DEPARTMENT OF THE INTERIOR

UNITED STATES GEOLOGICAL SURVEY

CHARLES D. WALCOTT, DIRECTOR

GEOLOGIC ATLAS

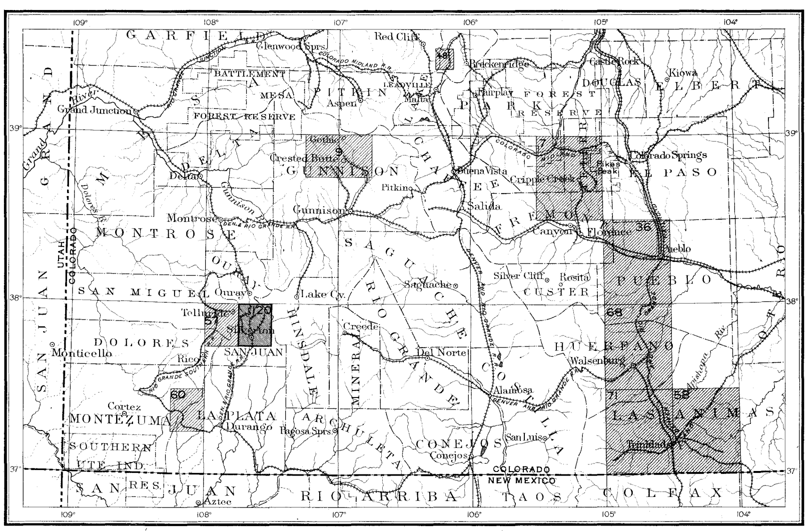
OF THE

UNITED STATES

SILVERTON FOLIO

COLORADO

INDEX MAP



SCALE: 40 MILES-1 INCH

SILVERTON FOLIO — OTHER PUBLISHED FOLIOS

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LIBRARY EDITION

SILVERTON FOLIO
NO. 120

WASHINGTON, D. C.

ENGRAVED AND PRINTED BY THE U. S. GEOLOGICAL SURVEY

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

1905

GEOLOGIC AND TOPOGRAPHIC ATLAS OF UNITED STATES.

The Geological Survey is making a geologic map of the United States, which is being issued in parts, called folios. Each folio includes a topographic map and geologic maps of a small area of country, together with explanatory and descriptive texts.

THE TOPOGRAPHIC MAP.

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

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

The manner in which contours express elevation, form, and grade is shown in the following sketch and corresponding contour map (fig. 1).

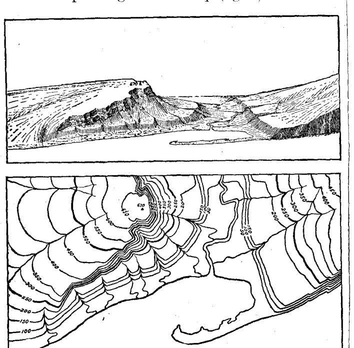


FIG. 1.—Ideal view and corresponding contour map.

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

1. A contour indicates a certain height above sea level. In this illustration the contour interval is 50 feet; therefore the contours are drawn at 50, 100, 150, and 200 feet, and so on, above mean sea level. Along the contour at 250 feet lie all points of the surface that are 250 feet above sea; along the contour at 200 feet, all points that are 200 feet above sea; and so on. In the space between any two contours are found elevations above the lower and below the higher contour. Thus the contour at 150 feet falls just below the edge of the terrace, while that at 200 feet lies above the terrace; therefore all points on the terrace are shown to be more than 150 but less than 200 feet above sea. The summit of the higher hill is stated to be 670 feet above sea; accordingly the contour at 650 feet surrounds it. In this illustration all the contours are numbered, and those for 250 and 500 feet are accentuated by being made heavier. Usually it is not desirable to number all the contours, and then the accentuating and numbering of certain of them—say every fifth one—suffice, for the heights of others may be ascertained by counting up or down from a numbered contour.

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

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

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

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

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

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

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

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

The atlas sheets, being only parts of one map of the United States, disregard political boundary lines, such as those of States, counties, and townships. To each sheet, and to the quadrangle it represents, is given the name of some well-known town or natural feature within its limits, and at the sides and corners of each sheet the names of adjacent sheets, if published, are printed.

Uses of the topographic map.—On the topographic map are delineated the relief, drainage, and culture of the quadrangle represented. It should portray to the observer every characteristic feature of the landscape. It should guide the traveler; serve the investor or owner who desires to ascertain the position and surroundings of property; save the engineer preliminary surveys in locating roads, railways, and irrigation reservoirs and ditches; provide educational material for schools and homes; and be useful as a map for local reference.

THE GEOLOGIC MAPS.

The maps representing the geology show, by colors and conventional signs printed on the topographic base map, the distribution of rock masses on the surface of the land, and the structure sections show their underground relations, as far as known and in such detail as the scale permits.

KINDS OF ROCKS.

Rocks are of many kinds. On the geologic map they are distinguished as igneous, sedimentary, and metamorphic.

Igneous rocks.—These are rocks which have cooled and consolidated from a state of fusion. Through rocks of all ages molten material has from time to time been forced upward in fissures or channels of various shapes and sizes, to or nearly to the surface. Rocks formed by the consolidation of the molten mass within these channels—that is, below the surface—are called *intrusive*. When the rock occupies a fissure with approximately parallel walls the mass is called a *dike*; when it fills a large and irregular conduit the mass is termed a *stock*. When the conduits for molten magmas traverse stratified rocks they often send off branches parallel to the bedding planes; the rock masses filling such fissures are called *sills* or *sheets* when comparatively thin, and *laccoliths* when occupying larger chambers produced by the force propelling the magmas upward. Within rock inclosures molten material cools slowly, with the result that intrusive rocks are generally of crystalline texture. When the channels reach the surface the molten material poured out through them is called *lava*, and lavas often build up volcanic mountains. Igneous rocks thus formed upon the surface are called *extrusive*. Lavas cool rapidly in the air, and acquire a glassy or, more often, a partially crystalline condition in their outer parts, but are more fully crystalline in their inner portions. The outer parts of lava flows are usually more or less porous. Explosive action often accompanies volcanic eruptions, causing ejections of dust, ash, and larger fragments. These materials, when consolidated, constitute breccias, agglomerates, and tuffs. Volcanic ejecta may fall in bodies of water or may be carried into lakes or seas and form sedimentary rocks.

Sedimentary rocks.—These rocks are composed of the materials of older rocks which have been broken up and the fragments of which have been carried to a different place and deposited.

The chief agent of transportation of rock débris is water in motion, including rain, streams, and the water of lakes and of the sea. The materials are in large part carried as solid particles, and the deposits are then said to be mechanical. Such are gravel, sand, and clay, which are later consolidated into conglomerate, sandstone, and shale. In smaller portion the materials are carried in solution, and the deposits are then called organic if formed with the aid of life, or chemical if formed without the aid of life. The more important rocks of chemical and organic origin are limestone, chert, gypsum, salt, iron ore, peat, lignite, and coal. Any one of the deposits may be separately formed, or the different materials may be intermingled in many ways, producing a great variety of rocks.

Another transporting agent is air in motion, or wind; and a third is ice in motion, or glaciers. The most characteristic of the wind-borne or eolian deposits is loess, a fine-grained earth; the most characteristic of glacial deposits is till, a heterogeneous mixture of bowlders and pebbles with clay or sand.

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

The surface of the earth is not fixed, as it seems to be; it very slowly rises or sinks, with reference to the sea, over wide expanses; and as it rises or subsides the shore lines of the ocean are changed. As a result of the rising of the surface, marine sedimentary rocks may become part of the land, and extensive land areas are in fact occupied by such rocks.

Rocks exposed at the surface of the land are acted upon by air, water, ice, animals, and plants. They are gradually broken into fragments, and the more soluble parts are leached out, leaving the less soluble as a *residual* layer. Water washes residual material down the slopes, and it is eventually carried by rivers to the ocean or other bodies of standing water. Usually its journey is not continuous, but it is temporarily built into river bars and flood plains, where it is called *alluvium*. Alluvial deposits, glacial deposits (collectively known as *drift*), and eolian deposits belong to the *surficial* class, and the residual layer is commonly included with them. Their upper parts, occupied by the roots of plants, constitute soils and subsoils, the soils being usually distinguished by a notable admixture of organic matter.

Metamorphic rocks.—In the course of time, and by a variety of processes, rocks may become greatly changed in composition and in texture. When the newly acquired characteristics are more pronounced than the old ones such rocks are called *metamorphic*. In the process of metamorphism the substances of which a rock is composed may enter into new combinations, certain substances may be lost, or new substances may be added. There is often a complete gradation from the primary to the metamorphic form within a single rock mass. Such changes transform sandstone into quartzite, limestone into marble, and modify other rocks in various ways.

From time to time in geologic history igneous and sedimentary rocks have been deeply buried and later have been raised to the surface. In this process, through the agencies of pressure, movement, and chemical action, their original structure may be entirely lost and new structures appear. Often there is developed a system of division planes along which the rocks split easily, and these planes may cross the strata at any angle. This structure is called *cleavage*. Sometimes crystals of mica or other foliaceous minerals are developed with their laminæ approximately parallel; in such cases the structure is said to be schistose, or characterized by *schistosity*.

As a rule, the oldest rocks are most altered and the younger formations have escaped metamorphism, but to this rule there are important exceptions.

FORMATIONS.

For purposes of geologic mapping rocks of all the kinds above described are divided into *formations*. A sedimentary formation contains between its upper and lower limits either rocks of uniform character or rocks more or less uniformly varied in character, as, for example, a rapid alternation of shale and limestone. When the passage from one kind of rocks to another is gradual it is sometimes necessary to separate two contiguous formations by an arbitrary line, and in some cases the distinction depends almost entirely on the contained fossils. An igneous formation is constituted of one or more bodies either containing the same kind of igneous rock or having the same mode of occurrence. A metamorphic formation may consist of rock of uniform character or of several rocks having common characteristics.

When for scientific or economic reasons it is desirable to recognize and map one or more specially developed parts of a varied formation, such parts are called *members*, or by some other appropriate term, as *lentils*.

AGES OF ROCKS.

Geologic time.—The time during which the rocks were made is divided into several *periods*. Smaller time divisions are called *epochs*, and still smaller ones *stages*. The age of a rock is expressed by naming the time interval in which it was formed, when known.

The sedimentary formations deposited during a period are grouped together into a *system*. The principal divisions of a system are called *series*. Any aggregate of formations less than a series is called a *group*.

(Continued on third page of cover.)

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

Stratified rocks often contain the remains or imprints of plants and animals which, at the time the strata were deposited, lived in the sea or were washed from the land into lakes or seas, or were buried in surficial deposits on the land. Such rocks are called fossiliferous. By studying fossils it has been found that the life of each period of the earth's history was to a great extent different from that of other periods. Only the simpler kinds of marine life existed when the oldest fossiliferous rocks were deposited. From time to time more complex kinds developed, and as the simpler ones lived on in modified forms life became more varied. But during each period there lived peculiar forms, which did not exist in earlier times and have not existed since; these are *characteristic types*, and they define the age of any bed of rock in which they are found. Other types passed on from period to period, and thus linked the systems together, forming a chain of life from the time of the oldest fossiliferous rocks to the present. When two sedimentary formations are remote from each other and it is impossible to observe their relative positions, the characteristic fossil types found in them may determine which was deposited first. Fossil remains found in the strata of different areas, provinces, and continents afford the most important means for combining local histories into a general earth history.

It is often difficult or impossible to determine the age of an igneous formation, but the relative age of such a formation can sometimes be ascertained by observing whether an associated sedimentary formation of known age is cut by the igneous mass or is deposited upon it.

Similarly, the time at which metamorphic rocks were formed from the original masses is sometimes shown by their relations to adjacent formations of known age; but the age recorded on the map is that of the original masses and not of their metamorphism.

Colors and patterns.—Each formation is shown on the map by a distinctive combination of color and pattern, and is labeled by a special letter symbol.

Symbols and colors assigned to the rock systems.

	System.	Series.	Symbol.	Color for sedimentary rocks.
Cenozoic	Quaternary	Recent; Pleistocene	Q	Brownish-yellow.
	Tertiary	Pliocene; Miocene; Oligocene; Eocene	T	Yellow ocher.
Mesozoic	Cretaceous		K	Olive-green.
	Jurassic		J	Blue-green.
	Triassic		Ꞧ	Peacock-blue.
Paleozoic	Carboniferous.	Permian; Pennsylvanian; Mississippian	C	Blue.
	Devonian		D	Blue-gray.
	Silurian		S	Blue-purple.
	Ordovician		O	Red-purple.
	Cambrian	Saratogan; Acadian; Georgian	Є	Brick-red.
	Algonkian		A	Brownish-red.
	Archean		AR	Gray-brown.

Patterns composed of parallel straight lines are used to represent sedimentary formations deposited in the sea or in lakes. Patterns of dots and circles represent alluvial, glacial, and eolian formations. Patterns of triangles and rhombs are used for igneous formations. Metamorphic rocks of unknown origin are represented by short dashes irregularly placed; if the rock is schist the dashes may be arranged in wavy lines parallel to the structure planes. Suitable combination patterns are used for metamorphic formations known to be of sedimentary or of igneous origin.

The patterns of each class are printed in various colors. With the patterns of parallel lines, colors are used to indicate age, a particular color being assigned to each system. The symbols by which formations are labeled consist each of two or more letters. If the age of a formation is known the symbol includes the system symbol, which is a capital letter or monogram; otherwise the symbols are composed of small letters. The names of the systems and recognized series, in proper order (from new to old), with the color and symbol assigned to each system, are given in the preceding table.

SURFACE FORMS.

Hills and valleys and all other surface forms have been produced by geologic processes. For example, most valleys are the result of erosion by the streams that flow through them (see fig. 1), and the alluvial plains bordering many streams were built up by the streams; sea cliffs are made by the eroding action of waves, and sand spits are built up by waves. Topographic forms thus constitute part of the record of the history of the earth.

Some forms are produced in the making of deposits and are inseparably connected with them. The hooked spit, shown in fig. 1, is an illustration. To this class belong beaches, alluvial plains, lava streams, drumlins (smooth oval hills composed of till), and moraines (ridges of drift made at the edges of glaciers). Other forms are produced by erosion, and these are, in origin, independent of the associated material. The sea cliff is an illustration; it may be carved from any rock. To this class belong abandoned river channels, glacial furrows, and peneplains. In the making of a stream terrace an alluvial plain is first built and afterwards partly eroded away. The shaping of a marine or lacustrine plain, is usually a double process, hills being worn away (*degraded*) and valleys being filled up (*aggraded*).

All parts of the land surface are subject to the action of air, water, and ice, which slowly wear them down, and streams carry the waste material to the sea. As the process depends on the flow of water to the sea, it can not be carried below sea level, and the sea is therefore called the *base-level* of erosion. When a large tract is for a long time undisturbed by uplift or subsidence it is degraded nearly to base-level, and the even surface thus produced is called a *peneplain*. If the tract is afterwards uplifted the peneplain at the top is a record of the former relation of the tract to sea level.

THE VARIOUS GEOLOGIC SHEETS.

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

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

Economic geology map.—This map represents the distribution of useful minerals and rocks, showing their relations to the topographic features and to the geologic formations. The formations which appear on the areal geology map are usually shown on this map by fainter color patterns. The areal geology, thus printed, affords a subdued background upon which the areas of productive formations may be emphasized by strong colors. A mine symbol is printed at each mine or quarry, accompanied by the name of the principal mineral mined or stone quarried. For regions where there are important mining industries or where artesian basins exist special maps are prepared, to show these additional economic features.

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

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

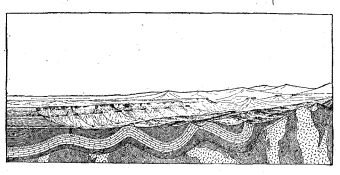


Fig. 2.—Sketch showing a vertical section at the front and a landscape beyond.

The figure represents a landscape which is cut off sharply in the foreground on a vertical plane, so as to show the underground relations of the rocks. The kinds of rock are indicated by appropriate symbols of lines, dots, and dashes. These symbols admit of much variation, but the following are generally used in sections to represent the commoner kinds of rock:

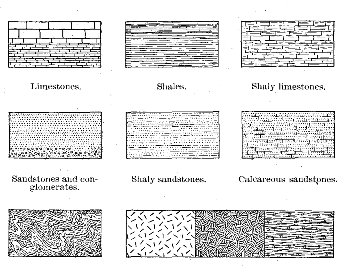


Fig. 3.—Symbols used in sections to represent different kinds of rocks.

The plateau in fig. 2 presents toward the lower land an escarpment, or front, which is made up of sandstones, forming the cliffs, and shales, constituting the slopes, as shown at the extreme left of the section. The broad belt of lower land is traversed by several ridges, which are seen in the section to correspond to the outcrops of a bed of sandstone that rises to the surface. The upturned edges of this bed form the ridges, and the intermediate valleys follow the outcrops of limestone and calcareous shale.

Where the edges of the strata appear at the surface their thickness can be measured and the angles at which they dip below the surface can be observed. Thus their positions underground can be inferred. The direction that the intersection of a bed with a horizontal plane will take is called the *strike*. The inclination of the bed to the horizontal plane, measured at right angles to the strike, is called the *dip*.

Strata are frequently curved in troughs and arches, such as are seen in fig. 2. The arches are called *anticlines* and the troughs *synclines*. But the sandstones, shales, and limestones were deposited beneath the sea in nearly flat sheets; that they are now bent and folded is proof that forces have from time to time caused the earth's surface to wrinkle along certain zones. In places the strata are broken across and the parts have slipped past each other. Such breaks are termed *faults*. Two kinds of faults are shown in fig. 4.

On the right of the sketch, fig. 2, the section is composed of schists which are traversed by masses of igneous rock. The schists are much contorted and their arrangement underground can not be

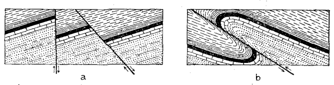


Fig. 4.—Ideal sections of strata, showing (a) *normal* faults and (b) a *thrust* fault.

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

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

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

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

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

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

Columnar section sheet.—This sheet contains a concise description of the sedimentary formations which occur in the quadrangle. It presents a summary of the facts relating to the character of the rocks, the thickness of the formations, and the order of accumulation of successive deposits.

The rocks are briefly described, and their characters are indicated in the columnar diagram. The thicknesses of formations are given in figures which state the least and greatest measurements, and the average thickness of each is shown in the column, which is drawn to a scale—usually 1000 feet to 1 inch. The order of accumulation of the sediments is shown in the columnar arrangement—the oldest formation at the bottom, the youngest at the top.

The intervals of time which correspond to events of uplift and degradation and constitute interruptions of deposition are indicated graphically and by the word "unconformity."

CHARLES D. WALCOTT,

Director.

Revised January, 1904.

DESCRIPTION OF THE SILVERTON QUADRANGLE.

By Whitman Cross, Ernest Howe, and F. L. Ransome.

GEOGRAPHY AND GENERAL GEOLOGY OF THE QUADRANGLE.

By Whitman Cross and Ernest Howe.

INTRODUCTION.

The term San Juan region, or simply "the San Juan," used with variable meaning by early explorers, and naturally with indefinite limitation during the period of settlement, is now quite generally applied to a large tract of mountainous country in southwestern Colorado, together with an undefined zone of lower country bordering it on the north, west, and south. The Continental Divide traverses this area in a great bow. The principal part of the district is a deeply scored volcanic plateau, more than 3000 square miles in extent, drained on the north by tributaries of the Gunnison River, on the west by those of the Dolores and San Miguel rivers, on the south by numerous branches of the San Juan, and on the east by the Rio Grande. All but the latter drainage finds its way to the Gulf of California through the Colorado River.

The San Juan Mountains, as that term is now understood, embrace the area bounded on the north by the generally abrupt descent to the sloping mesas extending for 25 miles to the canyon of the Gunnison, on the west by the great plateau of Colorado and Utah, on the south by the more gradual descent to the rolling plateaus of New Mexico, and on the east by the broad and level San Luis Park. From this main area a broad spur leads off to the southeast, losing its mountainous character near the Colorado–New Mexico line. The San Juan Mountains thus have a length of nearly 80 miles east and west, and a width of from 25 to 40 miles north and south, and their summits form a great group rather than a range.

In the western part of the San Juan Mountains the topography is very rugged. There are hundreds of summits exceeding 13,000 feet in elevation, and several which reach more than 14,000 feet above sea level. Here, too, the bounding scarps of the group are often very precipitous, while some of the valleys in the heart of the mountains have been cut down to 9000 feet or less above the sea. To the east the configuration is less rugged, and high table-lands, of varying extent, represent in a measure old plateau surfaces.

Within the bordering zone of lower country, having a general elevation of from 6000 to 9000 feet, are situated several small groups of high peaks bearing special names. The Needle Mountains on the south, the La Plata and Rico groups to the southwest, and the San Miguel Mountains on the west, are the most important of these outliers.

The Needle Mountains are almost continuous with the San Juan proper, but the local name is amply justified by the character of the group, which is a result of its geologic structure. The La Plata Mountains form an isolated group, and the Rico Mountains are also not connected with the San Juan in origin. The eastern summits of the San Miguel Range—the Mount Wilson group of the Telluride quadrangle—are geologically a portion of the San Juan, cut off by erosion.

Though the San Juan Mountains are surrounded by an arid plain country the annual snowfall and rainfall upon them is heavy, especially on the western portion. The higher peaks and basins are seldom entirely free from snow. This abundant moisture supports a heavy forest growth in many places upon the western and northern sides. Spruces and aspens cover the higher slopes, yielding to white pine, scrub oak, piñon pine, and cedar on the flanks, as the streams sink into canyons cut in the lower plains of sedimentary rocks. Timber line lies in the zone between 11,500 and 12,000 feet above the sea, and large areas in the interior are thus barren of tree growth, and support only a low alpine flora on favored surfaces.

Valuable deposits of the precious metals have been found in many parts of the San Juan region. Coal beds of great extent and fine quality occur along the southern base, and agricultural lands form the valley bottoms and certain of the lower slopes adjacent to the snow-fed streams from the mountains. With the development of these resources several important towns have been established in sheltered valleys on all sides. Railroads encircle the group and penetrate to some of the mining centers of the interior. Creede, Silverton, Telluride, Ouray, and Lake City, all situated in mountain valleys, are thus connected with the main lines of traffic.

The geological history of the San Juan region is too complex and as yet too imperfectly known to justify even an outline statement of satisfactory accuracy. The pre-Tertiary surface of the entire region was completely buried by the volcanic formations which now cover the main area, and, while erosion has again exposed some of the older rocks on all sides of the volcanic complex and even in some of the interior valleys, the reconnaissance observations of the Hayden and other early surveys were far too meager, and the present resurvey has thus far covered too small an area, to afford solutions to many of the problems concerning the earlier geologic development of this most interesting field.

In view of this condition, no attempt will be made at this time to present a thorough review of San Juan geology, but in order that the significance of the observations made in the Silverton, Telluride, and other quadrangles may be more fully appreciated, an outline sketch of the geologic development of the region will be given. This outline is particularly applicable to the western part of the San Juan, for it is in the valleys of this portion, near the mountain front, that the best exposures of the older rocks may be found.

The Animas Valley, between Silverton and the vicinity of Durango, shows apparently a complete exposure of all formations of the San Juan, from the Archean to the Puerco formation of the Eocene, inclusive. Much of this section has now been studied in detail, but definite correlations can not yet be made between the older formations here seen and the isolated exposures reported from some other parts of the San Juan Mountains.

Ancient granites, gneisses, and schists are known in the Animas Valley on the south and in the Uncompahgre Plateau on the north. These rocks have usually been considered Archean, but the granites are probably younger than the great series of quartzites exhibited in the Needle Mountains and seen beneath the volcanics in the canyon of the Uncompahgre above Ouray, which have been referred by Van Hise and Emmons to the pre-Cambrian age of sedimentation—the Algonkian. The Algonkian rocks have suffered great metamorphism and stand on edge or are greatly disturbed, and the relations of the isolated exposures to contemporaneous formations elsewhere are quite unknown. On the Hayden map these quartzites were called "Metamorphic Paleozoic." In this folio they are called the Uncompahgre formation.

Great continental movements of uplift, folding, and faulting, followed by enormous erosion, intervened between the deposition of the Algonkian sediments and the oldest Paleozoic formation. In the Animas Valley the Paleozoic section begins with a thin quartzite, less than 200 feet in thickness, which has been called the Ignacio quartzite, and which, on scanty fossil evidence, has been referred to the Cambrian. Following this quartzite conformably are thin limestones and shaly strata, the latter characterized by casts of cubical salt crystals, with a total thickness of less than 100 feet. These beds are distinguished as the Elbert formation and are assigned to the upper part of the Devonian, on the evidence of characteristic fish remains. Above them occurs, in conformity, a series of limestones with thin interstratified quartzites, 200 to 400 feet thick, known as the Ouray formation, the lower and middle portions of which are characterized by a definite upper Devonian invertebrate fauna.

Although these thin formations have been followed for many miles up the Animas Valley, no indication of Silurian or Ordovician strata has been found there, nor any evidence of the stratigraphic gap which must exist if there are no beds of those ages in the section. In the Uncompahgre Valley near Ouray the Ignacio formation is lacking and the Elbert formation is not everywhere present, and at certain localities in the Silverton quadrangle the Ignacio is absent. These facts show that the seeming conformity in the section seen on the slopes of the Needle Mountains is misleading and that there is a stratigraphic break of great importance between the Ignacio and Elbert formations.

The extreme upper part of the Ouray limestone contains Mississippian (lower Carboniferous) fossils at a few points observed in the Animas Valley. On this limestone occurs a reddish calcareous shale, the Molas formation, containing many chert nodules, and some of these cherts also carry a Mississippian fauna. Thin limestone layers in the shale contain Pennsylvanian (upper Carboniferous) fossils, so that there is evidence of the stratigraphic break following the Ouray. The Molas shales have been found everywhere lying on the Ouray limestone with but slight unconformity. There is no known indication of the extent of the Mississippian formations which may have overlain the Ouray limestone, or of their character, except that the basal portion must have been a cherty limestone very similar to the Ouray and grading into it.

The red shales of the Molas constitute the first sediments of a great complex of sandstones and fossiliferous shales and limestones, belonging to the Pennsylvanian. These beds reach a total thickness of 2000 feet and have been named the Hermosa formation. They form the great scarp on the west side of the Animas Valley and other prominent topographic features on both the southern and the northern side of the mountains.

Above the Hermosa strata appears an important series of reddish conglomerates, sandstones, marls, and thin limestones, in the upper part of which Triassic fossils occur. These rocks occupy a much larger area than the Hermosa in the zone adjacent to the mountains, and are conspicuous in the Animas, Dolores, San Miguel, and Uncompahgre valleys.

In the Rico Mountains a fauna that is related to the Permo-Carboniferous of the Mississippi Valley has been found in the lower portion of the reddish series, and this fossiliferous zone is called the Rico formation. It has also been identified in the Animas drainage, but its presence has not been recognized in the Uncompahgre Valley.

The non-fossiliferous portion of the reddish beds, which rests upon the Rico formation, and which is limited above by unconformable Triassic strata, has been called the Cutler formation. The name Dolores has been given to the Triassic portion, which is distinguished from underlying beds not only by fossil evidence, but also by an unconformity.

Above the red Triassic beds come other formations that are correlated in general with the fresh-water Jurassic of other parts of Colorado, and above these comes the upper Cretaceous, from the Dakota to the uppermost coal-bearing member, the Laramie. Below Durango the post-Laramie formation, made up of eruptive rock débris and known as the "Animas beds," rests upon the Laramie, and is in turn overlain by the Puerco and higher Eocene deposits.

Structurally, the most striking feature in the present attitude of the formations described, from the base of the Paleozoic upward, is their general southerly or westerly dip away from a point in the west-central part of the San Juan Mountains. As seen in the section of the Animas Valley, all of these formations appear to be conformable. None of the various unconformities by overlap, represented upon the Hayden map as occurring in the area between the Animas and San Miguel rivers, exist within that territory. But two great orogenic disturbances, not indicated in the Animas section, are clearly shown on the northern slopes of the San Juan, and possibly one of them also on the southern side, not far east of the Animas River. A pronounced unconformity exists between the Dolores and older beds in the Uncompahgre Valley, while the Dolores itself and all older sediments are wanting in the plateau traversed by the Gunnison and its southern tributaries east of the Uncompahgre River, and the granites and gneisses are overlain by the probable equivalent of the La Plata sandstone, of assumed Jurassic age. A similar condition exists east of the Animas, in the drainage of Los Pinos and Piedra rivers, according to the Hayden map, but reconnaissance observations by A. C. Spencer in the Piedra Valley show that pre-volcanic faulting may be the cause of the irregular relations in this district.

Other periods of uplift, erosion, or subsidence, in Paleozoic or Mesozoic time, are indicated by the apparent absence, or slight development, of Cambrian, Ordovician, and Silurian sediments, the presence of remnants of the Mississippian beds, the local development of the fossiliferous Triassic, and the absence of the marine Jurassic and of recognized equivalents of the great lower Cretaceous section of Texas.

The geologic structure and constitution of the San Juan Mountains of to-day are mainly the result of dynamic forces which were intensely active during three great epochs of Tertiary time. With the first of these epochs the long cycle of upper Cretaceous sedimentation was terminated by a continental uplift which was of unknown extent, but which may have been very great. To what extent the Cretaceous sea covered the San Juan Mountain area is not yet known, but the sediments of that sea are now exposed, dipping at generally low angles away from the mountains, on the northern, western, and southern sides. In the Telluride and Silverton quadrangles is evidence, to be cited more fully further on, that the erosion of the epoch under discussion produced a plain of moderate relief across the oblique edges of the entire series of Mesozoic and Paleozoic formations. This plain seems to have bordered a higher land mass in the heart of the San Juan Mountain area, and to have extended a considerable distance—how far, must ever remain a matter of hypothesis—to the north, west, and south. Upon this nearly plane surface, in the region where it is now exposed, the sandstones and conglomerates of the

Telluride formation were deposited and had already attained a thickness of several hundred feet when the great epoch of volcanic activity began, producing the complex of rocks out of which the present San Juan Mountains have been sculptured. From exposures in the Telluride quadrangle it was inferred that the earliest volcanic tuffs were water-laid deposits in the Telluride lake, but from the relations seen in the Silverton quadrangle it appears probable that the Telluride conglomerate is in part at least a fluviatile formation and that there was, locally, valley erosion below the plane of that conglomerate before the volcanic cycle opened.

The volcanoes and fissure conduits of the San Juan, assisted, perhaps, by vents in adjacent regions, emitted an enormous amount of volcanic material, partly in fragmental form and partly in lava flows, and this material covers an area of certainly not less than 15,000 square miles to a depth of many thousand feet in the central portion.

The lowest member of the volcanic complex thus far discovered is a bedded tuff of andesitic rocks that reaches 2500 feet in observed thickness, called the San Juan tuff. Its source is unknown. From the relations exposed in the Silverton quadrangle, it is certain that the San Juan tuff was in some places entirely removed by erosion before the eruptions of the next great volcanic epoch.

Succeeding the San Juan epoch came a time in which rhyolitic and andesitic magmas, together with others of intermediate composition, alternated, and built up the Silverton series of flows and tuffs to an aggregate thickness of 4000 feet or more. Above them comes the Potosi series, consisting predominantly of rhyolitic material, and observed to have a thickness of more than 1000 feet. During the Silverton epoch, and after it, there were intervals of great erosion.

The three series of lavas mentioned make up the greater part of the western San Juan Mountains. East of the Silverton quadrangle they have greatly diminished thickness, and disappear under other lavas of various kinds not yet fully investigated, but known to include rhyolite, andesite, and basalt.

The sources of most of the San Juan lavas are unknown, but the Silverton series were in part poured out through fissure channels now identifiable on account of the dike masses which fill them. The bedded series are penetrated by several massive bodies of often coarsely granular rocks, such as gabbro, diorite, and monzonite, and it now seems probable that the intrusive bodies of diorite-porphyry and the allied varieties found in the sedimentary beds adjacent to the San Juan Mountains on the west are also of later date than many of the surface lavas.

The volcanic eruptions in the San Juan area probably continued at intervals until late in Tertiary time, although only the products of the earlier outbursts are well known. Thus the volcanic period of building-up was in part synchronous with the third great period already referred to—that of sculpturing by erosion—by which the mountains now existing have been produced. Within the volcanic area little evidence has been discovered by which the sequence of events can be correlated with the established divisions of Tertiary time. Deposits of Eocene age are known in the zone bordering the volcanic area, but they have not been found in direct contact with the lavas. Certain calcareous tuffs of the Silverton quadrangle contain scanty plant and invertebrate remains indicating that they were formed in Oligocene or early Miocene times. While it may be safely assumed that the closer study of the San Juan will result in the recognition of different epochs of eruptive activity and of orogenic disturbance, the Tertiary history of this region may be summarized as a conflict between volcanic forces that built a plateau by stupendous emissions of lava and agencies of erosion that removed the igneous material and carved deep canyons to the very base of the vast lava plateau. The volcanic forces were most effective in the earlier periods, nearly the entire thickness of 5000 feet of volcanic rocks found in the western San Juan being of that epoch, while the agents of degradation are still actively at work upon the higher mountain masses.

Quantitatively, the work performed by the geologic agencies acting in this region in Cenozoic time was very great, but the estimation of the post-Cretaceous disturbance, as well as the general deciphering of all earlier geological history, has been rendered very difficult by the mantle of volcanic rocks; and the original extent of this covering is left to speculation on account of the more recent erosion. The detailed examinations now in progress have thrown much light on these great problems. Thus, the Telluride conglomerate becomes of first importance in their solution, since its base presents the best evidence as to the post-Cretaceous erosion and its top forms the surface upon which the volcanics rested in the western part of the district.

The present elevation of this entire region above sea level is to be regarded as the result of numerous oscillatory movements of uplift or subsidence which have taken place since the close of the Cretaceous, affecting greater or smaller areas. A slight tilting of the Telluride formation in an easterly direction may be connected with the uplift of the extreme western San Juan region, leading to the great erosion which has caused such an abrupt face to the mountains in and about the Telluride quadrangle. The complex fault system existing in the Silverton quadrangle, which traverses all volcanic rocks in its path, is further evidence of Tertiary movements.

The survey of the Silverton quadrangle was carried on during portions of the field seasons of 1898, 1899, 1900, and 1901, under immediate charge of Whitman Cross. During the first two seasons A. C. Spencer was regular assistant, while Ernest Howe served in that capacity for the remainder of the field work and in the preparation of the folio. Messrs. R. D. George, G. W. Stose, and J. Morgan Clements have rendered valuable aid as temporary assistants during portions of various seasons. The economic resources of the quadrangle were investigated by F. L. Ransome during the season of 1899 and 1900, and a detailed report on them was made in Bulletin No. 182.

The topographic base map available at the commencement of the survey was found so inadequate for the expression of the geology that a partial revision was undertaken. This proved the necessity for a complete revision, which could not be used by the geologist until late in 1901. For this reason many of the boundaries between formations, on the maps of this folio, are known to be inaccurate in detail, since they have been adjusted to maps which were not in hand during field work.

GEOGRAPHY AND TOPOGRAPHY.

Geographic position of quadrangle.—The Silverton quadrangle is situated in the southwestern part of Colorado and is bounded by parallels 37° 45′ and 38° N. and meridians 107° 30′ and 107° 45′ W., and has an area of 235.66 square miles. The quadrangle lies mainly within San Juan County, but includes parts of Hinsdale, Ouray, and San Miguel counties also. Its position and its relation to other areas which have been already surveyed are shown in the index map on the cover of this folio. The Lake Fork of the Gunnison, the Animas and Uncompahgre rivers, and the Rio Grande have their sources in the high mountains of the Silverton quadrangle, and the waters of all but the Rio Grande belong to the drainage system of the Colorado River. The quadrangle is in the western and most rugged portion of the San Juan Mountains, which in the Telluride quadrangle, to the west, end abruptly and give place to high plateaus that extend into Utah. To the north are many high peaks which naturally belong to this mountain group; to the south rise the sharp pinnacles of the Needle Mountains; while to the east lies the main part of the San Juan group.

Topographic features.—The entire quadrangle, it may be said, has a rugged, mountainous character. The average elevation is very high—about 11,500 feet. The highest point (14,008 feet) is Handies Peak, and the lowest (a little below 8200 feet) is in the canyon of the Uncompahgre River. Across the extreme southeast corner runs the Continental Divide, separating the waters of the Rio Grande from those of the Colorado drainage. The topographic features are those characteristic of a thoroughly dissected plateau whose forms have been more or less modified by subsequent ice erosion. The larger valleys are U-shaped as a rule. They are often precipitous near the valley bottoms and have gentle slopes above. Many of the peaks have well-rounded summits and relatively smooth, graded flanks; others are flat-topped, being capped by remnants of old lava flows, and of these Potosi Peak is a typical example. Characteristic of the whole region are glacial cirques or amphitheaters, which are found at the sources of almost all streams. Many of these are well brought out on the topographic map, or are shown in the illustrations.

Drainage.—The largest stream is the Animas River, which rises in the northeast corner of the quadrangle and flows southward, first through a narrow canyon, and then over the flood plain of a broader valley until it comes to Bakers Park, where it is joined by Cement and Mineral creeks. Below Bakers Park it plunges into the gorge of the Animas Canyon, in which it traverses the Needle Mountains. Flowing north from the divide at the headwaters of the Animas and its tributaries are the streams that unite to form the Uncompahgre River, which leaves the quadrangle on its way to the Gunnison through a deep, narrow canyon of singular beauty and grandeur. Near the northern and eastern boundaries of the quadrangle rise other tributaries of the Gunnison, the Lake Fork and Henson Creek, which join at Lake City, while in the southeastern corner of the area, under Canby Mountain, are the beginnings of the Rio Grande with its first important branch, Pole Creek. With the exception of the streams flowing from Ingram and Savage basins, which belong to the San Miguel drainage, all waters rising along the western boundary are feeders of the Animas or Uncompahgre rivers.

Forest growth and timber line.—The average altitude of the quadrangle is about 11,500 feet, and in consequence a very large part of the region is above timber line, which varies from 11,500 to 12,000 feet above sea level. Below 11,500 feet there is always a luxuriant growth of spruce, fir, and aspen, and at almost any elevation may be found alpine willows or alders. The pine, so common at lower levels to the north and south, is found nowhere within the limits of the quadrangle.

Culture.—The largest town in the quadrangle is Silverton, situated on the broad flood plain of Bakers Park, near the junction of the Animas River, Mineral Creek, and Cement Creek. It is the principal commercial center of the district and is the terminus of the Durango division of the Denver and Rio Grande Railroad. Branch railroads connect the town with Red Mountain, Eureka, and Gladstone, local mining centers and shipping points for the various mines. Excellent roads or trails lead into elevated basins and over high divides to all parts of the quadrangle. Probably no other high mountain district of Colorado of equally rugged character has been so thoroughly prospected by the miner and rendered so easy of access as the Silverton quadrangle.

DESCRIPTIVE GEOLOGY.

THE ROCK FORMATIONS.

METAMORPHIC ROCKS.

ARCHEAN SYSTEM.

SCHISTS AND GNEISSES.

Occurrence and structure.—Schists of supposed Archean age form the walls of the canyon of the Animas River from the monzonite stock below Silverton to a line a short distance beyond the southern boundary of the quadrangle, at Whitehead Creek, where they come in fault contact with Algonkian quartzites. They are exposed in an irregular area that extends from the canyon eastward, from which the volcanics have been removed by erosion, and in Cunningham Gulch down nearly to Stony Creek, as shown by the map. The rocks are all strongly foliated and also have a banded appearance, which is often due to the alternation of dark and light constituents. The schistosity, which seems to correspond with the banded arrangement of mineral particles, has within this area a northeast-southwest strike and a nearly vertical attitude, except in the lower part of the Animas Canyon, where the dip flattens out and the schistosity becomes almost horizontal. This schist section, while varying in petrographic detail from place to place, possesses no clearly marked divisions which it is practicable or desirable to recognize as cartographic units. The schists are cut by bosses of granite and their apophyses, as well as by numerous basic dikes. These intrusives are undoubtedly older than the first Paleozoic sediments, but may be younger than the great Algonkian series of the adjacent Needle Mountains.

Description of the schists.—The crystalline schists of this region vary in texture and in mineral constitution. The majority are dark colored, but some are light gray, or almost white. Even the commonly striking characteristic of schistosity is by no means uniform, some rocks being finely schistose, while others have been crushed and crumpled and might be described as coarse gneisses. Quartz and feldspar are present in almost all of the schists, usually in amount equal to or greater than the dark silicates, although the latter strongly predominate in dark-colored bands throughout the section. In certain schists quartz is of secondary origin. The feldspar is mainly orthoclase, but is in some cases albite, or possibly andesine. The common development of quartz and the feldspars in a fine mosaic makes it very difficult to estimate their relative amounts and to determine with any degree of accuracy the kind of feldspar.

The dark silicates are represented by biotite and pleochroic green hornblende or actinolite, seldom entirely fresh; biotite is generally more abundant than hornblende, but certain bands consist mainly of amphibole. Muscovite is not very common as an original mineral, but as an alteration product of biotite and the feldspars it is quite abundant. The darker minerals appear in blades or irregularly bounded particles in the quartz-feldspar mosaic.

Garnet is a very striking constituent in certain zones. East of the Molas mine a few bands in the hornblendic schist are extremely rich in large red garnets which are without crystal boundaries, and are either shattered or exceedingly strained, so that they crumble when removed from the matrix. Some of these garnets are an inch or more in diameter, and the schistosity of the inclosing rock seems to bend about them. Occurrences of this sort are rare, however, and the mineral is, when present, an accessory. At several places it was observed that the garnet, possibly almandite, has been wholly or in part altered to chlorite, the alteration taking place along cracks and fissures in the usual manner. Magnetite is a much more widely distributed accessory than garnet, though its presence is noted only under the microscope. Apatite, which is rare, occurs in minute crystals included in feldspar or hornblende. Hematite and zoisite are often present, but are probably alteration products. Chlorite is the most prominent secondary mineral in the schist, being found in almost all rocks in flakes or irregular patches derived from hornblende or biotite; that resulting from the alteration of garnet is fibrous. Zoisite, epidote, and muscovite are not uncommon alteration products in the feldspathic and hornblendic schists; in a few cases calcite occurs in crystalline grains.

Most of the schists have a medium, finely laminated banding, the individual bands averaging 1 millimeter in thickness and being rich in the light and dark silicates alternately. Sometimes there is no distinct banding, and in such cases there is an interlocking mesh of elongated mineral grains or aggregates whose greatest diameters are parallel. Rocks having this texture usually belong to the strongly amphibolitic schists and are ordinarily fine grained, but some are relatively coarse and are composed of equal amounts of light and dark silicates. In such rocks as these the ferromagnesian minerals are grouped together in small lenticular aggregates. The finest foliated rocks are usually the lighter colored ones, and are rather richer in muscovite than in dark micas or amphibole.

Evidence of great mashing or crushing is well shown when these rocks are examined under the microscope, and the parallel arrangement of mineral particles, so marked in hand specimens, is still more pronounced in the thin sections of the rocks. In many cases the strains have been so great that the original crystals have been completely granulated and appear as lenticular aggregates of minute grains of the same minerals. At other times a complete recrystallization of the minerals has taken place, and the resulting structure is that of elongated grains, generally without crystal boundaries, whose longest diameters lie in the same general direction. This elongation and parallelism is more marked in the micas and amphiboles than in the feldspars or quartz.

The crushing and recrystallization of these rocks have obliterated all traces of the characters of the original rock masses, so that it can not be determined whether they were sedimentary or igneous. Some of the amphibolitic schists resemble the mashed diabasic dikes that cut these rocks in various places, and it seems plausible to suppose that such schists are also derived from basic igneous masses. The feldspathic and quartzose schists may have been derived from either sediments or granitic rocks.

