eastward to the bend in Pennsylvania ground, where it is modified by a complex series of cross-faults; in this broken ground it is wide, and rich in chalcocite, and has an irregular dip, as low as 50°. Beyond the bend it takes a direct course about S. 80° E., with a uniform dip of 70° S. and a width of 5 to 15 feet, without spurs or branches. It is opened in this portion down to 4650 feet above sea.

Ground Squirrel: main and minor veins; shallowness of rich copper ores.

The *Ground Squirrel lode* outcrops in southeast Butte, about 600 feet below the Mountain View shaft-house. It has been opened in the Glengarry to a depth of 800 feet (4730), in the Ground Squirrel to 600 feet, and in the Harrington to 150 feet. It consists of one main vein and one or two subordinate and less prominent ones, less than 300 feet apart, whose average southerly dip is 50° to 60°, and in one case 70°, parallel to the main structure planes of the granite. The average strike is S. 80° E. In these veins the richer copper sulphides do not extend more than 350 feet below the surface. A number of other veins, some with a strike considerably north of east, have been opened in this vicinity, but the developments are not sufficient to show their connection with the Ground Squirrel system.

Syndicate: 1000 to 1400 feet deep; 5 to 100 feet wide. Humboldt galena vein. Complex fracture zone.

The *Syndicate lode* has been traced continuously by underground workings from the Yellow Jacket and Moscow on the west to the Wake-up-Jim on the east, a distance of 5500 feet. Its general course is N. 65° E. at the west end, bending gradually to S. 80° E. at the eastern extremity. It has an average dip of 65° S. The deepest workings are 1100 feet (4975) in the Mountain Con., and 1400 feet (4700) in the Green Mountain mine. The lode is remarkable for the width of its ore-bearing zone, which is often 40 to 100 feet, both near the surface and in depth, while at intermediate points it may decrease to 5 feet. At the west end are strong secondary fissures, nearly parallel in strike with the lode, and in places 50 feet wide, which have produced the appearance of two forking veins. To the west of this the ore becomes low in copper and high in zinc. In the Poulin and Estella ground the ore body was very wide near the surface and complicated by a galena vein (the Humboldt) coming in from the southeast. In the Buffalo ground the broad fracture zone of altered granite which constitutes the lode is traversed by secondary clay selvages in the lower levels. In the Mountain Con. ground the dip of the lode is 55° S. in the upper ends, steepening downward to the vertical at 1100 feet on one line of cross-section and to 60° to 70° S., with a spur going off northward at 70°, on another. In the Green Mountain ground several spurs go off to the north, and farther east, with the change of strike, the lode becomes double, the two veins being parallel and steepening in dip from the surface downward, with a varying width of 6 to 20 feet.

Bell-Modoc: complex vein system united at the end; cross-veins; transition ores from copper to silver.

The *Bell-Modoc lode* consists of an extremely complicated system of veins becoming single at either end. In the Modoc ground at the east end it consists of a single vein, 5 to 20 feet wide, dipping quite uniformly 55° to 60° S. The granite country is cut by a series of dikes of quartz-porphyry that unite at the surface in a single outcrop over 100 feet wide; they are mostly on the foot-wall and nearly parallel with the vein, but cut off by it in places. Farther west the lode includes the High Ore, Bell, and Speculator veins, the former of which is probably identical with the Modoc vein, though they have not yet been connected. The High Ore vein has an east course at the surface, but diverges 20° to the southward in depth. Underground it splits longitudinally and vertically several times, the two branches coming together again. It varies much in width (7 to 40 feet), and has not been traced below the 1000-foot level. The Bell vein, next north of the High Ore, has a strike N. 75° W., and stands vertical or with a dip of up to 70°, and outcrops 250 feet north of the Bell outcrop. Underground these veins have been followed 2500 to 3000 feet, but they are not readily traceable on the surface for that distance.

A cross-vein running N. 55° W. occurs at the west end of the Bell vein, which may connect it with the High Ore vein. Known only below the 500-foot level is another cross-vein, called the Diamond vein, which runs N. 65° E. and dips steeply southeast. It has been traced 500 feet, and probably connects the High Ore with the Bell vein; its ore zone averages 15 feet in width and is in places 100 feet wide. Between these various veins is a complex of small spur and branch veins. Westward the High Ore vein is connected on the surface by inconspicuous outcrops and occasional mine openings with the Old Glory lode, which is opened in Centerville near Main street. It there consists of two veins dipping 60° S. and 140 feet apart, of which only the southern is represented on the map. The ore contains manganese, zinc, and silver minerals, with only a small percentage of copper, thus constituting a transition to the silver veins.

Intermediate zone.—Between the Syndicate and the Anaconda lode is a series of veins, striking either east and west or about S. 60° E., which have not been connected with either of the main lodes. They are generally narrow veins with a steep southern dip, and carry quartz, pyrite, zinc-blende, and a little copper. Such are the Little Mina, Stewart, Oden, and Nipper. Farther east, on the slope toward Meaderville, are the Gambetta, Minnie Healey, and Tramway veins, which have yielded some good copper ore but have not been extensively developed.

SILVER LODES.

The northern arc; fissures of the Rainbow system.

Rainbow system. — This system comprises a group of veins whose most important developments are on the hill-slopes north of Walkerville. From this central zone, where the strikes vary but a few degrees from east and west, they have been traced eastward nearly to Silver Bow Creek, curving gradually to S. 60° E., and westward along Oro Fino and Beef Straight gulches, where they bend as much to the west of south.

The Rainbow lode divides the northern fissure system.

The veins in the central and most highly mineralized zone may be grouped under three heads: a system of nearly parallel veins which strike S. 75° to 80° E.; a system of cross-fissures striking nearly northeast; and the Rainbow lode, which crosses the former of these two systems diagonally in a direction somewhat north of east, dividing it into a northwestern and a southeastern group.

The Rainbow lode has been traced by mine workings to depths of 800 to 1500 feet (4800) nearly continuously from the Rising Star to the Valdemere mine. West of the former it appears to follow Beef Straight Gulch in a course S. 50° to 70° W., and east of the Valdemere it splits into a number of southeast veins difficult to trace on the surface. In the middle region it consists generally of two nearly parallel veins, which dip to the north from 85° to 90°. West of where it crosses the other veins in the Moulton ground the dip is to the south, sometimes as much as 70°. The veins vary in width from a mere seam up to 20 or 30 feet, and in places the country rock between them is intersected by a large number of small veins carrying gold and silver, so that a zone up to 100 feet in width is mined. Secondary movement or strike faulting has taken place along the veins, showing sometimes in one wall, sometimes in the other, but no such direct association of this movement with local enrichment of the ore bodies was observed as in the case of the copper veins.

From the Valdemere vein to the Curry.

Of the southeastern system, the veins in the eastern group, southward from the Rainbow lode, are the Valdemere, Moose, Magnolia, Hawkeye, Garfield, and Curry. They occur at nearly uniform distances of 200 feet apart, and strike S. 75° to 80° E., while their dip is uniformly 70° to 85° S. Those near the Rainbow lode have thus far proved the richest. The Valdemere and Moose have been very productive, the Hawkeye only a little less so. They have been disturbed somewhat by secondary cross-faulting. At least four cross-faults were noted in the Belle of Butte mine, of which the largest throws the vein 60 feet southward on the east.