SEDIMENTARY FORMATIONS.

Subaqueous Deposits.

General statement.—The subaqueous formations of the Silverton quadrangle older than the volcanic series are exposed only where the volcanic rocks have been removed by erosion—mainly in the southern zone of the area. The formations revealed range from the Algonkian quartzites and slates to the Permian red beds. None of the formations is so well exposed as in the adjoining quadrangles, but several of them will here be distinguished for the first time as stratigraphic units.

The Algonkian system of the Uncompahgre Canyon is unquestionably the same as that of the Needle Mountains, although the two areas were separated by erosion following enormous folding before the deposition of the lowest Paleozoic beds.

In striking contrast with the Algonkian, as well as with the Pennsylvanian and later formations, the earliest sediments of the Paleozoic in this region are thin. Paleozoic beds below the Carboniferous aggregate not more than 400 to 600 feet in thickness, and in them no planes marking stratigraphic breaks are evident, though such breaks are known to be present. On lithologic grounds, however, there are within these pre-Carboniferous sediments three practicable divisions which correspond with the divisions indicated by the evidence of the stratigraphy and of the fossils so far as now known. At the base are quartzites, at the top limestone, and between them is a series of calcareous shales characterized by pseudomorphous casts of salt crystals. The limestones above the "Salt shales" carry a well-defined Devonian invertebrate fauna from their base nearly to their top. A single Cambrian shell has been found in the lower quartzites, and the "Salt shales," which are usually barren of fossils, have yielded a few fish remains of upper Devonian types. The three lithologic units are here distinguished and named as separate formations. Below the "Salt shales" there must be a great stratigraphic break which the commonly observed stratigraphic relations do not suggest where the three units are all present. It is known, however, that the Cambrian quartzite is absent in the Uncompahgre Valley and in the area east of the Needle Mountains.

The limestone member of the section referred to has been found to contain Mississippian fossils in its upper portion in a few places. A stratigraphic break occurs above this horizon in the section. The lower strata of the upper Pennsylvanian, which possess distinctive lithologic characters and contain the record of the destruction of older sediments, are distinguished as a separate formation. The remainder of the prevolcanic sedimentary complex consists of the Hermosa, Rico, and Cutler formations, which have been described in detail in other publications.

The Tertiary lavas of the region are underlain by the well-stratified San Juan tuffs and a still older conglomerate which in the Telluride folio was called the San Miguel formation. A change in the latter name is necessary, since it is found to have been preoccupied for a Cretaceous formation in Texas. In this folio the formation is called the Telluride conglomerate.

ALGONKIAN SYSTEM.

UNCOMPAHGRE FORMATION.

The existence in the San Juan region of a great section of quartzites and slates or shales older than the lowest known Paleozoic beds, occurring on the south side in the Needle Mountains and on the north in the Uncompahgre Canyon, has long been known. The series has been described by Endlich, Emmons, and Van Hise. Similar rocks in the heart of the domal uplift of the Rico Mountains have been referred to the same great formation by Cross and Spencer (Twenty-first Ann. Rept. U. S. Geol. Survey, pt. 2, 1900, pp. 37–41). For convenience in future discussions of this complex of quartzites and slates, assumed to belong to the Algonkian system, it is proposed to call them the Uncompahgre formation. They are particularly well exposed in the canyon of that name in the Silverton and Ouray quadrangles.

Occurrence.—The exposures of the Algonkian rocks in the Silverton quadrangle embrace a part of the great section in the Uncompahgre Canyon and a small, isolated outcrop on the eastern side of Ironton Park. The section in the canyon of the Uncompahgre extends from the line, shown on the areal geology map, at which it passes beneath the San Juan tuffs, for 4 miles northward to the border of the town of Ouray, where it is overlain by the lowest Paleozoic beds. In this distance the strata vary in attitude from the vertical, near Ouray, to dips of less than 30°, near their southern limit. The stream cuts obliquely across the strike, and has carved a rugged canyon, in some places a thousand feet or more in depth, into these hard rocks. The stage road from Ouray to Red Mountain affords a fine opportunity to examine the section in detail.

The only other occurrence of the Uncompahgre beds within the Silverton quadrangle is on the eastern side of Ironton Park, at the mouths of Albany and Brooklyn gulches, but little more than a mile from the main area in Red Mountain Creek, and only about 350 feet higher than the nearest outcrops on that stream. The reappearance of the formation is doubtless due to the irregular surface upon which the Telluride conglomerate and the San Juan tuffs were deposited, details of which may be seen along the eastern side of the Uncompahgre Valley, as represented to some extent upon the map. The quartzites probably approach very near to the surface in the interval between the Ironton Park outcrops and the main area, where they are overlain by limestone referred to the Ouray formation of the Devonian. Details concerning this locality are given under the heading "Areal geology."

Structure.—The apparent base of the exposed Uncompahgre section is near its southern border, according to the structure to be described. Within the area of outcrop of the quartzite-slate series there is an elongated domal uplift, represented on the map by strike and dip symbols, the crest of which is in the angle between Red Mountain Creek and the Uncompahgre. Northward to Ouray the structure of the beds exposed develops into a series of steeply dipping beds which have a general northwest-southeast strike, and in which only minor irregularities in folding have been observed. Unless there is a gigantic overturn, of which the limited exposures afford no evidence, the base of this section of the Uncompahgre formation is beneath the dome on the southern border and the top is near Ouray. Observations have not yet been made in the Ouray quadrangle except along the canyon line, but the rocks are limited to a narrow belt on either side.

The Uncompahgre quartzites of Ironton Park are so massive that their structure has not been determined.

The structural relations of the Algonkian section in the Uncompahgre Valley to that of the Needle Mountains can not now be ascertained. These areas are 14 miles apart, and between them occur the older schists or the Tertiary volcanics.

Character.—The Uncompahgre formation is composed of quartzites and slates in beds of varying thickness. Certain zones are nearly pure quartzites, others are distinctly slates, while in still others there is an alternation of the two rocks in comparatively thin strata. On the whole quartzite is largely in excess over slate.

The quartzites are generally compact, fine grained, and well bedded. Rarely, certain members are so massive that no evidence of bedding can be distinguished in a thickness of 30 or 40 feet. More commonly thin partings of shale mark bedding planes, even of quite massive quartzites. Cross-bedding and ripple-marking are often very distinct.

In many quartzite strata small pebbles or gravel-like particles of quartz are present. They are rarely more than 1 centimeter in diameter, and are not abundant enough to make a true conglomerate.

The quartzites are often nearly white, with many shades of gray, and not infrequently pink colors appear. Specular hematite in scales is present in some places.

The original shales of this complex are now dark slaty beds, hard, and probably somewhat silicified. They show by their crumpling or schistosity evidence of great pressure by differential movements of the inclosing more massive rocks. Imperfect chiastolite crystals have developed in rare instances.

An incipient schistosity is caused by the development of secondary micas in fine blades or needles that have their longest diameters parallel. There is no observed indication that the quartzites have undergone dynamic metamorphism except in a few cases where the microscope has revealed a system of fine parallel fractures passing through the rounded quartz grains and filled with some secondary mica.

The section exposed in the Uncompahgre Canyon has an estimated thickness of over 8000 feet, and no evidence of repetition by faulting or infolding has been discovered, although some minor dislocations have been observed.

CAMBRIAN SYSTEM.

IGNACIO QUARTZITE.

Name and definition.—The lowest lithologic division of the Paleozoic section in the Animas Valley is made up of quartzites, and varies in thickness, in the area thus far examined, from a few feet to 200 feet. In layers near the middle of these quartzites a single generically determinable shell has been found. From the stratigraphic relations and the evidence of this fossil it is assumed that in this region the Cambrian system is represented only by a thin series of quartzites belonging probably to its upper division, and for those the name Ignacio formation or quartzite is proposed, from the lakes in the Animas Valley about 18 miles west of south from Silverton, near which the formation is well exposed. It is at present believed that all of the Paleozoic quartzites beneath the "Salt shales" belong to the Ignacio.

Lithologic character.—The Ignacio consists of nearly pure siliceous strata, with some feldspar locally in the lowest beds. The greater part is fine grained, white, gray, or pinkish, and highly indurated. The lower portion is commonly a massive quartzite of prevalent pink or reddish color, while the succeeding strata are nearly white. Distinct bedding is common, as is an irregular jointing. Above this the strata are often wavy in bedding, with shale partings, in which mud cracks, trails, and other markings are common. These layers are friable sandstones in places. More massive quartzite layers generally succeed this series, but not in a thickness equal to those below.

At the very base of the formation a true basal conglomerate is often found, but only in hollows of the granite, schist, or Algonkian quartzite floor. The hard Algonkian quartzites are most abundant among the pebbles, which range in size up to a diameter of (rarely) 1 foot.

Fossils.—The only identifiable fossil invertebrate yet obtained from the Ignacio beds was found on a remnant capping Overlook Point, one of the hills of Mountain View Crest, in the Needle Mountains quadrangle, south of Needle Creek. Specimens of this fossil were found scattered through a hard, dark quartzite above the middle of the formation, which was there 110 feet thick. Mr. Walcott identifies this shell as an *Obolus*, but is unable, from the material at hand, to determine its species. Three forms that are much like this are *Obolus matinalis*, *O. tetonensis*, and *O. loperi*, the latter occurring in the passage beds between the Cambrian and the Ordovician in the Crested Butte quadrangle, Colorado. Since the Cambrian is known in Colorado only in thin representatives of the upper division, it seems best to assume for the present that the Ignacio quartzite also belongs in that series.

A common apparent fossil of the Ignacio is thought by Mr. Walcott to be *Cruziana*, a problematic plant remain.

Occurrence.—The Ignacio quartzite is about 50 feet thick in the Animas Canyon region of the Silverton quadrangle. It is most conspicuous on the west side of the river, its hard beds often presenting ledge or bench forms between the schists and the Ouray limestone. East of the river it is not so well exposed, but it extends up to the volcanic rocks on the divide north of Whitehead Creek. Apparently this formation is absent in the fault block of Cunningham Gulch, in Ironton Park, and about Ouray.

DEVONIAN SYSTEM.

ELBERT FORMATION.

Name and definition.—The name Elbert formation has been proposed by Cross (Am. Jour. Sci., 4th ser., vol. 18, 1904, pp. 245–252) for a series of thin shales, quartzites, and limestones, aggregating not more than 100 feet in thickness so far as known, commonly occurring above the quartzites referred to the Ignacio formation and below the Ouray limestone. Fragmentary fish remains of upper Devonian types are found locally at the base and near the top of the formation. An important stratigraphic break occurs below the Elbert formation, as is shown in some localities by the absence of the Ignacio quartzite.

The name is derived from Elbert Creek, a western tributary of the Animas River, entering it at Rockwood. The creek drains the Ignacio lakes and flows for several miles along a bench between the Animas Canyon and the high escarpment of the Hermosa Carboniferous, on which all the lower Paleozoic formations are well exposed.

Lithologic character.—The formation is mainly composed of calcareous shales and thin sandy limestones that vary in details of development from place to place. The beds are drab, buff, or yellowish in color. The shaly layers break up readily on exposure, so that outcrops are obscured by the resulting scales and thin plates. Quartzites are present, but are always very thin and subordinate to the calcareous and shaly portion.

The shaly beds are in many places characterized by pseudomorphous casts after salt crystals. They occur, as noted by Endlich, on the under side of slabs, as is natural considering their origin. The crystals of salt, it must be supposed, formed on or near the surface of the mud of a desiccating body of salt water, and were dissolved by influx of fresh water, and the crystal space was filled by sand or mud of a new deposit. The crystals are usually more or less clearly skeleton cubes with sunken faces. Some of them are as much as an inch or more in diameter. So abundant are these casts that they may be found at nearly every outcrop, but they are larger and much more perfect in some localities than in others.

Fossils.—In describing the first observed occurrence of the "Salt shales" Endlich remarks that: "Besides these pseudomorphs [after salt], scales and fragments of bones are found, belonging to some fish of considerable size. Too little material could be collected to admit of any identification, even only generically. Small scutella also occur, probably belonging to the same animal." The locality at which Endlich found these bone or scale fragments, on the south slope of the Needle Mountains, was revisited and collections were made there. These fossils and a few from other localities have been described by C. R. Eastman and pronounced to represent a characteristic upper Devonian fauna, of which *Bothriolepis* is the most prominent form (Am. Jour. Sci., 4th ser., vol. 18, 1904, pp. 253–260).

Fish remains have also been found in the course of the present work, on a slab of quartzite in a talus pile near the limestone quarries south of Rockwood. The talus occurs below a bench where the Elbert formation is in place, but the stratum from which the fossil-bearing slab came could not be identified. The remains are referred by Eastman to the genus *Bothriolepis*, the dominant form found at the other localities.

Distribution.—The Elbert shales are naturally inconspicuous as compared with the quartzite and limestone formations between which they occur. They are present, however, throughout the southern portion of the quadrangle, but seem to be wanting on the north. In Cunningham Gulch the formation appears below the Ouray limestone in nearly its maximum thickness, in the fault block shown by the map, while the Ignacio quartzite is wanting.

OURAY LIMESTONE.

Name and definition.—The presence of Devonian strata in southwestern Colorado was first recognized, through collections of fossils made by F. M. Endlich, of the Hayden survey, on the southern slopes of the Needle Mountains, in 1874. The name Ouray limestone was proposed by A. C. Spencer, in 1900 (Am. Jour. Sci., 4th ser., vol. 9, 1900, pp. 125–133), after the strata had been reexamined in connection with the United States Geological Survey work; it is derived from the town of Ouray, on the southern border of which is a prominent outcrop of the limestone.

The name was proposed by Spencer for the Devonian limestone member, excluding the quartzites and shales here called the Ignacio and Elbert formations, although they were then thought to be possibly of Devonian age. It was supposed by Spencer that the whole limestone complex in question must be of Devonian age, but, as will be shown, it is known that an indefinite but subordinate part of the most prominent limestone ledge of the Ouray is Lower Carboniferous. Since it is impossible to draw a line between the two portions, the Ouray becomes a lithologic unit transgressing the formal boundary between the Devonian and Carboniferous systems.

General lithologic character.—The Ouray formation, as at present known, has a thickness varying from 100 to 300 feet. The upper and major part of the formation is massive limestone, either in one bed or with such thin intercalated shales that the ability of the limestones to cause mesas, benches, and prominent cliffs as characteristic topographic forms is always notable. Below the more massive portion, a third or less of the section is made up of beds of limestone with distinct shaly layers and, rarely, thin quartzites between them. Some of the lower layers have a wavy bedding, some are arenaceous or earthy, and large chert concretions, free from fossils, are common at a horizon near the base. The lowest stratum is characterized usually by crinoid stems and rarely by a cup coral.

The greater part of the formation is dense, compact limestone, but portions of the upper ledge are coarsely crystalline. In general the rock is nearly white, straw-yellow, or buff, with local pinkish tones. Some of the lower beds are strongly yellow, and these are commonly more or less sandy. The contrast with the dark-gray, dense limestones of the Hermosa is marked, layers of such color and character occurring only near the base of the Ouray.

The Carboniferous portion of the Ouray is at present indistinguishable lithologically from the Devonian. Its existence was detected through the presence of Mississippian invertebrate fossils in the chert pebbles of the succeeding formations.

In the Silverton quadrangle the Ouray does not possess its normal thickness and it is probable that the Carboniferous portion has been entirely removed.

Fauna.—The Devonian invertebrate fauna of the Ouray occurs from near the base to a horizon which in many places is not far below the top of the upper, massive ledge. The greater number of species are found in this upper horizon, but many of them range to within a few feet of the base. Fossils have not been collected in the Silverton quadrangle, but have been obtained at Ouray and at several localities in the Needle Mountains, Engineer Mountain, and Durango quadrangles, as well as at the point where Endlich first found a few characteristic species, a short distance south of the Needle Mountains quadrangle.

The invertebrate fauna of the Devonian portion of the Ouray has been fully described by G. H. Girty (Twentieth Ann. Rept. U. S. Geol. Survey, pt. 2, 1900, pp. 25–63), and compared with similar faunas hitherto collected in Colorado, but not separated from lower Carboniferous.

Correlation.—The Devonian fauna of the Ouray limestone has been shown by Dr. Girty to be represented more or less fully in older collections from various parts of Colorado, notably in the Elk Mountains, at Glenwood Springs on Grand River, near the head of White River, and on East Monarch Mountain, Chaffee County. Full correlations of the sections in these localities with the section in the San Juan region will not be possible, however, until further examinations have been made. Dr. Girty says:

In general the Devonian fauna of the Ouray clearly belongs to upper Devonian time. It is but distantly related to the Devonian faunas of New York, and its relation with those of the Mississippi Valley, or even with other known western Devonian faunas, is not close. It shows many points of approximation to the Athabascan fauna described by Whiteaves, and is somewhat strikingly similar to the Devonian of Russia.

CARBONIFEROUS SYSTEM.

MISSISSIPPIAN SERIES.

UPPER PART OF OURAY LIMESTONE.

It is known that the Ouray limestone contains, in certain localities, a Mississippian fauna in its upper part, which is separated from the uppermost Devonian fossiliferous horizon by about 50 or 75 feet of massive limestone in which no fossils have thus far been discovered. The erosion in the interval following Mississippian sedimentation removed these strata completely over large areas. As neither the upper Devonian nor the basal Carboniferous horizon is everywhere fossiliferous, it is impossible to decide in many places whether the upper portion of the Ouray limestone ledge is Carboniferous or not.

From the great quantity of Carboniferous chert nodules in the succeeding formation it must be assumed that above the known horizons of the Ouray there once existed in this region a considerable thickness of chert-bearing limestone of Mississippian age. It seems not unlikely that somewhere on the slopes of the San Juan Mountains notable remnants of these beds may be found. In the Silverton quadrangle no evidence has been noted to show that any portion of the Ouray limestone belongs to the Mississippian series.

PENNSYLVANIAN SERIES.

MOLAS FORMATION.

Name and definition.—The name Molas formation is proposed in this folio for the lowest of the three Pennsylvanian formations distinguished in the Animas Valley and adjacent regions. The name is derived from Molas Lake, which lies on the bench at 10,500 feet, west of the Animas Canyon and just south of the Silverton quadrangle. The lake basin is partly excavated in the Molas beds and they are well exposed for some distance south of the lake.

The Molas formation is distinguished as a cartographic unit on lithologic grounds, being a well-characterized element in the Carboniferous section, and because it records, in certain peculiarities of its sediments, important events of the preceding interval of erosion, including the almost total destruction of a Mississippian formation. There may also be a further reason for separating the Molas and Hermosa formations in certain observed faunal differences, which are, however, as yet, not sufficiently established to warrant laying much stress upon them.

The Molas beds were not included in the original definition of the Hermosa formation by A. C. Spencer (Twenty-first Ann. Rept. U. S. Geol. Survey, pt. 2, 1900, p. 48), although the Hermosa was said to rest on the Ouray limestone. In the localities examined before that definition was formulated there was, in fact, a hiatus in the observations, the thin Molas beds being nowhere well exposed.

The Molas formation may be defined as a thin series of reddish calcareous shales and sandstones, with many pebbles of chert and some of limestone, quartzite, and other rocks, and with thin, fossiliferous limestone lenses, the fossils showing intimate relations to those of the lower Hermosa limestones. It occurs immediately below the Hermosa formation and rests upon a surface of erosion. It represents the earliest sediments of the Pennsylvanian in this region.

Lithologic character.—The Molas formation is specially characterized by its deep-red, friable, sandy strata, which are variably calcareous and often shaly. It is seldom very distinctly bedded and disintegrates so rapidly on weathering that good exposures are rare. In the lower part of the formation dark chert nodules abound, and often form a large part of flat lentils or discontinuous layers.

Fauna.—Many of the chert nodules carry a Mississippian invertebrate fauna. In the uppermost part of the formation some thin limestones, observed in a single locality in the Needle Mountains quadrangle, contain the fauna which is described in a succeeding paragraph and which is believed to characterize the Molas beds.

On Stag Mesa, on the southern slopes of the Needle Mountains, some thin, discontinuous limestone beds, rich in fossils, were found intercalated in red and highly ferruginous sands of the Molas and only a few feet below the characteristic limestone at the base of the Hermosa. At no other point have the fossils of the Molas been discovered. These fossils have been studied by G. H. Girty, who has made the following summary statement concerning them:

The fauna of the Molas formation, though at present imperfectly known, comprises representatives of the echinoids in *Archæocidaris triplex?*, of the Bryozoa in *Rhombopora lepidodendroides*, of the brachiopods in *Rhipidomella pecosi*, *Spirifer boonensis?*, and *Seminula subtilita*, and of the pelecypods in *Myalina perniformis?*. The *Rhombopora*, *Spirifer*, and *Seminula* occur also in the Hermosa formation, and in the case of the latter with the same varietal modifications and with equal abundance. Thus the Molas fauna is seen to be related to that of the Hermosa formation, but contains no species in common with the Ouray limestone. Some points of individuality distinguish the Molas fauna from that of the Hermosa, but it can not be conjectured how far this would be borne out by full collections.

Stratigraphic relations.—In the Silverton, Needle Mountains, Engineer Mountain, and Durango quadrangles the Molas formation rests upon a surface due to the erosion whereby the lower Carboniferous formation was almost completely removed. Although it has not been observed to lie upon any other formation than the Ouray limestone, the nature of the case permits the supposition that somewhere in the region adjacent to the San Juan Mountains it must transgress the lower Paleozoic formations and rest upon Algonkian quartzites, granite, or schist.

From the nature of the Molas beds they waste away rapidly on exposure. At the base of the high Hermosa escarpment on the west side of the Animas is a bench underlain by the Ouray limestone. The bench represents the Molas horizon. Red sandy outcrops occur here and there and chert nodules are often scattered about, but talus and other débris conceal the contact with the Hermosa.

The Molas and Hermosa seem to be thoroughly conformable, and probably the former is the product of the first epoch within the long period of upper Carboniferous sedimentation. The red color of its sediments and the other peculiarities mentioned characterize it.

Distribution.—The Molas formation is not well exposed in the Silverton quadrangle except near the southern boundary. It is present, however, in a thin band above the Ouray limestone, except on the east side of the Animas, where pre-Tertiary erosion removed it. It is present, also, in the fault block of Cunningham Gulch, at least on the east side.

The Molas is present at Ouray, but its general development on the northern side of the San Juan Mountains is at present unknown. A portion of the conglomerate about the Ouray limestone in the eastern side of Ironton Park probably belongs to the Molas, but the exposures are too small and too indefinite to be mapped.

HERMOSA FORMATION.

Name and definition.—The Hermosa formation was named and defined by A. C. Spencer in 1900 (Twenty-first Ann. Rept. U. S. Geol. Survey, pt. 2, 1900, p. 48). It includes the series of alternating limestones, shales, and sandstones, having a maximum thickness of 2000 feet, which occurs on the northern and southern flanks of the San Juan Mountains. It lies between the Molas and the Rico formations, the latter of Permo-Pennsylvanian age. An extensive invertebrate fauna, especially characterized by brachiopods, is found in the formation from bottom to top. This fauna is distinctly Pennsylvanian in character. The name is derived from Hermosa Creek, a tributary of the Animas River which traverses a large area of these rocks in the Engineer Mountain quadrangle.

Description.—The Hermosa presents a variable development of limestone, sandstone, and shale in different districts. Thus at Rico there is a fairly well-defined division into three sections, the lower consisting chiefly of sandstones and shales with but little limestone, the middle portion being rich in massive limestone beds, the upper containing mainly black and gray shales alternating with green grits, sandstones, and a few limestone layers.

In the Animas Valley, near the mouth of Hermosa Creek, the lower third of the complex is made up of green sandstones and shales with some gypsiferous shales, while the rest of the formation shows limestone layers distributed throughout. Along the great scarp facing the Animas which extends for 10 miles in the Engineer Mountain quadrangle, the limestones become more and more prominent and certain bands are very thick.

Near and within the Silverton quadrangle the formation is characterized by limestone layers distributed with comparative regularity from bottom to top, none of them exhibiting the thickness which is reached by some of the strata to the south.

The limestones are usually massive and are bluish gray in color, and commonly contain bituminous matter that gives off a distinct odor when the rock is struck by the hammer. Many layers are rich in fossils, while others appear to be destitute of them.

The sandstones are generally fine grained, gray or greenish, and consist largely of quartz, but are often rich in feldspar. They are massive or thin bedded, with shale partings. The cement is calcareous as a rule, and the green color is due to an amorphous substance, the character of which has not been determined.

The shales vary from greenish and sandy to dark, calcareous, bituminous varieties.

With all this variety in constitution the basal stratum of the Hermosa over the entire area examined is constant. It is a highly fossiliferous limestone, somewhat less than 15 feet in thickness. The uppermost strata are not so well known, but in the Rico Mountains they consist of fine-grained, micaceous, greenish, sandy shales, beneath which is a thin but persistent dark limestone filled with the minute shells of *Triticites secalicus* (formerly called *Fusulina cylindrica*).

Few members of the Hermosa complex reach a thickness of 100 feet, but thicknesses ranging from 10 to 50 feet are much more common. Individual strata change laterally both in character and in thickness. Under these conditions it has been found impracticable to subdivide the complex into smaller lithologic units for purposes of mapping. As will appear from the statements concerning the fauna, no division lines on that basis can be suggested.

Fauna and correlation.—The following description of the fauna of the Hermosa is given by G. H. Girty:

The fauna of the Hermosa formation is distinctly upper Carboniferous or Pennsylvanian in age. It contains such characteristic species as *Triticites secalicus*, *Meekella striaticostata*, *Chonetes mesolobus*, *Productus nebraskensis*, *Spirifer cameratus*, *Acanthopecten carboniferus*, *Allerisma terminale*.

If the formation be divided into three portions, especially as the division was carried out in the Rico region, the fauna of each is to a certain extent characteristic. That of the lower division consists almost altogether of brachiopods. In the middle division a number of gasteropods are introduced, while in the upper, in addition to brachiopods and gasteropods surviving from the middle division, a considerable force of pelecypods appears. The brachiopods remain nearly constant in number, but form a diminishing proportion of the entire fauna. The brachiopodous representation remains fairly uniform, though some changes occur in species and in abundance. The lower bed especially is often characterized by *Productus gallatinensis*, *Productus inflatus*, and a large variety of *Spirifer* of the *rockymontanus* type.

The fauna of the Hermosa formation occurs also in the Weber limestone and lower Maroon formation of the Crested Butte district, and in the Weber formation of the Tenmile and Leadville districts. From this fact and the similarity in stratigraphic occurrence a correlation of these formations appears to be justified. The Hermosan fauna represents early Pennsylvanian sedimentation, and is probably older than the upper Coal Measure faunas of the Kansas and Nebraska sections.

Distribution.—The Hermosa beds are prominent within the Silverton quadrangle only in the southwestern section. Here they are present in a thickness of nearly 2000 feet on the southern slopes of the mountains capped by the San Juan tuffs. Along the eastern face of the Grand Turk and Sultan Mountain the thickness decreases northward from the angular unconformity at the base of the Telluride conglomerate to the contact of the monzonite stock.

On the east side of the Animas only a small remnant of the Hermosa remains south of Deer Park Gulch. In Ironton Park the exposures of grits on the western side are referred to the Hermosa formation. These show the westerly dip, which is normal to the Paleozoic section on the western flank of the San Juan.

On the western side of the Uncompahgre Canyon the lowest Hermosa beds are exposed for about 1 mile from the Ouray quadrangle line, where they are cut out by the volcanics that rest on the pre-Tertiary erosion surface. They have the northerly dip of the general section.

RICO FORMATION.

The formation succeeding the Hermosa in the normal section of the San Juan region was first identified in the Rico Mountains and was named and described by A. C. Spencer in the report on that area already cited. It is a thin formation, not easily identified in regions of poor exposures, and although its actual presence in the Silverton quadrangle and in the adjacent parts of the neighboring quadrangles has been demonstrated by Mr. Spencer through the finding of a few fossils, it was not possible to trace it or define its thickness. It is assumed, from the existence of fossils, that the formation is present in a narrow band between the Hermosa and Dolores formations, as shown by the map. Until the section of the Animas Valley lying farther south has been carefully examined a description of the Rico formation in its probable development in the Silverton quadrangle can not be given. A brief sketch, mainly in the language of Mr. Spencer, of its character in the Rico Mountains must, therefore, suffice.

The Rico formation, in the mountains from which it derives its name, is a series of sandstones and conglomerates with intercalated shales and sandy fossiliferous limestones, about 300 feet in total thickness. Lithologically it resembles the "Red Bed" complex above it more than the Hermosa below, but its fossils are clearly of Carboniferous type, and are related to those of the Hermosa. The general characteristics of the formation near Rico are, first, its calcareous nature, in which it resembles the strata above and below; second, the arkose character and the coarseness of its sandstones, in which respect it differs from the Hermosa and resembles the Dolores; and, third, its chocolate or dark-maroon color, which contrasts sharply with the gray or green of the Hermosa and which is more or less distinct from the bright vermilion of the Dolores. The color distinction was found to be insufficient for mapping purposes, even in the restricted area of the Rico Mountains.

PERMIAN (?) SERIES.

CUTLER FORMATION.

Name and definition.—The sandstones, grits, conglomerates, shales, and calcareous beds, mainly of reddish color, occurring between the Rico beds and the Triassic Dolores strata are here for the first time distinguished as a formation. The beds in question form the greater part of the well-known "Red Beds" section of the region, and have been hitherto provisionally included in the Dolores formation. In the Telluride and La Plata folios and in other publications the Dolores has been consistently defined as including the Triassic strata of southwestern Colorado, with the statement that fossils demanding a reference to the Triassic had been found only in the upper part of the "Red Beds" section. On the western and southern slopes of the San Juan Mountains no stratigraphic break in the "Red Beds" has been found, but the field work of 1904 in the Ouray quadrangle, on the northern side of the mountains, has revealed a notable angular unconformity occurring immediately below the most commonly fossiliferous bed of the Dolores formation. Through this unconformity the Dolores strata may be seen to transgress more than 1000 feet of older "Red Beds" and several hundred feet of the Rico and Hermosa formations, the full extent of the unconformity being obscured by erosion.

In view of these facts the strata between the Rico beds and the base of the Triassic have been distinguished as a formation and named from Cutler Creek, which enters the Uncompahgre River from the east about 4 miles north of Ouray, and along which a considerable part of the section is well exposed. As the Cutler beds are conformable with the underlying Hermosa and Rico strata, they are provisionally referred to the Permian series. The Cutler formation may belong, however, wholly or in part, to the Pennsylvanian series, the stratigraphic break above them being in that case much greater than the observed field relations indicate. No fossils have been found in the Cutler beds.

The name Dolores will continue to be applied to the Triassic strata as originally defined, embracing the fossiliferous conglomerate and overlying beds up to the La Plata sandstone, of Jurassic age.

Description.—The Cutler formation is a complex of sandstones, grits, and conglomerates, alternating with sandy shales and earthy or sandy limestones. The greater part of the formation has a bright vermilion-red color, but there are some pale-red or pinkish grits and conglomerates. A calcareous cement characterizes nearly all the strata. Individual beds of uniform character are seldom more than 25 feet thick, and the formation shows great lateral variation in composition and thickness.

Distribution.—The Cutler formation occupies the southwestern corner of the Silverton quadrangle, lying beneath the Telluride conglomerate. It also appears in the South Fork of Mineral Creek. Its southwesterly dip brings it against the Telluride conglomerate with angular unconformity, and the full thickness of the formation is not represented in the quadrangle, although the overlying Triassic strata occur at a short distance to the west and southwest, in the Telluride and Engineer Mountain quadrangles, respectively. The "Red Beds" of the Cutler formation are very prominent in the Animas Valley to the south, and they also occupy large areas in the Rico, La Plata, and other quadrangles of the southern and western slopes of the San Juan Mountains, while in the valley of the Uncompahgre River in the Ouray quadrangle to the north their unconformable relation to the Dolores is best shown.

TERTIARY SYSTEM.

TELLURIDE CONGLOMERATE.

Name and definition.—The Telluride conglomerate is a well-marked formation which underlies the San Juan tuff and was formed in the period immediately preceding the beginning of the long succession of volcanic eruptions in this region. It includes the sediments first deposited after the erosion that developed the peneplain on which it rests. It was first identified in the Telluride quadrangle, where it is finely developed and revealed for examination, and it is now renamed after the town of Telluride since the term San Miguel, under which it was originally described, was preoccupied for a Cretaceous formation in Texas.

Description.—The Telluride formation varies greatly in texture and thickness, ranging from a thin, coarse conglomerate in the Silverton quadrangle to a complex of fine-grained conglomerates, sandstones, and shales about 1000 feet in thickness as developed in Mount Wilson, on the western border of the Telluride area. Nearly all stages of this change can be studied in the distance of 17 miles between the eastern ledges of Grand Turk and the exposures on Mount Wilson. The formation is described in detail in the Telluride folio. It is made up of detritus of schist, granite, Algonkian quartzite, and slate, and lesser amounts of the harder sediments of the Paleozoic formations, in particular of limestone. In the coarse conglomerate of the southwest section of the Silverton quadrangle and adjacent portions of the Telluride, the lower half of the formation is rich in limestone and contains some red sandstone, while such materials become scarcer in the upper layers. This clearly expresses the change in character of the rocks exposed in the mountain area furnishing the débris as erosion removed the sedimentary shell covering the schists and granites. The lowest layers of the Telluride contained fragments of the formation immediately below, and these range from the schists to the Cretaceous shales underlying it in Mount Wilson. The bowlders of the conglomerate often exceed a foot in diameter, but are generally only a few inches. Many are well rounded, but subangular fragments are common, especially of the local material which has not been transported far.

The isolated exposures of the conglomerate found east of the Animas River and in the Uncompahgre Valley are naturally made up of local material.

Stratigraphic relations and distribution.—As stated in the definition, the Telluride formation conformably underlies the San Juan tuffs. While no volcanic matter appears in the Telluride proper, there is a zone of transition in some places, the pebbles of quartzite or schist being scattered through a few feet of the tuff and sporadically for a hundred feet or more. But in general the line is sharply defined by a sudden change in materials. The impression is that the mechanical process of deposition was practically continuous, but that there was a sudden change in the nature of the débris after the outburst which began the great volcanic period.

The thoroughly unconformable relations of the Telluride with all underlying formations are discussed at length under the heading "Geologic history," in considering the origin of the surface on which the conglomerate rests.

The distribution of the conglomerate is shown by the map. It is a continuous formation west of the Animas, but decreases to a minimum observed thickness of hardly more than 30 feet in some places. East of the river it is found at a few hundred feet higher elevation than on the west, along both the north and the south side of Whitehead Creek, in patches occupying hollows in the old schists, etc., and at various elevations. The largest of these are in the Needle Mountains quadrangle. In the drainage of Cunningham Gulch it occurs in Mountaineer Creek. A small outcrop of conglomerate, probably referable to the Telluride, appears on the south side of Deep Creek at an elevation of 11,350 feet.

In the northern portion of the quadrangle the most extensive outcrops are in Canyon Creek, where a thin band of conglomerate underlies the San Juan tuffs. In the Uncompahgre several local occurrences have been noted, in hollows in the hard Algonkian rocks. A poorly exposed quartzite conglomerate occurring above the Ouray limestone at the Saratoga mine, Ironton Park, is believed to belong in part to the Telluride. These northern exposures of the Telluride are nearly 2000 feet lower than the ledge on Sultan Mountain.

Age and correlation.—The Telluride conglomerate has as yet yielded no fossils by which its age may be determined. The reference to the Eocene in this place is in accord with the procedure in the Telluride folio, no additional data bearing upon the question having been discovered. The conglomerate is later than the great orogenic movement which affected the entire older sedimentary section of this region, and also later than the enormous erosion which produced the peneplain on which the conglomerate rests. The observed angular unconformity at its base transgresses the section from the Algonkian to the Mancos shales (Cretaceous).

The relations mentioned suggest a correlation of the Telluride conglomerate with the Arapahoe formation of the Denver region, and such a comparison carries with it the further correlation of the San Juan tuffs with the Denver beds, which are composed largely of andesitic débris. Both the Arapahoe and Denver formations are fossiliferous, and according to current paleontological opinion they should be considered Cretaceous, although they are separated from the Laramie proper by an interval of great orogenic disturbance and subsequent erosion.

The Denver beds have, in fact, an equivalent, indicated by plant remains, in the Animas beds of the section, well shown a few miles below Durango, but there is no conglomerate comparable with the Telluride in that section, and the correspondence of the San Juan tuffs and the Animas beds is purely lithological so far as known. Under these circumstances it is thought best to await further investigation in the San Juan region before making any positive correlations of the Telluride and San Juan formations. For a discussion of this question the reader is referred to the Telluride folio and to the monograph upon the "Geology of the Denver Basin" (Mon. U. S. Geol. Survey, vol. 27, chapter 3).

Subaerial Deposits.

QUATERNARY SYSTEM.

Certain surficial deposits of Pleistocene and Recent age that are characteristic of mountain regions are particularly well developed in the Silverton quadrangle. They comprise not only the alluvial or flood plain deposits of the larger valleys, with the associated fans of detritus at the mouths of tributary streams, but also moraines and terraces of glacial gravels, and accumulations, covering considerable areas, of disordered land waste, which have come to their present positions as landslides from the heights above. In addition to all these surface deposits, which are in no way unusual, there are in many of the high amphitheaters or cirques great talus heaps and other peculiar aggregations of material resembling ordinary talus in its constitution, though the form of these deposits and their relations to the cliffs from which their rock fragments have been derived at once preclude the possibility of considering them products entirely of the simple agencies of frost and gravity.

MORAINES.

Character.—The detritus formed, as is supposed, directly by glacial action, has only here and there a form indicating that it represents the outline of either a terminal or a lateral moraine, and in all such cases it lies in some small basin. Much more frequently the gravels or bowlder masses occur in isolated patches on the valley slope, in such position as to show that they belong to the junction moraine of two glaciers. Such patches usually form a local veneer, a remnant of a former mass. The scattered bowlders on many slopes and the absence of notable masses of gravel in many gulches where they must have once existed testify to the extensive removal of morainal débris.

In the lower portions of valleys the glacial materials have the character of till or ground moraine, or, as in Mineral Creek and Bakers Park, of rearranged gravels, perhaps more properly considered alluvial.

Distribution.—The principal morainal deposits of the quadrangle are in the immediate vicinity of the town of Silverton. They have been transported and laid down by the glaciers which once filled the valleys of the Animas River, Cement and Mineral creeks, and the South Fork of Mineral Creek. One of the largest morainal deposits lies on the slopes of the hill west of Bear Creek, south of the point where the South Fork joins Mineral Creek. It is a thick covering of sand, gravel, and bowlders, which extends from Bear Creek westward for over a mile and completely masks the solid rock for a thousand feet up from the river. Bowlders of the Telluride conglomerate are numerous, and with them are others of red sandstones and a gray quartz-monzonite of the kind occurring at Rolling Mountain, at the head of South Fork of Mineral Creek, in the Telluride quadrangle. The lower portions of this covering, as shown in ravines, have sometimes the character of till, or ground moraine, smaller bowlders and pebbles being embedded in a fine, sandy clay. There are similar bowlder deposits on the hillsides northwest of the forks of Mineral Creek, but of less extent. From the nature of the materials it is evident that they must have been supplied by the South Fork glacier.

Northeast of the forks of the creek is a terrace-like deposit of rearranged gravels and sands that have probably come from the head of Mineral Creek. This bench is at present covered in its upper portion by the talus cones which have descended from the west shoulder of Anvil Mountain, and no evidence was observed to indicate whether the vertical extent of glacial material was in any way comparable to that of the moraine directly south. These gravels are converted into conglomerate through cementation by iron-bearing waters.

On both sides of the Animas River, and on the northeast side of Cement Creek north of Silverton, there are terrace-like deposits of gravels and sands that are plainly of glacial origin, the bowlders being subangular and striated. Those along the Animas River suggest, by their smooth, even surfaces, that they were directly deposited by water, or at least had their forms modified by this agent. The gravels have been cut into by the river and by some side streams, while much of the surface is obscured by later torrential cones from small ravines and gulches. In Cement Creek the surface of the gravel deposits is more hummocked, and more truly suggests actual deposition by the ice as a ground moraine.

In very many of these deposits, especially those which are more in the nature of thin coverings on the hillsides, the gravels have been firmly cemented by the infiltration of ferruginous materials, and where exposed in road cuts and along the banks of streams have the appearance of outcrops of massive conglomerate.

All along the south side of the Animas as far as Minnie Gulch there is much morainal material. Below Arastra Gulch these deposits, which run up the slope into the timber, are not mapped because they are so intimately mingled with landslide and probable rock-stream detritus that they could not satisfactorily be distinguished from these. Farther up the valley, on either side of the mouth of Minnie Gulch, and south of Maggie Gulch, thick bodies of mingled bowlders, gravel, and sand extend up to an altitude of 12,000 feet above sea level. Smaller patches may be seen at intervals farther up Minnie Gulch.

In the Rio Grande drainage, in the neighborhood of Sheep and Canby mountains, the hillsides are covered by glacial gravels which are often so intimately mixed with the landslide material that the age relations of the two can not be determined. These last deposits can hardly be described as moraines; they are rather thin sheets of till.

Other morainal masses indicated on the map lie south of Mill Creek and across Spirit Gulch, the latter mass being a well-defined terminal moraine. A small but interesting patch of gravel occurs directly on the divide between Mineral and Red Mountain creeks. It is characterized by porphyry pebbles which are more like the small stock at the mouth of the Middle Fork of Mineral Creek than any other observed body. On the west side of Ironton Park glacial gravels occur in considerable extent.

From the nature of the topography of the quadrangle it is plain that glaciers filled all the valleys at one time, as their detritus is very commonly found in scattered bowlders or small gravel patches. No attempt is made to represent all these occurrences, as that would unduly obscure the solid rock geology. In landslide areas the glacial gravels are not outlined because slides have occurred at later dates, and these are shown by preference.

LANDSLIDES.

An extensive area occupied by landslide masses occurs on either side of Red Mountain Creek from Hendrick Gulch on the north to the head of the creek and across the divide for a short distance on the Mineral Creek side. Within this area there is but little rock in place, although several knolls of much-altered rock project at the Yankee Girl and other mines. The landslide character is primarily disclosed by the topographic details illustrated in figs. 6 and 7. The slopes are made up of a great many small knolls, mounds, or short ridges of fractured and disordered rock. No regular drainage channels exist, but here and there, behind a knoll, will be found a stagnant pool or hollow where water has stood at some time of flood or melting snow.

Some blocks exhibit portions of andesite flows or tuffs, but these stand in all manner of attitudes, and adjacent blocks are made of different materials with varying structure. The slide blocks from the western slope exhibit this varying character much more clearly than those coming from the east, since they are made of fresher rock, in more massive condition than the others, which come from slopes of much altered and jointed rock. The two kinds of slide masses mingle in the bed of Red Mountain Creek, which for 2 miles above Ironton winds its way around and between slides that have partially filled its channel, as can be seen in fig. 7.

In the area shown in fig. 6 there are hundreds of these small slide blocks. Many have not come far and the phenomenon is on the whole a superficial one. The upper line of a slide surface is often a trench-like ravine running horizontally or diagonally along the slope. In some places ravines of this sort are continuous for such distances that they border distinct sections of the slide surface. Such ravines, represented on the topographic map, lie west of Corkscrew Gulch and across the slope diagonally from the south side of Hendrick to Albany Gulch. The small slide masses are in various stages of disintegration, consequent upon the thorough shattering of the rock, which is often made easy by its much jointed or unconsolidated condition. Some masses appear as smooth gravel-covered mounds.