From the Silver Safe to the Goldsmith.

In the northwestern group the veins, northward, are the Silver Safe, Moulton, Amy, and Goldsmith. They are less uniform both in strike and dip. The dip in the Silver Safe is 45° S. at the surface, steepening to 60° at 200 feet. The Moulton and Amy have normal southern dips, and the Goldsmith dips 80° N. for 200 feet from the surface and then bends south. The strike changes to the westward, and finally assumes the bow to the south. The average width of the veins is 4 feet, the extreme variation from which is not over 3 feet.

The northeast cross-veins are observed just east of the Magna Charta shaft, where they connect the Valdemere vein with the Rainbow lode. They dip south at a lower angle than usual, and the most prominent one splits upward, one branch having a dip of 45° to the northwest. They have about the same average width as the southeast veins.

Lexington system.—The line of separation between the veins of this group and those of the Rainbow system is somewhat arbitrary. The veins have been traced continuously from Missoula Gulch eastward more than 5500 feet to the West Gray Rock mine. Though numerous, they do not seem to be closely related. The course of these veins forms a curve similar to that of the Rainbow lode, but without the minor distortions. The strike at the west end is N. 75° E., at the east end S. 65° E., and at the center nearly east and west. The dip is south at an angle which diminishes southward.

From the Blue Wing lode to the La Plata lode.

The Blue Wing lode forms the northern limit of the group. It consists of two veins 50 to 100 feet apart and has been cut in the workings of the Paymaster, Blue Wing, and Lexington mines. The north vein splits between the 100-foot and 200-foot levels and forms two veins 20 feet apart. The dip is between 80° S. and vertical. In width the vein rarely exceeds 5 feet. The south vein is parallel to the north vein and has been found to be throughout a single vein, varying in width up to 20 feet. Like the north vein, the ore, though irregularly distributed, is exceptionally rich in gold and silver. Between these veins, from 300 to 600 feet from the surface, there are a large number of small veins.

The Allie Brown vein, next south, has been worked through the Lexington Company's shafts. It is parallel in course to the Blue Wing, but its dip is more nearly vertical, or even locally to the north at a high angle. It is a strong vein, averaging perhaps 5 feet in width, though locally 20 feet wide, and sometimes includes large lens-shaped bodies of granite.

South of the Allie Brown vein is the Wappello, which consists of a number of parallel veins, only one of which is persistent throughout the workings of the mine. Near the surface and north of the Lexington shaft the main vein splits into a number of small veins, which seem to diverge downward.

These spurs are not persistent, and when they die out are frequently replaced by another small lens of vein matter in the adjacent country rock, which continues both longitudinally and vertically beyond the original spur. At its east end the main vein splits into a number of smaller veins which are nearly parallel to the main vein. These form the workings of the Sisters, the Flag, the Josephine, and the West Gray Rock, but in none of these mines does the vein have the size or richness of the parent ledge. The Wappello lode dips south at an angle of 70°. It has an average width of 5 feet, but locally broadens to several times this width.

The next lode south was not well seen except in the Lexington mine. It parallels the Wappello, but dips to the south at a less angle. It splits at the east end, forming the two south veins of the West Gray Rock.

The La Plata lode is the most southerly of the lodes in this group, and forms the southern limit of the northern silver belt. It consists of a series of short connecting veins which have been traced on the surface from Missoula Gulch to Main street.

Extent of ore-bearing fissures on the north.

Northern system.—North of the Rainbow lode are many veins which become gradually less numerous northward, until just beyond the northern limit of the district they cease. They are the Silver Lick, Glengarry Silver, Florida, Wabash, Springfield, Blackstone, and others. They are small veins, rarely exceeding 5 feet in width, and have not been great producers. Their course is a few degrees north of east and their dip always at a high angle, whether to the north or to the south. None of these veins have been followed more than 400 feet in depth, and most of the workings do not exceed 200 feet.

In the eastern portion the outcrops rarely extend above the enclosing country rock; hence the veins, though numerous, appear to be much less persistent than they probably are. In the western portion the veins, though not numerous, are very persistent, and appear as narrow projecting ledges rising from 1 foot to 10 feet above the enclosing country rock. It is largely due to this fact that the cross-fractures which disjoint the Blackstone and the Wabash veins could be recognized.

Intermediate system. — Between the western extension of the Parrott and the Syndicate lodes is a small area of silver veins extending possibly 3000 feet east of Missoula Gulch. The veins of this area have two distinct directions. Those adjacent to the Syndicate lode have a southeast course, while those near the Parrott lode run nearly east and west.

From the Late Acquisition to the Trifle mine.

Of the latter, the Late Acquisition is the most important. This lode consists of a single vein at the east end, with a steep southerly dip. At the west end it becomes complicated by a number of spurs and small, parallel veins. On this lode are the Late Acquisition, Little Joe, Mount Moriah, Anselmo, Bernard, and Trifle mines. The veins rarely exceed 5 feet in width.

Balm and Clear Grit.

The Balm and Clear Grit are the prominent northwestern lodes of this area, but are not known to connect with the Late Acquisition, toward which they converge eastward.

The Balm lode consists of four veins, of which the two southerly join longitudinally, and judging from their dips, also in depth. The two northern ones seem to diverge eastward, but the more southerly one dips north at a small angle and probably joins the northern vein in depth.

The Clear Grit was an important mine in early days, but its workings are no longer accessible.

From the Travona to the Pikes Peak.

Ancient–Star West group.—In the southwestern portion of Butte and east of Missoula Gulch is a complex group of veins in which the prevailing strikes are N. 65° E. and S. 65° E. To the former belongs the Ancient or Black Chief, a broad zone of highly silicified and manganese-stained rock, which forms a ridge 100 feet high and has been traced nearly 4000 feet from the gulch. The Neptune and Stevens, to the north, have a similar direction. Among the southeast lodes and veins are the Travona, Star West, Schonbar, Despatch, Northern Pacific, and Pikes Peak, which often consist of three or more veins, and between them is a network of smaller veins of varying directions. Some of the ores have been quite rich in silver and carried a good proportion of gold, but they are apt to be high in zinc. A narrow north-south dike of rhyolite cuts the veins south of the Ancient ridge. In the Star West ground it was found to increase in width rapidly with depth.

Czarina, Elbe, Germania, Orphan Girl.

Germania group.—West of Missoula Gulch and south of The Butte is a series of nearly parallel veins with a course from 10° to 20° north of east. The country rock is still granite, but the amount of aplite traversing it in dikes and sheets is very considerable. The veins cut the two rocks indifferently, but are often coincident in direction with the dikes. The Czarina lode in the southern part forms a projecting outcrop of quartz similar to the Ancient and on the same general strike. The Germania, Elbe, Orphan Girl, and others are said to have produced considerable amounts of rich silver ore in former years; the workings are, however, generally less than 400 feet in depth. The many dikes of rhyolite which traverse the area, not all of which reach the surface, cut off the veins very sharply, notably in the case of the Blackbird-Soudan lode.

Veins in aplite.—In the aplite area west of The Butte are many veins having a nearly east-west course and a relatively shallow southern dip, whose outcrops are generally prominent through the contrast of the black manganese stain with the light color of the country rock. They are generally strong and well-defined veins, and often have large bodies of sulphides, too high in zinc and too low in silver to be profitably worked.

Nettie, Independence, Fredonia, Bluebird.

Among the more important is the Nettie lode, which has three veins that have been traced underground from the contact with the rhyolite body westward about 2000 feet. They are broken and slightly displaced by three cross-faults whose planes dip east, and are cut diagonally by a dike of rhyolite, which is 200 feet thick on the 600-foot level of the Nettie mine and narrows upward. Westward the ore deposition has been resumed on veins arranged en échelon, the Independence to the north, and the Fredonia mine to the south. The Bluebird lode is a strong single vein, whose dip is very irregular, becoming in places flat for a considerable distance. It was followed about 2000 feet and opened to a depth of 600 feet; in the last hundred feet the vein proved to be on the contact between aplite and granite.

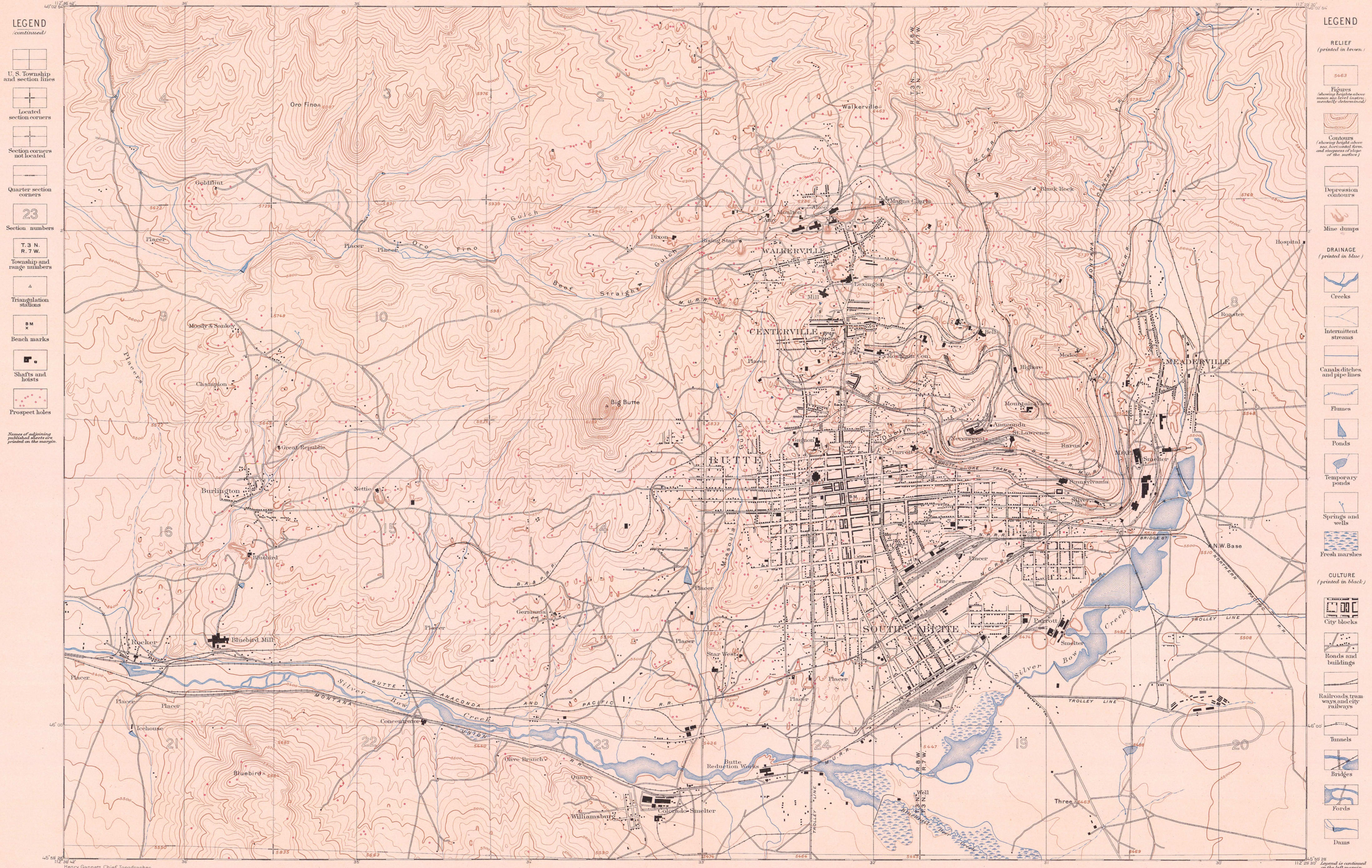
At the Goldflint, in the northwest corner of the district, in an area of granite surrounded by rhyolite and aplite, is a series of short veins, running in three different directions, which stand vertical or dip to the south. Their ores are said to have been unusually rich in gold, but work on them ceased long ago.

SAMUEL FRANKLIN EMMONS,
GEORGE WARREN TOWER, Jr.,
Geologists.

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

TOPOGRAPHIC SHEET

MONTANA
(SILVER BOW CO.)
BUTTE SPECIAL MAP



Henry Gannett, Chief Topographer.
E.M. Douglas, Topographer in charge.
Triangulation and Topography by R.H. Chapman.
Surveyed in 1895.

Scale $\frac{1}{15000}$

Contour interval 20 feet.
Datum is mean sea level,
based upon elevation of bridge 87 of N.P.R.R. taken as 5516 feet.
Edition of Feb. 1897.