On the western side of Ironton Park, north of Full Moon Gulch, a large part of the surface for 1500 feet above the park is to some extent covered by much disintegrated landslide débris, which creeps down to the road. This is only a veneer, as ravines testify in many places, and no representation of landslide appears on the map. The map simply shows the notable areas within which nearly all the surface is of slide rock. Within such areas there are some knobs of rock in place.

The other landslide patches of the quadrangle are comparatively small, being traceable to the fall of some projecting slab from the face of a cliff. The most interesting of these landslides are the ones of Cleveland Gulch, Sheep Mountain, Kendall Gulch, and Hayden Mountain. Details concerning some of them may be found in the descriptions of local geology. The cause of these landslides is discussed in a later paragraph.

ROCK STREAMS.

Many glacial amphitheaters of the Silverton quadrangle contain peculiar masses of rock débris which have been called "rock streams," since they appear to have moved, in a manner akin to the flow of a glacier, for some distance away from the source of the fragments. These masses have sharp outlines and are in many cases much older than the common talus accumulations of fragments of similar size and shape. There are cases, however, where the rock stream and talus of a certain character seem to blend, as in the basins south of Henson Creek, and in such instances the two are mapped together.

These rock streams are not unique; still they present such unusually well-defined characters and are so abundant that they become one of the formations characteristic of the quadrangle, and the question of their origin is discussed at some length in this text under the heading "Physiographic development of the quadrangle" (p. 25). For details as to their character the reader is referred to that discussion.

VALLEY ALLUVIUM.

The town of Silverton is built upon the flood plain of the Animas River. This flood plain extends up the Animas as far as the mouth of Boulder Gulch, and another higher one occurs between Howardsville and Eureka, the intervening space between Howardsville and Boulder Gulch being occupied by a narrow canyon cut in the older and broader floor of the valley. West of Silverton the flood plain extends up Mineral Creek a little beyond the forks, although between Burro Bridge and Chattanooga the floor of the valley is filled with alluvium. Ironton Park, through which Red Mountain Creek meanders before dropping into the narrow gorge of the Uncompahgre, has an almost level floor of alluvium 2 miles long and averaging one-half mile in width (fig. 2). In addition to these prominent occurrences many of the tributary creeks have developed flood plains of sufficient importance to be indicated upon the map. Among these may be mentioned Arastra, Cunningham, and Eureka gulches, Deep Creek, and a small part of Cement Creek at the forks at Gladstone.

TORRENTIAL FANS.

The youngest of the Recent deposits are the fan-shaped accumulations of detritus at the mouths of very many of the gulches which empty into the larger streams. These torrential cones are formed of bowlders and gravels which have been carried down the gulches at times of unusual activity on the part of the streams and deposited on the flood plains or broad bottoms of the large valleys. The greater number of these fans are now grass-grown or timber-covered, but a few that have derived their material from young ravines in the regions of much altered rock are still in process of formation and are without soil or trees. A capital example of this kind of cone is to be seen on the northeast side of Maggie Gulch, under Middle Mountain. No better cones of the older grass-covered sort can be found than in the immediate vicinity of Silverton, at the base of Anvil Mountain.

IGNEOUS FORMATIONS.

The oldest igneous masses of the quadrangle are the granites and dark basic dikes which penetrate the schist complex, as illustrated by the map. The greater part of the igneous rocks of the district belong, however, to the great complex of surface lavas, tuffs, and agglomerates of the San Juan volcanic series. The surface rocks are penetrated by a number of crosscutting stocks and dikes, of several types, some of which are similar in chemical and mineral composition and in texture to the lavas, while others are of different character. Some of these intrusive rocks occur in sheets or laccolithic masses.

The volcanic complex found in this quadrangle is divisible into several groups representing epochs of eruption. These large groups are in part those first distinguished in the survey of the Telluride quadrangle and described in the Telluride folio, but the development of these groups in the Silverton area is in strong contrast to that found either to the west or to the east. There are in the Silverton area some members of the volcanic succession which do not now occur in the Telluride.

Upon the Hayden map of the San Juan region the igneous rocks are classified as "trachoreite," trachytic breccia, and basalt. The former is a term devised by F. M. Endlich to include everything between rhyolite and basalt. All the volcanic series of the Telluride and Silverton quadrangles, fragmental or massive, as well as the granular stock rocks which cut them, are mapped as "trachoreite," and some of the intrusive masses of porphyry in adjacent sedimentary areas are also represented under the same designation. Basalt is known to have extensive development in and adjacent to the San Luis Valley, but no localities of "trachytic breccia" were examined during the recent survey, and the true character of the rocks so called is unknown. An examination of specimens collected by Endlich and preserved in the National Museum shows that rhyolite, a number of andesites, diorite, monzonite, gabbro, and several porphyries were obtained by him in areas mapped as "trachoreite.

Pre-Paleozoic Eruptives.

GRANITE.

There are three general areas within the Silverton quadrangle in which granite occurs. The first is the schist region south of Silverton, the second is near the head of the Lake Fork of the Gunnison River, while the third is in the extreme northern part, where dikes of granite-porphyry cut the Algonkian quartzites and slates.

Biotite-granite.—About half a mile south of the mouth of Sultan Creek, in the Animas Canyon, in a zone of garnet-bearing schist, there are exposed several dikes of granite, from 2 to 20 feet in thickness, the rock being of a grayish-pink color. These dikes follow approximately the schistosity, and rise on the east side of the canyon, in some cases for 1000 feet, giving off numerous branches, and gradually dying out. On the west side of the river the dikes may be seen cutting the walls to the top of the canyon, where they become more and more connected and interlaced, until they finally join a boss of the same rock a little distance west of the river. The map gives a necessarily much generalized representation of this mass and its apophyses.

Close to the southern boundary of the quadrangle, in the Animas Canyon, tongues and dikes of a reddish, irregularly grained granite cut the schists. These are offshoots from a large mass occurring east of the canyon and along the northern side of Whitehead Creek. This rock also occurs west of the canyon in a network of intersecting dikes in the schist, but the principal exposures are south of the Silverton quadrangle, in the Needle Mountains quadrangle. There are a few other small granite masses in the schist area which may be grouped with the Molas and Whitehead bodies, for the purpose of description, under the single head of biotite-granite.

The granites mentioned are even-grained or rather coarse-grained rocks, of a pink, light-red, or grayish color, and have the usual granitic texture, with a tendency, on the part of the Molas granite, to become porphyritic in apophyses.

The essential minerals of these granites are feldspar, quartz, and biotite, the first two always in abundance, the feldspar predominating. The potash feldspars strongly predominate over those of the soda-lime series. Orthoclase usually exceeds microcline in amount. In the porphyritic facies of the Molas granits both of these minerals occur as phenocrysts. Biotite, though always present, is in some places of minor importance, occurring as minute flakes sparingly disseminated through the rock, while in other places it is very prominent, giving the rock a decidedly gray color. In addition to these principal constituents muscovite is also found occasionally as an original mineral. Accessory minerals are unusually subordinate, magnetite and apatite being the commonest, titanite occasionally occurring, and rarely garnet, zircon, and rutile—the last being present as inclusions in biotite.

Muscovite-biotite-granite.—Along the Lake Fork of the Gunnison, reaching up the mountain slopes on both sides, occurs a large fault-bounded mass of granite distinct from that of the Animas Canyon and more nearly related to granites occurring just east of the quadrangle in Cuba Gulch and Cottonwood Creek. This granite is commonly coarse grained, often extremely so, and is pink or light in color. The dark silicates are never prominent. The mass forming Edith Mountain exhibits much variation, both in composition and in texture, and there may be a complex of intersecting bodies, but it is traversed by numerous fault planes and is locally much brecciated, and no original contacts of different facies were observed.

The constituents of this mass are orthoclase, microcline, quartz, biotite, and muscovite. Parts of the mass contain almost no biotite, and other parts are very poor in or entirely without muscovite, but the rock as a whole is essentially muscovite-biotite-granite. The principal feldspar is orthoclase, which is accompanied by microcline and rarely by plagioclase. In one specimen collected microcline was found to be considerably in excess of all other minerals, and this probably represents some local, distinct mass. Quartz, biotite, muscovite, and the accessories, magnetite, apatite, and titanite, have the development common in granite. Secondary muscovite, kaolin, and limonite are generally present as the alteration products of the feldspar and biotite. The granite is cut by aplitic and pegmatitic dikes which differ but little from the rock as a whole in mineral composition.

Porphyritic granite.—North of the Silver Link mine, on the east side of the Uncompahgre River, near where it is joined by Red Mountain Creek, a granite-porphyry cuts the Algonkian quartzites directly at the contact with San Juan tuffs. Only the lower irregular contact with quartzite is seen. The rock extends 100 yards northward from the small ravine next north of the Silver Link and forms a point of irregular shape that projects above the common tuff level. Another dike of granite, 2 feet wide, and some small pegmatite veins were also found in the quartzites of this vicinity.

The porphyry has a pink, fine-grained groundmass, in which are phenocrysts of feldspar (chiefly microcline) and quartz of extremely variable size and distribution.

DIABASE AND METADIABASE.

The Archean schists of the Silverton quadrangle are cut by two distinct series of basic dikes. The rocks of the older series have been so intimately involved in the regional metamorphism that they are now finely sheared amphibolites, though still possessing the usual field relations of intrusive bodies. The younger series of basic dikes can itself be subdivided into two classes: (1) fresh or slightly altered diabase and (2) metadiabase, hornblendic rocks exhibiting more or less evidence of having been derived from diabase through metamorphism attending great crushing and strain. In the description of these rocks the diabase will first be considered, then the metadiabase, and finally the rocks of the older series, the amphibolitic schists.

Diabase.—In the region south of Deep Creek, and along the Continental Divide, a number of dikes occur which may be broadly described as diabase. Some are remarkably fresh and possess the usual texture and mineral composition of diabase; others show signs of alteration and dynamic metamorphism, and in extreme cases are now totally different from the original rock. These differences have been observed in the same dike, one portion of which may be a normal diabase, while another is an amphibolite with schistosity often well developed.

The fresh and unaltered diabase is a medium-grained rock, brown-black in color, and possessing the usual ophitic texture. The individual minerals are almost too small to be readily distinguished by the naked eye, but in most cases rude crystals of a plagioclase (lime-soda) feldspar can be made out, associated with a dark silicate found to be a pyroxene. Under the microscope the ophitic texture is pronounced, broad laths of plagioclase being grouped in radiating aggregates, with grains of augite, magnetite, and occasionally biotite in the interstices. Augite and plagioclase are nearly equal in amount. The plagioclase feldspar has been found to be in almost all cases labradorite of the composition Ab_3An_4.

The alteration of the augite will be considered in the discussion of the metadiabase, and at this point it is sufficient to state that the usual product is hornblende. Epidote and chlorite, also, occur as secondary minerals after both augite and the plagioclase.

Metadiabase.—Many of the dikes of the Deep Creek region, although apparently belonging to the same series as those which have been just described, are, in fact, distinct mineralogically and texturally.

Megascopically these rocks are sometimes schistose rather than ophitic, and are somewhat coarse grained, and one does not require a microscope to discover that the dark silicate is hornblende instead of augite. When the rocks are examined under the microscope, it is at once evident that all of them have been crushed and sheared, some more than others, and that very little of their original texture remains. Green pleochroic hornblende is the most abundant constituent, and biotite is frequently associated with it. Some strongly calcic plagioclase has been recognized, but usually the strains to which the rocks were subjected have been so great that the feldspars are now crushed and granulated and are beyond satisfactory determination. Occasionally feldspar occurs as poikilitic inclusions or intergrowths with the hornblende

The accessory minerals are not prominent, but are more numerous than in the diabases, titanite and apatite being present in addition to the iron ores. The secondary minerals, epidote, kaolin, muscovite, and chlorite, are abundant, and zoisite and calcite are not uncommon.

These rocks were no doubt all originally diabase, but from the association and accompanying differences in character it seems probable that these two sets of dikes represent somewhat different periods of eruption of similar but not identical magmas. Some specimens have been found which show almost no sign of crushing, yet hornblende is the prominent ferromagnesian silicate, and enough original plagioclase is preserved to show that it was formerly present in lath form and that the rock had an ophitic texture. One specimen showed that shearing had followed the development of the hornblende rods, which were bent or crushed and partly mixed with the granular feldspar. These intermediate textures are not common, and the majority of the hornblendic dikes are very much crushed. Direct transitions from augite to hornblende have not been found in these rocks, although, as has been shown, there is a tendency on the part of the augite in the diabases to alter to hornblende. This change, however, is so common elsewhere that the absence, in the rocks examined, of examples showing the augite in process of passing into hornblende is not sufficient to disprove the derivative nature of the hornblendic dikes.

The altered dike rocks described are similar to a series of small dikes occurring in the granites and gneisses of the Royal Gorge of the Arkansas River, in which a change from an ophitic or granular to a very pronounced schistose texture can be observed. In these rocks the paramorphic nature of the hornblende is very clear.

Amphibole-schists in dike form.—The oldest dike rocks that can now be made out in the Archean area in the Silverton quadrangle are extremely fine-grained schists. Actinolite is the principal constituent of these rocks, a little granular feldspar and iron ores being associated with it. The actinolite occurs in small blades that lie parallel to the schistosity.

In view of what has been said of the metadiabase dikes and their derivation, it is highly probable that these schistose basic dikes have been derived from diabase originally, although they must have belonged to an earlier period of eruption. Their schistosity is parallel to that of the inclosing rocks and has nothing whatever to do with the dike walls. Small tongues or stringers are frequently seen as offshoots from a main dike and intruding the older rocks irregularly, but the schistosity is always in the same direction. Dikes of this sort are not numerous in the Silverton quadrangle, but farther south, in the Needle Mountains and in the Animas Canyon, they are common. No attempt has been made to map these dikes, as they are very small.

Tertiary Volcanic Rocks.

SAN JUAN TUFF.

The San Juan tuff and breccias constitute a well-stratified pyroclastic formation and may be said to belong with the sedimentary rocks, but as they distinctly form the first known member of a great volcanic series they are here included in that category.

Occurrence.—The series of bedded tuffs, breccias, and agglomerates which has been called the San Juan formation and which has an important development in the Telluride quadrangle, west of the Silverton area, is here much less important and is frequently represented by a thickness of less than 100 feet, in striking contrast to the 2000 or more feet found in the area to the west. This difference is largely due to the very uneven floor upon which the tuffs accumulated. Undoubtedly the upper parts of the formation were once continuous with beds to the west, but in the Silverton area were removed by the erosion which is known to have taken place before the outpourings of later lavas. In the western part of the quadrangle, at the extreme north and south, thick and very typical exposures of the San Juan tuffs occur, but in these localities the tuffs are connected directly with those of the Telluride and Ouray quadrangles. More or less isolated exposures occur in Deep Creek, Cunningham Gulch, and Snare Creek, while on the lower slopes of Kendall Mountain are deposits of tuffs, referred to the San Juan, that are so altered by intrusions of rhyolite and monzonite as to be barely recognizable. From the South Fork of Mineral Creek northward there is probably an extensive development of the San Juan, but it, together with later lavas, has been so decomposed and altered that in not a few cases it is practically impossible to distinguish between them.

Wherever the Telluride conglomerate occurs San Juan tuff rests upon it, but this conglomerate is not persistent east of the Animas River, and the San Juan there generally rests unconformably on other rocks. This unconformity is particularly striking in Whitehead Gulch, where the tuffs filled many depressions in the old land surface.

During the survey of the Telluride quadrangle the Silverton area was supposed to be the source of the materials constituting the San Juan tuffs, but no direct evidence has been obtained in the Silverton region of any center of volcanic outburst or explosion of sufficient magnitude to have supplied the vast amount of débris which goes to make up the San Juan formation. Its source is, therefore, still unknown.

Description.—The San Juan formation of the Silverton quadrangle, as in the Telluride, is a series of tuffs, breccias, and agglomerates of andesitic material, in part apparently water-laid and in part of subaerial deposition. A maximum thickness of 2500 feet has been found in Canyon Creek, but in other localities much less is present. The character of the section is apparently much the same whether the beds be thick or thin, but slight variations being noticeable in widely separated occurrences. A breccia often appears at the base, sometimes so filled with bowlders of granite as to be with difficulty differentiated from the Telluride conglomerate. This breccia usually extends upward for about 50 feet and is succeeded by finer tuffs, often very massive and without detailed evidence of stratification, although exposures when seen from a distance clearly show their bedded character. In the southwest portion of the quadrangle this is particularly true, but on the east side of the Uncompahgre there is a larger thickness of coarse agglomerate at the base and thin bands of tuff alternating with breccia above, while near Deer Park and Whitehead Creek the beds are fine grained and well bedded throughout, with no basal breccia. Occasional layers of thin-bedded muds or fine sands are found, which are plainly water-laid, and in striking contrast to the chaotic agglomerates. While no determinable fossil remains have been found in these tuffs, the finer-grained beds occasionally contain indistinct carbonized plant stems.

The colors of the formation when freshest are neutral blues, grays, and brownish-purples, with sometimes vivid greens and robin's-egg blues. Such colors may be seen in exposures in the southern part of the quadrangle as well as in the area lying beyond Bear Creek on the north, but in many places where there has been impregnation by iron sulphides subsequent oxidation has stained the tuffs red or yellow, and the decomposing action of mineral-bearing waters has often so changed the whole character of the rocks as to practically destroy all individuality. In view of the fact that the tuffs of the San Juan are so very generally decomposed in the Silverton quadrangle, no detailed petrographic study has been attempted; more especially as these same rocks, from fresh exposures, have been described in the Telluride folio, from which the following paragraph is taken:

A microscopical study of the fine-grained tuffs and of the larger rock fragments shows that all particles, large or small, belong to rock masses which have been broken up by some force, presumably an explosive outburst at one or more volcanic vents. As yet no true "bombs," or smaller particles, have been detected which can be considered as having been ejected in a partially fused condition at the time of eruption. Excepting the granitic and sedimentary débris found sparingly in the lower beds, the materials of the San Juan tuffs, etc., seem to be of various types of andesite. Hornblende- and augite-bearing varieties prevail, of many different textures. It is also probable that latite is abundant.

SILVERTON VOLCANIC SERIES.

General relations.—The San Juan tuffs of the western portion of the volcanic region are overlain by a series of lavas and fragmental accumulations whose characters indicate a phase of eruptive activity which it is desirable to distinguish upon the map and in discussion. The San Juan fragmental beds were very extensively eroded in the epoch preceding the Silverton eruptions, and the activity of the later time was of a character different from that of the first epoch.

The Silverton series is relatively unimportant in the Telluride quadrangle and was named the "Intermediate series," in the Telluride folio, as an expression of its position between the San Juan andesitic tuffs and the Potosi rhyolite series, and, further, of its transitional petrographic character. But in the Silverton quadrangle this series has a thickness of more than 3000 feet, and is the principal rock group; hence the indefinite term previously used is replaced by the more appropriate one, the Silverton series.

The distribution of the Silverton series within the quadrangle is shown by the map, and the variations in thickness also appear from the topographic features or are partially expressed by the structure sections. Although the amount of erosion in the interval following the Silverton eruptions can not be estimated, it was apparently very extensive, and this fact partially accounts for the rapid thinning out of this series to the south, west, and north. The relations to the east are not yet well known.

In its broader features the Silverton series is a mixture of lavas of two or three different chemical types which can not plausibly be supposed to have issued from a single volcanic vent. The number of different textural rock types exhibited in the Silverton quadrangle is much larger than in the Telluride area. Present knowledge of the distribution of these lavas indicates that they were of local origin. In this quadrangle the rocks occur in both flows and crosscutting bodies, and the rapid variations in thickness of the surface flows suggest that the sources of these rocks were near at hand if they were not actually the fissures occupied by observed dikes. No central vent for either of the lava types has been found.

Members of the series.—The lowest observed member of the series is the Picayune andesite, seen in the Animas Valley about the mouth of Picayune Gulch. It is not elsewhere known at the base of the series. A similar andesite, which is intrusive, occurs at the head of the Lake Fork of the Gunnison River.

The rock which rests on the Picayune andesite and is the oldest member of the series present in most places is the Eureka rhyolitic flow-breccia, with variable tuffs. This rock was first observed in the Telluride quadrangle.

Upon the rhyolitic lava rests a rock called the Burns latite, appearing in both flows and tuffaceous beds. It is a hornblendic rock, and other isolated latites are referred to this member of the series largely through petrographic similarity. In connection with the Burns latitic tuff there are some peculiar calcareous strata containing scanty fossil evidence of the age of these eruptions.

The Burns hornblendic latites were succeeded by a complex of dark pyroxene-andesites, mainly in flows, but with tuffs and agglomerates in many places. These probably constitute the last eruptions of the Silverton period, being followed after an interval of unknown length by the Potosi quartz-latite and rhyolite series.

The various members of the Silverton series will now be described more fully.

PICAYUNE ANDESITE.

The earliest lava of the Silverton series, as indicated by known exposures, has been called the Picayune andesite, from its occurrence at the mouth of the gulch of that name, tributary to the Animas between Eureka and Animas Forks. As shown by the map, the rocks included under this name occur there in an irregularly shaped area bounded in part by faults. The following description applies also to the intrusive andesite of the Lake Fork of the Gunnison, which represents a second eruption of the Picayune magma.

Description.—The Picayune type of andesite is a rock of pronounced porphyritic texture through its abundant tablets of labradorite, which lie in a groundmass usually much stained by chlorite, giving the rock a dark-green color. Altered prisms of a pyroxene now completely replaced by chlorite are also prominent, but less so than the feldspar tablets, which often exceed half a centimeter in diameter. The groundmass originally contained microlites of plagioclase and augite (?) with a dust of magnetite, but is now greatly obscured by alteration products. A good deal of the rock is highly amygdaloidal, the vesicles being filled with chlorite and calcite.

Some of the Picayune rock in the Animas area is breccia or tuff, many of the fragments being finer grained than the type above described. Fragments of rhyolite flow-breccia are also common in the tuffs. This shows that the Picayune tuffs can not be referred to the San Juan formation. Probably very little of the area is occupied by massive andesite. The crosscutting andesite of the Lake Fork of the Gunnison is petrographically identical with the Picayune type and needs no further description. The most common phase of this area is coarsely porphyritic. The finer-grained forms are not more so than fragments which appear in the Picayune tuffs of the Animas Valley.

Occurrence.—The rocks colored as Picayune andesite on the map distinctly underlie the flow-breccia, as seen in the bed of the Animas River, and fragments of the characteristic Picayune andesite occur in this overlying rock. From the river bed, near the Tom Moore mine, the contact of the two formations runs up the steep slopes and on the east side crosses into Grouse Gulch about 1800 feet above the Animas. On the west it does not ascend so high, owing to faults, as shown on the map. The same faults cut off the Picayune in Grouse Gulch. Exposures are very poor over much of the area, and the boundaries are correspondingly uncertain.

The upper and irregular surface of the Picayune rocks reappears in the Animas Valley above Grouse Gulch, and an arm extends up Cinnamon Creek to 800 or 900 feet above the river. This upper part is largely a breccia. The exposures are poor, owing to glacial material, on the slopes of Cinnamon Gulch, and a narrow strip in the bed of the gulch is all that is outlined on the map.

At Animas Forks there are exposures in the little canyon east of town which may belong with the Picayune, but since the rocks, which are mainly mechanical breccias, contain fragments of rhyolitic flow-breccia and grade into flow-breccias with rhyolitic matrix, the whole has been mapped with Eureka flow-breccia.

At the head of the Lake Fork of the Gunnison River there is an area of augite-andesite which would naturally be considered as representing the Picayune andesite were it not for the fact that it clearly cuts Eureka rhyolite flow-breccia and tuffs of the Burns latite. This intrusive rock resembles the Picayune type so much more closely than any other of the quadrangle that it seems plain that there was a recurrence of eruption of the Picayune magma. The map merely shows the limits of the area within which the augite-andesite is largely predominant over the other rocks. These relations are set forth more fully in describing the geology of the Lake Fork area.

EUREKA RHYOLITE.

The second member of the Silverton series is a rock belonging to the most siliceous of the magmas which were erupted during this epoch of San Juan volcanic history. It is so characterized by small included fragments of andesites, of rocks very similar to the rhyolite itself, or occasionally of granite, schist, etc., and has so commonly a distinct flow structure, that much of the rock may be called a flow-breccia.

The geographic name applied to it is appropriate on account of the very prominent and characteristic exposures in the cliffs of the Animas Valley near Eureka.

Description.—The Eureka rhyolite flow-breccia has not been found in fresh condition in the Silverton region, and it assumes various aspects according to the number, size, and character of its included fragments and the degree and kind of alteration it may have undergone. Normally it is a grayish rock exhibiting many small angular inclusions, averaging much less than half an inch in diameter, of dark, fine-grained andesites or of reddish or grayish rhyolite, and has a prominent fluidal texture in the dense felsitic groundmass which holds the fragments. The larger crystals, grains, or phenocrysts—variably numerous—which belong to the rhyolite are mainly feldspars, orthoclase and plagioclase together, generally angular fragments of crystals, with a subordinate amount of biotite. No augite or hornblende was seen. The proportion of orthoclase and plagioclase phenocrysts varies so greatly that in some cases it has been suspected that many of the latter may be foreign to the rock.

The groundmass was originally vitreous, in some places at least, and the fluidal texture, expressed by the curving of trains of trichites or ferritic grains about the included crystals and fragments of rock, is often still evident. At present the groundmass shows no glass, its place being taken by a cryptocrystalline, irregularly granular mass which consists of quartz and orthoclase, as may be inferred from the occasional coarser-grained spots and from the spherulitic bands which are not uncommon. That this groundmass had a vitreous constitution in some rocks is shown by the imperfectly preserved traces of curving perlitic fissures and by indications of axiolitic and trichitic forms, such as are seen in many other aporhyolites.

These rocks are so decomposed that no material suitable for chemical analysis has been found, but from the mineral composition mentioned it may be inferred that the magma of this rock was rich in silica, affording a considerable excess of quartz, and had little magnesia or iron, while the alkalies and lime were comparatively abundant. It is thought probable that these lavas resemble certain ones of the Potosi series which have been shown to be rhyolitic in character. They may possibly belong rather to the quartz-latites, the dominant rock of the Potosi series.

The great abundance of foreign mineral particles in some places and the subordination of the fluidal texture render the character of the rock obscure and it requires microscopical examination to show that some of these massive-looking altered rocks are not andesitic in character.

Occurrence.—The Eureka flow-breccia is very widely distributed in the quadrangle and presents somewhat different features in different places. It is mainly a huge surface flow, reaching a thickness of 2000 feet on the east side of the Animas just above Eureka, and thinning out westward until it becomes a subordinate part of the Silverton series. Intrusive bodies occur in the area extending from Deer Park around the western slopes of Kendall Mountain to Arastra Gulch, the rock cutting the San Juan tuffs. The map representation of this crosscutting relationship on the western slopes of Kendall Mountain is hardly more than a diagrammatic generalization, the best that could be done in view of the complex network of dikes and the poor exposures. In Cunningham Gulch the lower contact of the rhyolite cuts through schists and San Juan tuffs. In the area of the Picayune andesite small dikes interlace in complex fashion in several places.

The number of these crosscutting channels makes it appear possible that they represent the main conduits through which this magma came to the surface; but since the rock is known to occur in great thickness as far to the east as Lake City, it is regarded as more probable that there were other points of extrusion.

In some of the dikes in or near Kendall Gulch the rock is banded through the alternation of dark-gray felsitic and lighter microspherulitic streaks and is nearly free from inclusions. A dike below the Titusville mill, in Kendall Gulch, is full of greenish andesitic inclusions. Other common phases are reddish or dark gray in color and usually have abundant inclusions.

In the crosscutting zone of Arastra Gulch the fluidal texture is pronounced near the contact, especially on the western side of the gulch. The fluidal texture is also plain in Cunningham Gulch, but there much of the rock is dark and its character is somewhat obscure.

At the headwaters of the Rio Grande near Canby and Sheep mountains the Eureka rhyolite is not always present between the San Juan tuff and the overlying andesite, and when present it is not so rich in inclusions as usual. The biotite is here preserved, while the feldspars are kaolinized, contrary to the usual conditions.

In Maggie Gulch the typical flow-breccia appears near the crosscutting monzonite body, but in the upper horizons of the mass, here and northward, the fluidal texture becomes very subordinate and the rock appears like a fine tuff or a bleached, massive andesite. This is due to the great number of feldspar grains, many of which are broken plagioclase crystals, and to the small number of rock fragments. The matrix or groundmass is of the same character as in the typical Eureka flow-breccia.

The greatest and most typical development of this rock is found in the steep walls of the Animas Valley at and above Eureka. The massive character is seen to best advantage on the trail that zigzags up the cliff on the south side of Niagara Gulch. Here all is dark gray and rich in inclusions, and the fluidal texture is very distinctly exhibited until the upper 200 or 300 feet of flow is reached; within this zone the rock loses its fluidal texture.

The lower zone of the flow-breccia in the upper Animas Valley often contains fragments of the Picayune andesite. At Animas Forks much of what at first sight appears to be Picayune breccia or tuff has a fluidal matrix representing the Eureka magma, and this transition zone has been mapped as belonging to the latter rock.

In the northeastern section of the quadrangle the Eureka flow-breccia has a great development on either side of Henson Creek and often exhibits the characters described, but it is here greatly altered as a rule and much of the flow is rich in minute inclusions of foreign rocks, including quartz and microcline, which are doubtless derived from the underlying granite. The rock extends down Henson Creek to Lake City.

In the northern and northwestern parts of the quadrangle the Eureka rhyolite is of subordinate importance. It is lacking in Bear Creek, but appears in Poughkeepsie Gulch and in the tributaries of Canyon Creek, but is not there separated from the latite or andesite portions of the Silverton series. A small remnant of characteristic flow-breccia caps Sultan Mountain, in the southwestern portion of the quadrangle.

BURNS LATITE COMPLEX.

The division of the Silverton series succeeding the Eureka rhyolite contains several somewhat different kinds of lava, most of which are characterized by hornblende, in contrast to the succeeding pyroxenic member of the series. These rocks are often much decomposed, and the original ferromagnesian silicates can not always be recognized. All these rocks are plainly of similar chemical composition and belong to the group called latite, which is intermediate between trachyte and andesite, since it contains both alkali and soda-lime feldspars in large amount. These latites belong to one general epoch of eruption within the Silverton period. The greater part of the complex consists of more or less overlapping massive lava flows, but fine- and coarse-grained tuffs and breccias occur in variable development below, above, and between the flows. At two horizons thin-bedded tuffs are associated with calcareous layers, the uppermost beds of the section containing scanty fossil remains. The position of this complex within the Silverton series is very distinctly shown east of the Animas River, in the vicinity of Burns and Niagara gulches, where its most widely distributed and easily recognizable facies occurs between the Eureka rhyolite and the pyroxene-andesites.

The name "Burns" (from Burns Gulch, where the formation is finely exposed) is applied, for convenience, to all the hornblendic latites, their associated tuffs, and certain local masses which were apparently erupted between the epochs of the Eureka flow-breccia and the pyroxene-andesite. The textural variations among rocks that are otherwise similar are in some cases connected with certain local differences in conditions of occurrence, and therefore the complex may appropriately be described under the heads of the various types observed.

MASSIVE FLOWS.

Niagara Gulch type.—The most widely distributed variety of these hornblendic latites is named from Niagara Gulch, east of Eureka, where it occurs in a massive flow, several hundred feet thick, that lies between two notable tuff bands.

This rock contains feldspar and quartz in large excess over the total amount of the dark silicates and magnetite, but its feldspathic character is obscured by its predominant very dense aphanitic groundmass, of dull green, gray, or purplish tones, often exhibiting a distinct fluidal texture. In this groundmass the fresh rock carries some small feldspar (andesine-labradorite) crystals with hornblende prisms and biotite leaves. A little fresh augite occurs rarely, and this mineral was once probably sparingly present in many places. Usually both hornblende and biotite are now wholly decomposed and their former presence can be determined only on microscopical study. The hornblende was largely subject to magmatic resorption, as shown in the freshest rocks. Dark-green chlorite and yellowish-green epidote are the common decomposition products of these dark silicates.

The groundmass is rich in feldspar microlites (plagioclase) and contains an undeterminable amount of orthoclase and quartz. But little magnetite is present in the fresh rock and that has commonly been decomposed, the resulting hydrous oxide of iron aiding in obscuring the character of the rock.

The Niagara Gulch latite possesses the general character above described from Middle Mountain northward and westward. It usually has the dense groundmass, but occasionally becomes somewhat more coarsely crystalline.

The general chemical composition of the Niagara Gulch latite is undoubtedly fairly represented by the analysis given below, although the specimen analyzed came from the extreme southeastern border of the area within which these lavas are now preserved. No satisfactorily fresh rock for analysis could be found in the central area. The rock submitted for analysis has a dull-gray predominant groundmass that holds many small phenocrysts of nearly fresh labradorite ($Ab_1 An_1$) and hornblende. The microscope shows the groundmass to be rich in feldspar granules, presumably of orthoclase, with some quartz, these two minerals being to a large extent intergrown in poikilitic patches. Some plagioclase is also found in the groundmass in microlites—sufficient to bring out distinctly a fluidal texture. Augite, biotite, and magnetite are constituents of subordinate importance. The specimen came from the ridge north of the head of Pole Creek, and was analyzed by W. F. Hillebrand.

Analysis of quartz-latite.

SiO_2	62.09
Al_2O_3	16.77
Fe_2O_3	3.96
FeO	.99
MgO	1.63
CaO	4.26
Na_2O	3.77
K_2O	3.68
H_2O below 100° C	.50
H_2O above 100° C	1.32
TiO_2	.73
ZrO_2	Trace
CO_2	None
P_2O_5	.25
SO_3	None
Cl	Undet.
F	Undet.
FeS_2	None
MnO	.14
BaO	.10
SrO	.05
Li_2O	Faint trace
Total	100.24

A comparison of this analysis with that of the quartz-monzonite of Sultan Mountain, given on page 12, shows that these rocks are very nearly identical, and are also very like other rocks which have been described as monzonite, latite, or toscanite, as will be noted more fully elsewhere in this text.

The latite of Burns Gulch is sometimes fresh as regards its feldspars, though its dark silicates may be decomposed. A partial analysis by W. F. Hillebrand of such a rock gave the result: SiO_2 61.70, CaO 4.43, Na_2O 2.66, K_2O 4.37. These figures vary notably from those of the complete analysis in the ratio of the alkalies, but they are in close agreement as to silica and lime. The higher amount of potash in the Burns Gulch rock indicates that the rock is still more typically a latite than that at the Pole Creek locality. Most of the Niagara latite has the habit of the rock from Burns Gulch.

Canby type.—In the southeastern section of the Silverton quadrangle the Niagara Gulch latite gives way to a rock of similar composition but somewhat different texture, which is regarded as representing practically the same magma as the Niagara Gulch type. No distinction has been made in mapping, as the differences seem trivial in comparison with the similarities of the two rocks. This type is prominent in Canby Mountain and adjoining summits and receives its local designation from that fact. The Canby latite occurs in several flows of varying textures.

In this rock hornblende is megascopically prominent and is well preserved in many places, while augite is often of equal importance. The common presence of augite and the prominence of hornblende distinguish this type from that of Niagara Gulch more clearly than any other features. The higher flows are similar to the Niagara in having a dark, dense, fine-grained, microlitic groundmass. The groundmass of the coarser-grained facies has some recognizable orthoclase and a little quartz, but is still markedly microlitic through the development of the plagioclase.

The lower flow of the Canby rock is generally not so fine-grained and all the silicates exhibit a gradation in size from the larger phenocrysts, nearly 0.5 centimeter in diameter, to the groundmass particles. Orthoclase is a distinct component of the groundmass and appears to be more abundant than in the denser Niagara Gulch type. Quartz is very insignificant in amount when present at all.

The Canby facies of the Burns latite is restricted almost entirely to the southeastern portion of the quadrangle. It grades into the Niagara Gulch facies in the zone traversed by Maggie Gulch and into the Kendall facies to the west, in the general line of Arastra Gulch. The irregularity of the flows, the extensive areas of decomposition, and other areas of poor outcrops have prevented a direct tracing of a gradation between Canby and Niagara Gulch facies within a given flow.

The latite from north of Pole Creek, which was analyzed to show the general character of the Niagara Gulch facies, bears also a resemblance to the Canby facies, and it is considered not impossible that it represents the Canby magma as nearly as the Niagara.

Other rocks of the Burns complex.—As has been stated, the Burns complex of lavas is, in the greater part of the area, clearly a member of the volcanic section lying between the more siliceous Eureka rhyolite and the more basic pyroxene-andesites. The Burns latites extend into the southern and southeastern sections of the quadrangle, where the Eureka rhyolite has decidedly irregular relations and the pyroxene-andesites are wanting except for a few small remnants. The flow and tuffs of the Niagara facies can not be identified in the region south and east of the Animas River below Maggie Gulch, partly no doubt because of the greater decomposition of the rocks in this section, the interruption by monzonite masses, and the areas of scanty exposures, but also, in large degree, because the lavas of this region are not the continuation of the Niagara flows, although they are of similar character and are believed to belong to the Burns epoch of eruption.

The rocks correlated in this general way with the Niagara Gulch and Canby latites are not now sharply definable in the field, and they seem to grade into one another in petrographic character, though exhibiting some local peculiarities. They include: (*a*) the rocks which make up the high mountains south of the Animas and west of Cunningham Gulch; (*b*) the rock of the northern base of Kendall Mountain, which apparently cuts the Eureka flow-breccia; (*c*) the much decomposed greenish rock of lower Arastra and Cunningham gulches; (*d*) the rock of Galena Mountain, Ridgway Basin, and the cliffs at the end of the ridge between Maggie and Minnie gulches; (*e*) greenish rocks found on the west side of the Animas, below the clearly recognizable Niagara flows, as far north as Eureka, where crosscutting relations with the flow-breccia are shown.

The latite of Kendall Mountain.—This rock is characterized by irregularly and sparingly disseminated crystals of orthoclase, some of which have a diameter as great as one-half inch. Quartz phenocrysts occasionally appear in this rock. Like the Canby facies this rock has numerous small phenocrysts of andesine-labradorite, and it once possessed crystals of augite, hornblende, and biotite, variably developed. These minerals are now almost wholly unrecognizable in much of the rock, even their former crystal outlines being indefinite, while their decomposition products—epidote, chlorite, calcite, etc—are more or less abundant. The groundmass is composed largely of orthoclase and quartz and contains a variable amount of plagioclase in microlites and many particles of secondary minerals.

By comparing the Kendall latite with the coarser-grained Canby flows it appears that they are very similar in composition and may even be identical. The large orthoclase crystals are found sporadically in the rocks as far east as King Solomon Mountain. The external aspect of these rocks varies so much more from decomposition than from inherent differences that the tracing out of local modifications is almost impossible.

The dark rocks at the north base of Kendall Mountain, between the great monzonite stock and Arastra Gulch, are believed to cut the Eureka rhyolite and to be of the same latite facies as the lavas of the upper part of the mountain. They are seldom well exposed and are then either much decomposed or metamorphosed adjoining the monzonite stock, so that identification is difficult. The presence of large orthoclase phenocrysts here and there is suggestive of the equivalence with the upper rocks.

The latite of Arastra and Cunningham gulches.—The most distinct type of the rocks referred to the Burns complex is that which occurs at the mouth of Cunningham Gulch and extends down the Animas to Arastra Gulch. It is now commonly a greenish-gray rock of subordinate porphyritic texture, characterized by a groundmass fabric which takes the form of a patchy micropoikilitic intergrowth of orthoclase and quartz. A few phenocrysts of quartz also are visible. The original ferromagnesian silicates were augite, hornblende, and in many cases probably biotite, but decomposition often renders them now unrecognizable. No evidence of a composition essentially different from that of the other rocks under discussion has been observed, although the common presence of a few quartz phenocrysts and the pronounced micropoikilitic fabric of the groundmass are peculiarities of this rock.

The rock of Arastra Gulch is somewhat more coarsely crystalline than that of Cunningham Gulch and is very much decomposed. It is supposed to connect the rock of Cunningham Gulch with that at the north base of Kendall Mountain, but forest and débris-covered slopes prevent a definite proof of continuity. For the same reason it is not possible to trace the relations of the Cunningham rock to the fresher lavas of higher horizons on King Solomon or Galena mountains. The Arastra latite has occasional large orthoclase crystals, which suggest a close connection with the Kendall Mountain rock.

Above the Eureka rhyolite in Maggie Gulch the latite rocks closely resemble the Cunningham facies as far as the crest of the ridge south of Ridgway Basin. Very similar rock occurs also in the cliffs at the end of the ridge between Maggie and Minnie gulches, and in Minnie Gulch. Since the Niagara Gulch facies of latite occurs in flows of typical development at a much higher level in Middle Mountain, it appears either that this lower rock is older than the Niagara Gulch type or that it has been intruded between the Eureka rhyolite and the overlying latite flows. No definite evidence of intrusion was observed, although the presence of the Cunningham type along the west side of the Animas as far as Eureka and its absence on the opposite side of the valley above Minnie Gulch suggests that intrusive relations exist.

TUFFS ASSOCIATED WITH THE BURNS LATITE.

The tuffs of the Burns epoch of eruption are usually fine grained, but are occasionally of coarse texture. They are often locally developed between lava flows and are rather widely distributed at two general horizons, one at the base, the other at the top of the series of rocks referred to the Burns epoch.

The coarser tuffs and breccias have much the general character of the San Juan formation, consisting of more or less distinctly angular fragments of latite or andesite in a matrix of fine volcanic sand. Such rocks have commonly a dark-gray or purplish color. Rhyolitic flow-breccia and granitic or rarely quartzitic débris are occasionally found. The fragments seldom exceed a few inches in diameter.

The fine-grained tuffs of the complex are sometimes very homogenous in texture, forming greenish or gray sandstones not commonly much indurated. They are composed of fine angular particles, which may be less than 1 millimeter in diameter, representing the crystals or the groundmass of latites and other rocks. The ferromagnesian silicates are much decomposed and, in fact, are usually unrecognizable. Quartz grains are ordinarily accompanied by orthoclase and microcline, testifying to the destruction of granitic masses in the production of the tuff.

The lower tuffs.—Between the Eureka rhyolite and the Niagara Gulch latite flows there is usually present a greater or lesser thickness of greenish tuffs. These beds reach their greatest development east of the Animas River and north of Minnie Gulch, where they attain in some places a thickness of 250 feet. Usually these tuffs are very fine grained, well bedded, as if by water, and of a dull-green color. Coarse conglomerate or breccia has been noted locally. The tuffs in their present condition are often notable for their resemblance to green hornstone or dull clouded porcelain. Coarse, sandy layers look like massive rocks.

Microscopical examination of the dense tuffs shows fragments of plagioclase and orthoclase feldspars and no fresh particles of ferromagnesian silicates. There is also some quartz, orthoclase, and microcline feldspar, and much of this material was plainly derived from granitic rocks.

At the top of the lower tuff zone there occurs, locally, some massive limestone, either dark gray and well bedded, or marbleized by metamorphism. The limestone rests on well-stratified tuffs and is apparently a deposit in a body of water. It shows no micro-organisms under the microscope, and no fossils of any kind have been found in it. Its observed distribution is small in comparison with that of the fossiliferous calcareous layers of the tuffs above the massive Niagara Gulch latite.

The lower tuffs of the Burns complex are especially well shown in Niagara Gulch, east of Eureka, and in Minnie Gulch. They are often obscured by surficial materials and have less persistence apparently than the upper tuffs. Erosion succeeding their deposition may have something to do with this. In their typical dense hornstone-like development they can usually be detected, where the base of the formation is exposed, throughout the eastern part of the quadrangle.

The limestone at the top of the lower tuffs is best shown in the southeastward-facing cliffs that stand north of the mouth of Eureka Gulch, at an elevation of about 10,750 feet. Exposed here are from 5 to 6 feet of dark-gray limestone with interbedded tuffaceous and cherty material. An intrusive andesite sheet extends southwestward across the limestone, and probably the same mass cuts it off to the north. A small cavern occurs where this limestone is thickest. The rock here is singularly free from mineralization, although it lies in the midst of decomposed volcanic rocks.