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

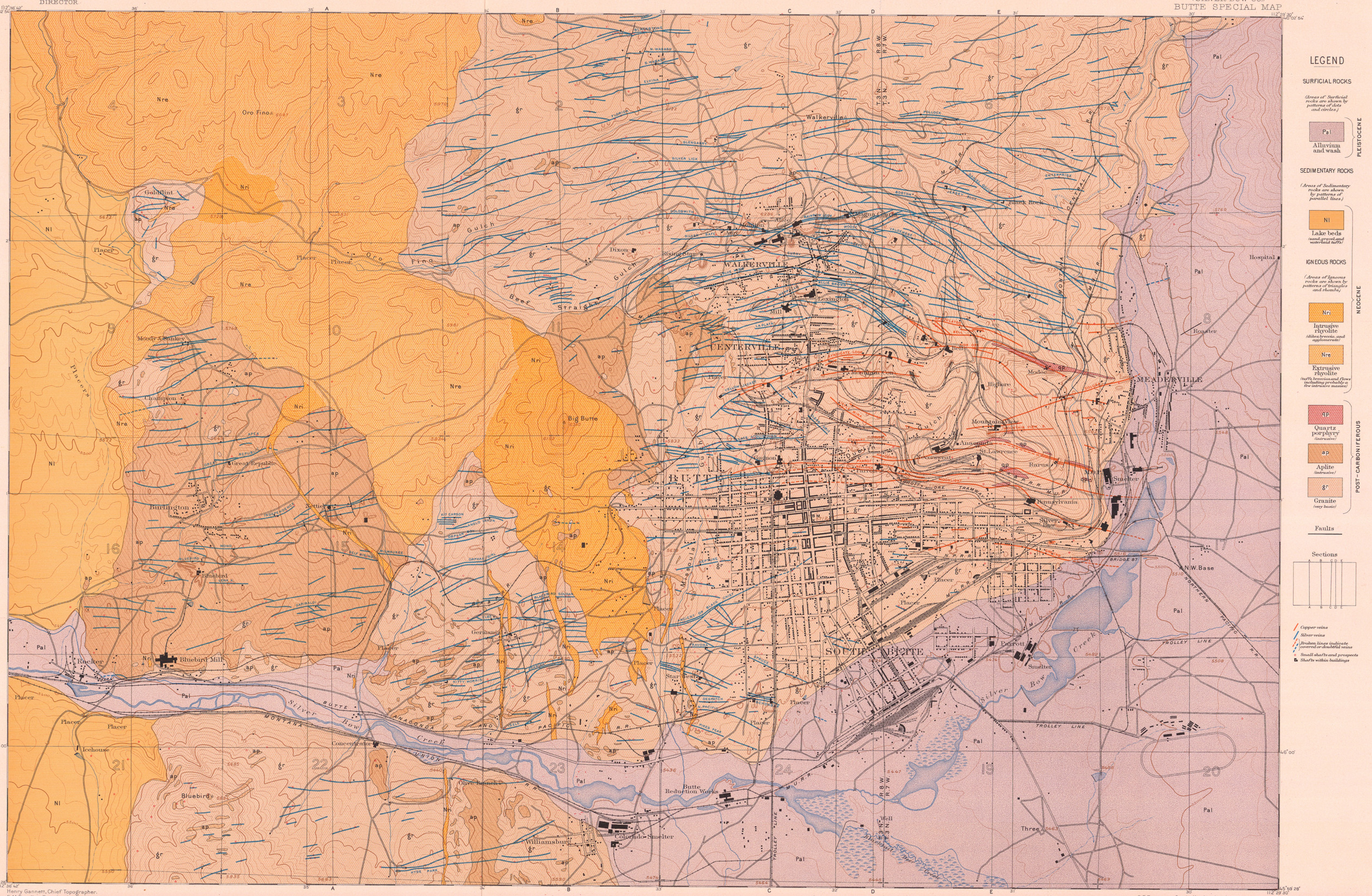
ECONOMIC GEOLOGY SHEET

MONTANA
(SILVER BOW CO.)
BUTTE SPECIAL MAP

LIST OF MINE OPENINGS AND THEIR LOCATION.

(The position on the sheet can be determined by reference to the margin which is divided into spaces of ten seconds of latitude and longitude.)