On the north side of Niagara Gulch, directly opposite the above mentioned limestone locality, some greatly marbleized limestone occurs at the top of the lower tuffs, but the exposures do not show relations clearly. No other occurrences were observed.

The upper tuffs.—A variable amount of fine-grained tuffs is usually found at the top of the Burns complex, especially in the region about the head of the Animas and farther eastward, beyond the quadrangle line. These upper tuffs are several hundred feet thick in some places, as in Maggie Gulch and on the Lake Fork of the Gunnison. Commonly these beds have nothing to distinguish them from the similar strata of other horizons already referred to, but through a considerable area they become calcareous shales in the upper zone, 50 or more feet in thickness, with thin beds of limestone, which have been observed at many points. Plant remains and gasteropod shells found in these uppermost strata give the only evidence yet noted of the age of these beds.

At the northeast base of Cinnamon Mountain some pieces of gypsum were found with loose shaly tuff. The manner of occurrence was not observed and no traces of gypsum were discovered elsewhere.

In some places in these calcareous shales layers of pure gray limestone an eighth of an inch or less in thickness alternate with similar sandy layers. On exposed surfaces the limestone layers are easily dissolved, the sandy beds project slightly, and a fine ribbed structure is produced. Among the sandy particles quartz, orthoclase, and microcline are prominent, and dark silicates are almost lacking.

The gray or black limestone layers are sometimes 2 or 3 inches thick and are very pure. No microscopic organisms have been found. Adjacent to fault planes, on the north shoulder of Cinnamon Mountain and on the divide north of Cleveland Gulch, the thin shaly layers have suffered marked plication and fragments may be found exhibiting, in model-like detail, folding, overthrust faulting, brecciation, and all the complicated structural relations that appear in strata of the most disturbed mountainous districts. It is clear that these soft and laminated beds, inclosed between massive lavas, were folded while the lavas were fractured.

On the crest of the Edith Mountain ridge opposite the head of Cleveland Gulch the sandy calcareous shales contain some determinable fossil plants. Concerning the specimens collected, Dr. F. H. Knowlton reports the identification of *Pinus florissanti?* Lesq. and *Cratægus Holmesii* Lesq., several cones of *Pinus*, and one form with leaves in threes. Of the species named the former occurs in the Oligocene lake beds of Florissant, Colo., while the type of the latter was obtained by Mr. Cross in a local rhyolitic tuff near Silver Cliff, Colo.

The suggestion of an Oligocene age for these tuffs receives a degree of confirmation from the gasteropod shells found by Mr. Clements in a thin limestone layer of what is clearly the same horizon on the divide between Cleveland and Schafer gulches. Concerning these, Mr. T. W. Stanton reports two species of a fresh-water shell, *Limnæa*. While not able to identify the species with certainty, Mr. Stanton states that the two species most nearly resemble *L. Meekii* Evans and Shumard, and *L. Shumardi* Meek, which occur in the White River beds, usually assigned to the Miocene but considered by some paleontologists as Oligocene. Therefore, according to the concurrent evidence of plant remains and of invertebrate fossils, the calcareous tuffs and shales of the top of the Burns complex may be regarded as probably Oligocene or early Miocene in age. This conclusion is of interest as indicating, at least roughly, the lapse of time since the beginning of the epoch of the San Juan tuffs, a question which is discussed more fully in another part of this text.

PYROXENE-ANDESITE FLOWS AND TUFFS.

The Burns group of lavas, tuffs, etc., is succeeded by dark fine-grained pyroxene-andesites in a complex of flows and tuffs reaching a maximum thickness of something over 3000 feet. The map exhibits the boundary between these two divisions of the Silverton series as far as it could be traced. By reference to the map it will be seen that these lavas are most prominently developed in the central portion of the quadrangle. They extend westward into the Telluride quadrangle (although not separable from the Burns latite) and eastward into the San Cristobal quadrangle, where they are covered by more recent volcanics. To the north they thin out and are wanting in some places, between the San Juan tuffs and overlying rhyolitic rocks. To the south also they are now missing, partly through erosion.

General description.—The most common lavas of this group are predominantly dark, fine-grained, almost aphanitic rocks, and although but few small crystals of feldspar and dark grains of augite are noticeable to the unaided eye, the mass has a crystalline appearance viewed with a hand lens. They are not so unlike the Burns latite as the megascopic appearance suggests, but differ sufficiently to justify the name andesite.

In the northeastern section of the quadrangle occur two somewhat different types, which are worthy of notice. The first of these is of conspicuous porphyritic texture, most prominent in Engineer Mountain and the divide between Bear Creek and the Uncompahgre. It also extends eastward into the drainage of Henson Creek. This rock has abundant labradorite feldspar crystals, 5 centimeters or more in diameter, and the augite and mica crystals are nearly as large. The other type of the northeastern section occurs as the uppermost flow of the complex and is prominent for several miles along the northern side of Henson Creek at the general level of the Dolly Varden mine. It is a somewhat more basic rock than any other of this group, being richer in augite and hypersthene and magnetite. It has usually a dark color and the cleavage planes of the tabular crystals of labradorite are noticeable in hand specimens.

The pyroxene-andesite complex is made up chiefly of massive flows, few of which exceed 300 feet in thickness. Vesicular and scoriaceous zones are occasionally found, but in many places are almost wanting. Vesicles usually contain opal, chalcedony, or quartz, but crystallized silicates are rare. Vitreous outer zones are but seldom found.

Tuffs and coarse breccia or conglomerate sometimes separate lava flows, but such masses usually have very irregular relations to the bodies of massive rock. On the larger cliff faces of amphitheaters the vesicular or tuffaceous bands are prominent and the alternation with massive rock leads to ledge or bench outcrops. Prominent shoulders of the central mountains are commonly due to massive flows. The tuff bands are very frequently bleached or stained in brownish or reddish colors.

There is clearly a very uneven and local development of tuffs. In the northeastern section of the quadrangle fine-grained tuffs play a more important rôle than elsewhere. Below the uppermost flow of unusually fresh andesite north of Henson Creek there is over 200 feet of very fine-grained sandy tuffs of pale-green or grayish color. Above the flow come more tuffs of extremely even grain, separating it from the Potosi series. These tuffs are commonly bleached and are so white in some places, as on the summit of Engineer Mountain, that they resemble rhyolitic ash. North of the quadrangle the tuffs are brown in color and consist of minute grains of andesite, some particles exhibiting hypersthene, and it is thought probable that by far the greater part of the tuff is derived from pyroxene-andesite.

A short distance north of American Flats, in the Ouray quadrangle, these tuffs reach a thickness of several hundred feet.

Petrographic details.—The common fine-grained pyroxene-andesite was in its fresh condition rich in labradorite—Ab_1An_1 and Ab_2An_3 both common—with much less pale-green augite, hypersthene, orthoclase, and quartz, and still less magnetite. Orthoclase is quantitatively of considerable importance, as demonstrated by analysis, but it can hardly be considered as so nearly equal to plagioclase as to justify the reference of the rock to the latite group. All constituents have characters common for such rocks, which are usually called augite-, hypersthene-, or pyroxene-andesite. Hornblende does not appear in any but a few outlying localities.

The texture naturally varies somewhat in different portions of the flows, ranging from vitrophyric (rare) and amygdaloidal to holocrystalline and dense aphanitic. But a large proportion of this rock exhibits under the microscope a gradation between the larger crystals of labradorite, some exceeding 4 millimeters in diameter, and the groundmass particles, which are seldom pronounced microlites. This transitional texture, together with the decomposition products, renders even the largest crystals inconspicuous. Orthoclase and quartz are seldom prominent except when a micropoikilitic intergrowth is present, but are discernible on close examination. They are often obscured by chlorite or ferritic hydroxides. Magnetite is very subordinate. The rock as a whole is by no means so basic as its dark aphanitic habit would suggest.

The pyroxenes, augite, and hypersthene probably occur in the fresh rock in nearly equal amounts. But although much of the andesite is dark and apparently nearly fresh, there is in fact no trace of the original hypersthene left except in a few localities, serpentine of yellowish-green color replacing it. It is often characterized by a cleavage parallel to some plane of the prismatic zone and seems like a massive mineral at times, but aggregate polarization is usually to be observed. The rock exhibiting most clearly the hypersthene in process of alteration occurs in the small cap of andesite on the point next north of Whitehead Peak. The hypersthene ordinarily occurs in well-formed prismatic crystals, and this form characterizes the serpentine, indicating that it does not come from either biotite or olivine. Augite occurs in prisms less perfectly formed than the hypersthene; its course of alteration is characteristically different from that of its associate, and often much fresh augite remains. The usual product of decomposition is rich in granules of calcite, with chlorite, etc. Biotite and hornblende are only sporadically present in these pyroxene-andesites. A vitrophyric modification was found in a small remnant of a flow resting on calcareous shales of a knob on the ridge west of Edith Mountain. In this rock, an analysis of which is given below, both augite and hypersthene (or bronzite) are fresh and there is also a small amount of unaltered biotite developed.

Andesite having a composition near that of the rocks described above, but much more prominently porphyritic in texture, occurs in the mass of Engineer Mountain and extends for some miles east and west. Mica is rather prominent in some places, but the serpentine pseudomorphs, indicating hypersthene, occur even where mica is most distinct.

An unusually fresh pyroxene-andesite occurs on the north side of Henson Creek as a flow extending for several miles and situated just below the Potosi series of latites and rhyolites. In this rock there is strongly pleochroic hypersthene and probably some olivine, now wholly altered. The ferromagnesian silicates are more numerous than in the fine-grained type, and the labradorite phenocrysts are larger and more tabular in shape.

Chemical composition.—The greater part of the pyroxene-andesite is too much decomposed to afford satisfactory analyses. But two comparatively fresh specimens have been subjected to analysis by W. F. Hillebrand, with the following results. Two partial analyses by the same analyst are given for purposes of comparison.

Analyses of pyroxene-andesites.

	I.	II.	III.	IV.
SiO_2	58.88	56.03		
Al_2O_3	16.10	15.97		
Fe_2O_3	3.12	4.78		
FeO	2.94	3.00		
MgO	2.30	3.36		
CaO	6.05	6.44	6.84	4.74
Na_2O	3.17	2.85	3.39	3.24
K_2O	1.86	3.29	2.99	3.20
H_2O below 100° C.	1.66	1.31		
H_2O above 100° C.	2.86	1.08		
TiO_2	.73	1.01		
ZrO_2	.02	Trace?		
P_2O_5	.17	.48		
MnO	.16	.16		
BaO	.12	.08		
SrO	.14	.04		
Li_2O	Trace	?		
FeS_2	.07			
Total	99.97	99.88		

I. Vitrophyric pyroxene-andesite from ridge west of Edith Mountain. This rock exhibits fresh hypersthene and is probably representative of the average rocks of this group more nearly than is II.

II. Pyroxene-andesite from tunnel in Copper Gulch, on Dolly Varden claim. This is the most basic looking rock of the group, but exhibits in thin sections much quartz and orthoclase. It contains much hypersthene in process of alteration to serpentine.

III. Gabbroic facies of pyroxene-andesite from dike cutting normal rock, Henson Creek, between Redcloud and Schafer gulches.

IV. Pyroxene-andesite from flow near top of Middle Mountain. Nearly fresh as regards its feldspars.

Scrutiny of these analyses shows that these rocks, in spite of their dark color and the presence of considerable hypersthene, are strongly feldspathic and may contain more than 10 per cent of quartz. The high percentage of potash in II, III, and IV agrees with the prominence of orthoclase as revealed by the microscope. The potash of II corresponds to 19.46 per cent of orthoclase, showing that this rock is by no means a typical andesite and inclines strongly toward latite. The smaller amount of lime in IV agrees with the smaller amount of pyroxene in this rock as compared with the others. There is little, if any, decrease in the amount of plagioclase in IV.

Occurrence.—The main horizon at which the pyroxene-andesite appears as a flow is distinctly above the more siliceous, hornblendic Burns latite and below the Potosi rhyolite. It is found above the former all through the eastern part of the quadrangle, from the head of Maggie Gulch northward. It caps many of the high peaks, as shown by the map, and is the most prominent rock in the central portion of the quadrangle.

The vents through which this large series of lavas ascended are not surely known. Some dikes have been found, as in Stony Gulch, on the west side, where a large one cuts San Juan tuffs and probably also the Eureka flow-breccia.

The relatively basic upper flow in the Henson Creek region may have issued through a set of fissures represented by those filled with the nearly granular rock from below Redcloud Gulch, of which a partial analysis (III) was given in the table.

POTOSI VOLCANIC SERIES.

The uppermost member of the volcanic complex found in the Silverton quadrangle received the name "Potosi rhyolite series" in the Telluride folio, where the development presented in the Telluride quadrangle was fully described. The name was derived from the high peak north of Canyon Creek in the Silverton quadrangle, the upper 1250 feet of which consists of these rocks.

The general appearance of the Potosi rocks is that characteristic of rhyolite, and they were so designated in the Telluride folio, although it was there pointed out that the single available analysis showed that the glassy form analyzed belonged to the series of highly siliceous lavas containing alkali and lime-soda feldspar in nearly equal amount which are properly designated quartz-latite. It is now certain that these quartz-latites are much more common than true rhyolite in this region and hence it is desirable to modify the name used in the map legend. The designation of certain lavas of the series as quartz-latite is consistent with the use of the term quartz-monzonite for the granular equivalents of certain of the Silverton lavas. It is probable that true rhyolite also occurs in the Potosi series, but in amount it is subordinate to the quartz-latites. There may also be a series of intermediate lavas connecting the extremes.

Three separate areas of lavas referred to the Potosi volcanic series are present in the Silverton quadrangle, and each presents certain peculiar features. In the western and northwestern portions of the area the series has the same character as in the Telluride quadrangle. In the northeastern section an isolated patch of supposed Potosi lavas caps the divide north of Henson Creek, while in the southeastern corner of the area appear closely related rocks which have a wide distribution in the central portion of the San Juan Mountains, to the east. It is not at present demonstrable that the lavas of these three areas belong strictly to one epoch of volcanic activity, and it is almost certain that they came from different centers, yet from their relations and petrographic characters it is probable that they do belong to the same epoch.

Northwestern area.—Where the full Potosi series of this section is preserved three divisions are noticeable. At the base is a coarse-grained tuff of flow-breccia. Above that comes the principal division, including the flows which cause cliffs or crenelated ridges where the mountain tops are formed of them. The uppermost member, which is present only in Potosi Peak in the Silverton quadrangle, is a succession of thin flows and tuffs, making much gentler slopes and presenting a reddish color, due to the andesitic ash in the tuffs.

The maximum observed thickness of the series is in Potosi Peak, where over 1200 feet of nearly horizontal flows and tuffs are present.

The lowest member of the series is composed of a variable amount of gray, gravel-like tuff below, succeeded by a flow-breccia so rich in fragments resembling the tuff that no distinct line can be drawn in many places. The tuff layer is less prominent in the Silverton quadrangle than in the Telluride. The fragments of the tuff are mainly of quartz-latite of reddish, gray, or white colors, with some of the dark latites or andesites of the Silverton volcanic series.

The flow-breccia is very similar to the Eureka flow-breccia. Its fragments are commonly but an inch or less in diameter and are of the same rocks as those in the tuff. The band of this rock forms the greater part of the lower 200 feet of the series.

The banded flows, two or three in number, which constitute the chief part of the Potosi series in this section are composed of a characteristic wavy, felsitic lava. The flows are 100 to 200 feet in thickness and are usually separated by thin tuff beds. Vertical jointing is common, causing columnar structure, steep cliffs, and jagged ridges, or divides. Benches or strong lines visible for miles mark the zones between these flows.

The rock of these flows is usually light gray, has a wavy fluidal banding or lamination, and contains many crystals of orthoclase and soda-lime feldspar with biotite in thin leaves as the only dark silicate. No quartz crystals have been noticed, but the felsitic gray groundmass is rich in quartz and orthoclase.

The prominent structure of the rock is caused by the irregular alternation of wavy, dull-gray or white earthy-gray bands usually less than a centimeter in thickness. The rock contains some fragments like those of the flow-breccia below, and the fluidal texture is seen in the curving of flow lines about such inclusions. The banding causes the rock to split easily into irregular plates.

Under the microscope it appears that much of the Potosi latite had a glassy groundmass and contains ferritic trichites by which the flow structure was emphasized. Glass is now rarely found but the devitrification, producing the usual cryptocrystalline mass, clearly proceeded from perlitic cracks the course of which can often be seen. A large portion of the rock is thus apolatite.

The more massive parts of certain flows are simply felsite-porphyries, there being no fluidal or banded texture. Obscure spherulitic crystallization is common in the banded rock and spherulites several inches in diameter occur in a few places, notably on the crest at the head of Ingram Basin.

The upper division of this section of the Potosi volcanic series consists of a complex of thin flows and reddish tuff layers, of which several hundred feet appears in Potosi Peak. The flows of this division are variable in color and in degree of crystallization. Some are reddish or pink felsites, others are gray, and locally black vitrophyre is found, with a dominant glassy base holding numerous feldspar and biotite crystals.

The upper flows are often reddish felsite-porphyries, and seem richer than usual in plagioclase and biotite. Dull, felsitic, streaked brown or gray bands, containing few crystals and showing flow structure, are numerous. Andesite or latite inclusions occur to some extent in all flows, and in the thin variable tuff layers between flows there is sometimes a considerable admixture of these rocks. The upper division as a whole is more or less reddish, its color making it conspicuous at long distances.

When examined microscopically, these rocks exhibit microstructures and stages of devitrification similar to those of lower flows. Some bands are rudely spherulitic, others are partly glassy.

Northeastern area.—An isolated area of rocks which are referred to the Potosi volcanic series forms the range of hills north of Engineer Mountain, a portion of American Flat, and the divide between the forks of Henson Creek. It extends northward a very short distance into the Ouray quadrangle. Dikes of similar rock occur on the north side of North Fork of Henson Creek a few miles east-northeast of Dolly Varden Mountain, and it is possible that an eruptive conduit exists beneath the sharp peak near that mountain.

The Potosi series here is mainly a succession of flows, differing in detail from those of the northwestern area, but of general correspondence. The lowest flow, of varying thickness, reaching a maximum of about 200 feet, is a dull-gray or pinkish felsitic rock characterized by many small black biotite leaves and many feldspar grains of small size. The biotite leaves are less than 3 millimeters in diameter and are usually fresh and hence conspicuous though a quantitatively subordinate constituent. In some places hornblende occurs, but it is generally rare and is commonly decomposed. Among the feldspars a plagioclase near oligoclase exceeds orthoclase in amount. Both appear in sharply angular fragments of crystals, in all parts of this section of lavas. Quartz phenocrysts occur much less abundantly than either feldspar. They are also much broken, and the fragments have been rounded and embayed by resorption, while such action is almost lacking in the case of the feldspars.

The groundmass possesses characters that are very common in rhyolite, since it is a fine cryptocrystalline mass of quartz and orthoclase, sometimes microspherulitic, occasionally exhibiting fluidal texture, and often resembling a devitrification product, though seldom affording evidence on that point.

Above these lower flows occurs a flow-breccia with more or less vitreous matrix, as in the hills north of Engineer Mountain and in some other places, while the glass base has been devitrified in the corresponding rock of Dolly Varden Mountain and vicinity.

Dull-gray rhyolite-porphyry, some of which is aporhyolite, occurs above the flow breccia of the former locality, and some vitrophyre also appears in the same place.

The sharp unnamed peak northeast of Dolly Varden Mountain is made up, in its upper portion at least, of a gray rhyolite-porphyry, occasionally banded but more commonly massive. This rock is a true rhyolite, as will appear from the chemical analysis to be given in a later paragraph.

Rio Grande drainage area.—On either side of the head of the Rio Grande, in the southeastern section of the quadrangle, the mountains are capped by light-colored lavas belonging to a group which becomes very prominent in the San Cristobal quadrangle. The principal rock is a quartz-latite very similar to that of American Flat and associated with it are felsitic rhyolites. The former rock occurs at the base and in this section rests unconformably on San Juan tuffs or upon a thin representative of the Silverton volcanic series, as shown by the map. An eastward dip carries these Potosi rocks beneath a considerable thickness of later lavas in the central portion of the San Juan Mountains. The character of these upper lavas is not known in detail, although it appears from a distance that they do not all belong to one kind of rock.

In Greenhalgh Mountain a thickness of more than 1000 feet of these rocks remains. Considerably more than half of this, from the base upward, consists of quartz-latite, while the upper part is rhyolite proper, forming the summit rock of both Sheep and Greenhalgh mountains, the contact being concealed by talus.

The latite is trachytic in appearance, since quartz is restricted to the groundmass. It contains many glassy sanidine crystals, with fresh brown mica leaves as the most conspicuous phenocrysts, embedded in a pink or gray groundmass which clearly exhibits fluidal texture when examined with a hand lens. There are also many white and usually much-altered plagioclase crystals in the rock, the prevalent decomposed condition of this constituent standing in marked contrast to the fresh state of the sanidine and mica.

The particularly fresh rock of this type, of which an analysis is given below, resembles the lower flows of the northeastern section, already described. Some of the rock is very like the common wavy banded rock of the western Potosi series.

Chemical composition of Potosi lavas.—A complete analysis of one of the Potosi lavas was given in the Telluride folio. Further analyses have now been made and it has become plain that the greater portion of the series consists of quartz-latite, while rhyolite proper also occurs. In the table below are given two complete analyses and several partial ones illustrating the composition of these rocks.

Analyses of rocks of the Potosi volcanic series.

	I.	II.	III.	IV.	V.	VI.	VII.	VIII.
SiO_2	64.72	64.93						
Al_2O_3	14.18	16.79						
Fe_2O_3	1.58	3.54						
FeO	.40	.32						
MgO	.50	.65						
CaO	2.62	2.11	2.04	1.76	1.30	1.20	.65	.61
Na_2O	3.88	3.33	3.07	2.93	3.93	3.94	2.74	3.53
K_2O	1.82	4.76	4.25	5.26	4.11	3.16	5.31	4.84
H_2O below 110° C	2.68	1.12						
H_2O above 110° C	6.82	1.65						
TiO_2	.43	.53						
ZrO_2	......	.03						
P_2O_5	.08	.17						
BaO	.28	.15						
SrO	.21	Trace						
Totals	100.20	100.08						

Specimen I contains traces of CO_2, SO_3, Cl, S, and MnO; II contains traces of S, NiO, MnO and Li_2O.

I. Dark vitrophyric quartz-latite from ridge between Marshall and Virginius basins, Telluride quadrangle. Analyst, H. N. Stokes.

II. Felsophyric quartz-latite from bench south of Greenhalgh Mountain, Silverton quadrangle. Analyst, W. F. Hillebrand.

III. Felsophyric quartz-latite from American Flat, Silverton quadrangle.

IV. Vitrophyric quartz-latite from Potosi Peak, Silverton quadrangle.

V. Vitrophyric quartz-latite from mountain next north of Engineer Mountain, Silverton quadrangle.

VI. Vitrophyric quartz-latite from contact zone of dike on north side of North Fork of Henson Creek, Lake City quadrangle.

VII. Fluidal, felsitic rhyolite from summit of Greenhalgh Mountain, Silverton quadrangle.

VIII. Felsophyric rhyolite; débris from peak northeast of Dolly Varden Mountain, Silverton quadrangle.

All partial analyses were made by George Steiger.

In the rocks of which complete analyses were made there is more than enough alumina to go with lime and the alkalies for the formation of the orthoclase, albite, and anorthite molecules. Assuming that the same is true of the other rocks they may be compared on that basis as in the following table.

Mineral analysis of Potosi volcanic rock.

	Orthoclase.	Albite.	Anorthite.
I	10.56	32.49	13.07
II	28.36	28.30	10.56
III	25.58	25.68	10.29
IV	31.14	25.15	8.62
V	24.46	33.01	6.39
VI	18.90	33.54	5.84
VII	31.14	23.58	3.34
VIII	28.36	29.34	3.06

In each of the rocks a reduction in the anorthite figure is necessary, as some lime goes to form apatite.

These tables show that the Potosi lavas vary considerably in the ratios between the alkalies and lime, and between the alkalies themselves. The ratio of plagioclase to orthoclase depends, of course, on the composition of the former. The optical determinations made of the plagioclase show that it varies from a sodic oligoclase to andesine. It is plain that these rocks contain much plagioclase; but that in two of them the alkali feldspar comes to such dominance that they may be properly termed rhyolite, since there must be from 20 to 30 per cent of quartz in each rock.

Intrusive Rocks.

ANDESITES.

Under this heading are included upon the map a number of somewhat different rocks. They correspond petrographically in some cases to rocks which have already been described, but they are separately mapped, because in such instances they represent intrusions of different periods from the main ones of the same kind. Thus the Picayune andesite and the intrusive of the Lake Fork of the Gunnison are practically the same rock, although apparently of different age. Some of the intrusives are much like the Niagara Gulch latite and others are like the pyroxene-andesite, but belong to earlier or later epochs than the main masses of these types.

The several kinds of rocks grouped for convenience under this heading are described below:

Augite-andesite: Picayune type.—The rock of the area shown by the map as occupied by intrusive andesite, in the drainage of Lake Fork, is similar in composition to the Picayune andesite, already described. The rock is commonly much decomposed and it may be that not all of the area is occupied by rock of one type. It seems possible that the Picayune andesite—that is, augite-andesite earlier than the Eureka rhyolite—occurs also on the Lake Fork, and that later eruptions of the same magma occurred there. It is clear that most of the andesite mapped as intrusive on the Lake Fork is later than the tuffs belonging to the upper part of the Burns complex. So abundant are the tongues or inclusions of tuffs and occasionally of massive Niagara Gulch latite in this region that it was considered impossible, in view of the poor exposures, to map them all in detail, and the intrusive rock was represented as occupying the entire area.

Latites resembling the Niagara Gulch type.—Eruptions of magmas similar to that of the Niagara Gulch latite occurred in the Silverton quadrangle after the Burns epoch, to which the principal masses of that type belong.

One of these rocks occurs as a crosscutting mass in Hurricane Basin that extends to the summits of the mountains on both sides, where it spreads out in sheet form in the upper tuffs of the Burns complex. This rock differs from the Niagara latite in composition mainly through a marked increase in the amount of biotite and possibly by a greater richness of the plagioclase phenocrysts in soda. Determinations by the Fouqué method show that nearly all of the plagioclase crystals are soda-rich oligoclase. The rock must tend toward the trachytes, but it is too decomposed to permit this point to be determined by chemical analysis.

The felsitic gray or greenish predominant groundmass is cryptocrystalline and seldom exhibits the microlitic texture characteristic of the Niagara Gulch latite. The rock certainly once contained hornblende and in some places a little augite, but those minerals, as well as the greater part of the biotite, are entirely decomposed and are recognizable as former constituents only by their outlines or their alteration products. That the groundmass is rich in orthoclase and quartz must be inferred from the allied coarser-grained latites of the district.

The intrusives on either side of Schafer Basin are nearly like the above-described latite in composition but have a much more pronounced porphyritic texture, the plagioclase phenocrysts being larger, and containing occasional orthoclase crystals an inch or more in diameter.

Quartz-latite of ridge south of Bear Creek.—The broad ridge between Bear Creek and the east fork of the Uncompahgre is capped by a rock bearing a close resemblance to the Niagara Gulch latite. This mass seems to rest upon a variable amount of pyroxene-latite tuffs, but the dike or crosscutting relations seen at some points and shown by the map indicate an intrusive origin for this mass at some later date than that of the principal surface flows of the Niagara Gulch latite.

The rock of the mass in question, in its freshest observed condition, is very dark and dense, with minute feldspar, augite, biotite, and hornblende crystals lying in a predominant very fine-grained groundmass which is sometimes microlitic, sometimes granular. Usually there is a dull reddish tinge to the mass, and a strong fluidal texture is common, especially in the upper and lower zones. In the freshest rocks of these zones the groundmass has the appearance of a devitrification product. In most specimens examined microscopically the augite and hornblende are entirely decomposed, while the mica is sometimes fresh. Hornblende was apparently not always developed. The groundmass often resembles that of the typical Niagara Gulch rock, but may be richer in soda-lime feldspar.

The rock is certainly much nearer the Niagara Gulch latite than the pyroxene-andesite in composition, but no specimen was found sufficiently fresh for a chemical test which might permit a close correlation.

The fluidal banding is very marked in much of the rock, and where the decomposition has far advanced the product resembles a stratified tuff of gray gravelly material. The disintegration on decomposition is more pronounced than in any other rock of the quadrangle.

Dike andesites and latites.—Narrow dikes of andesite and latite occur sparingly over the entire quadrangle. Most of these rocks are now much decomposed, especially as to their dark silicates, hence close correlation with the principal types of the larger masses is impossible. But it is clear that they are nearly related to the Canby or Kendall latites, or to corresponding rocks with more strongly predominant lime-soda feldspars, which are properly andesites.

A number of these cut San Juan tuffs in the southwestern section of the quadrangle. The age of these rocks is, of course, not well indicated. In the group of mountains southeast of Silverton are many of these dikes, there cutting members of the the Burns complex. Some of these are hornblendic and related to the Canby latite.

Various dikes observed in the western zone of the quadrangle—in Richmond or Imogene basins, on Hayden Mountain, and elsewhere—seem related to the andesitic dikes of the Telluride quadrangle. None of these has been observed to cut the Potosi rhyolite, and it may be that all these dikes are older than that lava.

Some dikes of the pyroxene-andesite type occurring in the eastern portion of the quadrangle seem so naturally to belong with that rock that they have received the same color upon the map.

The only dike rock of the kind under discussion that was observed to cut surface lavas younger than the pyroxene-andesite is a dark aphanitic augite-andesite which penetrates the Potosi latite of the extreme southeastern corner of the quadrangle.

RHYOLITES.

At several localities there are dikes or intrusive masses of rhyolite which can not be closely correlated with the Eureka or Potosi rhyolites.

Intrusive sheets.—The area particularly characterized by rhyolite dikes and intrusive sheet-like bodies lies west of the Animas River, between Eureka and California gulches. A prominent dike traverses Houghton Mountain.

All these bodies consist of a peculiar white or dull-gray felsite, usually with a very pronounced lamellar structure, and almost wholly without phenocrysts. In some places a zone of distinct spherulitic texture runs parallel to the contact zone, as along the Houghton Mountain dike. The fine lamellæ, often but 2 or 3 millimeters thick, are also commonly parallel to the walls, and this structure develops into a pronounced platy cleavage on weathering. Much of the rock is bleached very white and often it is stained in brilliant shades of red or yellow.

The microscopic texture is cryptocrystalline, granular, or in some cases spherulitic or poikilitic. Biotite blades rarely appear, and lime-soda feldspars are wholly lacking.

Closely related to this rhyolite is the rock in Cinnamon Mountain and the high crest leading southward from it. This rhyolite occurs in an intrusive sheet which has been dislocated by several minor faults. Tuffs of the Burns series remain upon the rhyolite in one place. The rock here apparently has slightly more biotite and plagioclase than that west of the Animas.

Dikes in the Picayune andesite.—The Picayune andesite is cut by numerous dikes of a fine-grained porphyritic rock of greenish gray color, now much altered, apparently a quartz-latite or rhyolite originally. It has many small, deeply embayed quartz crystals and others of orthoclase and plagioclase, generally much broken, in a predominant groundmass which is now cryptocrystalline, is believed to consist chiefly of quartz and orthoclase, and is in part probably a devitrification product. Biotite was formerly present, but if other dark silicates were originally constituents they have now been replaced by epidote and chlorite.

These dikes are so abundant within the Picayune area that they seem related to one another in time, but one of them was found to cut above the Picayune andesite into the Eureka flow-breccia, and the age relation thus indicated by that dike is confirmed by the occurrence of precisely the same rhyolite-porphyry cutting through the intrusive andesite of the Lake Fork and into the tuffs of the Burns complex, at a point above the Bon Homme mine on the north spur of Handies Peak. All dikes of this rock are narrow and it was considered impracticable to represent them on the map.

PORPHYRIES.

The geologic map exhibits the distribution of a group of related porphyritic rocks occurring as intrusive masses within or below the volcanic complex. These intrusive rocks may correspond, in some cases, to certain surface lava flows but their different occurrence renders them worthy of distinction upon this map.

Some of these masses are laccolithic in character, some are rather like stocks or cross-cutting conduits, and some are clearly dikes.

Canyon Creek laccolith of granite-porphyry.—This rock occurs in a large intrusive mass, as an asymmetric laccolith, extending from Canyon Creek across the line into the Ouray quadrangle. Its plane of intrusion is partly beneath and partly above the Telluride conglomerate, as represented by the map. The mass is about 500 feet thick adjacent to its abrupt southwestern border, and considerably thicker in the central portion.

The rock is characterized by its prominent hornblende and plagioclase crystals, some of which are nearly 1 centimeter long, lying in a gray microgranular groundmass of orthoclase and quartz with a little magnetite. Quartz seems confined to the groundmass, where it is abundant and developed in distinct dihexahedral crystals only slightly modified by contact with the less regularly formed orthoclase. This groundmass is so largely in excess of the phenocrysts of much altered plagioclase that it seems necessary to call the rock granite-porphyry in spite of its strong resemblance to the normal habit of quartz-monzonite-porphyry.

Deadwood Gulch laccolith of granite-porphyry.—A small laccolith is exposed at the eastern base of Sultan Mountain and Grand Turk being crossed by Deadwood and Cataract gulches. The mass occurs within the Hermosa formation almost at its base. The laccolithic nature of the occurrence is indicated by the distinct upturning of the fossiliferous limestones on the southern edge of the mass. The maximum thickness of the body seen is about 300 feet. On the north it is cut off by the monzonite stock.

The rock is a strongly marked granite-porphyry exhibiting both orthoclase and plagioclase phenocrysts, with biotite, in a gray, dense groundmass consisting almost wholly of orthoclase and quartz. Some of the orthoclase crystals reach more than 1 centimeter in diameter. The texture is that which is common to laccolithic rocks in the western United States.

A dike 15 to 20 feet wide, of similar rock, with very prominent groundmass and few small phenocrysts, cuts the schists of the canyon wall below the laccolith, but it is apparently not continuous and was not mapped. It is supposed to mark the channel through which the laccolithic magma ascended.

Sheets of Mineral Creek area.—At the forks of Mineral Creek and extending up each branch for nearly 2 miles occur several monzonite-porphyry or granite-porphyry masses which are represented on the map as intrusive sheets with irregular connection. The sheet character is very plain where they intrude the sedimentary rocks in the ravines on the north side of the South Fork of Mineral Creek and also in the principal ravine west of the main fork, but the exposures are so disconnected, owing to vegetation and slide rock, that the representation of the map may not be fully correct in detail.

In general the rock of these intrusive masses is a marked porphyry exhibiting many distinct feldspar crystals embedded in a felsitic, gray, even-grained groundmass. In some places there are large orthoclase phenocrysts, reaching an inch or more in length, as in the sheets in the Dolores formation, but commonly both feldspars are much smaller. Biotite and quartz occur variably as phenocrysts. The rock ranges in composition from granite-porphyry almost free from plagioclase, as in the bed of the main fork, near the northern limit of the porphyry, to quartz-monzonite-porphyry, such as the more common facies along the South Fork. In these latter rocks plagioclase is the more abundant in phenocrysts, although pinkish orthoclase tablets are usually present. The groundmass consists of quartz and orthoclase in all cases. The rock along the southern border of the valley of the South Fork exhibits the same variations and commonly has a coarser-grained groundmass than the rock farther north.

The granite-porphyry forming a ledge on the south bank of the South Fork, a little below the stream from the amphitheater under Bear Mountain, contains tufts of dark tourmaline resembling phenocrysts of a dark silicate to the naked eye. Near by there are some larger clumps of the same mineral, in a much decomposed portion of the porphyry. This development of tourmaline is presumably due to emanations of boric acid from the monzonite stock, but it is singular that so little trace of tourmaline has been observed, if such is the case.

The porphyry outcropping about the forks of Mineral Creek, along the road up the South Fork, and at certain points on the southern bank of the stream, is much decomposed and has also a fine lamellar parting, so that it breaks into thin flakes like a partially indurated shale and its character as a massive rock is obscured. The cause of this parting is not evident. Portions of the same rock near by are decomposed with similar products but retain their massive texture.

These porphyries are so nearly like the quartz-monzonite of the adjacent stock that it seems natural to consider the sheets of Mineral Creek as actually offshoots from the stock. But along the northern border of the stock above Mineral Creek there are few outcrops, and evidence of a transition from the common granular monzonite to the porphyry was not observed. On the contrary, in Snowslide Gulch, which enters Mineral Creek opposite its forks, the finely granular monzonite was found cutting porphyry sharply at about 9900 feet. Above this spot the rock is plainly granular, while lower in the ravine the much altered rocks are referable to the porphyry. It is believed that if the magmas of the porphyry sheets rose through the stock conduit they were cut off by later eruptions through the same channel and are not to be represented as direct offshoots from the monzonite mass. No indications of the porphyry sheets were found east of Snowslide Gulch, the lower slopes being here covered by glacial débris or the torrential fan of Bear Gulch.

Quartz-syenite-porphyry.—Scattered through the quadrangle are several occurrences of allied porphyries, most of them plainly intrusive masses, which are characterized by their large orthoclase or anorthoclase crystals. These rocks are represented by one color on the map.

Nearly all of the rocks here referred to are quartz-syenite-porphyries, that is, they consist principally of alkali feldspar, but contain enough quartz to require recognition of that constituent in the name. They also carry some plagioclase rich in soda and usually both augite and biotite, sometimes abundantly, in distinct phenocrysts.

The rocks possess a dark aphanitic groundmass, which predominates over the phenocrysts in most cases. The microscope shows that this groundmass consists mainly of fine scales or microlites of orthoclase with a fine magnetite dust so uniformly scattered through it as to cause the dark color. There are some small particles of augite and biotite in the groundmass, together with apatite and titanite, and a variable amount of quartz.

The various masses included in this group will be briefly mentioned:

1. A dark porphyry with fresh crystals of anorthoclase, some of which reach an inch in diameter, forms a round hill 600 to 700 feet high east of Summit on the divide between Mineral and Red Mountain creeks. The dark groundmass is here strongly predominant. But little feldspar of the albite-anorthite series is present.

The contact plane of this mass was nowhere found, owing to talus accumulations. No doubt the body is a small stock.

2. The crosscutting mass forming the summit of Red Mountain No. 3 is very similar to the preceding. It has fresher and more abundant dark silicates and yielded on partial analysis, by George Steiger, the following results:

Analysis of quartz-syenite-porphyry.

SiO_2	55.54
CaO	5.38
Na_2O	2.72
K_2O	5.42

A large part of the lime belongs to the pale-green augite, which must be rich in the diopside molecule.

3. Several small dikes of allied porphyry occur about the head of Red Mountain Creek. Two have been noted in the knoll north of the American Belle mine, one of them on the east side by the railroad, and the other in a railroad cut on the north side. Neither is represented, because of very limited outcrops.

The landslide blocks of this region sometimes exhibit dikes of this porphyry One such outcrop is on the wagon-road a short distance south of the Yankee Girl mine. This rock has more numerous orthoclase crystals and is lighter colored than the type described, but a part of the latter difference is due to decomposition. This rock is called "monzonitic porphyry" by Ransome (Bull. U. S. Geol. Survey No. 182, 1901, p. 127), who gives an analysis of it showing that it is much decomposed. It may be more closely allied to the monzonite than to the syenite group.

4. The small stock at the head of Full Moon Gulch varies much in texture, only a part of the rock possessing notably large orthoclase phenocrysts. The coarsest-grained modification has many pinkish orthoclase phenocrysts, some smaller ones of plagioclase and much altered dark silicates with a groundmass which is subordinate in some places. Much of the rock is of usual porphyritic texture, and decomposition with kaolinization is prevalent. No significant relations of textural variation to the shape of the mass could be detected.

5. In the northeastern section of the Silverton quadrangle this porphyry appears in several bodies, one of the most notable being the cap rock of Engineer Mountain. This is strongly porphyritic, possessing many glassy orthoclase crystals, which are colored reddish by a fine ferritic pigment, and some of which reach 2 or 3 inches in diameter. It has also a number of quartz, plagioclase, biotite, and hornblende phenocrysts. The ferromagnesian minerals are resorbed to a large extent and are marked by ferritic material in small particles. The dark ash-gray groundmass is about equal to the phenocrysts in amount.

A partial analysis of this porphyry by George Steiger yielded: SiO_2 60 20, CaO 3.22, Na_2O 3.38, K_2O 4.71.

The contacts of this mass are concealed by débris. It is apparently not intrusive because pieces of the rock are contained in the fragmental bed at the base of the Potosi rhyolite-latite series in the hill next north of Engineer Mountain. If not intrusive it rests upon the upper, bleached andesitic tuffs of the pyroxene-andesite division of the Silverton series.

This porphyry carries some inclusions of finely granular rock of very nearly the same mineral composition, with less quartz and dark components.

6. A small dike of this porphyry was observed on the ridge leading northwest from Engineer Mountain and another was found on the trail from California Gulch to Poughkeepsie Gulch, just east of the divide. Both have very prominent groundmasses.

Quartz-monzonite-porphyry at the head of Bear Creek.—The mountain between the forks of Bear Creek and American Flat is mainly made up of an apparently crosscutting mass of strongly-marked porphyry, which is also represented by dikes in the adjacent portion of the Ouray quadrangle.

This rock contains many labradorite phenocrysts, a few of which reach a diameter of 1 centimeter, a much less number of glassy orthoclase of irregular size, but some of them as much as 2 centimeters long, embayed quartz crystals, and abundant fresh biotite tablets. Diopside and green hornblende are subordinate constituents and both are much decomposed, the former mainly by resorption.

The groundmass is composed chiefly of orthoclase feldspar and quartz, the texture resembling that of the syenite-porphyries described above. Magnetite and particles of other dark minerals, such as chlorite, render the groundmass gray or greenish.

As a whole this rock resembles the syenite-porphyry in composition except for the amount of labradorite present. It belongs to nearly the same period of eruption as the syenite-porphyry, but may be somewhat more recent, as it clearly cuts across and upturns tuffs of the Potosi series on its southeastern contact. Elsewhere talus or slide débris conceals the contact, but the form of the mass plainly indicates that the body is of stock-like character.

Granite-porphyry dikes.—The map represents a unique dike of peculiar character which extends from the ridge north of Deer Park eastward through the mountains, crosses Cunningham Gulch, and has been traced up the eastern slope for nearly 2000 feet.

This rock is a typical felsophyre having abundant phenocrysts of orthoclase and quartz, with a much smaller number of biotite and plagioclase, in a felsitic groundmass of orthoclase and quartz. This groundmass is usually very finely and evenly granular, the two minerals being sometimes interlocked in graphic intergrowth.

The dike is from 20 to 30 feet wide in most places and has very marked porphyritic texture in the center, with contact zones of dense, greenish felsite, carrying a few quartz phenocrysts, the zones being 3 or 4 feet wide. The green color is due to minute particles of chlorite which may be an infiltration product from the adjacent volcanic rocks.

This dike has a number of bends, some of them rather sharp. On the west side of Cunningham Gulch, in the schists, it splits and presents in outcrop two overlapping portions.

Fragments of the same rock were found on the north slope of Galena Mountain and it may be that the dike thus indicated is connected with the main one, as the course in crossing Cunningham Gulch would carry the dike toward Galena Mountain.

Other porphyry masses.—The irregular intrusive body of porphyry represented upon the map as occurring in San Juan tuffs north of Middle Fork of Mineral Creek is of the common type of quartz-monzonite-porphyry.