Name.	Latitude.	Longitude.
Adams	46° 0' 50"	112° 30' 48"
Adelaide	46 1 42	112 30 35
Alex Scott No. 1	46 1 26	112 30 43
Alex Scott No. 2	46 1 28	112 30 45
Alice	46 2 05	112 32 14
Allie Brown, East	46 1 53	112 32 10
Allie Brown, West	46 1 51	112 32 18
Amador	46 2 00	112 31 49
Amy-Silversmith	46 2 04	112 32 37
Amy Incline	46 0 45	112 35 37
Anaconda	46 1 11	112 31 25
Anderson	46 0 43	112 31 15
Andy Johnson	46 0 27	112 33 03
Anglo Saxon	46 0 55	112 33 58
Anselmo No. 1	46 1 12	112 32 53
Anselmo No. 2	46 1 12	112 32 41
Apex	46 1 14	112 35 25
Atlantic	46 1 35	112 29 31
Azor	46 0 44	112 35 28
Balm	46 1 22	112 32 28
Batchelor	46 1 48	112 33 21
Belcher	46 1 51	112 33 01
Bell	46 1 36	112 31 24
Belle of Butte	46 2 01	112 32 06
Belle of Butte, East	46 2 01	112 31 54
Belle of Butte, L. S.	46 2 02	112 32 03
Belmont	46 0 49	112 31 21
Bernard	46 1 12	112 32 48
Blackbird	46 0 35	112 33 38
Black Rock	46 2 10	112 31 04
Blackstone	46 2 51	112 33 13
Bluebird	46 0 42	112 35 38
Blue Jay	46 1 03	112 31 49
Blue Wing	46 1 55	112 32 13
Boston	46 2 12	112 31 34
Brazil No. 1	46 0 36	112 33 31
Brazil No. 2	46 0 32	112 33 29
Brittania	46 0 21	112 33 23
Buffalo	46 1 30	112 32 14
Cambers	46 0 53	112 31 20
Candlestick	46 2 48	112 31 38
Carrie	46 0 56	112 32 44
Champion	46 1 22	112 35 43
Clark's Fraction	46 2 07	112 32 08
Clear Grit	46 1 19	112 32 09
Columbia	46 0 50	112 33 01
Colusa, East	46 1 28	112 30 24
Colusa, West	46 1 24	112 30 44
Colusa-Parrott	46 1 08	112 31 40
Comanche	46 1 21	112 30 42
Corra No. 1	46 1 49	112 31 42
Corra No. 2	46 1 52	112 31 46
Cuerpo Bazzo	46 1 08	112 31 12
Curry	46 1 57	112 32 19
Czarina, East	46 0 19	112 33 38
Czarina, West	46 0 19	112 33 48
Daly Shaft (See Original Butte)		
Daniel Quilp	46 2 18	112 31 20
Darling Fraction	46 1 52	112 31 52
Despatch	46 0 11	112 32 43
Destroying Angel	46 0 52	112 32 12
Diamond	46 1 36	112 31 29
Dixon	46 1 58	112 33 10
Elbe	46 0 31	112 33 58
Elm Orlu	46 2 09	112 31 18
Elvina	46 2 39	112 32 58
Emma	46 0 43	112 32 13
Enterprise	46 2 16	112 30 40
Estella	46 1 28	112 32 18
Eveline	46 1 44	112 32 55
Flag	46 1 46	112 31 56
Four Johns Tunnel	46 2 09	112 30 47
Fredonia	46 0 48	112 35 15
Gagnon	46 1 09	112 32 20
Gambetta	46 1 21	112 30 39
Gambrinus	46 1 03	112 32 49
Garibaldi	46 0 34	112 34 58
Gem	46 1 50	112 30 59
Geneva	46 0 16	112 33 11
Germania	46 0 28	112 33 50
Glengarry	46 0 45	112 30 44
Glengarry Silver	46 2 25	112 32 41
Gold Hill	46 1 05	112 32 05
Gold Hill No. 2	46 1 05	112 32 21
Goldflint	46 2 11	112 35 49
Goldsmith	46 2 05	112 32 49
Gopher	46 0 53	112 31 06
Gray Rock, East	46 1 38	112 31 31
Gray Rock, West	46 1 42	112 31 44
Great Republic	46 1 08	112 35 27
Green Mountain	46 1 34	112 31 42
Ground Squirrel No. 1	46 0 44	112 31 01
Ground Squirrel No. 2	46 0 47	112 31 02
Ground Squirrel No. 3	46 0 47	112 30 57
Harrington	46 0 44	112 30 41
Henry George	46 0 51	112 31 13
Hesperus	46 0 49	112 31 38
Hibernia, East	46 0 59	112 34 40
Hibernia, West	46 0 58	112 34 42
Highland	45 59 39	112 33 43
High Ore	46 1 26	112 31 11
Humboldt	46 0 25	112 33 50
Hyde Park	45 59 32	112 34 26
Iduna	46 0 49	112 31 09
Illinois	46 2 20	112 33 02
Iowa	46 1 40	112 35 33
Isele	46 0 06	112 33 46
Jersey Blue	46 2 14	112 31 22
Josephine	46 1 48	112 31 57
Kit Carson	46 0 55	112 34 11
Kitty Morris	46 0 16	112 34 12
Kossuth	46 1 39	112 35 48
La Plata	46 1 43	112 32 13
Late Acquisition, East	46 1 15	112 32 12
Late Acquisition, West	46 1 15	112 32 19
Lena K., East	46 0 38	112 35 22
Lena K., West	46° 0' 39"	112° 35' 26"
Leonard	46 1 23	112 33 31
Lexington	46 1 49	112 32 08
Little Darling	46 0 39	112 35 49
Little Gold Hill	46 1 07	112 32 08
Little Joe	46 1 14	112 32 28
Little Mina	46 1 23	112 31 59
Little Mina, East	46 1 19	112 31 51
Little St. Lawrence	46 1 30	112 32 43
Lloyd Tunnel	46 1 02	112 31 00
Lloyd Shaft	46 1 03	112 30 59
Magna Charta	46 2 07	112 31 57
Marget Ann	46 2 22	112 32 36
Mat	46 1 42	112 30 28
Maximilian No. 1	46 0 51	112 32 38
Maximilian No. 2	46 0 50	112 32 44
Milwaukee	46 0 46	112 34 26
Minnie Healey	46 1 19	112 30 34
Missoula	46 1 38	112 32 41
Modoc	46 1 31	112 30 49
Modoc Extension	46 1 29	112 30 42
Modoc, West	46 1 35	112 31 01
Mono	46 0 47	112 35 26
Moody & Sankey	46 1 36	112 35 41
Moonlight	46 1 02	112 31 34
Moose	46 2 01	112 31 41
Morning Star	46 1 02	112 32 44
Moscow	46 1 25	112 32 34
Moulton	46 2 04	112 32 25
Mountain Boy	46 0 27	112 33 58
Mountain Chief	46 1 37	112 30 40
Mountain Con. No. 1	46 1 30	112 31 59
Mountain Con. No. 2	46 1 29	112 32 05
Mountain View	46 1 16	112 31 06
Mount Moriah No. 1	46 1 15	112 32 37
Mount Moriah No. 2	46 1 13	112 32 44
Neptune	46 0 44	112 32 47
Nettie No. 1	46 0 57	112 34 53
Nettie No. 2	46 0 53	112 35 01
Nettie No. 3	46 0 54	112 34 40
Neversweat	46 1 09	112 31 34
Nipper	46 1 15	112 31 45
Nonesuch (Union Co.)	46 1 51	112 33 38
Nora	46 0 55	112 31 03
North Pacific, East	46 0 08	112 32 44
North Pacific, West	46 0 09	112 32 49
North Star	46 2 54	112 22 59
Oden	46 1 11	112 31 43
Old Glory	46 1 34	112 32 07
Olive Branch	45 59 52	112 33 54
Ophir	46 0 18	112 32 13
Original	46 1 08	112 32 17
Original Butte (Daly Shaft)	46 1 08	112 32 27
Oro Butte	46 1 24	112 32 35
Orphan Boy	46 0 48	112 34 00
Orphan Girl	46 0 40	112 34 05
Ottowa	46 2 29	112 31 20
Pacific	46 1 27	112 32 26
Parnell	46 1 19	112 31 20
Parrott	46 1 07	112 31 46
Parrott No. 5, East	46 1 04	112 31 29
Paymaster	46 1 55	112 32 24
Pennsylvania	46 1 00	112 30 54
Pikes Peak, East	46 0 04	112 32 43
Pikes Peak, West	46 0 06	112 32 49
Pollock	46 2 31	112 31 31
Poorman	46 0 43	112 35 54
Poser	46 2 06	112 31 32
Poulin	44 1 27	112 32 24
Ramsdell-Parrott	46 1 07	112 31 38
Rarus	46 1 09	112 30 46
Rarus No. 2	46 1 08	112 30 45
Raven	46 1 34	112 32 26
Rising Star	46 1 58	112 32 46
Rose	46 1 02	112 31 26
St. Lawrence	46 1 10	112 31 12
St. Lawrence No. 2	46 1 12	112 31 12
Salvadore	46 1 36	112 32 48
Schonbar	46 0 12	112 32 22
Self Rising	46 0 46	112 34 48
Silver Bow No. 1	46 0 55	112 30 44
Silver Bow No. 2	46 0 53	112 30 34
Silver Gate	46 0 26	112 34 21
Silver-Lick	46 2 19	112 32 37
Sioux Chief	46 1 37	112 30 50
Sisters	46 1 47	112 31 51
Snohomish	46 1 05	112 30 34
Snow Drift	46 2 24	112 32 55
Soudan	46 0 36	112 33 35
Speculator, East	46 1 40	112 31 12
Speculator, West	46 1 38	112 31 22
Springfield	46 2 50	112 32 55
Spruce	46 0 22	112 32 30
Star West, E. shaft	46 0 16	112 32 47
Star West, W. shaft	46 0 21	112 32 55
Stevens	46 0 46	112 32 37
Stewart	46 1 13	112 31 54
Sunshine	46 1 32	112 31 04
Tecumseh	46 0 12	112 32 28
Tramway	46 1 12	112 30 34
Travona	46 0 24	112 32 45
Trifle	46 1 10	112 32 52
Tuolumne	46 1 42	112 30 51
Union Co.	46 2 33	112 32 18
Valdemere	46 2 05	112 31 46
Valley, East	46 0 46	112 31 42
Valley, West	46 0 09	112 32 38
Virginius (Parrott)	46 1 08	112 31 54
Wabash No. 1	46 2 45	112 33 00
Wabash No. 2	46 2 43	112 33 02
Wake-up-Jim	46 1 34	112 31 34
Washoe	46 1 05	112 31 57
Wedge	46 2 28	112 30 25
Wild Bill	46 1 44	112 31 30
Yellow Jacket	46 1 24	112 32 40



Henry Gannett, Chief Topographer.
E.M.Douglas, Topographer in charge.
Triangulation and Topography by R.H.Chapman.
Surveyed in 1895.

Scale $\frac{1}{15000}$

0 500 1000 2000 3000 4000 5000 5280 Ft. or 1 Mile

1 ¾ ½ ¼ 0 1 Kilometer

Contour interval 20 feet.
Datum is mean sea level,
based upon elevation of bridge 87 of N.P.R.R. taken as 5516 feet.
Edition of Mar. 1898.

S.F.Emmons, Geologist in charge.
Areal Geology by Walter Harvey Weed.
Economic Geology by G.W.Tower Jr. and S.F.Emmons.
Surveyed in 1896.

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

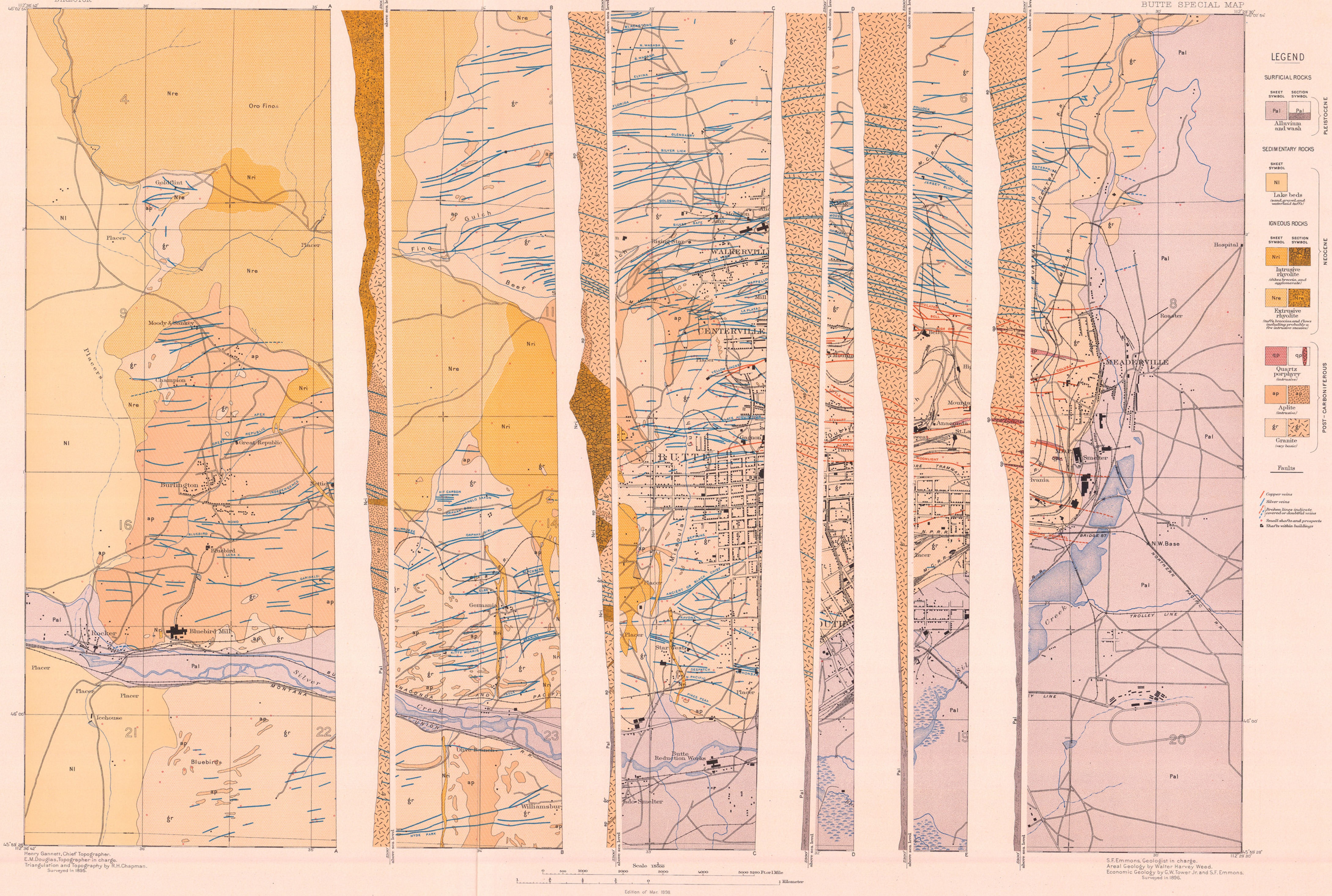
STRUCTURE-SECTION SHEET

MONTANA
(SILVER BOW CO.)
BUTTE SPECIAL MAP

LIST OF MINE OPENINGS AND THEIR LOCATION.

(The position on the sheet can be determined by reference to the margin which is divided into spaces of ten seconds of latitude and longitude.)