This rock carries many distinct plagioclase and biotite phenocrysts in a fine granular groundmass of orthoclase and quartz. Chlorite and epidote are abundant, biotite having been completely decomposed. The contacts of this mass are visible in but a few places.

On the north side of Mill Creek, a western tributary of Mineral Creek, is another large porphyry body, clearly crosscutting, as seen on its western contact, the rock being so thoroughly decomposed that its original character can not be fully determined.

This rock consists now chiefly of quartz, orthoclase, and muscovite. Quartz was abundant. Whatever other phenocrysts were present originally, they are mainly replaced by an aggregate of muscovite. The groundmass orthoclase is also largely muscovitized. The rock is white, with prominent quartz grains.

QUARTZ-MONZONITE.

STOCK OF SULTAN AND BEAR MOUNTAINS.

Occurrence.—The southwestern section of the Silverton quadrangle is characterized by the presence of a large crosscutting mass of granular quartz-monzonite similar to several bodies of the same or allied rocks existing in the Telluride quadrangle. This mass has a length, east and west, of about 5 miles and a width of 2 miles. As shown on the map, its boundaries are very irregular in detail, there being frequent short apophyses and sharp angles at several points.

From Copper Gulch eastward across the Animas the crosscutting nature of the southern boundary is clearly exposed for almost the entire distance of 5 miles. On the north, however, the line is seldom visible, being for the greater part of the distance buried beneath the recent deposits of Mineral Creek. The vertical distance through which the crosscutting of this great stock is visible is nearly

4000 feet, from the Animas River to the summits of Sultan and Bear mountains. The formations intruded embrace schists and overlying sediments for a distance of 3600 feet, and San Juan tuffs for about 1300 feet. From the granular texture of the rock at the highest levels and from the fact that similar stocks of the Telluride quadrangle penetrate lavas of the Potosi series it is to be assumed that the monzonite magma ascended through several thousand feet of the bedded volcanic complex above the tuffs.

In spite of the close agreement between the analyses of the quartz-monzonite of Sultan Mountain and the Niagara Gulch latite, it is believed that the stock is of much later date than any lavas of similar composition now visible in the Silverton quadrangle, although it may well represent a channel through which lavas ascended to the surface.

Character of the monzonite.—The average rock of this great stock is pinkish in color, granular in texture, and of medium fine grain. The eye can readily distinguish in it orthoclase, the pink constituent which tinges the whole mass, white plagioclase, quartz, and dark silicates which are very subordinate in amount. The microscope shows that pale-green augite is the commoner dark constituent, and that biotite and green hornblende are variable elements. There are the usual number of accessories, including magnetite, titanite, and apatite.

While the feldspars—orthoclase and plagioclase—are often nearly equal in amount and quartz is abundant, so that the rock is to be called quartz-monzonite, there are variations from this composition in several directions. Orthoclase sometimes strongly predominates over plagioclase and the rock becomes a granite, while a corresponding dominance of plagioclase was not observed.

The ferromagnesian minerals increase in amount locally, generally with accompanying fine grain, and a much darker and nearly aphanitic rock results. Oftentimes these darker rocks are near the borders of the mass, but they are not always present in the contact zone. There is sometimes a gradation from the darker monzonite into the common facies, and in other places dike contacts were seen.

Complementary to the facies richer in darker silicates are small dikes of aplitic granite or quartz-monzonite, almost free from augite or other ferromagnesian minerals. These dikes are variable in grain from very fine to coarse, and an irregular porphyritic texture is also often developed.

The quartz-monzonite becomes porphyritic in many places, there resembling the intrusive porphyry sheets of the Mineral Creek area, as has been stated in describing those rocks.

Chemical composition.—The quartz-monzonite at the eastern base of Sultan Mountain on the wagon road has the composition given under I in the table below. It is probable that the visible mass of the stock is somewhat richer in ferromagnesian silicates than the specimen analyzed. For comparison the analysis of the Niagara Gulch quartz-latite north of Pole Creek and that of a quartz-monzonite-porphyry forming a laccolith in the Elk Mountains, Colorado, are given:

Analysis of monzonitic rocks from Colorado.

	I.	II.	III.
SiO_2	63.91	62.09	65.36
Al_2O_3	17.07	16.77	15.48
Fe_2O_3	4.39	3.96	3.09
FeO	1.51	.99	1.21
MgO	.81	1.63	1.53
CaO	4.47	4.26	4.14
Na_2O	3.48	3.77	3.58
K_2O	3.74	3.68	3.41
H_2O below 110° C	....	.50	.82
H_2O above 110° C	.33	1.32	.70
TiO_2	....	.73	.52
P_2O_5	.21	.25	.25
MnO	....	.14	.19
BaO	....	.10	.08
SrO	....	.05	
Total	99.92	100.24	100.36

I. Quartz-monzonite from east base of Sultan Mountain. Analyst L. G. Eakins.

II. Quartz-latite from ridge north of Pole Creek, Silverton quadrangle. Analyst, W. F. Hillebrand.

III. Quartz-monzonite-porphyry from Mount Carbon, Anthracite quadrangle, Elk Mountains, Colorado. Analyst, T. M. Chatard.

From the analysis of the Sultan Mountain rock, it appears that it contains about 20 per cent of quartz and 70 per cent of the feldspar molecules, orthoclase, albite, and anorthite. It is closely related to the other two rocks, one of which is a surface lava, while the other is a laccolithic intrusion.

SMALL BODIES OF MONZONITIC ROCKS.

Dike crossing Cunningham Gulch.—A wide dike of monzonitic rock crosses Cunningham Gulch at the mouth of Stony Gulch and runs up the east fork of the latter. It is difficult to outline this mass accurately because of the extensive alteration to which all rocks of this vicinity have been subjected, rendering the fine-grained porphyritic facies of the dike almost indistinguishable from the altered lavas of the Burns complex or even from the Eureka flow-breccia. Morainal material in Stony Gulch and the torrential fan at the mouth of this stream obscure a good portion of the body.

The rock within this dike is by no means uniform in character. It varies in composition from an aplitic granite to monzonite-porphyry, but the latter is greatly predominant. The texture also varies from granular to porphyritic, with very fine-grained groundmass, the latter being the more common.

At the forks of Stony Gulch the rock is an almost granular aplite, rich in quartz, with much orthoclase and but very little plagioclase, both feldspars being cloudy on account of decomposition. A hundred yards farther up Rocky Gulch is quartz-monzonite-porphyry with sufficient augite and biotite to make the rock dark in color. The irregularly-grained groundmass is rather coarse textured.

More commonly the rock of this mass is a granophyric porphyry with a strong contrast between the phenocrysts and groundmass, resembling the rock of the intrusive sheets and laccoliths. Usually the feldspar phenocrysts are of plagioclase with a lesser number of orthoclase, quartz, biotite, and in some cases augite. Chlorite, epidote, calcite, sericite, etc., are abundant secondary minerals. This dike occupies perhaps one of the conduits through which lavas of the Burns latite complex ascended, but no definite correlation can now be made.

Dike crossing Maggie Gulch.—A wide dike of monzonitic rock crosses Maggie and Porcupine gulches and extends nearly to Minnie and Cunningham gulches. It is thus about 3 miles in length and has a maximum width, in Maggie Gulch, of about 2500 feet. To the west of Porcupine Gulch the dike plainly forks, and the arms run approximately as represented on the map.

The rock of this dike is quartz-monzonite similar to the Sultan Mountain stock in composition. It is usually granular or nearly so, but has decidedly porphyritic facies in some places. The variation in composition is exhibited mainly by a decrease in the amount of plagioclase and sometimes of dark silicates, so that granitic or aplitic facies result. The rock has sufficient biotite or augite to give it a dark tone, but the feldspars and quartz always predominate very strongly.

Other monzonitic or granitic dikes.—A small quartz-monzonite dike of the same type as the last described occurs in Edith Gulch, and is shown on the map. A smaller dike of the same general character occurs in the cliffs on the north side of Eureka Gulch. It is not represented. A narrow dike of nearly white granite is exposed in the little canyon of the Animas below Howardsville.

This rock has a subordinate porphyritic texture, as it contains a few small plagioclase phenocrysts in a groundmass consisting largely of quartz and orthoclase in micrographic intergrowth. A little chlorite represents the original biotite of the rock.

CHEMICAL RELATIONS OF THE MAGMAS.

The various magmas that make up the great volcanic complex of the western San Juan Mountains are very much more closely related in their fundamental characteristic of chemical composition than appears from the names given to the rocks in the preceding discussions. Even when stress is laid upon the quantitative development of the various minerals it is difficult to convey a correct impression, nor do the chemical analyses themselves without interpretation serve to fully characterize the rocks. In order to bring out the inner relations of the representative rocks that have been analyzed recourse is had to the quantitative system for the classification of igneous rocks recently proposed by Cross, Iddings, Pirsson, and Washington (Jour. Geol., vol. 10, 1902, p. 555 et. seq. Also, in book form, "Quantitative Classification of Igneous Rocks," Chicago, 1903).

Without going into details concerning this system, which are unessential to the present discussion, it will suffice to explain that a complete rock analysis is treated as representing the composition of a magma from which a potential or *standard* theoretical mineral composition may be calculated. By following the same method of calculation in each case comparable results are obtained which form the basis of classification.

Taking now the foregoing analyses of lavas and the stock monzonite, and calculating the amounts of the standard mineral molecules which by reason of their abundance become in such rocks the factors in classification by the quantitative system, the figures of the subjoined table are obtained.

Normative mineral composition of rocks analyzed.

Name and locality of rock.	Quartz.	Orthoclase.	Albite.	Anorthite.	Total of these standard minerals.
Potosi quartz-latite: Greenhalgh Mountain	22.32	28.36	28.30	8.62	90.56
Potosi quartz-latite-vitrophyre; Telluride quadrangle	28.92	10.56	32.49	13.62	86.20
Burns quartz-latite; north of Pole Creek	15.24	21.68	31.96	18.07	86.93
Quartz-monzonite; base of Sultan Mountain	19.32	21.68	29.34	20.29	90.63
Pyroxene-andesite; Dolly Varden mine	10.44	19.46	24.10	21.13	75.15
Pyroxene-andesite; Edith Mountain	17.64	11.12	26.72	24.19	79.67

This table shows that the range between the extremes is really small. The quartz and the three feldspars make up more than 75 per cent of all the rocks. They are so extremely abundant in four rocks that they fall in Class I of the new system, Persalane, while the other two rocks come in the Class Dosalane, with strongly dominant salic (silico aluminous) mineral molecules. For the further expression of the classification and to bring out the important points that characterize these rocks as a series, another table is presented. The subrang names in the quantitative system, ending in "ose" are given.

The table expresses the various chemical relations used in classifying such rocks down to the division called subrang, and gives the name of the subrang represented. First, it is to be noted that all the rocks contain quartz in such ratio to the combined feldspars that they belong in the fourth orders of the respective classes. Next, considering the ratio of the combined alkalies to lime of the feldspar molecules (the ratio upon which the division called *rang* depends), it is found that in four rocks these factors nearly balance, in one the alkalies dominate, and in one the rock is on the dividing line. Finally, in the alkali feldspar molecules, soda and potash are approximately equal in four rocks, while soda dominates in two, these relations determining the subrang names given in the table.

Quantitative classification of rocks analyzed.

	Class.	Order 4, Quardofelic.	Rang. 2, Domalkalic.	Rang. 3, Alkalicalcic.	Subrang. 3, Sodipotassic.	Subrang. 4, Dosodic.
Potosi quartz-latite=toscanose	I	x	x	....	x	
Potosi quartz-latite-vitrophyre = lassenose - yellowstonose	I	x	x		....	x
Burns quartz-latite = amiatose near yellowstonose	I	x	....	x	x	
Quartz monzonite of stock = amiatose	I	x	....	x	x	
Pyroxene-andesite=harzose	II	x	....	x	x	
Pyroxene-andesite=tonalose	II	x	....	x	....	x

SEQUENCE OF LAVAS.

From the preceding discussion of the chemical relations of the Silverton lavas it is evident that in view of the long time during which the various magmas were erupted, there has been much less progressive change in their character than is usually found in a petrographic province. The earliest lava was intermediate in composition and furnished the andesitic and probably also the latitic rocks of the San Juan tuffs. Then followed Picayune andesite, Eureka rhyolite, Burns quartz-latite, quartz-bearing pyroxene-andesite, Potosi quartz-latite, and rhyolite, and afterward the series of stock and dike rocks. Among the stock eruptions, which were later than all the surface volcanics known in this part of the San Juan, are several magmas which are much like earlier lavas. The quartz-monzonite of Sultan Mountain is very near in composition to the Burns latite analyzed. The large stock of Rolling Mountain and San Miguel Peak, Telluride quadrangle, is chemically near the quartz-latite from Greenhalgh Mountain, but cuts rocks of the Potosi series to which the latter rock belongs. A gabbroic facies in the stock of the Ophir Needles, Telluride quadrangle, is much like the vitrophyric pyroxene-andesite from Edith Mountain. The most basic stock rocks yet known in the San Juan Mountains are the gabbros of Stony Mountain and Mount Sneffels; no corresponding lavas have been found in this region.

It is too early in the investigation of the region to discuss the lavas of the San Juan Mountains as a whole, but in spite of the facts pointed out for the Silverton quadrangle it is very probable that among the later lavas will be found more siliceous and alkalic rhyolites on the one hand and more basic andesites or basalts on the other. But the western San Juan surely does not show the progressive change ordinarily observed in a long series of eruptions from one center and currently explained as due to magmatic differentiation.

LAVAS FOLLOWING THE POTOSI SERIES.

There are no means of ascertaining the thickness of the surface lavas in this region after the eruptions of the Potosi epoch, yet it probably amounted to thousands of feet. The fact that later lavas are known above the Potosi east of this quadrangle does not prove beyond question that such lavas existed in corresponding development here, for the extent of older lavas has been seen to be limited in certain cases. But the mere existence of the great granular stocks of monzonite, diorite, and gabbro in the Silverton and Telluride quadrangles proves that there must have been a considerable amount of lavas present at the times those stock magmas were erupted, to say nothing of the floods that may have poured out of these immense conduits.

It is not known what minimum depth below the surface is necessary to secure the conditions for coarse granular texture in such magmas, cooling in such conduits. Manifestly it is not so great as was supposed not long ago and may not exceed a very few thousand feet unless a thickness of late lavas be assumed in this region which seems remarkable, to say the least. These granular rocks, in immense crosscutting masses, form the highest peaks of the western San Juan, rising above 14,000 feet in Mount Wilson and Mount Sneffels, and approaching that elevation in several other peaks. Unless the time-honored conception that the granitic texture is a deep-seated phenomenon is disregarded it must be assumed that at least 1000 or possibly 2000 feet of lavas were once present above the summit of Potosi Peak and this region generally when the great stock eruptions took place. If the stocks belong to different dates, then the great thickness was maintained for a long period. It is easy to conceive, further, that great outpourings took place through these channels.

Considering all these factors it seems within the bounds of reason to conclude that the sum of the lavas extravasated after the Potosi epoch may have exceeded that of all those which were erupted to the end of that time.

AREAL GEOLOGY.

As has been shown in the general account of the San Juan geology at the beginning of this folio, the area included within the boundaries of the Silverton quadrangle is near the southern and western borders of a region of igneous rocks, the products of a great series of volcanic eruptions which began in early Tertiary time and continued throughout the greater part of that period. In the Telluride quadrangle, to the west, the rocks of the volcanic series have been so far removed by erosion that they extend only over a part of the area, the rest being occupied by the earlier sedimentary formations. In the region particularly under discussion, however, the lavas and breccias and accumulations of volcanic ejectamenta, are in higher degree the prevailing rocks, and it is only at the extreme north and south that erosion in the valleys of the Rio Grande and Uncompahgre and Animas rivers, has revealed the underlying formations that constitute the floor upon which the younger rocks rest.

NORTHWESTERN CORNER OF QUADRANGLE.

The area between the northern and western quadrangle boundaries and the high crest separating the drainage area of Red Mountain Creek from that of the San Miguel River and Canyon Creek is comparatively simple in its geologic features and is more like the adjacent portion of the Telluride quadrangle than the main area of the Silverton. The volcanic succession—San Juan, Silverton, and Potosi—is here developed as it is found farther west rather than as it occurs in the remaining parts of the Silverton quadrangle. The gorge of Canyon Creek cuts through the volcanic and exhibits Paleozoic sediments beneath them.

Potosi Peak.—The dominant summit of the northwestern section is Potosi Peak (13,763 feet), the steep southern face of which affords a section for more than 3200 feet through the complex of nearly horizontal volcanic tuffs and flows. Of this thickness about 1200 feet belongs to the light-colored rhyolitic and latitic series named after this mountain. In this vicinity there are two very massive bands within the Potosi series, separated by a zone of thin flows and tuffs several hundred feet thick. The upper massive band causes the precipitous cliffs of the summit, while the lower one produces shoulders bounded by inaccessible cliff scarps, not only in this peak but in many others to the north, west, and south. A view of the mountain from the southwest may be found in the Telluride folio.

From the summit high divides extend northwestward characterized by the same rugged topography; on the north lies a group of mountains in the Ouray quadrangle (Whitehouse Mountain and others) of the same general character.

The prominent cirques on the north and east of the peak contain great accumulations of rock débris and in each is a rock stream of notable dimensions.

In Potosi Peak the Silverton series of andesites and rhyolites is represented by only about 400 feet of thin flows and tuffs, mainly andesitic. Below them the San Juan tuffs extend to the bed of Canyon Creek.

Canyon Creek.—The deep erosion of Canyon Creek exposes the base of the San Juan tuffs at the eastern foot of Potosi Peak and below that point the stream cuts deeper and deeper into the underlying sedimentary section until at Ouray, about 2 miles north of the quadrangle, the stream enters the Uncompahgre through a small gorge cut in the Algonkian quartzites. The striking, buttress-like forms of the San Juan tuffs facing the lower part of the canyon on either side are well shown by the topographic map.

The Telluride conglomerate appears under the tuffs in Canyon Creek wherever their base has been observed, but the formation is very thin, 40 feet being the maximum thickness seen, and possibly it is not continuous, as represented on the map. The Telluride is here a pinkish, coarse grit with variable number of pebbles distributed through it and with coarse conglomerate layers locally developed. The pebbles are mainly of Algonkian quartzites, but some of them are of granite, limestone, and other rocks. The formation lies nearly horizontal where it first appears beneath the San Juan, but the level here is 500 feet lower than at the head of the San Miguel Valley above Telluride, the nearest exposure to the southwest.

Below the Telluride conglomerate there are red grits and sandstones which are referred to the upper part of the Hermosa Carboniferous without definite proof of their age. The horizon must be near the top of the Hermosa and may be within the Cutler Permian. In this region the Pennsylvanian beds have a decided red color like that of the Permian and the line between the two is not readily determinable where outcrops are poor. Débris from the cliffs obscures so much of the sediments that only small detached patches can be studied.

The structure of the sedimentary rocks is poorly shown. In general they have a southwesterly dip, but locally exhibit marked variations. Thus at 9500 feet, on the wagon-road, a strike of N. 80° W. and a southerly dip of 15° was observed by Mr. Howe. Farther down the valley the prevalent strikes are 20° or 25° west of north with westerly dips of 7° to 10°. The structure is shown in generalized form in structure section A–A.

On the northwest side of Canyon Creek occurs a mass of granite-porphyry, which is intruded below the San Juan tuffs and either just above or just below the Telluride conglomerate. The mass is believed to have the character of an asymmetric laccolith, since it has an abrupt western contact and still is traceable for some miles at the general horizon mentioned. Above it are San Juan tuffs, the contact being very irregular in detail, and the sheet-like mass extends an unknown distance into the Ouray quadrangle. The mass is about 600 feet thick, yet it does not extend across the canyon to its southeast side. It is comparable to the laccoliths of Gray Head and Whipple Mountain in the Telluride quadrangle, north of the San Miguel River.

Good examples of torrential fans may be seen on the southeastern side of the canyon, and all along it talus piles or avalanche débris from the cliffs obscure the solid rocks below the San Juan tuffs. Glacial bowlders may be found scattered over the slopes for several hundred feet above the creek, but form no considerable mass except near the border of the quadrangle. At the point of Hayden Mountain a landslide or a series of landslides has descended to the stream, blocking its course in places with huge masses from the San Juan cliffs. A part of this slide area is shown on the map, but the larger part is within the Ouray quadrangle. Glacial gravels, which would otherwise form an important area, are largely covered by this detritus.

Crest south of Canyon Creek.—The high divide which extends southwest from Hayden Mountain exhibits many of the features seen in Potosi Peak, since the same great volcanic members are the most prominent factors. The Potosi rhyolitic flow or tuff caps the higher points of the divide and near the Telluride line is continuous. This light-colored rock, far above timber line, contrasts so strongly with the dark andesites below that their contact line can be clearly located from distant points of observation.

As shown by the areal geology map the Silverton series of this ridge is much thicker than in Potosi Peak. The numerous cirques of this region have their floors as a rule in the San Juan tuffs, while the precipitous walls above them are formed of the lower massive band of the Potosi series.

No area of the quadrangle exhibits the peculiar masses of rock débris called rock streams so well as the basins on the north side of this high ridge. In Imogene, Pierson, and Silver basins are some of the most remarkable of these accumulations, especially described on page 25 and illustrated by fig. 4. Other similar masses seem to be indicated by the topography of some basins which were not visited.

Savage and Ingram basins.—The upper parts of two notable basins drained by tributaries of the San Miguel come within the Silverton quadrangle, namely, Savage and Ingram basins. They lie for the most part within the Silverton series, with walls of the Potosi about them, and the solid rock of their floors is almost wholly covered by talus and subordinate rock streams. In Savage Basin are the Tom Boy and Japan mines, which are referred to in the section on "Economic geology," by Mr. Ransome.

CANYON OF THE UNCOMPAHGRE.

The Uncompahgre River cuts nearly to the level of 8000 feet as it crosses the northern boundary of the quadrangle, and, together with its tributary, Canyon Creek, reveals the structure of the sedimentary formations which underlie the volcanics on this border of the San Juan Mountains. That part of the canyon within the Silverton quadrangle exhibits fine sections of two great geological formations of widely different age and character. The lower portion of the canyon is carved to a depth of over 1000 feet in the hard quartzites and slates of Algonkian age which have been named the Uncompahgre series, while the cliffs above those rocks for 2000 feet or more are made of the nearly horizontal San Juan tuffs. The lower gorge of Red Mountain Creek is here discussed with the Uncompahgre, of which it is really the most important fork.

The quartzite part of the canyon.—The section of the quartzite and slate rocks exposed in Uncompahgre Canyon has been described on page 3, and the structure expressed in the attitude of the strata has also been discussed. The structure is shown also by the strike and dip signs of the map and by structure section A–A.

The canyon cut in the hard rocks has a most rugged character, well displayed from the celebrated stage road leading from Ouray to Red Mountain, one of the favorite routes for tourists in the State of Colorado. This road is always at some little distance above the stream. It is cut out of solid rock in some places, supported on projecting timbers in others, and at many turns gives excellent viewpoints for both canyon geology and scenery. Cascades and small falls are numerous, the highest of these being that of the tributary stream Bear Creek, which enters the Uncompahgre just north of the quadrangle line through a deep gorge that is second only in interest to that of the main stream.

The cliffs of San Juan tuffs.—The upper canyon walls are formed of the San Juan tuffs, a formation wholly unlike the Uncompahgre series, yet capable of producing great cliff faces and bold mountain forms. The topography of this upper part of the Uncompahgre gorge is identical in character with that of Canyon Creek, already described.

On either side of the canyon the tuffs rise in cliffs or very abrupt slopes for more than 2000 feet above the quartzites. Their dark blue-gray tones stand in contrast to the prevailing white or gray of the quartzites below.

The surface of older rocks upon which the tuffs rest is very irregular on the eastern side of the canyon, and of lesser unevenness upon the west. From Bear Creek, for instance, the surface against which the tuffs abut is an eastward-facing cliff several hundred feet in height. The projections of quartzite south of the Silver Link mine are too small to be expressed by the map, yet amount to more than 100 feet in some cases. Similar irregularity is shown by the workings of the Silver Link mine, which are upon a vein in the tuffs, reached through a crosscut tunnel starting in quartzites. At the ravine next north of the Silver Link mine a pinnacle formed of porphyritic granite, cutting the quartzites, rises for 200 feet above the general level of the San Juan base.

Exposures of Telluride conglomerate.—On account of the uneven surface of the Uncompahgre rocks the Telluride conglomerate does not appear in continuous outcrops, as in Canyon Creek. It does occur, however, in some of the hollows of the old land surface, as on the west side of Red Mountain Creek at the point where it first reaches the quartzites, and at a point north of the Silver Link mine.

Paleozoic formations.—On the border of the quadrangle and on the western side of the canyon the Ouray limestone and the lower Hermosa strata appear with a northwesterly dip which soon causes them to be cut off by the old erosion surface on which at this point occurs the Telluride conglomerate, in a thickness of 50 feet. Probably the Molas formation is present between the formations named, and it is so represented. The bench above the Ouray has few outcrops, and the character of the Molas was not recognized when this locality was visited. The limestone descends from this place to the flat near Ouray, where the Mineral Farm mine has exploited replacement deposits in it.

Detrital material.—Much débris has fallen from the cliffs of finely jointed San Juan tuffs on both sides of the canyon. The confused mingling of landslide, avalanche, and ordinary talus detritus has greatly obscured the contact of the San Juan, Telluride, and Paleozoic rocks all about the point of Hayden Mountain. South of the Silver Link mine great blocks have fallen, covering the slopes to the stream bed. Just below the mouth of Red Mountain Creek a slide mass of quartzite makes a very noticeable fan, shown by the map.

IRONTON PARK, RED MOUNTAIN CREEK, AND ADJACENT TERRITORY.

Above the Algonkian quartzite area Red Mountain Creek flows through the swampy alluvial flat of Ironton Park, which is situated just at the base of the San Juan tuffs. Still higher the stream winds through a maze of landslide blocks which have descended from either side. Only the upper portions of the valley and its tributaries are carved in solid rock of the volcanic series.

Ironton Park.—Ironton Park extends for 2 miles northeastward from Ironton with an average width of nearly one-half mile and through it Red Mountain Creek meanders with many small ponds or miniature oxbows on either hand and with pools fed by springs of iron-bearing water along the western side. Were it not for the landslide débris, which has crept down the adjacent slopes to the level of the park in many places, the base of the San Juan tuffs and the structure of the sedimentary beds under them would be shown for considerable distances on either side of the park; even as it is the exposures supplement those of the Uncompahgre Canyon in some important particulars.

As shown by the map the Algonkian quartzites and a band of Ouray limestone above them are exposed on the eastern side of the park in and between Brooklyn and Albany gulches, while a very narrow strip of Carboniferous sandstones borders the alluvial flat on the western side of the park at the mouth of Full Moon Gulch. The general interpretation of the structural relations thus indicated is shown in profile B–B of the structure-section sheet. Fig. 2 is a view of the park from the upper end, showing the locality of the sediments on the eastern side above the Saratoga mill.

At the mouths of Albany and Brooklyn gulches there is exposed a gray or white quartzite of texture so massive that its bedding was not definitely determined. The Saratoga mill rests on this rock, which extends slightly farther up the eastern slope. A boring through the gravels encountered this same rock for some distance below the park level. As this quartzite resembles the Algonkian quartzites of the Uncompahgre, which appear under the San Juan tuffs only $1\frac{1}{2}$ miles farther down the valley, and which in several places rise to higher elevations than the outcrops in Ironton Park, it is necessary to refer it to the Uncompahgre series. The appearance on these quartzites, or separated from them by only some thin quartzitic rocks, of a limestone corresponding to the Ouray confirms the correlation, since the Ignacio does not occur in its usual development on the northern side of the San Juan.

The Ouray limestone remnant has been greatly altered by mineral-bearing waters, and ore deposits of considerable extent have been found in it and exploited in the Saratoga, Brooklyn, and other mines, as described in this text under the heading "Economic geology." The original bedding is not readily detected except locally in the mine workings, but the distribution of the limestone shows it to lie nearly horizontal. Apparently there is a gentle anticlinal fold with a north-south axis, since the general structure requires that the limestone should dip westward, while in the mine workings the formation seems to descend eastward. This is true also of the erosion contact with the overlying andesitic material. The crushed and faulted condition of the mineralized formation and the obscuring effects of oxidation and hydration have rendered the observation of structure difficult. From the outcrops of Albany Gulch the limestone can be traced by isolated exposures northward a short distance and it is then concealed by loose volcanic material. This is in part landslide débris, and limestone fragments in it mark the extension of the Ouray beyond outcrops. It probably ends in this direction through removal by pre-volcanic erosion, so that the San Juan tuff rests on quartzite slightly below the park level.

Faulting on northeast-southwest fissures, revealed in the mine workings, on which the downthrow is to the southeast, terminate the surface exposures of the Ouray on the south. There is no means of knowing how far the Paleozoic sediments extend eastward, since the base upon which the volcanics rest is not exposed in that direction until the granite bodies of the Lake Fork and Cottonwood Gulch are reached. The limestone can not be traced southward beyond Brooklyn Gulch owing to the zone of faulting above referred to.

The sandstone exposed along the road at the mouth of Full Moon Gulch and farther south is considered Carboniferous and not Algonkian, because it is a comparatively loose-textured rock in which considerable kaolin is associated with the quartz. If this kaolin is supposed to represent original feldspar grains, as is natural, the rock is then like the feldspathic grits or sandstones of the Hermosa formation rather than the dense quartzite seen near the Saratoga mill. It is plain that a slight westerly dip to the Ouray limestone will cause it to disappear beneath the level of Ironton Park and bring it into its proper position below these grits. Faulting on the line of the park might interfere with this simple relation, but no evidence of such faulting was observed. This interpretation is in harmony with the structure assumed for the Paleozoic and Mesozoic sediments beneath the San Juan tuffs west of this point, and is required by the known relations of the stratified complex below the San Juan in the Telluride quadrangle. Only 5 miles directly west of Ironton Park, in Ingram Creek, the Telluride conglomerate below the San Juan is seen resting on the upper part of the Dolores "Red Beds." The greater part of the Dolores formation and the entire Carboniferous section must come against the Telluride conglomerate or the San Juan tuffs in this interval of 5 miles, as represented in profile section B–B.

A small exposure of greatly fractured and decomposed conglomerate, occurring just above the upper tunnel of the Saratoga mine and represented by similar outcrops in Brooklyn Gulch, is thought to belong either to the Telluride conglomerate or to the Molas formation. Perhaps both may be represented.

According to Mr. G. E. Kedzie (Trans. Am. Inst. Min. Eng.) there is a "pink quartzite" above the Ouray in this vicinity. He refers to it as "changed into a cherty conglomerate" on the north side of Brooklyn Gulch. The top of the "quartzite" is, further, said to be "a fine-grained conglomerate, consisting of worn fragments of white quartz, with red argillaceous groundmass." These references to conglomerate fit the assumption that the Molas is present. Unfortunately the character of the Molas was not known when the examination of Ironton Park was made, and the scanty outcrops attracted little attention. The structure of the sedimentary formations of Ironton Park presented by Mr. Kedzie is quite different from that described above. The massive quartzites, here referred to the Uncompahgre series, he places above the limestone, a relation for which no evidence could be found. He also refers to thin-bedded quartzites in considerable thickness under the limestone in mine workings. These might well belong to the Algonkian series, but no such development of quartzite below the limestone is found near the town of Ouray, and therefore it does not seem likely that the Ignacio formation is here present. The mine workings showing these quartzites were inaccessible at the time of visit.

The landslide area adjacent to Red Mountain Creek.—From Hendrick Gulch to the Mineral Creek divide both slopes adjacent to Ironton Park and Red Mountain Creek are made up in very large degree of landslide material, either in still distinguishable blocks of large size, or in disintegrated form, as wash or slide rock, making smooth, rounded knolls or mounds. The border of nearly continuous landslide material is shown by the areal geology map, while in the sheet of illustrations figs. 6 and 7 bring out the more striking features of the landslides. Fig. 6 is from a photograph taken near the mouth of Galena Lion Gulch, looking across Red Mountain Creek to the landslide-covered slope under Red Mountain No. 2. From the level of the creek as high as the timber-covered bench in the middle of the picture, a difference of over 1000 feet in elevation, the slopes are covered by landslide blocks having trenches and sinks behind them, which are often occupied by pools of stagnant water. Springs are numerous, and the surface drainage channels are irregular wherever there is flowing water. Fig. 7 shows the landslide topography about the Robinson, Guston, and Yankee Girl mines. In the midst of the mounds and ridges of the landslide blocks are outcrops of rock in place which, even on the ground, are with difficulty distinguished from the more numerous landslide hummocks that surround them. The landslide débris is hence a thin mantle. These outcrops have the same altered appearance as the rocks in place on Red Mountain No. 3, to the east, and are not shattered as are the landslide blocks. One excellent example, a hill not far from the Paymaster mine, is seen above the upper line of the railway near the left margin of fig. 6. This hill is encompassed on all sides by landslide material, and stands out with its simple outline in striking contrast to the confused topography surrounding it. This, with the less conspicuous outcrops farther south, where the various mines are situated, strongly indicates that in the time immediately preceding the landslide epoch the topography must have been much more rugged than it is now; that the valley of Red Mountain Creek must have been steep and narrow, with many points and sharp ridges between the tributary ravines; and that the present gentler slopes were formed both by the downfall of the higher points and by the filling in of the lower portions of the valley by landslides. A few of the more prominent points and ridges which, for some reason, escaped destruction, now remain, but otherwise obliteration of the details of the old topography is almost complete.

North of Corkscrew Gulch the landslide surface is less plainly marked by distinct blocks. A long trench traversing the slope diagonally from Albany Gulch, at about 10,000 feet, to the south side of Hendrick Gulch at 10,500 feet is a marked feature. The slopes on the west side of Ironton Park are much more evenly rounded than those on the east side, and several side gulches expose nearly continuous sections of solid rock, but from Half Moon Gulch to the north end of the park all of the lower slopes are covered with loose slide rock, which is apparently the result of the disintegration of landslide blocks. These blocks came from as high as 11,500 feet on the shoulder of the high divide next northeast of Hayden Mountain. Adjacent to the fault represented by the map as running N. 15° E. and opposite Abrams Mountain, there are landslide blocks with trenches behind them, which are shown by the map contours.

Areas of the Silverton series.—Above Ironton Park and the landslide-covered slopes the valleys of Red Mountain Creek and its western tributaries are for the most part carved out of the somber-hued andesites and latites of the Silverton series. Remnants of the Potosi rhyolites or quartz-latites capping many points on the divide to the west stand in striking contrast to these darker rocks below. In this region the Silverton series has not been resolved into the various members distinguished farther east. This is partly because those members are not so clearly defined and because the series was mapped as a whole in the adjoining Telluride quadrangle. Moreover, if a subdivision had been made it could not have been carried through the zone of great decomposition to the east. The predominant rocks are the latites of the Burns complex and pyroxene-andesite, in both tuffs and flows. In and near Commodore Gulch there are several crosscutting or sheet-like intrusions of dark andesite. The rapid thickening of the Silverton series from northwest to southeast causes it to occupy the interval of nearly 3000 feet between the Potosi and the valley bottom.

Syenite-porphyry intrusions.—Intrusive masses of syenite-porphyry are specially prominent in this area. The most notable one is that just east of the divide at the head of Red Mountain Creek. It presents cliff faces on nearly all sides and the talus heaps conceal contacts, but in view of the intrusive relations seen in other occurrences of the same rock there can be little doubt that this mass is a crosscutting stock with a diameter of 1800 to 2700 feet. This body is generally fresh.

The mass of similar dark porphyry occurring at the summit of Red Mountain No. 3 may also be mentioned here. It is so much obscured by talus and slide rock débris that its outlines on the map are necessarily more or less generalized. Exact mapping is made still more difficult by the extensive decomposition to which this and all other rocks of the mountain have been subjected, rendering them indistinguishable except on most careful study.

It is probable that the landslide area west and north of the two syenite-porphyry masses mentioned is one in which dikes of this rock were numerous, their fragments being found in several landslide blocks. One of these exposures is on the road a short distance south of the Yankee Girl mine. This may possibly be in place, but only a few square feet of the rock is shown and landslide débris surrounds it.

Near the head of Full Moon Gulch a small stock of syenite-porphyry cuts the Silverton series near its top. This mass is very much kaolinized, but exhibits fairly fresh rock in some spots. The texture varies greatly within the body and has no discoverable connection with contact outlines.

Rock decomposition and coloration.—The region lying east of Red Mountain Creek and extending to the divide that separates it from Cement Creek is characterized by extremely decomposed rocks, some local areas of which are so deep-red as to well justify the application of the color term to the three mountain summits. This decomposition is most extreme in the knolls of whitish, highly quartzose rock which project through the prevalent landslide material at the Robinson, Guston, and other mines or prospects of the district. The extreme alteration of the rocks in the area named contrasts very strongly with the freedom from the same kind of decomposition on the western side of the valley, a point discussed under the heading "Faulting and tilting of the volcanic complex," p. 23.

The decomposition to which the Silverton series of latites and andesites has been subjected consisted chiefly in the replacement of all silicates by sericite (a dense, fine-grained aggregate of muscovite) or kaolin, causing the rocks to become gray or almost white. The dark silicates are no longer recognizable and their iron content has been lost, or it may have concentrated in disseminated grains of pyrite. The red stains are usually but superficial and represent the destruction of the pyrite by weathering.

The altered rocks are much jointed by many fissures and the mountain slopes are often made up of the resulting small angular fragments. In this way the red rock of some ledge of small extent often gives strong color to a streak of talus below it.

Patches of dark purplish rock which have undergone the more common propylitic decomposition are visible here and there, but truly fresh andesite or latite of the Silverton series can hardly be found in the area under discussion.

The knolls at the Red Mountain mines are peculiar features of the region. These knolls are seldom larger than the landslide mounds about them, and were it not for the demonstration through the mine workings of their continuation in depth some of them might easily be overlooked. The larger hill of the Paymaster mine, shown in fig. 6, is a marked exception.

Glacial.—The valley of Red Mountain Creek has no extensive glacial deposits. At the upper end of Ironton Park, especially on the western side, there is a gravel bench consisting of bowlder till. It is more or less obscured by landslide débris. Doubtless some glacial material is mingled with the landslide débris at many localities, but it does not preserve its individuality. McIntyre Gulch cuts deep into morainal material, bowlders, and gravel which form a narrow ridge north of the stream. A distinct local moraine forms a barrier across Spirit Gulch at an elevation of about 11,500 feet.

Torrential fans.—The torrential fans of Ironton Park and the valley above it are among the most instructive examples of these accumulations to be found in the quadrangle. That of Hendrick Gulch is the largest, extending nearly 500 feet above the valley. The present stream runs on the northern border of the fan, but numerous older courses can be identified on its surface, some being ravines 15 or 20 feet deep.

The relation of a fan to the stream causing it is admirably illustrated by the alluvial cones or fans at the mouths of Governor and Galena Lion gulches. These are simply deep ravines cut in the graded slope of the main valley with older and much longer gulches on either side. The cutting of the two ravines is so recent a process that the greater part of the rock removed is now in the fan built up by the rapid erosion. In contrast with this is the fact that the much more mature Commodore Gulch has practically no fan at its mouth. The conditions at Governor and Galena Lion gulches are practically the same as in the still less developed ravines represented in fig. 5.

CENTRAL AREA.

General character.—The area included between the Animas River, Mineral and Red Mountain creeks, and the East Fork of the Uncompahgre River is a high mountainous tract into which Cement Creek on the south and Poughkeepsie Gulch on the north have cut deeply, while Eureka Gulch to the east has also been active in its attack but to a less degree than the other two streams. Nearly half of the area has an elevation of at least 12,000 feet, while more than twelve summits rise above 13,000 feet, and into the very heart of this region Cement Creek has cut a section that is more than 3500 feet in depth.

In its geology the central area exhibits the peculiar or distinctive geologic features of the quadrangle. It contains scarcely any other formation than the various members of the Silverton series, and the upper member in particular is much thicker than elsewhere.

Areas of pyroxene-andesite.—The upper member of the Silverton series has been represented on the map by its distinguishing pattern as occupying fully a third of the area. It also occurs as a part of the undivided Silverton complex in the district traversed by Mineral and Red Mountain creeks. Below the summit of Storm Peak the thickness of the accumulations of pyroxene-andesite is more than 3000 feet. The base of these rocks can be traced from Cement Creek eastward and northeastward to the faulted area north of Eureka Gulch, and there is no doubt that the entire section of dark andesites, seen in comparatively fresh condition in the mountains east of Cement Creek, represents an unusual development of one member of the series, which only a few miles away, in Potosi Peak, aggregates a thickness of but 200 to 300 feet for all members combined.

It is a fact readily perceived by a glance at the geologic map that this great mass of andesites occupies a space of basin-like form in the center of the quadrangle. The origin of this basin is a difficult problem to solve. It may here be pointed out that the observed structure of the andesite flows and fragmental masses does not establish the existence of a large hollow at this place when the materials were erupted. That the low level occupied by these lavas is due partly to faulting is clear from the downthrow movements shown by the Cinnamon fault and the connecting fault passing through Ross Basin.

The complex here, as elsewhere, is made up of flows and tuffs or breccia beds. This composition results in bluish-gray cliffs with rugged promontories or points on the divides about the many glacial cirques. Distinct benches often mark the top of a massive flow above which tuffs are present. Fine-grained tuffs, such as those of Maggie Gulch or Henson Creek, are wanting. Flows and tuffs bear irregular relations to each other, and few flows, if any, are continuous through this central area. Not many flows exceed 200 feet in thickness.

The area of metamorphosed rocks.—The line of transition between the differentiated and the undifferentiated Silverton series as drawn on the map does not indicate an abrupt change in the condition of the rocks on either side, but merely connects on the north and south the westernmost localities to which the Burns latite can be traced. In Cement Gulch the pyroxene-andesite probably extends below the stream bed. The Burns latite could doubtless be traced from Gray Copper and Cement gulches around into Mineral and Red Mountain creeks were it not for the great metamorphism of all rocks in this zone. In addition to decomposed rocks there is much landslide, talus, and forest-covered ground in the region southwest of Gray Copper Gulch, all of which interferes with the recognition of latite or andesite.

The most thoroughly altered area is that of Anvil Mountain and the ridge to the northwest. As Ransome has shown (Bull. U. S. Geol. Survey No. 182), much of the country rock here is a mass of quartz, kaolin, and sericite, in varying proportions, with perhaps barite and alunite, in which sometimes no trace of the original rock texture can be distinguished, so complete has been the recrystallization. In many places it can not be told whether the rock was massive, or breccia, or tuff. The portions especially rich in quartz usually offer great resistance to erosion or further decay and often project from the gentler mountain slopes in bold and striking knobs or ledges. The brilliantly colored shoulders on the southwest side of Anvil Mountain, above the railroad, are of this character.

The greater part of the broad ridge extending from Anvil Mountain to Red Mountain No. 3 exhibits rock in which there has been less silicification than on Anvil Mountain. This rock breaks into small angular fragments and forms smooth graded slopes, often of strong red or yellow color. Dark, more or less purplish patches here and there represent areas of less metamorphism, as on the eastern side of McMillan Peak. The areas of greatest decomposition are not always those of valuable ore deposits, as many prospectors have found to their disappointment.

Distribution of Burns latite and Eureka rhyolite.—In the northern portion of this central area the Burns latite and the Eureka rhyolite abruptly become the more prominent portions of the Silverton series, and it is clear that this changed condition is due largely to displacements on the faults which have been referred to above. In Poughkeepsie and California gulches the massive Burns latite is the prominent rock, with the Eureka flow-breccia becoming more and more important toward the northeast. Abrams and Houghton mountains, especially the latter, exhibit the Burns rocks in typical form, the particular variety called the Niagara Gulch type being there well developed. A facies carrying small quartz phenocrysts occurs at the base of the Burns complex, as mapped, on the southeast ridge of Houghton Mountain.