Name.	Latitude.	Longitude.
Adams	46° 0′ 50″	112° 30′ 48″
Adelaide	46 1 42	112 30 35
Alex Scott No. 1	46 1 26	112 30 43
Alex Scott No. 2	46 1 28	112 30 45
Alice	46 2 05	112 32 14
Allie Brown, East	46 1 53	112 32 10
Allie Brown, West	46 1 51	112 32 18
Amador	46 2 00	112 31 49
Amy-Silversmith	46 2 04	112 32 37
Amy Incline	46 0 45	112 35 37
Anaconda	46 1 11	112 31 25
Anderson	46 0 43	112 31 15
Andy Johnson	46 0 27	112 33 03
Anglo Saxon	46 0 55	112 33 58
Anselmo No. 1	46 1 12	112 32 53
Anselmo No. 2	46 1 12	112 32 41
Apex	46 1 14	112 35 25
Atlantic	46 1 35	112 29 31
Azor	46 0 44	112 35 28
Balm	46 1 22	112 32 28
Batchelor	46 1 48	112 33 21
Belcher	46 1 51	112 33 01
Bell	46 1 36	112 31 24
Belle of Butte	46 2 01	112 32 06
Belle of Butte, East	46 2 01	112 31 54
Belle of Butte, L. S.	46 2 02	112 32 03
Belmont	46 0 49	112 31 21
Bernard	46 1 12	112 32 48
Blackbird	46 0 35	112 33 38
Black Rock	46 2 10	112 31 04
Blackstone	46 2 51	112 33 13
Bluebird	46 0 42	112 35 38
Blue Jay	46 1 03	112 31 49
Blue Wing	46 1 55	112 32 13
Boston	46 2 12	112 31 34
Brazil No. 1	46 0 36	112 33 31
Brazil No. 2	46 0 32	112 33 29
Brittania	46 0 21	112 33 23
Buffalo	46 1 30	112 32 14
Cambers	46 0 53	112 31 20
Candlestick	46 2 48	112 31 38
Carrie	46 0 56	112 32 44
Champion	46 1 22	112 35 43
Clark's Fraction	46 2 07	112 32 08
Clear Grit	46 1 19	112 32 09
Columbia	46 0 50	112 33 01
Colusa, East	46 1 28	112 30 24
Colusa, West	46 1 24	112 30 44
Colusa-Parrott	46 1 08	112 31 40
Comanche	46 1 21	112 30 42
Corra No. 1	46 1 49	112 31 42
Corra No. 2	46 1 52	112 31 46
Cuerpo Bazzo	46 1 08	112 31 12
Curry	46 1 57	112 32 19
Czarina, East	46 0 19	112 33 38
Czarina, West	46 0 19	112 33 48
Daly Shaft (See Original Butte)		
Daniel Quilp	46 2 18	112 31 20
Darling Fraction	46 1 52	112 31 52
Despatch	46 0 11	112 32 43
Destroying Angel	46 0 52	112 32 12
Diamond	46 1 36	112 31 29
Dixon	46 1 58	112 33 10
Elbe	46 0 31	112 33 58
Elm Orlu	46 2 09	112 31 18
Elvina	46 2 39	112 32 58
Emma	46 0 43	112 32 13
Enterprise	46 2 16	112 30 40
Estella	46 1 28	112 32 18
Eveline	46 1 44	112 32 55
Flag	46 1 46	112 31 56
Four Johns Tunnel	46 2 09	112 30 47
Fredonia	46 0 48	112 35 15
Gagnon	46 1 09	112 32 20
Gambetta	46 1 21	112 30 39
Gambrinus	46 1 03	112 32 49
Garibaldi	46 0 34	112 34 58
Gem	46 1 50	112 30 59
Geneva	46 0 16	112 33 11
Germania	46 0 28	112 33 50
Glengarry	46 0 45	112 30 44
Glengarry Silver	46 2 25	112 32 41
Gold Hill	46 1 05	112 32 05
Gold Hill No. 2	46 1 05	112 32 21
Goldflint	46 2 11	112 35 49
Goldsmith	46 2 05	112 32 49
Gopher	46 0 53	112 31 06
Gray Rock, East	46 1 38	112 31 31
Gray Rock, West	46 1 42	112 31 44
Great Republic	46 1 08	112 35 27
Green Mountain	46 1 34	112 31 42
Ground Squirrel No. 1	46 0 44	112 31 01
Ground Squirrel No. 2	46 0 47	112 31 02
Ground Squirrel No. 3	46 0 47	112 30 57
Harrington	46 0 44	112 30 41
Henry George	46 0 51	112 31 13
Hesperus	46 0 49	112 31 38
Hibernia, East	46 0 59	112 34 40
Hibernia, West	46 0 58	112 34 42
Highland	45 59 39	112 33 43
High Ore	46 1 26	112 31 11
Humboldt	46 0 25	112 33 50
Hyde Park	45 59 32	112 34 26
Iduna	46 0 49	112 31 09
Illinois	46 2 20	112 33 02
Iowa	46 1 40	112 35 33
Isele	46 0 06	112 33 46
Jersey Blue	46 2 14	112 31 22
Josephine	46 1 48	112 31 57
Kit Carson	46 0 55	112 34 11
Kitty Morris	46 0 16	112 34 12
Kossuth	46 1 39	112 35 48
La Plata	46 1 43	112 32 13
Late Acquisition, East	46 1 15	112 32 12
Late Acquisition, West	46 1 15	112 32 19
Lena K., East	46 0 38	112 35 22
Lena K., West	46° 0′ 39″	112° 35′ 26″
Leonard	46 1 23	112 33 31
Lexington	46 1 49	112 32 08
Little Darling	46 0 39	112 35 49
Little Gold Hill	46 1 07	112 32 08
Little Joe	46 1 14	112 32 28
Little Mina	46 1 23	112 31 59
Little Mina, East	46 1 19	112 31 51
Little St. Lawrence	46 1 30	112 32 43
Lloyd Tunnel	46 1 02	112 31 00
Lloyd Shaft	46 1 03	112 30 59
Magna Charta	46 2 07	112 31 57
Marget Ann	46 2 22	112 32 36
Mat	46 1 42	112 30 28
Maximilian No. 1	46 0 51	112 32 38
Maximilian No. 2	46 0 50	112 32 44
Milwaukee	46 0 46	112 34 26
Minnie Healey	46 1 19	112 30 34
Missoula	46 1 38	112 32 41
Modoc	46 1 31	112 30 49
Modoc Extension	46 1 29	112 30 42
Modoc, West	46 1 35	112 31 01
Mono	46 0 47	112 35 26
Moody & Sankey	46 1 36	112 35 41
Moonlight	46 1 02	112 31 34
Moose	46 2 01	112 31 41
Morning Star	46 1 02	112 32 44
Moscow	46 1 25	112 32 34
Moulton	46 2 04	112 32 25
Mountain Boy	46 0 27	112 33 58
Mountain Chief	46 1 37	112 30 40
Mountain Con. No. 1	46 1 30	112 31 59
Mountain Con. No. 2	46 1 29	112 32 05
Mountain View	46 1 16	112 31 06
Mount Moriah No. 1	46 1 15	112 32 37
Mount Moriah No. 2	46 1 13	112 32 44
Neptune	46 0 44	112 32 47
Nettie No. 1	46 0 57	112 34 53
Nettie No. 2	46 0 53	112 35 01
Nettie No. 3	46 0 54	112 34 40
Neversweat	46 1 09	112 31 34
Nipper	46 1 15	112 31 45
Nonesuch (Union Co.)	46 1 51	112 33 38
Nora	46 0 55	112 31 03
North Pacific, East	46 0 08	112 32 44
North Pacific, West	46 0 09	112 32 49
North Star	46 2 54	112 22 59
Oden	46 1 11	112 31 43
Old Glory	46 1 34	112 32 07
Olive Branch	45 59 52	112 33 54
Ophir	46 0 18	112 32 13
Original	46 1 08	112 32 17
Original Butte (Daly Shaft)	46 1 08	112 32 27
Oro Butte	46 1 24	112 32 35
Orphan Boy	46 0 48	112 34 00
Orphan Girl	46 0 40	112 34 05
Ottowa	46 2 29	112 31 20
Pacific	46 1 27	112 32 26
Parnell	46 1 19	112 31 20
Parrott	46 1 07	112 31 46
Parrott No. 5, East	46 1 04	112 31 29
Paymaster	46 1 55	112 32 24
Pennsylvania	46 1 00	112 30 54
Pikes Peak, East	46 0 04	112 32 43
Pikes Peak, West	46 0 06	112 32 49
Pollock	46 2 31	112 31 31
Poorman	46 0 43	112 35 54
Poser	46 2 06	112 31 32
Poulin	44 1 27	112 32 24
Ramsdell-Parrott	46 1 07	112 31 38
Rarus	46 1 09	112 30 46
Rarus No. 2	46 1 08	112 30 45
Raven	46 1 34	112 32 26
Rising Star	46 1 58	112 32 46
Rose	46 1 02	112 31 26
St. Lawrence	46 1 10	112 31 12
St. Lawrence No. 2	46 1 12	112 31 12
Salvadore	46 1 36	112 32 48
Schonbar	46 0 12	112 32 22
Self Rising	46 0 46	112 34 48
Silver Bow No. 1	46 0 55	112 30 44
Silver Bow No. 2	46 0 53	112 30 34
Silver Gate	46 0 26	112 34 21
Silver-Lick	46 2 19	112 32 37
Sioux Chief	46 1 37	112 30 50
Sisters	46 1 47	112 31 51
Snohomish	46 1 05	112 30 34
Snow Drift	46 2 24	112 32 55
Soudan	46 0 36	112 33 35
Speculator, East	46 1 40	112 31 12
Speculator, West	46 1 38	112 31 22
Springfield	46 2 50	112 32 55
Spruce	46 0 22	112 32 30
Star West, E. shaft	46 0 16	112 32 47
Star West, W. shaft	46 0 21	112 32 55
Stevens	46 0 46	112 32 37
Stewart	46 1 13	112 31 54
Sunshine	46 1 32	112 31 04
Tecumseh	46 0 12	112 32 28
Tramway	46 1 12	112 30 34
Travona	46 0 24	112 32 45
Trifle	46 1 10	112 32 52
Tuolumne	46 1 42	112 30 51
Union Co.	46 2 33	112 32 18
Valdemere	46 2 05	112 31 46
Valley, East	46 0 46	112 31 42
Valley, West	46 0 09	112 32 38
Virginius (Parrott)	46 1 08	112 31 54
Wabash No. 1	46 2 45	112 33 00
Wabash No. 2	46 2 43	112 33 02
Wake-up-Jim	46 1 34	112 31 34
Washoe	46 1 05	112 31 57
Wedge	46 2 28	112 30 25
Wild Bill	46 1 44	112 31 30
Yellow Jacket	46 1 24	112 32 40



Henry Gannett, Chief Topographer.
E. M. Douglas, Topographer in charge.
Triangulation and Topography by R. H. Chapman.
Surveyed in 1895.