Occurrence of monzonite.—What is considered an arm from the great quartz-monzonite stock occurs at the mouth of Cement Creek and forms one shoulder of Anvil Mountain. It may not actually connect with the larger mass at the horizon beneath the surficial materials, but a connection at no great depth must be assumed.

Rhyolite intrusions.—A prominent feature of the ridges between Eureka, Picayune, and Mastodon gulches, and at the knoll lying at the northeast base of Houghton Mountain and extending to the divide southwest of it, is a dense felsitic rhyolite with fine, platy jointing. It appears in several dikes and in injected sheets. This rhyolite is a very striking feature of the region because it forms so many benches or flat surfaces, and by reason of its very light color can be seen for long distances. Many of the faults of this region could not have been detected, much less measured, were it not for these rhyolite bodies.

Quaternary phenomena.—The high mountains of this section exhibit many excellent examples of glacial amphitheaters, as a glance at the topographic sheet will show. In some of these cirques are blue lakes whose basins are often excavated in solid rock. The larger cirques are, as usual, on the northern sides of the peaks or divides, but some of the most striking are on the southern slopes, such as those at the heads of Cataract and Hematite gulches.

Glacial débris seldom appears in large deposits, but erratic bowlders and small gravel or morainal patches occur in many places. The most noteworthy of these accumulations lie along Cement Creek.

Landslide movements, so extensive on the slopes facing Red Mountain No. 1, occurred also above the line of major disturbance drawn upon the map. Even at the very head of Gray Copper Gulch there was considerable slipping of small blocks. One large slide, indicated on the map, lies on the slope east of Poughkeepsie Gulch.

Some small rock streams occur near the head of Poughkeepsie Gulch and on the northeast slope of Tuttle Mountain.

In Cement Creek nearly every tributary ravine produces a small but very characteristic torrential fan, the conditions of steep grade and much jointed rock being most favorable.

DRAINAGE AREA OF MINERAL CREEK.

The North Fork of Mineral Creek lies in the zone between the central area of the quadrangle, where the andesitic portion of the Silverton series is so strongly developed, and the high divide on the west, in which the San Juan and Potosi series are important factors. Together with Red Mountain Creek, it bounds the central area on the west. In this north-south zone, traversed by Mineral Creek, the volcanic rocks are so greatly decomposed that their characters and relationships are very much obscured for almost its entire length and it is necessary to go to the western tributaries of these creeks for data as to the relations of the formations.

Relations of the volcanic formations.—The extreme western heads of Mineral Creek—Porphyry Gulch, Mill Creek, and Middle Fork—all rise in basins excavated in the Silverton and Potosi volcanics. In the first two the underlying San Juan tuffs are apparently not exposed, but in the last two it is probable that the base of the Silverton has been reached by gulch erosion, although the exact line has not been accurately determined.

There are few exposures of fresh rock in these gulches, and the key to the geology of the area west of Mineral Creek is to be found in the deep valley of the South Fork. This stream, even at its head, in the Telluride quadrangle, has cut through the volcanics and completely isolates the tract of those rocks on its southern side from the main area to the north.

By reference to the map it will be seen that on the north side of the South Fork the base of the San Juan tuffs crosses the quadrangle line at an elevation of 11,700 feet, more than 1500 feet above the stream. A little farther west, in the Telluride quadrangle, it rests upon the Telluride conglomerate; beneath that is the Dolores Triassic. If the base of the San Juan were continued northward at this level the sedimentary rocks would be prominent in all the branches of the North Fork of Mineral Creek, and even at the divide at Summit; but, in fact, no sediments appear to the north of the South Fork, and the eastern descent of the volcanics must be so rapid that the Mesozoic formations disappear before the junction of the forks of the creek is reached. In the ravine north of and opposite Copper Gulch the sedimentary strata and several intercalated porphyry sheets are well exposed. The porphyry bodies, which are more massive than the sediments, can be traced almost continuously around into the valley of the North Fork, where they are found to cut much-altered volcanic rocks. The strata, however, can not be traced more than a short distance east of the ravine above mentioned, nor can the reason for their disappearance be found, owing to a dense growth of aspens and a veneer of snowslide débris, talus, and torrential cones. The much-silicified and otherwise extremely altered volcanics here and there exposed in the eastward coursing ravines between the South and Middle forks simply prove that the volcanics occur there at the level occupied by the sedimentaries a short distance to the west. Faulting might accomplish this, but the continuity of the porphyry sheets negatives such explanation. The south bank of the South Fork affords no further evidence because the great monzonite stock occurs there, and the porphyries extend across the valley and abut against the monzonite. The structure of the mountain between South and Middle forks is not plain, for the rock is all extremely decomposed, stained, and irregularly jointed, and its smooth, graded slopes are mainly covered by fine débris. Dark andesitic tuffs, assumed to belong to the San Juan, occur in the Middle Fork near the quadrangle line and for several hundred feet up its southern branch, an occurrence in harmony with the adjacent part of the Telluride quadrangle.

The facts briefly stated above show that the surface of the sedimentary rocks, upon which the volcanics of this area rest, dips rapidly to the east or northeast, and that the San Juan tuffs also disappear, for some reason which is at present not known. In discussing the volcanic history of the quadrangle it is shown that this sudden disappearance of the sedimentaries and of the San Juan tuffs in the central area and the great thickness there of the Silverton andesites produce relations similar to those seen west of Ironton Park and on the east side of the Uncompahgre, where it is clear that post-San Juan erosion made a valley or hollow in the area in which the Silverton series is now so thick. On the eastern side of Mineral Creek, where the San Juan must occur if not cut out in some way, the rocks are intensely altered and their original character is more or less in doubt.

Faulted area of Potosi rhyolite.—At the head of Mineral Creek, on its western side, is an area of banded rhyolitic rock, identical in character with the Potosi rhyolite but surrounded by the Silverton andesite and occurring far below the normal horizon for the Potosi series. The general relations of the mass show that it must be either a crosscutting body or a block of the Potosi dropped, along a number of intersecting fault planes, for at least 2500 feet below the base of that series to the west. No evidence favoring the former explanation could be found and the fault-block alternative has been adopted.

The positive evidence bearing on the case consists, first, of numerous exposures of the outer boundaries of the mass, which seem in all cases to be fracture planes or zones; second, of a distinct fault, parallel to the western boundary, by which the Potosi is let down several hundred feet; third, of the presence of an andesite flow beneath the rhyolite for a short distance, in Porphyry Gulch, adjacent to the western boundary; fourth, of the identity, in composition and texture, of the rhyolite with the Potosi lavas, the texture showing nowhere a resemblance to that massive porphyritic habit which must be expected in some parts at least of a large conduit more than 3000 feet below the surface; fifth, of the fact that the wavy lamination of the rock bears no constant relation to the walls, being at times nearly parallel to them but more frequently abutting against them a various angles; sixth, of the presence of many fissures traversing the block, interrupting the lamination and indicating that the mass is thoroughly shattered by cross fractures, a most natural condition if the adopted explanation of occurrence be correct. These various lines of evidence will now be presented somewhat in detail.

The nature of the eastern and western boundaries is well shown. The former is traceable for nearly a mile in or near the ravine of Mineral Creek, crossing it twice and at all points bringing rhyolite on the west against andesite (breccia or massive) on the east. Prospecting has been done on it in several places. The fault is not a single fissure, but a fault zone. It has the general course shown by the map, but curves in detail and is vertical or dips south of east at very steep angle.

Situated on this eastern fault zone is the Silver Ledge mine. A description of this mine is given by Ransome in Bulletin No. 182, and some of the data here used are quoted from him. The workings consist of a shaft, 400 feet deep at the time of visit, with drifts at several levels, all of which are in rhyolite. The ore-bearing veins strike about N. 27° E. and dip steeply southeastward. A crosscut from near the bottom of the shaft runs 100 feet eastward and should have penetrated the Silverton series beyond the fault if the structure is as simple as it appears at the surface, but the much altered rock at the end of this crosscut is, according to Ransome, so nearly like the altered rhyolite that it is not certain that the fault has been reached. Still some of the Silverton rocks, such as fluidal portions of the Niagara Gulch type of latite or the Eureka flow-breccia, would be indistinguishable from the altered rhyolite. It may well be, therefore, that a strong fissure, with much gouge material, crossed by this drift 70 feet from the shaft may be the easternmost fissure of the fault zone.

In the ravine south of the mine the fault separates black andesite on the east from the rhyolite. Possibly the decreased dip of the fault, indicated in the Silver Ledge mine, corresponds to the change in dip, observed farther south, that permits a tongue of Silverton rocks to run up on the end of the ridge between Porphyry and Mill gulches, as represented on the map. The line bounding this tongue is not very well exposed, but the map expresses a relation of rocks probably due to a local flattening of the fault. Except at certain exposures in the railroad cuts the evidence as to the extent of the rhyolite southward is poor. It is not present on the ridge south of Mill Creek, hence its boundary must run beneath the fans or alluvium of that valley.

The western line of the fault block is easily traced from Mineral Basin southward to the crest of the ridge south of Porphyry Gulch. On this ridge are several fissures, and it is probable that a fault zone runs parallel to the main western fissure, and that at least one cross fault within the block joins the main fault at this place. In the bed of Porphyry Gulch, on the north side, a prospect tunnel explores the border fault zone, showing on the west massive andesitic breccia, then a narrow zone of crushed andesite, followed by one of similarly broken rhyolite, each several inches thick. Adjacent to the zone of rhyolite is a zone of crushed rock opposite the contact of andesite and rhyolite to be described. Some evidence of a fault zone may also be seen on the contact line in the bed of Mineral Creek, but on the slopes between gulches only the general limit of the rhyolite can be traced.

The northern boundary of the rhyolite north of Mineral Basin is sharply defined at only one place, where a tunnel runs through crushed rhyolite close to the line of faulting, as shown by the surface distribution, but does not actually disclose the outer fissure of the zone.

The sharp angular form of the mass is fairly well defined by outcrops, though the contact planes may not be exposed. At the reentrant angle between Mineral and Porphyry gulches the rhyolite is well outlined. The contact east from this point is followed by a drain which seems due to the crushed and easily eroded rock of a fault zone.

At the northeast corner of the mass a smaller reentrant angle is sharply defined.

The fault bounding the block on the west runs almost parallel to the marked fault by which the Potosi is let down on either side of Porphyry Gulch. This fault, or another plane of the zone, is explored in the Silver Fountain workings on the southern ridge. The strike of the fault across Porphyry Gulch is N. 15° E. and it has a very steep but variable easterly dip. On the ridge north of Porphyry Gulch the base of the Potosi series is dropped about 400 feet, while on the ridge to the south the dislocation is somewhat greater. This fault passes into the Silverton series on the north and south, where exceptional exposures would be necessary for its identification. Mr. Stose observed dislocations of Silverton rocks on the ridge between Mill Creek and the Middle Fork of Mineral Creek, nearly in the line of this fault, but it has not been thought best to represent the fault as continuous for this distance.

The presence of andesite below the rhyolite adjacent to the western boundary in Porphyry Gulch is revealed on the north bank of the stream, while on the south side glacial and slide débris conceal the rocks. This dark, dense andesite is exposed in a thickness of about 150 feet from the creek bed near the fault, and its top is marked by a bench back of which the rhyolite begins. Near the bench the rock is more or less vesicular, but is denser below, thus presenting the structure of a flow. It is crushed near the fault on the west. Since so little is known as to this andesite, and its representation on the map would require assumptions as to the occurrence, it has been omitted.

A minor fault extending, apparently, almost due north and south, is indicated by an abrupt dislocation of the andesite bench, by which it is elevated about 75 feet. A short distance east of this bench it is dropped out of sight by a fault which crosses the rhyolite area from the reentrant angle on the northeast to the ridge south of Porphyry Gulch. This is in part generalized on the map, for the slope south of the gulch exhibits no outcrops except near the point where the faults are shown as coming together, where there is, in fact, a distinct fault striking toward the east limit of the andesite to the north.

This andesite is in all probability a flow belonging to the fault block and may lie below the base of the Potosi, since no andesite has been found between rhyolite flows in this vicinity. The Silverton rocks below the Potosi vary so much in character that it is not strange to find no andesite of this character below the Potosi on the ridges on either side of Porphyry Gulch.

The wavy lamination of the fault block rhyolite is perfectly comparable with that of the Potosi flows. Over most of the block it is horizontal or inclined at various low angles. Near contacts and on lines of crushing and fracture within the mass it may be vertical or may dip very steeply. Above the andesite benches described it is nearly horizontal. The fact that the rhyolite is dropped more than 400 feet below the surface at the Silver Ledge mine shows that the fault block is compound and that its eastern parts have sunk a thousand feet or more lower than the apparent base of the rhyolite on the western border.

The 400-foot level of the Silver Ledge mine is about 2300 feet below the base of the Potosi series north of Porphyry Gulch and how much below that mine level the rhyolite extends is unknown. This dislocation has been effected on several fissures of a north-south zone. The block form of the rhyolite area is caused by cross faults. Although no positive identification of the various north-south fissures was possible beyond the rhyolite area, it is probable that they have such extension, and if the major fault, that on the eastern side, is present to the south, it may well explain the disappearance of the San Juan tuffs on the general line of Mineral Creek. In the later discussion of the epoch of faulting the view is presented that these Mineral Creek faults belong to a zone extending north-northeastward as far as Ironton Park, passing through the notable Red Mountain zone of rock decomposition.

Porphyry intrusions.—Two small stocks of coarse-grained porphyry occur in this area. One of these is situated on the north side of Mill Creek, and the rock is so completely altered that its original character can not be fully determined. It contained numerous quartz and feldspar phenocrysts and presumably some ferromagnesian constituent, but has been so extensively sericitized as to obliterate the form of most of the silicates.

On the north side of the Middle Fork is a similar mass of quartz-monzonite-porphyry of the common type.

The principal porphyry intrusions of this valley occur at and near the forks of Mineral Creek. They are, however, not at all prominent as a rule, being covered to a large extent by glacial and talus débris and vegetation. They can be seen in the little canyon of the North Fork above the junction, and on the north side of the South Fork in the ravine opposite Copper Gulch, where they are intruded into the sedimentary rocks. These porphyries range from granite-porphyry to quartz-monzonite-porphyry, as described elsewhere.

The same porphyry occurs across the South Fork and is cut by the quartz-monzonite stock. No intercalated sediments have been found there, but the exposures are poor. It is supposed that the channel through which the magma rose is indicated by the union of several sheets in the North Fork, as represented by the map.

Sedimentary formations.—The sedimentary beds beneath the Telluride conglomerate in the South Fork and its tributary gulches have been referred to the Cutler formation, although it is possible that the Rico formation and the uppermost beds of the Hermosa are exposed. The presence of rather massive limestones between the porphyry sheets on the north side of the creek and near the mouth of Copper Gulch suggests the Carboniferous, but no fossils have been found in spite of repeated search for them, and the marbleized condition of the limestones is such as might result from metamorphism of the Cutler limestones. The sandy and shaly beds near the creek bottom do not have the red color of the Cutler, but owing to the degree of metamorphism shown by calcareous strata it is not likely that the diagnostic color could be preserved. In view of the uncertainty of the case it has been decided to refer all the beds to the Cutler.

In the Telluride quadrangle the red beds of both the Permian and Triassic are exposed in an excellent section in Cataract Creek, which enters Mineral Creek less than half a mile beyond the quadrangle line. The metamorphism through which they have lost their color, with the formation of new minerals, is more and more evident as the quartz-monzonite stock and the general area of decomposition are approached. The southwestward dip at the quadrangle line would tend to bring the Carboniferous to the surface, but just below Copper Gulch the axis of an anticlinal fold is passed and between the porphyry sheets in the deep ravine on the north side of the valley the strike is N. 75° W. and the average dip is N. 15° E. at an angle of about 5°.

It is plain that if the top of the Carboniferous is not exposed in the apex of this fold it must be very near the surface at the mouth of Copper Gulch.

The Telluride conglomerate.—The Telluride conglomerate is exposed in an area lying south of the South Fork of Mineral Creek between the quadrangle line and the monzonite stock, but is missing on the north side of that stream. On the Telluride map the formation was represented as extending to the quadrangle border on the north side of the South Fork, but that was an error, as the conglomerate ends just before that line is reached, although the manner of its ending is not clear. Possibly there are patches of it within the Silverton area north of the South Fork, but it certainly is not continuous, and direct evidence of its presence there could not be found. It is supposed that the ending of the Telluride ledge is explained by the observed rapid descent of the San Juan base immediately east of this locality. The slopes are much covered by detritus and vegetation where the base is represented as cutting down to the upper porphyry sheet, and the mapping is probably incorrect in detail.

The character of the base of the San Juan is discussed in another place.

Landslides and glacial débris.—The landslide area at the head of the North Fork of Mineral Creek is continuous with that lying farther north and needs no special discussion. Its boundary as drawn on the map is generalized, and there are small blocks or patches beyond this line.

That the gulches of this area contained glaciers is evident, yet their deposits of moraine and gravel are not conspicuous except about the forks of Mineral Creek. One of the most extensive morainal accumulations of the quadrangle lies on the south slope, facing the forks, and extends for nearly 1000 feet above the stream bed. This is a mass of bowlders and gravel, some blocks being as much as 20 feet in diameter. From the number of fragments of Telluride conglomerate, red sandstone, and quartz-monzonite of the type of the Rolling Mountain stock seen near the head of the South Fork, in the Telluride quadrangle, the source of this material is evident. Scattered bowlders of the same rocks occur on the opposite slope, between the forks, but there is no continuous mass there.

In contrast with the above moraine is the bench of well-rounded bowlders and gravel on the east side of the North Fork near the junction, represented by a small patch on the west side also. This material is clearly rearranged morainal débris. It is much obscured by talus and fan detritus of recent accumulation. At the divide between Mineral Creek and Red Mountain Creek is a small deposit of gravel, which also appears to be morainal in character. In it were found several bowlders of porphyry very similar to that which occurs near the mouth of the Middle Fork and at places in the lower portions of Mineral Creek. This rock has not been found elsewhere in the quadrangle, and it must be assumed that these gravels have been transported from the south, possibly by a glacier which for a time sent a distributory branch northward to the Red Mountain Creek drainage.

Torrential fans and alluvium.—The torrential fans of Mineral Creek are among the most striking accumulations of this character in the district. Some are almost model-like in form, such as the large one in South Fork Valley, that at the mouth of Snowslide Gulch, and all those of the main stream below the forks. The largest of all, that of Bear Creek, is for the most part older than the others, there being a small modern one in process of formation at the actual mouth of the stream, which cuts a deep ravine through the older fan. The ancient portion is heavily wooded in places, its material is often very coarse, and some glacial débris is undoubtedly mingled with it.

The bottom land of the South Fork is partly a swamp, with pools here and there, and through it the stream has a meandering course. A smaller area of alluvium occurs at the mouth of Mill Gulch.

Mineral springs and cemented gravels.—In a region of such extensive mineral deposits and impregnation of altered rocks by pyrite it is natural that the surface waters percolating through masses of detrital material should become heavily charged with iron in solution. Springs of iron-bearing water are common and probably have been still more numerous in the past. A group of such springs occurs in the South Fork nearly opposite the stream from Bear Mountain, and others appear in the pools shown on the map. The former abundance of these iron-bearing waters is attested by the frequent appearance of "iron cap" or iron-cemented gravels or fan detritus. The most noteworthy occurrence of this kind is in the canyon of the North Fork of Mineral Creek, where the gravel bed overlying the porphyry is cemented into a dark conglomerate for nearly a mile. It is not uncommon to find the débris of a torrential fan thus cemented where it is exposed by the cutting of the main stream.

SOUTHWESTERN CORNER OF THE QUADRANGLE.

The geology of the area lying south of Mineral Creek and west of the Animas is comparatively simple in its elements. It represents two features of the local geology particularly well, namely, the relations of the volcanic sequence to the great series of Paleozoic and Mesozoic formations, stretching south and west for many miles, and the characteristics of the large crosscutting stocks of granular rocks which occur at intervals through at least the western part of the San Juan region.

Area of Paleozoic formation.—The largest area of sedimentary rocks in the Silverton quadrangle is that in its southwestern corner. A view of this portion of the quadrangle, looking north from the western slopes of Snowdon Peak, in the West Needle Mountains, is shown in fig. 1 of the sheet of illustrations. The small sheet of water in the middle distance is Molas Lake, lying just south of the southern boundary of the quadrangle, which crosses the view from right to left. The lake itself rests upon the lower Paleozoics and is partly surrounded by outcrops of the Carboniferous red shales called the Molas formation. Just to the left of the lake begins the section of the Hermosa formation, whose alternating hard and soft layers cause the step-like terraces on the hillside. The light bands diagonally descending the slopes devastated many years ago by forest fires are nearly all limestone strata of the Hermosa formation. Some are massive light-colored grits. Above them, and still in conformable relation, are the red beds of the Cutler formation, whose upper portions have been bevelled and covered unconformably by the pinkish Telluride conglomerate which forms the first prominent horizontal escarpment.

The general structure of the sedimentary formations between the Animas Canyon and Copper Gulch is not complicated, and is well illustrated in fig. 1 by the gentle terraced slope due to the alternating hard and soft strata of the Hermosa. The beds above the Molas red shales, including the Cutler formation, have a gentle southwesterly dip as far north as Cataract Gulch, on the Silverton wagon road. Here the structure suddenly changes and the beds assume a steep northerly dip which, in less than half a mile, carries the Ouray limestone and underlying formations down 800 feet to the level of the Animas River, where they come in contact with the monzonite stock.

Unconformity below the Telluride.—The nature of the peneplain on which the Telluride formation rests is well illustrated along a line running westward for a distance of 12 miles from the face of the Grand Turk to Sheep Mountain in the Telluride quadrangle. In the Silverton quadrangle the transgression is from a horizon near the top of the Hermosa nearly to the La Plata, which is crossed only half a mile beyond the quadrangle border. This angular unconformity is clearly brought out on the map by the descending course of the band representing the Rico formation.

The Telluride conglomerate.—In this area the Telluride conglomerate may be well studied, as it increases in thickness from 30 feet or less on the eastern slope of Sultan Mountain to 200 feet or more locally on the quadrangle border. It is generally coarse in texture, its constituent bowlders varying in character as has been described. The conglomerate usually forms a cliff, and owing to the many joints traversing it, huge blocks often become detached and fall down the steep slopes below.

San Juan tuffs.—The mountains and ridges on the sides of Bear Creek at its head are capped by bluish-gray well-stratified tuffs, thoroughly typical of the San Juan formation. These tuffs are of rather fine grain and are not greatly indurated, except near the monzonite stock, and the topographic forms present the combination of bold cliffs and rounded slopes that is characteristic of the formation. These features are well illustrated in fig. 1. The full thickness of the San Juan here is about 1900 feet, as shown by the presence at the very summit of Sultan Mountain of a small remnant of the rhyolite flow-breccia at the base of the Silverton series.

The monzonite stock.—The great mass of quartz-monzonite which extends from the summits of Sultan and Bear mountains to Mineral Creek has an extremely irregular outline on its southern side, as expressed by the map, and is characterized by many sharp, wedge-like arms or short dikes and some larger projections. It is notable that it sends off no sheet-like intrusions and no long dikes.

The massive rock produces more rugged topography than the bedded and rather crumbling San Juan tuffs, the contrast being very striking in some places.

Contact metamorphism.—Adjacent to the stock the San Juan tuffs and the sedimentary rocks are much indurated by new mineral formations, such as garnet and pyroxene, and become so hard and resistant to weathering that the contact line usually does not prominently indicate a change in character of the rocks. The limestone beds are marbleized, and those originally impure are sometimes masses of garnet and pyroxene, containing epidote and probably vesuvianite at times. Specular hematite impregnates the rocks for some distance from the stock, but is seldom abundant.

Other intrusions.—The other igneous rocks of this section include the laccolith of granite-porphyry intruded near the base of the Hermosa formation at the east base of Sultan Mountain. This is cut off on the north by the monzonite stock, as may be seen on the toll road. The fissure through which the magma of this body rose is possibly exposed by a dike of much denser rock of the same composition, seen in the schists below, but a connection was not observed.

A dike of very much decomposed porphyry, probably monzonitic in character, occurs in the extreme southwest corner of the quadrangle. It is very poorly exposed, the surface being covered by fallen timber.

In the San Juan tuff area are several pyroxene-andesite dikes which are not represented because of their small size. One of these, in the mountain west of the head of Bear Creek, cuts the Cutler beds of the southern slope.

Faults.—A number of small faults have been observed in this region. They seem to have no system and are not traceable very far. Those cutting the Telluride conglomerate horizon and those affecting the lower Paleozoic formation are most conspicuous, and several have been shown on the map. Others no doubt exist in the areas of Hermosa and Cutler sediments, but are there not so easily detected.

Glacial and landslide phenomena.—Glacial deposits are not prominent in this region, but the cirque-like amphitheaters on both Sultan and Bear mountains are doubtless due to local glaciers. A double cirque on Bear Mountain is very conspicuous.

On the east slope of the Grand Turk, at a point directly below the cliffs shown in fig. 1, south of the monzonite of Sultan Mountain, the sedimentary beds have been covered by a large landslide, the tuffs and Telluride conglomerate having slipped far down the hillside, leaving a great scar in the cliffs above and completely obscuring with their disordered waste the lower formations.

ANIMAS VALLEY FROM ANIMAS FORKS TO SILVERTON.

Before proceeding with the description of the remaining mountainous portions of the quadrangle, it will be convenient to consider the Animas Valley, the deep gorge which makes a natural dividing line. In this sketch little will be said of the solid rock geology of the valley slopes, for this can best be treated in another connection. Nor is it necessary to give details as to the surficial deposits, since they have been described in a preceding part of the text.

Two sections of the valley.—There are two distinct portions of this stretch of the Animas Valley. From Animas Forks to Eureka the stream bed is at the bottom of a narrow, V-shaped canyon for the greater part of the way. Between Eureka and Silverton, on the other hand, the river flows through a comparatively broad and U-shaped valley, for part of the distance meandering on a flood plain. The change from the canyon to the flood plain just above Eureka could hardly be more sudden, and there is no correspondingly abrupt change in the rocks to account for it.

In its upper canyon the river descends about 1350 feet in 4 miles. At first it crosses the great fault zone within which it cuts into the Picayune andesite, the lowest formation in the stretch under discussion. Then it passes into the Eureka rhyolite flow-breccia in its most massive development. This rock is undoubtedly one of the most resistant to erosion found in the quadrangle, and it is natural that the canyon should have steep cliffs and a narrow bed so long as the stream is cutting into bed rock. This formation ends just below Eureka, while the flood plain begins above the mouth of Niagara Gulch. In this upper part of the valley there is, of course, very little accumulation of fans or other detritus.

From the beginning of the flood plain above Eureka to the entrance to the great canyon below Silverton, a distance of nearly 10 miles, the stream descends about 650 feet, having there a gradient only one-fifth of that in the upper part.

Relations of side streams to the Animas.—On the one side, at the head of the Eureka flood plain, is Niagara Gulch, a hanging valley in its relation to the Animas, since its stream falls almost to the river in a cascade 1200 feet high, while above the falls the valley has a comparatively gentle grade. Cataract and Hematite gulches, on the north side of the river, are still more striking in their relation to the main stream.

Eureka Gulch enters the Animas almost at grade nearly opposite Niagara Gulch, as do Minnie, Maggie, and Cunningham gulches, farther down.

The lower stretch of the river does not flow upon a flood plain for the entire distance between Eureka and Silverton. At the mouth of Arastra Gulch and for nearly a mile on either side the Animas has cut a small box canyon for 100 feet or less into the solid rock beneath the glacial gravels. Arastra Gulch has also cut through these same gravels.

Bakers Park.—At Silverton the Animas River is joined by Mineral and Cement creeks, and the town itself is built upon the comparatively broad flood plains of these streams. The slopes of Anvil Mountain rise back of the town between Cement and Mineral creeks, while the mountain in the center of the picture is the southern spur of Storm Peak.

All forms of detrital material mingle in Bakers Park. The oldest are the glacial gravels, notably exhibited at present on the north side of the valley, on either side of Cement Creek. The rearranged gravels are now much obscured by débris of various kinds washed down upon them. But at the foot of Anvil Mountain, at and back of the town of Silverton, the confusion is greatest.

The glacial deposits are most distinct in a narrow gravel bench adjacent to Cement Creek and in a hummocky area west of town and north of the railroad to Red Mountain. The hummocky area has a kind of kettle-moraine topography, similar to that of landslide knolls, but the monzonite and other rocks found here could not have come from the steep shoulder of Anvil Mountain above, which consists of much-silicified volcanic breccia. This material has come down in talus form upon the glacial deposit and partially concealed it.

Extensive talus accumulations lie at the base of the Anvil Mountain cliffs, and it is no wonder that these masses have locally fallen as landslides. A slide from the northern shoulder of Anvil Mountain has descended upon and almost covered the glacial bench. Conditions are favorable for the formation of a torrential fan in the ravine in the face of Anvil Mountain and a large one has already covered the glacial and ancient talus débris and extended down upon the alluvial terraces below. Modern talus is descending over all these older detrital accumulations. These various minglings of loose rock make the mapping of different classes a matter of rather rude generalization.

The town of Silverton is built upon a series of low alluvial terraces. Carved below the lowest of these is the present flood plain of Mineral Creek and the Animas.

Torrential fans.—The entire flood plain stretch of the Animas is characterized by torrential fans from side streams, many of them large enough for representation by the contours of the map. Nearly all streams have produced them. A large stream exhibits broad fans of low angle, while a ravine that is young and is being rapidly eroded has the steeper, if not the larger accumulation at its mouth. This contrast is very noticeable in the fans from Maggie and Otto gulches. The fan at Maggie Gulch is of very low angle and spreads out widely. The combined fans, which begin in the ravine 400 feet above the river and merge with a smaller detrital cone from an adjacent ravine, spread less at their fronts than does that of Maggie Gulch.

ANIMAS CANYON AND THE SCHIST AREA.

In the Silverton quadrangle, the Animas Canyon proper is a gorge cut in Archean schists, which extend eastward from the river nearly to the eastern quadrangle line. It is convenient and appropriate, for purposes of local description, to consider the topographically distinct features of canyon and plateau together.

Animas Canyon.—The great canyon of the Animas may be said to begin opposite the mouth of Mineral Creek. It continues with true canyon character for 20 miles, nearly due south, passing through the heart of the Needle Mountains as a gorge several thousand feet deep, and then, gradually shallowing, ends as the river flows quietly out into the broad level plain of the valley in the northern part of the Durango quadrangle. Only the first 3½ miles of the chasm lie within the Silverton quadrangle.

For the first mile of its course the deep valley has a flood plain, and its steep slopes, cut in the monzonite stock, are hardly different from those of other mountain valleys. The gorge gradually contracts on approaching the south border of the stock, and just after the contact is passed the flood plain abruptly ends and the true canyon features begin with the passage into the schists. As has been shown in describing these rocks, the river cuts a fine section across them, for they strike nearly east and west, and several intrusive granite masses are also revealed. The fall of the stream from the mouth of Deadwood Gulch to the quadrangle border is only about 200 feet.

The schist plateau.—As is shown clearly by the contours of the map the steep-walled gorge of the river is about 1000 feet deep near the mouth of Deer Park Creek, while north of Whitehead Creek a sudden change from an abrupt wall to gentle slope takes place at an elevation of 2500 feet above the river. On the western side of the canyon the walls end just below the bench on which the Ignacio quartzite lies. In a subsequent part of this text it will be shown that the old Paleozoic floor, after being covered with thousands of feet of sediments, was laid bare and somewhat carved by erosion prior to the epoch of the Telluride conglomerate. It was then again buried by volcanic accumulations and has now been once more brought to light. That the old surface corresponds nearly to that of the schist plateau that lies east of the canyon and extends southward along the Continental Divide for some miles is shown by the rise of the Paleozoic beds south of Deer Park to a height of 1200 feet or more, and by a remnant of Ouray limestone, and probably of the underlying Elbert shales, on the schists some distance south of the Silverton line. The sediments in Cunningham Gulch also bear on this question.

Granite and basic intrusions.—The schists are penetrated by several granite masses which are similar to or identical with the much larger masses intruding the schists on the south side of the Needle Mountains. One of these granite bodies west of the river is very complex in its ramifications, and the outlines of the map are simply generalizations. The others are simpler in form.

The rocks grouped as "basic dikes" upon the map are much more numerous than the granite bodies but occur only in narrow dikes. These rocks show in fact, considerable diversity of composition, ranging from olivine-diabase to varieties of rock containing some quartz and orthoclase, but all have undergone alteration tending to make them amphibolitic rocks of some kind.

THE SOUTHERN VOLCANIC AREA.

Between the Animas and Cunningham Gulch is a rugged mountainous area presenting some of the most complex as well as some of the simplest elements of local geology. The area is underlain by the schists and by the remains of the older Paleozoic sediments, the distribution of which has been considered. The geologic features of this area that are of most interest are the earlier volcanic formations, the phenomena of glaciation, and the succeeding history.

Distribution of the Telluride and San Juan formations.—The Animas Canyon marks a line between regions in which the Telluride conglomerate and the San Juan tuffs show very different conditions. West of the river these formations were deposited as continuous and conformable strata upon a generally even surface. East of the canyon both were deposited upon a very uneven floor. The Telluride, being of slight thickness, was collected only in hollows or drainage channels; the San Juan, of greater thickness, follows all the unevenesses not obliterated by the Telluride. Its base is, moreover, not only irregular in detail but exhibits many larger variations from the plain surface everywhere characterizing it to the west.

The Telluride conglomerate was observed in two small mounds on the patch of Elbert shale and Ignacio quartzite south of Deer Park, at two places on the south side of the ridge west of Whitehead Peak, and, as a longer band, in Mountaineer Gulch.

As for the San Juan tuffs, Whitehead Peak and outlying ridges, near the quadrangle line, are similar to the mountains west of the Animas, except that the base of the tuffs is more irregular. But farther north the tuffs plunge downward below any level at which the Telluride occurs west of the Animas until, adjacent to the monzonite stock, they are more than 2000 feet below their base on Sultan Mountain, only a mile to the west. The base of the tuffs also descends rapidly into Cunningham Gulch and eastward into the Rio Grande Valley.

From the low level reached by the San Juan near the monzonite it is natural to suppose that it must reappear east of Silverton, on the south slopes of the valley, and certain observed clastic volcanics have been referred to it, as shown by the map. Between Silverton and Cunningham Gulch is one of the most difficult areas to study in the whole quadrangle. Here metamorphosed or decomposed rocks and crosscutting masses are common and the ground is greatly obscured by various kinds of detritus as well. It is not certain that the dense breccia shown in Arastra Gulch belongs to the San Juan, nor that it occupies all of the space assigned to it, for talus and glacial débris, mingled, cover the slopes effectually, except for a few outcrops.

The Eureka flow-breccia.—At the west base of Kendall Mountain the San Juan tuffs are penetrated by a network of dikes of gray or reddish rock having the characters described for the Eureka rhyolite flow-breccia. These unite upward and from this point the massive sheet or flow extends northeast and southeast, as indicated on the map. The representation of the dikes on the map is much generalized, as it is impossible to show, on a map of this scale, half the observed tongues of rhyolite or intruded masses of tuff; and besides, much of the surface is covered by vegetation, talus, or landslide débris. Except the local Picayune andesite the San Juan tuff is the only volcanic formation older than the rhyolite, hence the flows of the latter rock must have issued upon a floor of San Juan tuffs modified by whatever erosion may have taken place in the interval preceding the rhyolite eruptions. The upper limit of the flow breccia is a nearly horizontal line around Kendall and Hazelton mountains, but the breccia rises nearly to 13,000 feet at the head of Deer Park Creek, at which point it also thins out.

The point of eruption of the Eureka rhyolite at the base of Kendall Mountain is but one of several presumably existing in the quadrangle, one other, described in a later paragraph, being in Cunningham Gulch.

The occurrence of the Burns latite.—Above the Eureka rhyolite in all mountains of this area occur the dark-colored lavas and tuffs of the Burns latite. These rocks are in some places more that 1500 feet thick. In the field it may appear that two or three separable types occur, but microscopical examination throws them together as slight variants of one magma. The Kendall Mountain type has a few scattered phenocrysts of orthoclase, but these may occur in almost any of the local rocks. Hornblene is likewise broadly diagnostic, but fails at times. In an earlier part of the text the somewhat diferent facies of Burns latite are described.

As shown by the map the lavas which rest upon the rhyolite flow-breccia are presumed to be directly connected with those of the lower slopes of the Animas Valley.

Pyroxene-andesite was found to form the cap of the first point on the divide north of Whitehead Peak, where it rests on San Juan tuffs. Possibly there are other remnants of this rock in the summits of this area, but they were not recognized. The rock of the point named is unusually fresh, much hypersthene being preserved, and is no doubt the pyroxene-andesite type.

Dikes cutting the volcanics.—The region between Kendall Peak and Kendall Mountain is characterized by several andesite dikes related to pyroxene-andesite. Farther south is a long dike of granite-porphyry which runs from the point of the ridge north of Deer Park for several miles eastward across Cunningham Gulch.

Monzonite.—The Sultan Mountain monzonite stock extends eastward up the slopes of Kendall Mountain. Its contact line presents several sharp angles and may have as much irregularity in detail as on Sultan Mountain, but outcrops are poor.

Glacial sculpturing.—No part of the Silverton quadrangle exhibits more beautiful glacial cirques than this southern district. Swansea, Blair, and Arastra gulches, the last with three cirques in turn tributary to it, are excellent examples of the amphitheaters or basins which have been carved by glacial ice at the heads of most of the streams in the mountains. These particular cases are essentially hanging valleys, in the sense that their waters flow over comparatively flat floors in their upper parts and do not enter the main stream at grade, but cascade down narrow ravines to the flood plain of the Animas. Arastra Gulch not only exhibits three elevated cirques, but its lower basin has the form of an amphitheater, the floor of which is but little above the Animas, while at the back it has a steep semicircular wall 1500 feet high. Several small cirques are situated at the heads of streams tributary to Cunningham Gulch.

No deposits of glacial gravels or moraine materials of consequence were found in this section except those on the lower Animas slopes, which were doubtless derived from distant sources.

Landslides.—Several well-defined landslides of consequence have occurred in this region. One of them is on the south side of Kendall Gulch, the fallen mass having come from a high cliff. The disintegrating slide material causes a bench, indicated by the contours of the map. Another slide, of more ancient date than the first one, occurred on the west slope of Kendall Mountain and is not shown on the map. The débris of this slide obscures the dikes of Eureka rhyolite over a considerable space.

A third slide area is situated between Blair and Swansea gulches. Only the more clearly defined part of this slide is shown by the map. In fact, the débris of this slide is mingled with that of a rock stream and with glacial gravels all the way to the river. It was practically impossible to map the various kinds of detritus on this steep wooded slope.

Other landslides have taken place on the slope between Blair and Arastra gulches, but their boundaries are scarcely determinable in the thickly wooded slopes, where there is also much loose material of other origin.

Rock streams.—Three rock streams are shown on the map. In Blair Gulch the slide area includes two streams. The older and larger occupies the bottom of the gulch, is covered by trees, and at the lower end mingles with the landslide débris. From the appearance of the slope below, it is believed that this stream may have extended to the river. The younger portion of the area is a stream of fresh talus-like material from the western cliff which has moved out upon the older stream. It is still free from vegetation. In Swansea Gulch are two streams.

CUNNINGHAM GULCH.

Cunningham Gulch, together with its branches, Stony and Rocky gulches, is one of the most interesting of the smaller valleys of the quadrangle. It is the largest and deepest of the tributaries of the Animas above Silverton, entering it at grade and with such a gentle rise that a wagon road follows it for 3½ miles from the river. Some of the oldest mines of the district are situated here, and the road leading up Stony Gulch has long been the principal route of approach from the Rio Grande Valley. The gulch proper is a deep canyon with precipitous walls rising over 3000 feet to the summits of Galena and King Solomon mountains.

The geology of the gulch is interesting because it is the only branch of the Animas above Mineral Creek to penetrate below the volcanics and reveal the relations of the underlying schists and sedimentary formations. The meager exposures of some of these rocks, together with the irregular contact line of the volcanics and the extensive decomposition in certain areas, make the study of the gulch very difficult.

The schist exposures.—The largest schist area of the gulch is directly connected with the main region to the south. The gulch is in fact carved in schist to a point less than 3 miles from the Animas, and the abrupt eastern wall is of schist for 700 to 800 feet above the stream, clear to the line of the intrusive body of Eureka flow-breccia, which cuts off the older rocks. North of this contact the schists appear in Stony Gulch, where the road crosses it at about 11,100 feet, and at the forks of Rocky Gulch, at a little lower level. These two exposures are doubtless connected beneath the glacial gravels of the vicinity.

There is plainly a ridge of the schists under the volcanics on the east side of Cunningham Gulch and this, together with the Ouray limestone outcrops, to be mentioned, gives evidence of the rough topography which existed in this vicinity before the San Juan tuffs were deposited.

Paleozoic formations.—A significant exposure of several sedimentary formations occurs on the east side of Cunningham Gulch opposite Mountaineer Creek. The Elbert, Ouray, and Molas formations are all present in a narrow band between two pre-Tertiary faults. The same formations are represented on the western side, but a landslide has greatly obscured the relations. The three formations named can be distinctly seen in their normal position. The two faults do not penetrate the overlying San Juan, and thus show the relative age of the faulting. As no sediments occur under the tuffs on either side of the fault block, the amount of the downthrow can not be determined, but it was probably more than 1000 feet, for the schists occur at nearly 1500 feet above the base of these sediments less than a mile to the southeast, on the Continental Divide.

No Ignacio quartzite was noticed below the Elbert shales of this fault block, but the three formations present occur in their normal development. The presence of Devonian limestone in Cunningham Gulch was noted by Endlich during the Hayden survey, but he does not refer in his report to the faults which explain its occurrence.

The landslide block on the west side of the gulch clearly includes the Ouray limestone, which appears in tumultuous heaps of huge blocks from near the bottom of the gulch to a thin ledge of Telluride conglomerate that can be traced from Mountaineer Gulch above the fault block and for a short distance north of it. But the top of the sedimentary rocks in the landslide is covered by San Juan tuff which was brought down by the same slide from the cliff just to the west, and the tuff débris conceals the Telluride conglomerate below this cliff, as well as the limestone or Molas formation below. The map shows the sediments rather than the landslide material, because it seems desirable to make this pre-volcanic fault structure as distinct as possible.

Other outcrops of Ouray limestone in Cunningham Gulch lie below the schist exposures and are surrounded by igneous rocks, as represented on the map. These outcrops show no sediments but limestone, for schist is not exposed, although it must be present at small depth under the limestone. These limestone masses are conceived to represent projecting knobs belonging to the uneven surface upon which the San Juan tuffs were laid down. The tuffs rest on them and in places descend over the surface of the limestone toward the gulch. The anomalous appearance of the outcrops is due to the Eureka rhyolite flow-breccia, which is clearly a crosscutting body in this portion of Cunningham Gulch, as especially shown by its relations to the schists and tuffs. Apparently the rhyolite occurs as a dike on the line of Cunningham Creek; separating the limestone areas of the two banks and taking the place which would naturally be occupied by the schists in the stream bed. Actual contact with the limestone is seen only at the southern end of the exposure, on the western bank, but various exposures of the rhyolite occur below the limestones.

The greatest thickness of limestone seen is in a ravine entering the gulch from the east and crossing the road a few yards north of the Pride of the West buildings. The limestone appears about 20 feet above the road and is continuously exposed in the bed of the ravine in nearly horizontal strata having a total thickness of more than 125 feet, above which come San Juan tuffs. The limestone can be traced southward through the timber to the line of the Pride of the West tramway, while to the north it is abruptly concealed by talus and vegetation, though the upper part of the section referred to appears in the next ravine and the outcrops are connected on the map. San Juan tuffs separate this limestone area from the one immediately to the north, where the tuffs again come over and wrap around the limestone in most irregular fashion.

The map shows the Eureka rhyolite as limiting these eastern limestone outcrops on the lower side, but the contact may not be so simple as represented. In fact the lower contacts are not seen, and San Juan tuff very probably comes down below the limestone in places.

The limestone on the west side is peculiar in its apparent relations. At the southern end of the outcrop it seems like a dike in the San Juan, but by putting various separated exposures together, and omitting the San Juan, which rests on it most irregularly, an area is shown here that is comparable in extent to those on the opposite side of the gulch.

It is reported that limestone occurs on the point of the ridge between Stony and Cunningham gulches, but this outcrop was not found, as the slope is heavily wooded.

On examining the relation of these limestone exposures to the occurrences mapped, it is plain that there must be a fault between the two, probably corresponding in age to those of the fault block higher up the gulch, and having a direction about N. 20° E. Such a line, extending from the schist exposure in Rocky Gulch to the western edge of the main schist tongue in Cunningham Gulch, passes just east of the Pride of the West limestone area.

There has been little mineralization in these limestone masses, the only notable instance observed being on the Osceola claim, north of the Pride of the West mine. This seems rather peculiar in view of the situation of the limestone beneath great bodies of igneous rock in which there has been abundant circulation of waters and some ore deposition in veins not far away. The appearance is, however, possibly deceptive, since exploration has not been conducted with reference to the presence of these limestones.

San Juan tuffs.—Enough has been said in connection with the preceding discussions of the occurrence of schist and sediments to explain in large degree the local distribution of the San Juan tuffs. That they lie upon a very irregular surface has already been shown, but the formation is also of greatly varying thickness owing partly to the unevenness of the floor upon which it rests and partly to erosion preceding the next volcanic eruption, presumably that of the Eureka rhyolite. Above the fault block the tuff is purplish and more or less friable. In the complicated area of Stony Gulch and lower Cunningham Gulch it is much altered and not easily recognized. The San Juan was not found north of Stony Gulch, so that it either plunges under the volcanics of the central area or is cut out by the intrusive rhyolite and latite.

Eureka rhyolite flow-breccia.—The manner in which the rhyolite cuts across the end of the schist arm and also separates the limestone areas on either side of Cunningham Gulch has been spoken of. This same intrusive relationship is further illustrated by several dikes or arms that penetrate San Juan tuffs between the eastern limestones and the schist, and by a large dike in tuffs in Stony Gulch. South of the main gulch crossing, the rhyolite appears in its common position between the San Juan tuffs and the Burns latites. This position may be due to its intrusion into the tuffs, in which case the part above the rhyolite was eroded before the Burns epoch, but it is not possible to determine where rhyolite reached the surface of the tuffs. The rhyolite certainly has a thickness of a thousand feet at the base of Galena Mountain but is interrupted, above the mouth of the gulch, by rocks assigned to the Burns latite.

The Burns complex.—The lavas and tuffs or breccias of hornblendic latite which come above the Eureka rhyolite on both sides of Cunningham Gulch belong properly to mountainous tracts which are described elsewhere. But at the mouth of the gulch occurs the fine-grained greenish latite which cuts off the rhyolite, either by intrusion or by resting on an erosion surface. This rock extends up both sides of the gulch and is of large mass. Repeated attempts to determine the relations of this latite to the upper portions of the complex failed because it shows transitions in texture to other phases of the Burns latites, is often decomposed, or is covered by débris or forest.

Occurrence of dike rocks.—The wide dike of monzonite crossing Cunningham Gulch and passing up Rocky and Stony gulches is an important intrusion, but its form is only approximately indicated by the map. As the map shows, glacial and fan detritus conceal a large part of it and much more is really hidden by talus or vegetation, while the decomposition and staining of the dike and of the rocks it cuts is so extensive in many places as to defy identification of the dike material except on most careful examination, foot by foot. As the dike rock is in places porphyritic and fine grained, it can with difficulty be distinguished from the similar latite mass on the west. The granular rock, fresh in spots, is seen in Rocky Gulch.

The long, narrow granite-porphyry dike, traceable from Deer Park, crosses Cunninghan Gulch, being quite prominent in the schists on the western side, where a peculiar interruption, through an obliquely crossing tongue of schist, can be seen from a distance. Its course lies nearly parallel to the schistosity along the western side of the gulch.

Dikes of hornblendic latite occur on the east side of the gulch in the San Juan tuffs, and on the west side of Stony Gulch is one of the largest dikes of pyroxene-andesite found in the quadrangle.

Surficial deposits.—Mention has already been made of the glacial gravels, which unfortunately cover so effectually the schists and monzonite dike rocks of the ridge between Stony and Rocky gulches. This deposit is apparently the morainal accumulation of two local glaciers in their last stages.

The torrential fan of Rocky Gulch is extensive but not greater than would be expected in view of the fact that the gulch heads directly in the cliffs of Galena Mountain.

On the west side of the gulch are several small fans caused by intermittent streams heading in elevated cirques and plunging into the valley over cliffs into which they have cut no definite channels.

RIO GRANDE DRAINAGE AREA.

Nearly all of the southeastern section of the quadrangle, on the Atlantic side of the Continental Divide, is occupied by volcanic rocks and is in a state of development representing a transition from the conditions characterizing the Silverton quadrangle to those prevailing in adjacent portions of the Rio Grande Valley.

The Continental Divide, while maintaining an elevation of over 12,500 feet, passes from the schists across the San Juan tuffs and the members of the Silverton series on the southern line of the quadrangle, to rhyolite, supposed to belong to the Potosi series, on its eastern border. All the volcanics show an easterly or northerly dip, which causes their successive appearance along the nearly even level of the divide.

The schists of this section belong to the plateau area already described. Basic dikes are here particularly prominent and several of them are shown on the map.

The San Juan tuff.—The tuffs of this region are light blue-gray or greenish, and of rather fine grain. They are not much indurated and as a rule form gently rounded slopes. The principal local interest in this formation attaches to its relation to the underlying schists. This is very irregular, testifying to great diversity in the pre-volcanic topography. From the divide the schist-tuff contact runs almost straight down Deep Creek nearly to the quadrangle line, then turns abruptly southward, rising rapidly again. There is a bluff of the schists on the south of Deep Creek, and it is perhaps significant that the course of the creek is nearly in line with the south fault of the block in Cunningham Gulch. It seems possible that the existence of a fault scarp, or at least of softer rocks north of this fault line, controlled the erosion of the pre-volcanic time.

The tuffs are exposed down the Rio Grande for several miles until they are covered by the descending Potosi series.

The diminishing Eureka rhyolite.—The rocks mapped as Eureka rhyolite at the head of the Rio Grande are not the flow-breccia throughout but consist largely of light-colored tuffs which are distinct from the San Juan and occur below the Burns latite complex. Some flow-breccia occurs with them. The contact with the San Juan is a marked angular unconformity, as in the deep ravine next north of Deep Creek. The tongue of tuff running from that ravine up on the ridge to the south is of a peculiar color, which makes it plainly visible from points far southward.

The Burns complex.—Canby Mountain and the summits farther southwest present in their upper parts the dark flows of hornblende-latite specially described as the Canby type. There are two or three flows with tuff of variable thickness between. Beneath these flows, especially to the northeast, occurs the facies of the Burns latite described as the Niagara Gulch type. It is that rock, with its associated tuffs, which extends into Sheep Mountain and northward along the divide. Nothing suggesting the calcareous tuffs has been found above or below the Niagara Gulch latite in this vicinity.

The Burns complex thins out eastward, as the map clearly shows, but the adjacent region has not been studied sufficiently to demonstrate whether this thinning is original or is due to erosion.

Pyroxene-andesite.—On the divide at the head of the northern branches of Pole Creek (unnamed on the map) the dark massive flows of pyroxene-andesite reach their present southern limit. They rest on a surface of tuffs of the Burns complex which dips sufficiently to carry them rapidly down to the east, as will be specially pointed out in the description of the region lying farther north.

Potosi volcanic series.—The Potosi quartz-latites and rhyolites of the area under consideration are best developed in Sheep and Greenhalgh Mountains. The quartz-latite is the lower rock and the rhyolite appears only in the summit portions of the two mountains. In this locality the underlying rock is the Burns latite, which has a thickness of about 500 feet.

Across the Rio Grande, in the extreme southeast corner of the quadrangle, the Potosi latite rests on San Juan tuffs or in places on schist.

These two areas of the Potosi lavas rest upon a surface that dips eastward at a low angle. They testify to great erosion of the Silverton series and the still lower San Juan tuffs in the interval preceding their eruption. Both are isolated by tributaries of the Rio Grande. The lavas of the southeast corner rise with the ridge for a few miles toward the Needle Mountains.

Intrusive latite.—Near the quadrangle line south of Greenhalgh Mountain is a small plug of hornblende-pyroxene-latite cutting San Juan tuffs. It presents precipitous faces toward Deep Creek and the ravines on either side, but is partially covered above by landslide débris. The rock is similar to some of the flows of the Canby type, and the plug may occupy one of the conduits through which lavas of the Burns complex reached the surface.

Glacial deposits.—Glacial gravels, occurring partly in distinct morainal form, partly as a veneer of scattered bowlders, are widespread in the basin at the head of the Rio Grande and on the slopes of Sheep Mountain. The more distinct moraines are shown upon the map, but the thin coating of the mountain side is omitted to permit expression of the landslide areas. Occasional erratic blocks occur on the slopes of Deep Creek.

Landslides.—The southern slope of Sheep Mountain is covered to a large extent by landslide material of somewhat unusual character. The greater part, if not all, of it was primarily talus from the cliffs of the mountain. Apparently this talus accumulated in a great bench-like mass below the cliffs and perhaps it moved after the manner of rock streams for some little distance. Finally it lost equilibrium and plunged down the smooth and steep slope as a landslide of detrital material. The process outlined seems now in operation at the large bench south of Sheep Mountain summit, indicated by the 12,200-foot contour. The outer edge of this great talus mass is somewhat higher than the flat back of it, and the cliff face shown by the map is a fresh landslide scarp. The slides have been numerous and practically extend to the stream below. A similar slide track occurs west of the summit. The map exhibits the talus slopes and the slide together.

A landslide area of more common character occurs on the east side of a point on the Continental Divide southwest of Stony Pass. The material here comes from cliffs of the Canby latite and many small slides have taken place. A block split off from the mass behind and thoroughly shattered forms the apex of this area. This block will soon fall farther and break into many smaller blocks, and thus add to the general slide mass which reaches to the stream, more than 600 feet below.

Rock stream.—One of the most notable rock streams of the quadrangle is that in the basin north of Sheep Mountain. Like the landslide mass on the south side the débris forming this stream seems to be the talus from the cliffs, which has flowed after the manner of a glacier for three-fourths of a mile from the cliff of rock in place. The stream is sharply defined and the relief is much greater than that which appears to the eye, as one can readily see on examining the map, where several sunken areas are expressed and the steep sides are represented by two or more contours.

Torrential fans.—On the south side of the Rio Grande are two small fans formed by new ravines which are rapidly cutting back into the forested slope of the San Juan tuff. Apparently the fans represent nearly all of the rock excavated in forming the ravines above.

CENTRAL EASTERN SECTION.

The area to be described in this section extends from the Continental Divide northward to the crest south of Henson Creek. It is traversed north and south by a narrow range of high peaks. West of this crest are a number of short gulches, tributary to the Animas, with glacial cirques at their heads. On the east the drainage is wholly into the Lake Fork of the Gunnison River.

Maggie and Minnie gulches.—Heading against the Continental Divide at the southern extreme of this area are two deep gulches in which the eol ogy is strikingly simple as compared with that in the nearby Cunningham Gulch. These valleys, Maggie and Minnie, although cutting more than 2000 feet below Middle Mountain, which lies between them, do not reach the horizon of the San Juan tuffs, and their slopes simply show the local development within the Eureka rhyolite, the Burns latite complex, and the lower part of the pyroxene-andesites. The only irregularity is caused by a wide dike of monzonite crossing Maggie Gulch and some faults which disturb the bedded volcanics in Minnie Gulch.

The Eureka rhyolite flow-breccia is shown in its typical development on the southwest side of Maggie Gulch, between the monzonite dike and the mouth of Ridgway Creek. But over much of the area it occupies the rock is so decomposed and stained as to make its recognition difficult. The rhyolite sinks northward so that it barely appears at the very mouth of Minnie Gulch.

The Burns latite complex has an unusual amount of tuff in it at the head of Maggie Gulch. The variable thickness of flows and tuffs is well shown in the cliffs of both these gulches. Near the base the Burns tuffs of this vicinity are rather coarse, being agglomeratic in places, and often contain granite fragments in abundance.

The monzonite dike crossing Maggie Gulch is much better exposed than that of Cunningham, but the extensive decomposition of all rocks near it is a hindrance to study. This dike extends southwestward across Porcupine Gulch almost to Cunningham and in the opposite direction across the ridge into Minnie Gulch, but its ending is much obscured by detritus and vegetation. In the sides of both Minnie and Maggie gulches there is a marked change in the structure of the bedded volcanic rocks. In their upper portions they have a gentle dip to the southeast, but at about the point where the falls occur in Maggie Gulch, and at a corresponding point in Minnie, the dip changes to a northwesterly one, which carries the members of the lower series well down toward the Animas River. This structure is to some extent complicated by faults which are undoubtedly related to those of American Basin.

Galena Mountain.—The rugged mountain between Cunningham and Maggie gulches is composed almost wholly of the dark flows and tuffs of the Burns complex. Hornblendic and augitic latite of the Canby type is the ruling rock. Propylitic decomposition has been extensive here, and possibly some of the summit rocks are pyroxene-andesite. The many distinct quartz veins of this mountain have lead to much prospecting, even in the almost inaccessible cliffs of the southwestern face.

Mountain crest of pyroxene-andesite.—From the head of Maggie Gulch northward to the head of American Basin the summits are composed of dark pyroxene-andesite, chiefly of two or three flows with intervening tuffs. These make cliff faces for the glacial amphitheatres on either side of the narrow winding divide from Crown Mountain northward. South of that peak the divide seems to represent a part of an old plateau surface, for upon it are several remnants of rhyolite, massive or tuffaceous, supposed to belong to the base of the Potosi series. If not of that age, they probably belong to some much later epoch of the volcanic period, not yet recognized. Crown Mountain has a cap of this rhyolitic material, much decomposed.

The eastern slope. Cuba and Snare gulches.—Cuba and Snare gulches are branches of Cottonwood Gulch, one of the principal heads of the Lake Fork. Here, even more than in the Rio Grande Valley, the quadrangle line comes near a boundary between areas showing very different geologic conditions, although the map gives no indication of a change. The great change in conditions in Cottonwood Gulch is due partly to a large mass of granite, probably of pre-Cambrian age, which between Snare and Cuba creeks approaches within a few hundred yards of the eastern boundary of the Silverton quadrangle. Upon this granite the pyroxene-andesite rests in some places. While on the Animas side of the divide the andesite has apparently several thousand feet of latite, rhyolite, and tuff below it, only thin representatives of the San Juan and the Eureka rhyolite are present in Snare Creek or Cuba Gulch.

From the divide eastward the surface has an irregular hummocky appearance, suggesting a succession of landslide blocks, but examination of this slope shows that the andesite flows of the divide, not more than two in number, are continuous, and no definite landslide blocks were seen. Apparently the flows, which are not very thick, came down an uneven valley or mountain side for a distance of 1200 feet or more, and some of the irregularities may emphasize the features of the old surface.

Until the Cottonwood Gulch region has been further studied the changes in the volcanic section can not be explained, although they probably are due to various erosion intervals. A small amount of spherulitic rhyolite occurs in Snare Creek between the San Juan tuffs and the pyroxene-andesite. Whether this belongs to the Eureka rhyolite is not definitely known, but it is provisionally shown on the map by the same color. No such rock occurs in Cuba Gulch, but tuffs referred to the San Juan appear just beyond the quadrangle line.

The granite mass of Cottonwood Gulch extends for some miles down that stream to the Lake Fork. So far as examined, it does not seem to be bounded by fault planes near the boundary of the Silverton quadrangle, yet it is natural to compare it with the mass of Edith Mountain, which is outlined by fault planes.

Handies Peak.—The highest mountain in the Silverton quadrangle is Handies Peak (14,008 feet), situated almost on the quadrangle line east of American Basin. The cliffs facing the basin are of pyroxene-andesite, at the base of which is a coarse agglomerate containing huge granite bowlders. The andesite complex does not extend farther north in this vicinity except for the small black knoll on the ridge leading to Handies Peak. This remnant of the andesite rests on the calcareous tuffs at the top of the Burns series, which rise toward the north and are thus carried well up the slope of the peak. At the summit, not far below the calcareous horizon, are fine-grained tuffs which are so light in color that they seem almost rhyolitic. They show a marked southeastward dip varying from 25° to 40°.

The Burns complex is largely tuffaceous here and in consequence the slopes of Handies Peak are usually smooth, except where the intrusive augite-andesite occurs. That rock is very irregularly intruded into the tuffs and flows of the Burns latite, and the accurate delimitation of the andesite was found impossible, hence the map expresses only the general distribution of the andesite with some of the more distinct arms of the interlocking contact. The massive appearing rock in the side of the peak is mainly andesite, but it contains numerous tongues or inclusions of the Burns rocks. The southerly dip of the upper tuffs must be, in part at least, due to this mass of intrusive andesite.

On the north shoulder of the peak complications caused by the great fault zone begin to appear, and at the north base occurs the upraised granite mass to be specially described.

Head of the Lake Fork and its rock streams.—The extreme head of the Lake Fork, known as American Basin, has a wide amphitheater form with an irregular, rapidly descending floor. Excepting the cliffs of andesite at its head the only two rocks occurring here, down to the granite, are the Burns latite and the irregularly intrusive augite-andesite. The complexity of the local geology is greatly increased by several notable faults, represented on the map, and other lesser ones.

The rock streams of American Basin are in some respects particularly interesting and instructive. It has been noted that a sharply defined apparent talus accumulation is present all along the base of the pyroxene-andesite cliffs at the extreme head of the basin. In fact, the sharp line is caused by a ridge of débris that lies at some distance from the base of the cliff and is separated from it by a depression. The common talus pile resting against the cliff is also present. The most plausible explanation of the outer ridge and the depression behind it is that the heavy winter snows remain banked against the northward-facing cliff and that each year a great deal of the material loosened by frost in the upper part of the cliff must fall upon this snow bank and be carried to some distance. The line of most rapid accumulation is thus the border of the snow bank.

Perhaps there has been some movement in the mass of these great heaps of loose rock, but if so, it has been slight compared with the evident slipping down of a limited portion of this material directly in the center of the basin, forming one of the best defined rock streams of the region. A near view of this stream shows how sharply defined it is and its relations to the cliff and talus ridge just described. The length of this stream from the talus ridge to the point is about 1200 feet, and the height of the steep slope above the trail crossing its end is about 100 feet.

The surface of the stream shows concentric lines like the flowage lines of a glacier, giving the impression that while the flow took place above a drainage channel of the underlying rock and was due to the loss of equilibrium in the talus ridge, the fall was not sudden, as in a landslide, but the movement was more nearly like that of a glacier.

A small rock stream occurs on the western side of the basin, at its head, and a large one descends from the divide opposite Grouse Gulch. This stream is remarkable for its situation on the side of the Lake Fork Valley and for the distance it has moved in glacier fashion over a floor of comparatively slight grade. The head of this stream is under cliffs that still furnish talus, but not much in excess of that at many points where there are no rock streams.

While glacial work in excavating the cirque portions of this basin and smoothing off certain benches, as well as forming the valley itself, is very evident, morainal débris is lacking in any considerable accumulation. Sloan Lake occupies a solid rock basin.

The granite mass of the Lake Fork.—A mass of coarse granite bounded entirely by fault planes is cut through by the Lake Fork on the quadrangle line. While the fault planes show that this mass is an upthrust block, there is no means of measuring the amount of throw, and if the granite mass of Cottonwood Creek is a projecting point about which the volcanics piled up until it was covered, the Lake Fork body may perhaps be in part of that character also. The granite is seen to extend from the stream to the summit of Edith Mountain, making very precipitous cliffs more than 1000 feet high. It also rises to about the same elevation on Handies Peak and on White Cross Mountain, which lies to the east. The mass has not been entirely outlined, but it is known that at a point about a mile east of the quadrangle line volcanics are again brought to the Lake Fork, apparently by a fault of general north-south trend.

The faults bounding the mass are clearly visible except a part of the one on the west, near the jog or offset. The fractures plainly belong to the fault zone which is so marked a feature of this region. The south fault is mineralized to some extent and is developed by the workings of the Bon Homme claim.

Edith Mountain ridge.—The ridge extending west from the granite point known as Edith Mountain presents some very complex crosscutting masses of andesite, and as several faults traverse the ridge the deciphering of all the intrusive masses is most difficult. The rocks intruded belong to the Burns latite complex and are chiefly tuffs of the upper horizons. Near the western end of the ridge a small knoll is capped by a remnant of partly vitreous pyroxene-andesite, of which a chemical analysis has been given (p. 9). The andesite is supposed to represent the lowest lava of the pyroxene-andesite member of the Silverton series, because immediately beneath it occur the calcareous tuffs and thin limestones marking the top of the Burns latite, in which fossil plant remains were found.

Cleveland Gulch.—This branch of the Lake Fork is specially characterized by the many prominent quartz veins which cross it and by the combined landslide and rock stream on its northern slope. The veins are for the most part on fault fissures, represented on the map. They bring the intrusive andesite and the Eureka rhyolite flow-breccia into complex relations.

The landslide area of Cleveland Gulch extends from the divide on the north to the stream bed, a vertical distance of 1200 feet. The upper part is made of large blocks, much shattered and in process of disintegration into finer débris, like that which covers the slope below. The blocks which have fallen must have constituted a part of the narrow divide when it was higher and broader than it is now.

The lower, narrower part of the area mapped as landslide is practically a rock stream, the material of which came from the slide. This stream has the concentric flow lines and the sharp outline characteristic of rock streams. It has caused a little lake by damming the creek.

Area between Lake Fork and the Animas.—This area is perhaps the most complicated in the quadrangle by reason of the number of igneous formations present, some of them intrusive, and the large number of faults. Were it not for the calcareous tuffs and thin limestones of the Burns latite complex, which are especially well developed in this area, the structure could hardly have been worked out.

The Picayune andesite, Eureka rhyolite, and Burns latite, of the volcanic succession, as well as intrusive andesite and rhyolite, are all found in this area. In general the map must be left to give details of distribution, without taking up all the separate fault blocks. The rapid changes in thickness or the dying out of some formations are not fully understood, and it is freely admitted that additional faulting, not detected on the ground, is undoubtedly present in this area, so that some portions of the map are inaccurate or incomplete in their representation of the geology.

Three formations of the area require some special description of their occurrences.

The Picayune andesite extends far up into Grouse Gulch. Its appearance more than a thousand feet above the Animas is due mainly to the Rainbow fault, on its northwestern side, together with the Anaconda fault, which doubtless unites with the Rainbow fault in Grouse Gulch, the point of junction being hidden. The southeastern boundary of the mass, crossing Burns Gulch, appears also to express the relations of a fault, but the actual contact was not found to have that character in the few places where it was seen. In the bed of the Animas the contact is with a formation older than the Eureka rhyolite. The upper limit of the Picayune in Grouse Gulch is much obscured, but is shown near the Anaconda fault and on the ridge between Burns and Grouse gulches.

The latite mass in the Burns complex of Cinnamon Mountain is clearly intrusive in character and occurs just below or splitting the calcareous tuffs at the top of that complex, as usually developed. The shaly tuffs are crushed and crumpled at the blunt end of the body, north of the summit, and can be traced, above the intrusive, all along the northwestern slope to the Tabasco fault, the throw of which they reveal. This intrusive sheet-like mass has the composition of the Niagara Gulch latite, but, as shown by its occurrence, it clearly belongs, with other intrusions of this rock, to a time later than that of the Burns complex as here distinguished. The wedging out of this mass north of the Rainbow fault was not observed, but there seems no place for the body south of that fault.

Above the calcareous tuffs of Cinnamon Mountain another intrusion occurs, mainly of andesite, but apparently associated with a latite of the Niagara Gulch habit. These are considered to be intrusive because there are tuffs still higher which seem to belong in the Burns complex, although they lie above the calcareous layers which are usually found to be at the very top of that complex.

The rhyolitic rock at the summit of Cinnamon Mountain and along the divide to the southeast is deemed to be intrusive, because it is also found intercalated in the tuffs just referred to. A small patch of these tuffs above the rhyolite occurs on Cinnamon Mountain, on the lower side of the Tabasco fault, and a much greater thickness of the same is seen on the rhyolite adjacent to the Rainbow fault. The rhyolite contacts are almost everywhere concealed by débris, and the rock is always much altered, but it is thought most reasonable to correlate this rhyolite with the more plainly intrusive rock found in the pyroxene-andesites west of the Animas. The rhyolite breaks up readily into sherd-like fragments and its débris not only obscures the boundaries of the rhyolite but by sliding far down the western slopes conceals fault lines and other rock contacts.

NORTHEASTERN SECTION.

The area described in this section embraces the drainage basins of Henson and Bear creeks and the divides bounding them. The district is a natural unit because its geology is in the main peculiar to it so far as this quadrangle is concerned and exhibits the transition to conditions prevailing to the north and northeast.

The Eureka rhyolite is the oldest volcanic formation and it has a great thickness for many miles along Henson Creek as far as the Lake Fork at Lake City. Contrasting with this development the Burns complex disappears in this region, so that the pyroxene-andesite comes into contact with the rhyolite.

The Potosi series has here a somewhat local character and occurs in association with the andesite not elsewhere observed. Various intrusives cause complexity in the igneous geology.

No other part of the quadrangle contains so large rock streams as are found here, and landslides also appear in a few localities.

A return to the plan of description by formation is here desirable.

Occurrence of Eureka rhyolite.—Adjacent to the eastern quadrangle line the high mountain ridge south of Henson Creek is formed of Eureka flow-breccia from the crest to the creek bottom, a vertical distance of more than 3000 feet. This is greater than is elsewhere exhibited and probably does express an increased thickness of this peculiar lava in this direction.

The rhyolite is here a very massive rock, so much decomposed and stained that its character is not quickly made out. In all its thickness there is not sufficient indication of tuffs or of distinct flows to give the whole a distinctly noticeable structure. Even in detail, the rock, in its present condition, reveals no special lamination. In its freshest form it is merely a gray felsitic porphyry having a predominant groundmass and containing some angular fragments of similar rhyolite, or, less frequently, of dark andesites or latites. A fluidal structure about inclusions is common and sometimes is seen extending as a lamination through the rock.

Adjacent to the fault zone in the divide south of Henson Creek the rhyolite is greatly sheeted, decomposed, and outwardly stained. Its jointed condition leads to the accumulation of large amounts of detritus, seen in the enormous talus heaps and rock streams of the basins on this side.

Remnants of Burns latite.—The mountains west of Wood Mountain exhibit at their very summits the limestones and calcareous shales diagnostic of the upper zone of the Burns latite complex. These are underlain by an intrusive sheet to be referred to later, and below that come the lower tuffs and flows of the latite in a thickness of about 800 feet, as mapped. The base was not closely located here. This area of the Burns latite is isolated, but whether the fault represented as cutting it off on the southeast is, in fact, the sole cause of its disappearance is not certain. Wood Mountain is made up of Eureka flow-breccia on its southeast side to the summit, and one or more of the quartz veins lying to the northwest must represent a fault that lets down the Burns complex. The shearing and decomposition of rocks adjacent to these veins, together with talus slopes, prevented definite observations to settle this question. In the peak east of Hurricane Basin the Burns rocks seem to be cut out by a sheet-like intrusion from a dike, as represented by the map.

Another remnant of Burns tuffs and other rocks occurs on the north slope of Cleveland Gulch, extending up to the fault on the crest. At the summit, adjacent to the fault, appear the uppermost calcareous tuffs, etc., upturned and contorted in detail in very marked degree. In one of the thin limestones at this place occurs the fresh-water shell *Limnæa*, found by Mr. Clements.

Pyroxene-andesite and its occurrence.—As expressed by the map, the pyroxene-andesite complex of flows and tuffs rests upon the Eureka rhyolite on the north side of Henson Creek and in the divide to the west. From its relations to the San Juan tuffs, the rhyolite, and the Burns latite, as exhibited at the western end of this andesite area on the eastern side of the Uncompahgre, it is clear that a hollow or valley of erosion existed in this district at the beginning of the andesite period of eruption. The Eureka rhyolite must have presented a northerly slope even steeper and of greater elevation than that of to-day. The grade of that slope is shown by the course of the andesite boundary from the pass at the head of Hurricane Basin as it rapidly descends on either side, and by the tongue of andesite which starts up the mountain side from the mouth of Schafer Gulch. Above this tongue there are scattered patches of tuffs containing some rhyolite fragments mingled with andesite and dipping northwestward at an angle of nearly 60° in some places. These appear to be local in character but belong below the andesite. A corresponding northerly slope is seen at the west extremity of this andesite area, east of Poughkeepsie Gulch, followed by a rapid rise to the top of the San Juan bluffs above the Uncompahgre Canyon. In fact, nearly all the lower contact line is irregular except that on the north side of Henson Creek, which is very nearly horizontal.

The pyroxene-andesite of this area differs in character somewhat from that which is dominant in the central region of the quadrangle. The great hollow at the head of the Animas and of the east head of the Uncompahgre was largely filled by agglomerate or coarse tuff to a thickness of several hundred feet. A layer of similar character is found in places on the north side of Henson Creek, where granite fragments are abundant in it and, rarely, bowlders of rhyolite, similar to the Potosi type. The last occurence is not yet understood, but bears on the possibility, to be mentioned later, that the Potosi rocks and the pyroxene-andesite were at times of practically contemporaneous eruption.

The most striking lava flow in the section is the uppermost one, that of the Dolly Varden mine horizon, an analysis of which has been given. It is probably more basic than the average lava of the series. This flow is continuous beneath the Potosi series, and is separated from it only by tuffs.

The fine tuffs occurring between andesite flows and especially those above them, which reach a great thickness in the adjacent part of the Ouray quadrangle, are peculiar to this section. The upper tuffs carry rhyolite particles as well as grains of quartz and microcline.

As has been mentioned, it was for a time supposed that the ridge between Redcloud and Schafer gulches might be the site of an eruptive center of the pyroxene-andesite. But careful examination shows that there is at this place simply a special thickness of one facies of the andesite, an accumulation no doubt due to some topographic feature of the pre-andesite surface. The dikes of almost granular rock, between monzonite and gabbro in composition, which cut this ridge gave color to the idea of a conduit of larger dimensions. These dikes are very much like the uppermost flow of andesite, but the issue of the flow from these dike fissures could not be established.

The Potosi series and its relations.—The Potosi quartz-latites and rhyolites of American Flat and Dolly Varden Mountain contrast very strongly with the somber andesites below them. Seen from Engineer Mountain or other favorable point of view, the débris-covered slopes of these rocks and the cliffs of the sharp peak beyond Dolly Varden Mountain are most striking. In spite of slide rock the green tuff horizon between latite flows can be followed by the eye for long distances.

In American Flat only the lower flows of the quartz-latite are present. The crest north of Engineer Mountain showing several summits, exhibits some of the higher flows of dull felsitic or vitrophyric quartz-latite. There is either a basin structure or there has been a local synclinal folding at this point, for the several flows dip northward as seen on the Bear Creek side of this ridge, while they rise somewhat to the north.

The peak northeast of Dolly Varden Mountain has the usual quartz-latite flows at its southern base, but its summit, rising above Dolly Varden Mountain some hundreds of feet, has rhyolite in it, as previously stated. The differerence between the rocks was not realized in time to make examination as to the relations of the two rocks.

Intimation has already been given that the mingling of quartz-latite materials with the pyroxene-andesite tuffs, observed in the neighboring Ouray quadrangle, points to the conclusion that these very different lavas must have been produced almost contemporaneously or in alternation, but further study is desirable before such a condition be accepted as a fact.

Intrusive rocks.—In describing the Burns complex reference has been made to the occurrence, in the mountains at the head of Hurricane Basin, of dike and sheet intrusions of a rock nearly like the Niagara Gulch latite. The dike connecting the sheet portions on either side is clearly to be seen in the cliffs below the sheets and is also exposed in a small island outcrop surrounded by rock streams in the floor of Hurricane Basin. It also descends into Horseshoe Basin. Similar rock occurs on either side of Schafer Basin.

A still larger mass of quartz-latite megascopically resembling the Niagara type, in some specimens very closely, forms the capping mass of the broad ridge lying west of Bear Creek and descending to the western ravine at its head. This body has very irregular relations to the pyroxene-andesite, and one dike arm is shown by the map. It lies upon a fragmental part of the andesite series as a rule.

The gravel produced by the disintegration of this rock is different from anything observed to result from weathering of the Niagara type. It is probable that the rock is by no means identical with that facies of the Burns latite, yet it is so similar as to induce special comparison. The gravel of disintegration resembles a rotten tuff so closely that the character of the mass was not understood for some time.

Other intrusives of this section embrace the monzonite-porphyry which rises in stock-like form on the west edge of American Flat and overlooks the forks of Bear Creek. All contacts of this mass are concealed by talus except on the southeast side, where Potosi tuffs are upturned against this porphyry.

Engineer Mountain has a cap of peculiar quartz-syenite-porphyry, distinguished by its large reddish sanidine crystals. The contacts are so much hidden that it could not be determined whether the mass was crosscutting or not. The same rock does occur as a dike cutting the intrusive latite on the ridge to the west, and the Engineer Mountain rock may be a remnant of an intrusive mass in the upper tuffs of the pyroxene-andesite complex.

Rock streams and talus.—The glacial basins on the south side of Henson Creek are notable for the great amount of débris which has fallen from surrounding cliffs and which completely covers their floors over considerable areas. A large part of this débris occurs in the form of masses which have moved down the basin floor, glacier-like, and are included in the bodies called rock streams. Hurricane and Horseshoe basins have very large masses of this character, while Schafer Basin has a still larger amount, proportionate to its size. In these amphitheaters may be seen the intimate connection of rock stream and talus as well as the great contrast with what is ordinarily understood to be the normal talus heap, or cone.

In fig. 3 is shown the upper portion of the great rock stream in Horseshoe Basin as it appears when seen from the pass through which the trail goes over into Cleveland Gulch. The cliffs on the right hand have produced common talus slopes. Those on the left (south) side have yielded débris which has plainly moved far out from the cliff proper and assumed glacier form, the ridges or depressions simulating crevasses on its surface greatly heightening the resemblance to an ice flow.

Below the pond seen in the corner of the view this rock stream is bounded on the north for some distance by a spur from the mountain on the west, but at the end of the spur the stream turns northward, following a depression in the rock floor. It is joined by a stream from Gravel Mountain cliffs, and the united stream extends three-fourths of a mile farther down the basin. The more distant parts are in places covered with enough vegetation to show their great age.

An eastern branch of Horseshoe Basin contains a rock stream which merges with the talus bench at the base of the eastern cliffs.

The large streams of Schafer and Hurricane basins are so similar to those of Horseshoe that special descriptions are unnecessary.

On the north side of the mountain of monzonite-porphyry at the head of Bear Creek, near the northern boundary of the quadrangle, a rock stream descends to the bed of the creek. It appears to have originated in part from a landslide from the cliffs. Other smaller streams occur near the head of the South Fork of Bear Creek, on the slopes of the ridge of Potosi quartz-latite. One of the largest is represented on the map. Others are found in the Dolly Varden Mountain region.

Landslides, glacial gravels, and torrential fans.—In the amphitheaters south of Henson Creek there are several places where falls of talus or other material have occurred, forming distinct areas on the surface of the rock streams. Three such slides are distinguished on the map.

Glacial materials do not form any mass of areal importance so far as observed. But the results of glacial carving are everywhere prominent, in the form of the elevated cirques.

Torrential fans are in process of formation at many places in the valley of Henson Creek, but none of them is comparable in size to many of those previously described. Some of the Henson Creek fans are almost perfect in form.

GEOLOGIC HISTORY.

In the foregoing portion of this text there has been presented a statement of the essential facts as to the character and relations of the various rock formations and as to their general and local distribution. It now remains to use this information in sketching the geologic development through which the district has passed in reaching the condition in which we find it to-day. The record is of course far from complete, yet from what has been stated it is plain that the Silverton area has been the field of action for a great diversity of geologic processes, making its history more than usually complicated.

The volcanic rocks conceal such a large area of the older formations that not a great deal can be deduced from the local occurrences as to the pre-volcanic history of the quadrangle, but they do contribute various important data as to the early development of the San Juan country, so that a brief discussion of the more important observations will be given, in order that the reader may obtain a clearer idea of the geology of the quadrangle and of its broader significance.

PRE-PALEOZOIC HISTORY.

Archean schists and their origin.—The schists and gneissic rocks which are exposed in a narrow belt along the southern border of the quadrangle, and which doubtless underlie much of the volcanic area, are supposed to be of Archean age, chiefly because they correspond in character to schistose rocks of that age found elsewhere and are associated with the Uncompahgre quartzites and slates, which are most plausibly of Algonkian age. But the original relations of those rocks to the schists have not been fully ascertained, since the observed contacts are on fault lines.

The hornblendic schists can confidently be assumed to be metamorphic products of diabasic or allied intrusive rocks. The origin of the intruded schists and their condition when invaded by the basic magmas are not yet plain. The schists belong with the much more extensive area of the same rocks in the Needle Mountains quadrangle, now under investigation. Some observed indications that certain ancient sediments have been metamorphosed into schistose rocks are paralleled by clear evidence in other cases that igneous masses have also yielded schists or gneisses, and the category to which the Silverton schists belong is still uncertain. It is presumed that the Archean rocks had been rendered schistose and had undergone extensive folding and erosion before Algonkian time.

The Uncompahgre formation.—After the period of formation of the Archean schist and some great erosion of that rock which may be supposed to have occurred, there were deposited, in this region, thousands of feet of sandstones and shales, the present quartzites and slates of the Uncompahgre formation. No limestones were formed, but the conditions oscillated many times between those favorable to one or the other of the two kinds of deposits named. No trace of life has been discovered. The section measured embraces over 7000 feet of strata, and the total thickness of the series may be greatly in excess of that figure.

Granitic and other intrusions.—Whether the granite and diabasic intrusions in schist seen in the Silverton quadrangle are earlier or later than the Uncompahgre quartzites is mainly a matter of inference. The Algonkian rocks are cut by small dikes of granitic rocks in both the Needle Mountains and the Uncompahgre Canyon, but the large granite masses have not yet been observed to cut the quartzites. The granite bodies and diabase dikes, however, seem to cut upward with relation to the present steeply upturned attitude of both schists and quartzite, so that it seems unnatural, without good reasons, to suppose that they are older than the sediments. The intrusives are, furthermore, unchanged in their textures except in comparatively minor degree and can hardly have undergone such complex folding and faulting as that to which the Uncompahgre series has been subjected.

On these grounds it is believed that the granites, gabbro, diabasic dikes, and other unmetamorphosed igneous rocks which belong to the complex upon which the Ignacio quartzite was laid down are younger than the Algonkian sediments. They thus correspond in relations and approximate age to the Pikes Peak granites, which hold large and small masses of supposed Algonkian quartzites as inclusions.

The Cottonwood Creek and Edith Mountain granites are doubtless of the same period of eruption as the granites of the Needle Mountains.

The post-Algonkian interval.—A very long period elapsed after the Uncompahgre formation was deposited before the next sediments now known, the Ignacio quartzites and shales, were laid down. Apparently the region was a land area until the Ignacio epoch, which is tentatively thought to be Upper Cambrian. The events of that long period of which we have evidence may be grouped as orogenic movement, metamorphism, intrusion of granite and other rocks, and erosion.

The orogenic movements by which the gneisses and quartzites were brought into approximately their present relations were certainly of great magnitude. So much is covered by the volcanics that little detail of this structure is visible. The main result was the steep upturning by faulting or folding, so that the subsequent erosion separated the two quartzite areas of the Uncompahgre Canyon and the Needle Mountains by a schist zone. This general effect would be produced by an east-west anticline passing through the Silverton quadrangle, the crest being eroded. That this was a simple fold is not probable, since the upturned Uncompahgre sediments a few miles south of the Silverton quadrangle are largely bounded by faults. The domal folding in the Uncompahgre Canyon is probably a comparatively local feature.

The induration and general metamorphism producing quartzites and slates out of the Algonkian sediments is plausibly to be connected with the period of folding and faulting, although the production of chiastolite in the slates is readily explainable as a contact phenomenon of the granitic intrusion. This mineral is seldom developed in notable degree except in the Needle Mountains.

The erosion by which the basin later occupied by the Ignacio sea was produced can be safely called enormous in its amount, and yet we have no means of determining its extent. It produced a surface, now seen at the base of the Ignacio quartzite, of but very gentle undulations and unevenness as far as it has been studied. For this region the erosive interval was closed with the subsidence which formed the body of water in which these earliest known Paleozoic strata were deposited.

EVENTS OF PALEOZOIC AND MESOZOIC TIME.

The history of this particular district during the Paleozoic and Mesozoic eras was in almost all respects that of the San Juan region generally, and the record is found mainly in the sedimentary rocks. Concerning this history little can here be said in addition to the statements made in the introductory sketch and the facts brought out in describing the various formations. Records of an interval of deformation and erosion which immediately preceded the Triassic have not been preserved within the Silverton quadrangle, nor are they evident in the adjoining regions to the south and west. Such an interval, however, is clearly indicated in the Uncompahgre Valley, less than 6 miles north of the Silverton quadrangle, and its place in the geologic history of this area must be recognized. Above the Dolores beds the sedimentary sequence was no doubt completed here, as in the adjacent region, by the deposition of the Jurassic and upper Cretaceous formations, including the coal-bearing Laramie. There are a few places in the local section indicating conditions peculiar to this area, and except for these there will be no further general discussion of the formations in question, as it is intended to treat them more fully in the Durango folio, the entire section being represented in that quadrangle.

One local peculiarity of importance is the apparent absence or the insignificant development of the Ignacio and Elbert formations on the northern side of the San Juan. It is not certain that they are everywhere unrepresented below the Ouray limestone of the Uncompahgre Valley, but they are not recognizable in the few feet of shaly and sandy beds below that formation near Ouray. Whether this actually means a stratigraphic break, such as one naturally looks for, below the Ouray limestone, at the horizon where Silurian beds would appear were the ordinary section complete, is a matter possibly to be determined by further examinations in the Ouray and adjacent quadrangles. In Cunningham Gulch the Elbert shales are present but the Ignacio is wanting, and this fact seems to indicate a break between the thin representatives of the Cambrian and Ordovician systems, as well as above the latter.

It is necessary to a comprehension of the events next to be considered that the reader should realize the thickness of the sedimentary section probably covering the schists, granites, and Algonkian strata of the Silverton quadrangle at the close of the cycle of upper Cretaceous deposition. That the upper formations of the section were present here is indicated by the nearly complete section still preserved on both northern and southern slopes of the San Juan and the existence of the Dakota and Mancos Cretaceous formations on South Fork of Mineral Creek, less than 3 miles from the boundary of the Silverton quadrangle. By assuming that the various formations once had the development they exhibit in the Animas Valley it is seen that the Paleozoic and Mesozoic strata once present in the Silverton quadrangle must have aggregated in thickness nearly 12,000 feet. With the close of the Laramie proper, this region was involved in a great orogenic movement, and the erosion began which produced the pre-Telluride peneplain and the adjacent area of more rugged topography.

THE PRE-VOLCANIC PERIOD.