S. F. Emmons, Geologist in charge.
Areal Geology by Walter Harvey Weed.
Economic Geology by G. W. Tower Jr. and S. F. Emmons.
Surveyed in 1896.

forming another gradation into sedimentary deposits. Some of this glacial wash was deposited in tunnels and channels in the ice, and forms characteristic ridges and mounds of sand and gravel, known as osars, or eskers, and kames. The material deposited by the ice is called glacial drift; that washed from the ice onto the adjacent land is called modified drift. It is usual also to class as surficial rocks the deposits of the sea and of lakes and rivers that were made at the same time as the ice deposit.

AGES OF ROCKS.

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

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

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

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

Strata often contain the remains of plants and animals which lived in the sea or were washed from the land into lakes or seas or were buried in surficial deposits on the land. Rocks that contain the remains of life are called fossiliferous. By studying these remains, or fossils, it has been found that the species of each period of the earth's history have to a great extent differed from those of other periods. Only the simpler kinds of marine life existed when the oldest fossiliferous rocks were deposited. From time to time more complex kinds developed, and as the simpler ones lived on in modified forms life became more varied. But during each period there lived peculiar forms, which did not exist in earlier times and have not existed since; these are characteristic types, and they define the age of any bed of rock in which they are found. Other types passed on from period to period, and thus linked the systems together, forming a chain of life from the time of the oldest fossiliferous rocks to the present.

When two formations are remote one from the other and it is impossible to observe their relative positions, the characteristic fossil types found in them may determine which was deposited first.

Fossil remains found in the rocks of different areas, provinces, and continents, afford the most important means for combining local histories into a general earth history.

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

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

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

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

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

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

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

THE VARIOUS GEOLOGIC SHEETS.

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

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

Economic geology sheet.—This sheet represents the distribution of useful minerals, the occurrence of artesian water, or other facts of economic interest, showing their relations to the features of topography and to the geologic formations. All the formations which appear on the historical geology sheet are shown on this sheet by fainter color-patterns. The areal geology, thus printed, affords a subdued background upon which the areas of productive formations may be emphasized by strong colors. A symbol for mines is introduced at each occurrence, accompanied by the name of the principal mineral mined or of the stone quarried.

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

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

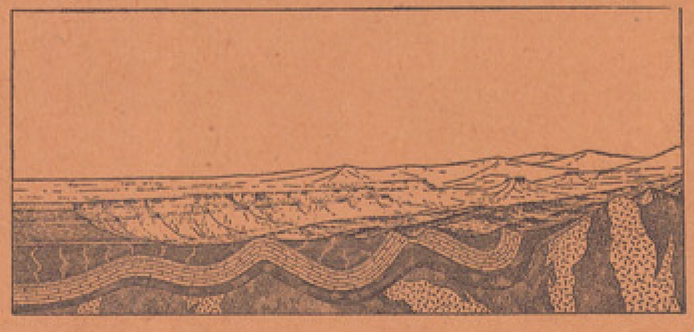


Fig. 2.—Sketch showing a vertical section in the front of the picture, with a landscape beyond.

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

The kinds of rock are indicated in the section by appropriate symbols of lines, dots, and dashes. These symbols admit of much variation, but the following are generally used in sections to represent the commoner kinds of rock:

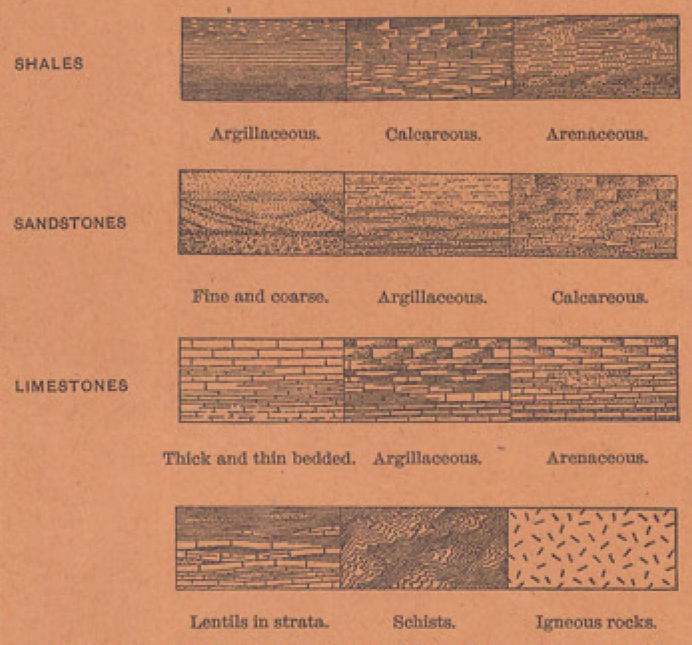


Fig. 3.—Symbols used to represent different kinds of rock.

The plateau in fig. 2 presents toward the lower land an escarpment, or front, which is made up of sandstones, forming the cliffs, and shales, constituting the slopes, as shown at the extreme left of the section.

The broad belt of lower land is traversed by several ridges, which are seen in the section to correspond to beds of sandstone that rise to the surface. The upturned edges of these beds form the ridges, and the intermediate valleys follow the outcrops of limestone and calcareous shales.

Where the edges of the strata appear at the surface their thickness can be measured and the angles at which they dip below the surface can be observed. Thus their positions underground can be inferred.

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

On the right of the sketch the section is composed of schists which are traversed by masses of igneous rock. The schists are much contorted and their arrangement underground can not be inferred. Hence that portion of the section delineates what is probably true but is not known by observation or well-founded inference.

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

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

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

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

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

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

The rocks are described under the corresponding heading, and their characters are indicated in the columnar diagrams by appropriate symbols. The thicknesses of formations are given under the heading "Thickness in feet," in figures which state the least and greatest measurements. The average thickness of each formation is shown in the column, which is drawn to a scale—usually 1000 feet to 1 inch. The order of accumulation of the sediments is shown in the columnar arrangement: the oldest formation is placed at the bottom of the column, the youngest at the top, and igneous rocks or other formations, when present, are indicated in their proper relations.

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

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

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

CHARLES D. WALCOTT,
Director.

Revised June, 1897.