Between the cessation of Laramie sedimentation and the deposition of the San Juan tuffs, the earliest known epoch of the volcanic period, there was continental elevation of the whole region, permitting erosion of the entire section of sediments. As there is no evidence of further aqueous deposition on a large scale in this region it may be said that the erosion period has extended to the present time. In this immediate area, however, the only product of that erosion, aside from recent detritus, is the interesting conglomerate which underlies the lowest tuffs, the Telluride formation.

Post-Laramie movement.—The uplift that terminated Laramie sedimentation in the San Juan region was undoubtedly the broad continental elevation which embraced the whole Rocky Mountain province, perhaps with local structural centers. One of these was in the San Juan Mountains and its main product appears to be a broad anticlinal fold, near the western end of which Silverton is situated. The Needle Mountains appear to be the center of a local domal uplift superimposed upon or added to the larger San Juan structure. But the region east of the Silverton quadrangle must be examined in detail before the structural relations can be fully determined.

That there were local irregularities in the structure produced is shown by the abrupt fold at the east base of Sultan Mountain and by the fault block of Cunningham Gulch. It is noteworthy that the faults of this block strike toward the point where the fold is sharpest. But the remnants of Ouray limestone near the mouth of Stony Gulch seem explicable by a cross fault, as has been suggested. The details mentioned simply show that there subordinate and local movement occurred in the area covered by volcanics to an extent which can not be inferred from the border zone exposures.

Post-Laramie erosion and the resultant surface.—It is to be assumed that erosion began with the retreat of the Laramie sea and continued after the elevation of the land ceased. It is not known to what sea the detritus of this erosion was carried to form new sediments; only the result of the long period of degradation can now be seen, and that over a limited area. The surface on which the Telluride conglomerate rests affords the measure of the post-Laramie erosion.

On the north-south line of the Animas and Uncompahgre rivers in the Silverton quadrangle the sum of the erosion amounted to the removal of nearly 12,000 feet of Paleozoic and Mesozoic sediments. To the east it was more; to the west, less.

The surface resulting from this enormous erosion was a gently undulating plain—a peneplain—from the line of the Animas and Uncompahgre westward. It is known to have had this character from the east base of Sultan Mountain for 24 miles westward to Dolores Peak, where the fine-grained Telluride grits and sandstones have been found resting on Mancos (Cretaceous) shales. Probably no remnants of the Telluride formation exist west of Dolores Peak and there are none south of the Silverton quadrangle except small patches on the adjacent slopes of the Needle Mountains, the post-volcanic erosion having cut below the level of that formation. Northward the conglomerate has not been positively identified beyond the point of Hayden Mountain, but it is believed to extend far in this direction.

The pre-Telluride peneplain was a planation of the domal uplift previously discussed and on its surface the various sedimentary formations must, therefore, have outcropped in more or less concentric zones which were rendered irregular in detail by minor structures of which little or no evidence is now visible.

There is evidence that the surface was much more irregular east of the Animas-Uncompahgre line than to the west. The Telluride is there either lacking or is represented by small detached exposures of conglomerate. These occur in drainage channels or hollows and have been referred to the Telluride on the map but may not in all cases be strictly contemporaneous with the main formation—a question to be considered in a later section.

The Telluride peneplain evidently did not truncate the whole post-Laramie dome, but came against a region of bolder relief which furnished the material for the Telluride conglomerate. The subject of this more rugged pre-Telluride surface is intimately connected with the origin of the conglomerate produced in its degradation, and the two will be discussed together.

The formation of the Telluride conglomerate.—The Telluride formation changes gradually in character from a coarse conglomerate 30 feet thick in Sultan Mountain to a series of fine conglomerates, grits, sandstones, and shales, 1000 feet thick, in Mount Wilson, 16 miles to the west. The development from Canyon Creek westward is similar. The conglomerate consists of pebbles or bowlders of gneiss, granite, quartzite, limestone of various textures (some containing Hermosa fossils), and other rock types.

The facts of distribution, composition, and change of thickness and texture seem to show beyond question that at the period when the peneplain on which the conglomerate rests had been formed there still remained, immediately adjacent to that plain on the east, a tract of higher country from which the Paleozoic sediments had not been entirely removed. The conglomerate then presents a record of further erosion by which the remnants of those sediments were almost completely stripped from the older rocks, and the latter cut into to a considerable depth.

The Telluride deposits were characterized as lake sediments in the Telluride folio, and the fine mud or sand layers of numerous localities in the Telluride quadrangle seem plausibly of such origin. The character and relations of the thinner and coarser strata clearly suggest that the entire formation may be fluviatile in origin, perhaps grading into lake beds at some distance. The strata can hardly have been sediments in the delta of a large river; they were rather the wash from a mountainous tract upon a plain stretched out at its base, such as that which has accumulated in many valleys adjacent to mountain ranges in the Great Basin province.

The Needle Mountains seem to represent a high tract capable of furnishing the materials of the Telluride conglomerate, but the facts concerning that formation that are emphasized above seem to require that the elevated area should have extended over the Silverton quadrangle east of the Animas-Uncompahgre line, for the Canyon Creek conglomerate is nearly as coarse and thin as that of the Grand Turk. The Silverton area can not have been thus elevated, however, unless considerable erosion took place before the San Juan tuffs were deposited, for the great irregularities of the surface beneath the tuffs extend far below the level of the Telluride peneplain. Such post-Telluride erosion is not suggested in the region west of the Animas, the tuffs seeming to rest upon the Telluride conglomerate with conformity or to grade into them within a narrow zone.

The post-Telluride interval.—The Telluride and San Juan formations are of similar texture as seen in many places in the Telluride quadrangle and appear to have been deposited under practically similar physical conditions. The materials are, however, of radically different character, volcanic rocks suddenly and completely replacing the Telluride sediments, consisting of ancient rocks. Unlike the Telluride quadrangle the Silverton area gives ground for supposing that the accumulation of the Telluride deposits may have ceased and important events intervened before the San Juan epoch of deposition began.

The most striking facts seeming to indicate the correctness of this view pertain to the character of the surface on which San Juan tuffs rest east of the Animas and Uncompahgre. The San Juan tuffs descend almost with the dip of the Paleozoic strata from an elevation of about 11,700 feet in Deer Park to the 10,000-foot level, or still lower, in the Animas Canyon opposite Deadwood Gulch. This is 1600 feet below the Telluride ledge of Sultan Mountain, little more than a mile to the west. As the structure of the sedimentary formations shows, this can not be explained by a fault, and it appears that when the first San Juan tuffs were deposited here there was an eastward slope from the Telluride plateau as abrupt, or nearly so, as the present one of Sultan Mountain, for perhaps 2000 feet.

On the east side of the Uncompahgre Canyon a similar abrupt cliff of Algonkian sediments, facing east, against which the San Juan tuffs abut, is shown where the contact descends into Bear Creek from the ridge to the south. This cliff is but 500 or 600 feet as now exposed. Irregularity of contact characterizes the whole quartzite-tuff boundary, and is further illustrated, at the base of Abrams Mountain, by the descent of the tuff base into both Mountain Red Creek and the Uncompahgre.

South Fork of Mineral Creek exhibits relations of the tuffs which have been expressed on the map in harmony with the view of great post-Telluride erosion. On either side of Copper Gulch the San Juan base is at about the 12,000-foot level, while on the north side of the South Fork, $1\frac{1}{2}$ miles away, the tuffs seem to descend, with no Telluride beneath them, to below 10,000 feet.

To sum up this evidence, it may be said that wherever the San Juan rests directly on the schists its base exhibits irregularities indicating a hilly surface similar in its topography to that of the present day.

This topography is supposed to have developed from post-Telluride erosion. Whether this erosion was mainly from the Needle Mountains and directed north and east by differential orogenic movements or was headwater erosion of a great stream like the Rio Grande remains to be determined.

VOLCANIC ACTIVITY.

The Silverton quadrangle contains records of a considerable portion of the volcanic history of the San Juan region. It is the earlier part of that history, since the structural relations of the lavas and tuffs show that farther east the Silverton rocks pass beneath later volcanics of considerable but unknown thickness. The members of the great complex represented on the map and already described belong to special epochs of the volcanic cycle. Some mark changes of importance in the composition of the lavas extruded; others present relations of occurrence showing that long intervals of erosion separated the eruption of similar magmas.

In some respects it appears that in the Silverton quadrangle the records of the events of certain epochs are much clearer and fuller than any that are likely to be found elsewhere, and many complex details thus have more than local significance. This is particularly true of the happenings in the Silverton epoch of eruption.

Much has already been said concerning the relations of the various lavas, and the present discussion will be directed to giving a more connected account of the volcanic phenomena, with as little repetition as possible.

EVENTS PRECEDING THE SILVERTON EPOCH.

Origin of the San Juan tuffs.—The San Juan tuffs exposed in the Silverton quadrangle give no clue to their source. From the variety of andesites in the materials and the absence so far as observed of true bombs or smaller particles ejected in a semifused condition, it must be inferred that the tuffs do not as such represent the first volcanic eruption of the San Juan region, but rather the destruction of earlier flows. Whether this accumulation of tuffs was directly due to an explosive outburst, shattering lavas, already extruded, or came about through much slower agencies, is not determined. No gradual increase in coarseness or in chaotic arrangement has been observed in any direction and there is no suggestion of near approach to the source of this detritus. Conditions in the Telluride quadrangle suggested that such a center might be found in the Silverton area, but such expectations were not realized. The tuffs of this quadrangle are probably finer grained, on the average, than those of the Telluride quadrangle. They have been so distinctly modified by erosion that no satisfactory conclusions as to their original thickness or extent can be based upon the remaining portion. The uppermost tuffs of Sultan Mountain are nearly 4000 feet above the lowest level of the formation in the Animas Canyon, and it seems not impossible that there may have been nearly this thickness of the San Juan beds in parts of the Silverton area.

The discovery of the rugged character of the surface upon which the San Juan tuffs were laid down in the Silverton quadrangle shows that the idea expressed in the Telluride folio, that the tuffs were sedimentary deposits in the same body of water which was supposed to have arranged and stratified the Telluride conglomerate, must be in large measure incorrect. The process of deposition can not have been continuous, with a simple change in materials. But until the location of the region which furnished the andesitic débris has been discovered and the character of the formation in the districts lying north of the Silverton and Telluride quadrangles has been established, the nature of the processes that were active in this early period in the volcanic history of the region must remain in considerable measure a matter of speculation. The indications that fluviatile agencies were prominent in the accumulation of the tuffs seem clear, and that a great volcanic mass was destroyed in some manner to furnish the detritus is evident.

Erosion of the San Juan tuffs.—It is difficult to make out whether or not a long interval elapsed between the deposition of the San Juan tuffs and the eruption of the first massive lava now exposed in this vicinity—the Picayune andesite. The extent of this rock is unknown. Its present occurrence at a low level compared with the position occupied by the San Juan is not by any means proof of erosion, since the andesite may have been lowered by folding or faulting. It is clear, however, that great erosion must have taken place prior to the eruption of the Eureka rhyolite. Much of this may also have antedated the Picayune andesite and its low level may be due to this fact. The relation of rhyolite-bearing tuffs to the San Juan at the head of the Rio Grande is significant. The tongue of tuffs which extends south from Stony Pass, and which is classed with the Eureka rhyolite, is only a few hundred feet above the base of the San Juan and is in sharp unconformity with it, as can be seen from the map. North of Whitehead Peak, also, the Eureka rhyolite, partly clastic, is seen very near the San Juan base.

The San Juan is certainly a very subordinate formation in Snare Creek and Cuba Gulch and nothing identified with it was found in the Lake Fork. If the granite there seen was overlain by San Juan at the time of its upthrust, the amount of this movement was indeed very great.

THE SILVERTON EPOCH.

The complexity of the geology of the San Juan volcanic rock from one point of view is illustrated by the fact that in the western part of the Telluride quadrangle the Potosi lavas rest directly on the San Juan tuffs, while in the Silverton quadrangle there is evidence that between the epochs of those members of the great complex there was a period of eruption in which several different varieties of lava were poured out or gathered as fragmental masses to a thickness of several thousand feet. Also, that between the times at which these various lavas were extravasated there were intervals of great erosion, producing rugged topography and entirely removing some of the members of the series. In the southeastern part of the Silverton quadrangle the same condition mentioned as seen to the west is repeated, and Potosi lavas come to lie upon a surface of San Juan tuff or schist.

It is then natural that this epoch of varied activities should receive the name Silverton and that the partial deciphering of its events should be considered the most important result of the study of the local geology.

An attempt will be made to follow the principal events of the Silverton epoch, as outlined by the divisions of its rocks distinguished upon the map and their relations.

The first andesite eruption.—Very little is known concerning the relations and importance of the rock called the Picayune andesite, the oldest of the Silverton series. Its fragments are so abundant in the lower zones of the Eureka rhyolite that its relative age seems certain, but its relation to the San Juan tuff is unknown. It may possibly be older than that formation and may represent a remnant of the lava flows which supplied the fragments for the tuffs. But this does not seem plausible in view of the situation of the mass. A fact in favor of the interpretation of the Picayune andesite as the earliest eruption of the Silverton epoch is the appearance of a similar rock as an intrusive in the Burns tuffs on the Lake Fork.

Eruptions of Eureka rhyolite.—The Eureka rhyolite marks the first eruption of highly siliceous and alkalic lavas, differing very materially in composition from the preceding andesites. It appears not to have been poured out from a central volcano, but to have issued from many fissures, some of which are distinctly seen in the Silverton quadrangle. Tuffaceous layers are associated with the flows and possibly there were explosive outbursts as well as fissure extrusions, but no indications of such centers have been discovered.

It has been shown that the local topography at the time of these eruptions displayed considerable relief. But the rhyolite flood must have obliterated the unevenness in large degree, for the lava has a thickness of over 2000 feet in the valleys of Animas River and Henson Creek. Possibly the extension of the lavas down Henson Creek and for an unknown distance below Lake City, on the Lake Fork of the Gunnison, is due to some ancient valley leading in that direction. The rhyolite is found in the thin Intermediate series of the Telluride quadrangle and a remnant caps Sultan Mountain, so that its original distribution was quite extended.

The texture of this rock deserves notice. It is almost everywhere characterized by small angular fragments of rhyolite or quartz-latite with many of andesite. These fragments occur in dikes as well as in surface flows, and in the aggregate represent a very large mass of rock, which was shattered in a wonderfully uniform degree to furnish these small particles. The rock thus shattered must have occurred at some depth, yet it is of dense, fine-grained groundmass, similar to that of surface flows. The texture is repeated in some of the Burns and Potosi latite flows.

The time consumed in the rhyolite eruptions is not known. The rock is almost massive in its greatest thickness and appears to be the result of few eruptions, occurring probably within a short time.

Erosion interval between Eureka and Burns epochs of eruption.—The interval succeeding the Eureka rhyolite eruptions may have been long. Its measure is found in the relations of the rhyolite to the Burns latite complex. Through the northern part of the quadrangle the two rocks seem generally to lie in conformable relations. In the fault zone the Eureka is represented with greatly varying thickness, an expression of the facts as made out, but liable to be incorrect through faults not recognized.

Evidence of extensive erosion seems plain in the southern part of the quadrangle, where the Eureka rhyolite is absent beneath the Burns latite on the divide south of Green Mountain, and again north of Whitehead Peak. In this vicinity the Burns rocks are in contact with rhyolite, which is mainly crosscutting as regards the San Juan, and much erosion of both earlier formations was necessary to produce the surface below the Burns complex in Green Mountain.

It has been assumed that the descent of latite rocks into the Animas Valley from the mountains on the south, covering the Eureka rhyolite on the north slope of King Solomon Mountain, is largely due to a topography of erosion in this interval. But it is also thought that from Arastra Gulch toward Silverton the latite has in places crosscutting relations to the rhyolite and the older San Juan tuffs. Whatever the true situation may be in this locality, it must be concluded that the region underwent much modification by stream erosion after the rhyolite eruptions ceased.

The Burns latite epoch.—After the erosion which has just been discussed came another epoch of upbuilding by the eruption of lavas and accumulation of tuffs. The points of eruption are not definitely known, but the complex is made up of alternating flows and tuffs, and, moreover, the lavas are not all of one type, though they are intimately related in composition. No indications of any particular volcanic center were observed and it seems probable that fissure eruptions may have produced most of the flows seen. The tuffs form an important part of the complex and suggest explosive outbursts, though some of them are undoubtedly merely the accumulations of land waste in favorable places.

In the petrographical description of the Burns complex it was made plain that the region south of the Animas presents a mingling of rock varieties, which may have had local sources, not identified.

In the northern part of the quadrangle the Burns complex exhibits simpler composition and a persistent fossil-bearing horizon was discovered there at the top of the section as ordinarily developed. These fine-grained, thin-stratified, calcareous shales or tuffs, with thin limestones, testify to the existence of a level plain, with shallow lakes and at least a scanty vegetation, near the close of the Burns epoch. From the fossils found in those shaly tuffs it is probable that this time was early in the Miocene epoch, or in the late Oligocene. This affords a rough measure of the probable duration of the volcanic history since the deposition of the Telluride conglomerate, assumed to have occurred at the beginning of the Eocene.

At the end of the Burns epoch of accumulation there appears to have been a nearly plain surface underlain by fine-grained tuffs. This condition existed over the area of the calcareous lake deposit and elsewhere as far as the upper horizon of the latite complex can now be recognized.

Erosion interval succeeding Burns latite eruptions.—The building up of the Burns epoch was followed, in this region at least, by another long interval in which the erosive forces again attained the upper hand and succeeded in making a hilly or mountainous topography where there had been a plateau of gentle relief, shown by the lake beds of the upper Burns horizon. Of this erosion there is most distinct evidence in the relations of the pyroxene-andesites to older rocks, and this will be plain to the student of the geologic map.

The region where this erosion is most evident is in the northeastern section. There the pyroxene-andesites occupy a valley of general east-west trend. Henson Creek and the east head of the Uncompahgre are excavated so nearly on the line of this old valley that its depth is clearly revealed. A cross section of the valley is shown by the base of the andesites north of Tuttle Mountain. From the summit of that mountain the line descends for 2300 feet, crossing the Burns latite and the Eureka rhyolite, and cutting into the San Juan tuffs. It then rises rapidly for 1800 feet across tuffs only, and then descends again for 1000 feet into Bear Creek. From the crossing of Henson Creek near Rose's cabin the base of the andesite rises over 2000 feet to the pass at the head of Schafer Gulch, and it is to be inferred that the south slope of this valley passed above the summits now seen south of Henson Creek, making the depth of the old valley there over 3000 feet.

The descent of the andesites from the Continental Divide into Cuba and Snare gulches is more than 1000 feet, on a surface of erosion which cuts across the Burns latites and much of the Eureka rhyolite. The remnants of the andesites south of Green Mountain and north of Whitehead Peak show the erosion here to have been a planation of all earlier lavas, with relief not now visible.

It is uncertain how much this erosion had to do with the occurrence of the andesites at such low levels in the center of the area. This matter will be discussed in connection with the faulting which certainly caused much of the depression.

Eruptions of pyroxene-andesite.—The last eruptions of the Silverton epoch produced andesitic lavas, similar to many of those represented in the San Juan tuffs. They issued in part through fissures, as certain small dikes testify, but it is not probable that the main conduits have been discovered. It is thought that some of the principal fissures are occupied by dikes in the Ouray quadrangle, seen as yet only at a distance. The source of the tuffs or agglomerate layers between flows is not known.

From the presence of more than 3000 feet of these andesites in the central part of the quadrangle, and the abundant evidence of faulting and great erosion elsewhere, it appears probable that the pyroxene-andesite eruptions covered a large area to a thickness measured by thousands of feet. From present knowledge it seems that these andesites are not now preserved in similar development in the adjoining quadrangle, and it may be impossible to ascertain even approximately their former extent. The character of the topography at the close of the Silverton epoch is also, of course, no longer to be made out.

The comparatively fresh hypersthene-bearing andesite forming the last flow of the Silverton complex in the northeastern part of the area is somewhat more basic in composition than any other flow and may be of local origin. The tuffs, too, both above and below this flow exhibit local character and have a thickness of nearly 1000 feet in the Ouray quadrangle. It has been pointed out that the Potosi quartz-latite appears more or less mingled with these tuffs in a way to suggest contemporaneous eruption of two rocks, but this question must be solved through future work in the Ouray area.

EROSION FOLLOWING THE SILVERTON EPOCH.

The suggestion just made that the pyroxene-andesite tuffs and the Potosi quartz-latite flows of the Ouray quadrangle, adjoining American Flat, may have been contemporaneous or nearly so, refers to a state of affairs quite different from that exhibited in the Rio Grande drainage area. It is evident that in that region erosion preceding the Potosi lavas had removed even the San Juan tuffs in places, so that the Potosi quartz-latite comes directly in contact with the schists at one point shown by the map. But it is manifestly impossible to distinguish between the erosion preceding and that following the pyroxene-andesite on this north flank of the Needle Mountains except where the few remnants of the andesites occur. These show that the pre-Potosi erosion probably did little more than to remove the greater part of the pyroxene-andesite itself. Farther north the small patches referred to the Potosi appear at various levels and give some clues to the undulating topography of the pre-Potosi surface.

The central part of the quadrangle, with its andesite peaks, rising to 13,500 feet in Tower Mountain, or 1000 feet above the base of the Potosi lavas on the Telluride divide, shows that there must have been considerable relief to the pre-Potosi topography. This is all the more evident when the faulting by which this central portion has been let down some hundreds of feet at least is taken into account.

In the western zone of the Silverton quadrangle the Potosi lavas rest on a plateau surface, as in the Telluride region. At present this surface dips to the northwest. It has an altitude of from 12,700 feet in Hayden Mountain and 12,000 feet in Potosi

Peak. There is some unevenness in the floor on which the Potosi rests in the Telluride quadrangle, but it is of small amount compared to the hills that existed in the Silverton district.

THE POTOSI EPOCH.

Importance of the division.—The Potosi epoch of eruption was recognized during the Telluride survey as exhibiting definite and characteristic features. In the western part of the Silverton quadrangle the formation has precisely the same characters and relations, but in the eastern portion the rocks classified with the Potosi differ somewhat in both respects from the western series. The lavas of American Flat correspond fairly well in position but differ somewhat in character from the Telluride Potosi, while the quartz-latites of the Rio Grande are distinct mainly in their relations to underlying rocks. The important fact first recognized was that after the alternating eruptions of rhyolitic and andesitic lavas grouped in the Silverton ("Intermediate") series there had come an epoch of rhyolite extrusions or explosive eruptions, producing a complex far exceeding in amount the mixed lavas below. At the present time the recognition of the long succession of events within the Silverton epoch makes the eruptions of the Potosi appear as possibly of no greater significance than those of some divisions of the Silverton. This view will receive substantial support if the pyroxene-andesite tuffs and the Potosi lavas are actually contemporaneous in the Ouray quadrangle. On the other hand, the Potosi lavas of the Rio Grande Valley seem likely to develop as one of the persistent and prominent members of the central San Juan volcanic section, while the rôles of all older units thus far proposed are more problematical. Since the entire volcanic field must be examined before the comparative importance of the various petrographic or time divisions can be permanently established, the Potosi is retained at present as one of the major elements of San Juan geology.

Character of the rocks.—The lavas of the Potosi epoch are predominantly quartz-latite, the older, with rhyolite, the younger, in subordinate development. Probably there is no great difference between the Eureka rhyolite and some Potosi lavas. The eruptions do not, therefore, signalize the appearance of a chemical type new to the region, but the reappearance of a certain magma.

The Potosi flows are seldom very thick, 200 or 300 feet being the maximum observed. They are persistent laterally, indicating a nearly even floor. Tuffs sometimes aggregate hundreds of feet in thickness between flows, and the angular character of their particles indicates explosive eruptions.

No conduits for the flows have been found within the quadrangle unless one occurs in the peak near Dolly Varden Mountain, but dikes are plain in the region north and northeast of this quadrangle. No indications of an explosive center have been noted.

INTRUSION OF VARIOUS MAGMAS.

A further chronologic account of the volcanic history is not possible, although that history was by no means ended with the Potosi eruptions. At times which can not now be determined intrusions of various magmas took place into the body of rocks now exposed, and doubtless lavas piled up above the Potosi rhyolite. These intrusive rocks have been described, and in most cases nothing essential can be added to the facts already given. Few of the dike rocks can be plausibly connected with known surface lavas, even where the two may be much alike. It is probable, on the other hand, that several dikes represent later eruptions of magmas that had been poured out as lavas in earlier periods. Instances of this kind appear in the intrusions of quartz-latite of the Niagara type after the close of the Burns epoch, and in the Sultan Mountain stock, which is similar in chemical composition to the hornblendic latite of the Burns series. We have no means of knowing whether the large stock and the smaller ones of syenite-porphyry, etc. represent conduits for magmas that reached the surface or not, but they may well have played that rôle.

Several of the intrusive rocks are peculiar to the Silverton quadrangle so far as present knowldge goes. Others are similar to intrusions of like character in the Telluride quadrangle. The granite- and monzonite-porphyries occurring in laccolith or sheet form are much like masses of Ophir Gulch or large laccoliths described in the Telluride folio.

The great quartz-monzonite stock near Silverton must be thought of as belonging to the group of such occurrences known to the west. Even in petrographic character this rock is similar to that which occurs in a still larger stock at the head of the South Fork of Mineral Creek. The Telluride stocks evidently cut through the Potosi series and an unknown thickness of higher lavas, and the same relation must be assumed for the Sultan Mountain monzonite.

FAULTING AND TILTING OF THE VOLCANIC COMPLEX.

General statement.—At some period later than the eruptions of the volcanic complex the Silverton area was the scene of unusually extensive fissuring. Apparently none of the intrusives is younger than this fracturing. The great majority of the fissures are filled by quartz and other common vein materials and carry ore minerals in sufficient amount to make them attractive to the prospector. Some of the veins contain valuable ore bodies. A general discussion of the fissuring of the district is presented by Mr. Ransome under the heading "Economic geology," and attention will here be given only to those fractures which have structural importance through the faulting which has occurred on them. Dislocation has taken place on many fracture planes, but proof of slipping is often difficult to obtain, even where it is suspected, and to measure the fault is in many cases impossible.

The faults shown upon the geological map are not all simple fissures, but are rather fault zones, and in the principal fault region, crossing the head of the Animas Valley, there are so many large veins and the geology is so complex that in some cases the wrong vein may have been chosen as the one on which a more or less evident dislocation has occurred. Complex as the faulting of this area is represented to be, it is in fact much more so.

As Mr. Ransome shows in his discussion, there is little system in the fissuring of this quadrangle, taken as a whole. He, however, points out a noticeable greater frequency of the northeast-southwest and northwest-southeast fractures, although almost all other directions are represented by at least a few veins. Faulting has taken place in a great many directions, often without reference to system, but one very notable fault zone extends from the center of the area northeastward for an unknown distance beyond the quadrangle border. A system of less importance is shown in the valley of Mineral Creek.

The faults as a rule exhibit a curving course and vary in dip from 45° to the vertical. The displacement ranges from more than 1000 feet down.

Great northeast-southwest fault zone.—The most important area of faulting is a zone about 3 miles wide which has been followed from the western side of the Animas northeastward for about 7 miles and is known to extend much farther, into the San Cristobal quadrangle. The general character of the faulting which has taken place in this zone is plain from the map. The curving fissures unite or send off numerous cross fractures which make a network that is complicated even when faults alone are considered, and doubly so when all fissures are taken into account. The effect of this faulting is complex, as will appear from the details to be given.

The northernmost distinct fault cuts the crest of the ridge between Cleveland Gulch and Henson Creek and is easily identified as a fault where it lets down the shaly portion of the Burns complex for several hundred feet on the south. The calcareous layers are contorted and as a whole steeply upturned against the fault. To the west this fracture is traceable with difficulty. It undoubtedly splits into several fissures which pass into landslide or rock débris but reappear in a number of veins crossing Wood Mountain and apparently combining with the main Cinnamon fault.

The fault traced for the greatest distance may be called the *Cinnamon fault*, since it runs for a mile or more near the bed of Cinnamon Creek, being marked by a very prominent quartz vein. It is traceable without question, though not continuously, across the Animas and up a ravine to the north shoulder of Treasure Mountain and into Mastodon Gulch. Near its western end, at the head of Mastodon Gulch, it divides, forming a plexus of white veins in much altered rock, and it has been represented as identical with the Sunnyside vein, which crosses into Eureka Gulch. Possibly the dislocation is divided among the various branches mentioned. This fault could not be identified southwest of Eureka Gulch, and its location seems to be taken up by a fault which crosses it nearly at right angles, passes through Ross Basin and the head of Cement Creek, and is lost in the area of decomposed rock and landslide débris at the head of Gray Copper Gulch. Farther east the Cinnamon fault splits into several branches, including the Wood Mountain veins and one passing down Cleveland Gulch. Throughout its entire extent this fault is of much structural importance, as the map shows, the downthrow on the southeast approximating 1000 feet.

Another fault that is traceable for a long distance has been called the *Rainbow fault*, from a mining claim located upon it. Its outcrop has a very wavy course, due mainly to a northwesterly dip, and it sends off many fractures that connect with other major fissures. The fault is most clearly distinguishable from the mountain crest south of Cinnamon Pass, whence it extends northeastward across Edith Mountain and Cleveland Gulch, on the north slope of which it unites with a branch of the Cinnamon fault.

The continuation of the Rainbow fault westward from the mountain crest is somewhat conjectural, for rhyolite and other débris conceal it for some distance. But a fault limiting the Picayune andesite crosses Grouse Gulch and runs as shown on the map, up the slope toward Cinnamon Mountain. Although this fault probably divides, one branch connecting with the Anaconda vein, an important arm must in all likelihood be identical with the Rainbow fault. This fissure is the southeastern border of a downthrown block, the dislocation amounting to 700 or 800 feet on the Animas slope but decreasing to much less in Edith Mountain.

West of the Animas this fault helps to explain some very complex associations of formations in and south of Picayune Gulch. It clearly does not continue southwestward from the bed of Picayune Gulch—at least not with its full throw—while a diversion to a north-south trend is exactly what is required to explain the contact of pyroxene-andesite and Eureka rhyolite. This locality is densely wooded, shows few outcrops, and the structure is most difficult to ascertain and interpret. If the Rainbow fault curves in this manner it must soon meet the well-defined break coming across from Eureka Mountain and may plausibly be connected directly or by offset with the north-south fault crossing Eureka Gulch near its mouth.

A minor fault which is very plain on the ground crosses the summit of Cinnamon Mountain and may be named after the Tabasco mine, which has various workings upon it. It faults downward, on the southeast, the rhyolite cap of Cinnamon Mountain. The connection of the Tabasco with the Rainbow fault is not perfectly plain.

The *Anaconda fault*, named from a claim southeast of Cinnamon Pass, is most clearly seen as it crosses the mountain ridge, cutting off the intrusive rhyolite. It can be identified at the upper limit of the Picayune andesite on the western slope, but below that level passed under débris. Its course would make it join the Rainbow fault near the bed of Grouse Gulch. Farther eastward this fault must join that which limits the granite block on the south, but the point of union could not be seen owing to forest and rock débris. One fork of this fault is represented as passing into the granite and offsetting the western fault boundary of that rock mass. This connection is more or less conjectural, although the offset is plain.

A fault zone, 50 feet wide or more, within which the rock is highly silicified, crosses the north spur of Handies Peak and forms the southeastern fissure of the great zone under discussion. The amount of dislocation upon it is difficult to determine, as the irregular intrusive andesite is one of the formations involved. This fault divides on the western side of the Lake Fork Valley, one arm running south through American Basin. On the western slope the branches of the main break could not be followed across Burns Gulch, but it is probable that some one of them connects with the Eureka Mountain fault.

The north-south fault crossing Eureka Gulch is clearly defined in the canyon a few yards above its entrance and can be found in the cliffs of the southeastern spur of Eureka Mountain. It assists in lowering the central area of the quadrangle some hundreds of feet, not closely determinable. Farther north this fissure is lost under débris, but it can hardly cross the Eureka Mountain fault unless by the hypothetical union with the deflected Rainbow fault, above referred to. Farther south the fault may play an important part in explaining the low level of the base of the pyroxene-andesite series all along the northwest side of the Animas, but in that case it is for the most part below the valley deposits and can not be seen.

The *Ross Basin fault* may be considered as a member of this system of faults because it takes up the throw on the Sunnyside vein. It is very plain as a zone of fissures, as seen in Ross Basin, the rock being finely sheeted between the larger veins. It drops the Burns latite out of sight by a displacement which must amount to nearly a thousand feet. The shattering of the rocks and the abundant veins seen near the almost right-angled junction of the faults in Eureka Gulch show that each main fissure is continued to some extent, but no persistent vein was found to represent either.

To summarize now the main results of the faulting in this zone, it appears that in a northwestern band, lying between the Cinnamon and Rainbow faults, there was downthrow, while near the main southeastern fracture lies a zone of decided upthrust, especially noticeable because it brings to light the granite and the Picayune andesite. Beyond the border fissures, the base of the Burns latite around Animas Forks on the one side and at the head of Burns Gulch on the other seems to have suffered little disturbance. Adjustment of strains has been effected by many branches of cross fissures.

The granite mass of the Lake Fork is a block within the upthrust zone, bounded wholly by faults, the extent of the elevation being undeterminable, but not improbably reaching 2000 feet. The mass is traversed by many veins or shear zones, showing that the whole block was thoroughly shattered in the movement. The bounding faults are sharply defined and stand nearly vertical. There is some mineralization in the south fault vein, exploited in the Bon Homme mine. This fault extends eastward into White Cross Mountain.

The Picayune andesite area is less easily understood. It seems to express the combined effect of simple upthrust adjacent to the Rainbow fault, with tilting beyond the Eureka Mountain fracture, explaining the southerly dip of its upper surface and its final disappearance in the bed of the Animas. It is indeed plausible that the general rise of all contact lines from the south as the fault zone is approached is due to a general tilting adjacent to the zone of upthrust faulting.

Mineral Creek fault zone.—The zone of faulting in Mineral Creek, which has been described in certain details in connection with the sunken block of Potosi rhyolite, deserves some further attention in this place, although the interest involved is chiefly hypothetical. The rhyolite block is difficult to understand if its bounding fissures are limited to the area of the downthrown rock. It is not so difficult to comprehend if we assume the existence of a system of deep fissures with connecting fractures, for it then expresses a part of the adjustment by which the various stresses producing the fissures found relief.

By referring to the map it will be seen that the east and west boundaries of the block, the parallel fault to the west, and the diagonal fault within the block make a system of four approximately parallel fissures. Another one has been explored as a vein in the Silver Fountain claim south of Porphyry Gulch. The general trend of the system is a few degrees east of north.

On looking for further evidence of this fissure system adjacent to Mineral Creek it is found that the Silver King vein in Mill Gulch and the Henrietta lode, northeast of McMillan Peak, noted by Mr. Ransome, have a north-northeast course. Further, it is certainly worthy of note that the peculiar chimney-like ore bodies of the National Belle, Yankee Girl, Guston, Genesee-Vanderbilt, Paymaster, and other mines occur in a narrow belt of north-northeast trend. By examining the economic sheet it will be further seen that east of this chain of noted mines there is a line of similar character that extends from the St. Paul on the south to the Charter Oak on the north, with the Alexandra not far from line some distance farther north. In the descriptions of these mines by Mr. Ransome it is stated that north-south fissures have often been noted, or that the ore bodies have a maximum development in that direction, although this is by no means universally the case, and fissures of nearly east-west course are frequently mentioned. In some mines it has been noted that the ore bodies seem to develop at the intersections of the fissure systems.

The principal mines have been located at mineralized knolls of hard quartzose rock that project above the prevalent landslide débris where structural observations can not be made and where the former configuration of the surface can not be determined except by inference from the adjacent rock in place. But the Yankee Girl and Guston shafts penetrate over 1000 feet, the latter 1300 feet, below the surface. Both shafts were in andesitic (or latitic) material—massive or brecciated. At the bottom of the Guston shaft the rock, it is said, was andesitic breccia. Presumably this was of the San Juan formation.

In Ironton Park the Algonkian and Paleozoic rocks are let down on the southeast by a series of small step faults developed in the Saratoga, Brooklyn, Maud S, and Mono claims, and are finally dropped an unknown distance below the surface on parallel fissures, so that the Jay Eye See (J. I. C.) shaft, at the mouth of Parole Gulch, encounters only tuffs, though it has been sunk for several hundred feet. Details of this structure are given by Mr. Ransome. The trend of these veins is directly toward the Guston and other mines noted.

Another condition requiring consideration is the fact that a throw of nearly 1000 feet is assumed for the Ross Basin fault, the western extension of which is not known. The fault does not cross into the high region west of Red Mountain Creek, although veins trending in that direction do occur. The displacement might have been taken up on the hypothetical fault system.

Another feature for which no explanation has been advanced is the extreme alteration which the rocks have undergone in the zone east of the lines of Red Mountain and Mineral creeks. The existence of a broad zone of deep fissures with numerous fault blocks would be quite adequate to explain this fact.

Taking all these points into consideration, it appears plausible to assume the existence of a system of fissures that have a general north-south trend in Mineral Creek and the ridge to the east and that curve gradually to a north-northeast course in Red Mountain Creek. The many intersecting fissures which may have connection in origin with the northwest-southeast veins of the divide on the west and the Ross Basin fault present conditions favorable to the deposition of the chimney-like ore deposits of the National Belle type. The rhyolite fault block is merely a result of adjustment, easily comprehended on this conception of the local structure.

Origin of the fault fissures.—A general discussion of the fissures of the quadrangle and their origin is given by Mr. Ransome in this folio, and in more extended form in Bull. U. S. Geol. Survey No. 182. It does not seem desirable to add anything at present to that discussion, in view of the complexity of the problem and the fact that observations in adjacent districts will give a broader basis for speculation. So far as known, the Silverton area exhibits much more extensive fissuring and vein formation, as well as ore deposition, than other parts of the San Juan region, and it appears reasonable to look for local causes in explanation. Contrary to expectations aroused during the Telluride work, the Silverton area has not proved to be so distinctly a center of eruptive action as was expected, and it does not seem probable that the great lava masses to the east came in any large degree from this quadrangle. It is not clear, therefore, why a readjustment due to the outpouring of the vast lava floods should have been centralized in this place.

Tilting movements.—A definite recognition of tilting or slight differential elevation in the Silverton quadrangle is clearly difficult in view of the many topographic changes due to the erosional periods which have been discussed. It appears probable, however, that the Needle Mountain area has been a center of domal uplift ever since the post-Laramie revolution. It is certainly true that in each of the recognized erosion periods the volcanics in the southern belt of this quadrangle have been removed nearly or quite to the schist surface. This may have been due chiefly to the location of the streams that attacked the volcanic pile.

One major element of tilting independent of the Needle Mountains center was brought out in the Telluride folio. It is desirable to explain the abrupt western front of the San Juan Mountains and the much greater amount of erosion accomplished by the streams on that side. The northeasterly dip exhibited by the base of the Telluride conglomerate, from a level of 12,000 feet in Mount Wilson to 10,000 feet near Telluride and 9500 feet in Canyon Creek, is evidence of a movement which might increase the erosive powers of the western and southern streams if continued through a long time. The base of the Telluride in the southwest corner of the Silverton area is also at or near 12,000 feet and a local northeasterly dip for the Telluride floor is visible, as well as minor folds. It is demonstrated by the increasing thickness of the Telluride conglomerate westward, and by the evident source of its bowlders, that there must have been a westerly dip for the Telluride peneplain during the whole time of accumulation of the conglomerate upon it.

Local tilting adjacent to the faults of the main systems is a natural condition which can often be observed in fact. But many observed dips of tuffs or flows must be parallel to the erosional surfaces upon which they lie.

ROCK DECOMPOSITION AND ORE DEPOSITION.

After the extensive fissuring and faulting of the rocks there came an epoch in which solvent and mineral-bearing waters circulated freely through the multitude of channels provided for them. In the horizons now open to view or penetrable by mine explorations the result of this action was a thorough decomposition of the country rock in several ways and the formation of quartz veins and lodes and localized metalliferous deposits either within the veins or by replacement of country rock. The various processes involved and the results of their operation have been carefully studied by Mr. Ransome, who describes them fully in abridged form in this folio. It is, therefore, unnecessary to enter into a discussion of the subject in this place further than to summarize the geological bearing of the epoch.

Without doubt the circulation of heated and chemically active waters is, like the formation of fissure channels for the solutions, a phenomenon intimately connected with the volcanic history of the region and even to be regarded as one of its last phases. That solfataric emanations, probably absorbed by circulating waters near the surface, played a rôle here is rendered almost certain by the abundant formation in the kaolinized rocks of the region of alunite—a hydrous sulphate of alumina and the alkalies—and its companion mineral diaspore. The decomposition of rocks in this manner is discussed by Mr. Ransome (Bull. U. S. Geol. Survey No. 182), and the examinations made by the present writers have yielded practically nothing additional.

The time at which the rock decomposition was effected must be placed after the close of the actual eruption of magmas, as no rocks have been found that have escaped both fissuring and profound alteration. Later eruptions of secondary importance may have occurred in other parts of the San Juan region, however, and the epoch of these can only be said to belong late in Tertiary time.

The most general effect of the circulating waters on the andesites and latites is known as propylitization, whereby the dark silicates are most extensively attacked, yielding epidote, serpentine, bastite, and chlorite, with calcite, quartz, etc. This is widespread and is not confined to the immediate vicinity of identifiable fissures. This kind of alteration of the Burns latites is particularly illustrated by analyses made for Frank R. Van Horn of rocks collected mainly from the masses of Galena and King Solomon mountains (Bull. Geol. Soc. America, vol. 12, 1900).

The bleached and stained rocks near veins, prominent especially between Anvil and Red mountains, are shown by Mr. Ransome to be products of kaolinization or sericitization with frequent increase of quartz to the extent of rendering the rock mainly quartzose, as in some projecting shoulders of Anvil Mountain.

PHYSIOGRAPHIC DEVELOPMENT OF THE QUADRANGLE.

The existing topography of the Silverton quadrangle is the result of various agents of degradation, which have been at work upon the volcanic plateau for a long time. Their operations may well be considered according to their epochs, namely, (1) the epoch of pre-Glacial erosion, (2) the epoch of glaciation, (3) the Recent epoch, continuing to the present time.

PRE-GLACIAL EROSION.

Extent.—In the discussion of the probable magnitude of the volcanic effusions after the Potosi epoch it was shown that several thousand feet of lavas and tuffs must have existed in this region long after the close of that time. In all probability the plateau extended in all directions far beyond the present bounds of the San Juan volcanics. Upon this huge mass of materials the streams began work and, before the recognized stages of the Glacial epoch of the region, had carved it almost into the forms exhibited to-day. The amount of work accomplished on the western front of the San Juan is much greater than that done here, in the interior of the old plateau, but the Animas and Uncompahgre both cut below the base of the volcanics in their canyons, while thousands of feet of lavas were wholly removed.

The drainage system.—Apparently the streams which accomplished this great task were but little influenced by the structure of the rocks upon which they began their sculpturing. From the evidence of the various erosion intervals of the Silverton epoch it appears that some streams, perhaps belonging to the Rio Grande, the Gunnison, or the San Juan drainage systems, repeatedly cut into the Silverton area north of the Needle Mountains, but none seems to have carved corresponding channels into the same volcanic rocks of the Telluride quadrangle. How much differential elevations of parts of the San Juan may have contributed to control the system of erosion can not be determined. The date of the tilting shown by the Telluride conglomerate is unknown. It was referred to in the Telluride folio as one of the factors that might explain the great erosion accomplished by the San Miguel and Dolores rivers, while the much longer Rio Grande, with a length of 65 miles from San Luis Park to its head, has accomplished much less. The Animas River has carved its canyon with such disregard for the physical character of the rocks in or near its course that special reference to this case seems desirable.

The Animas Canyon.—It is difficult to imagine why the Animas, if it existed in its early stages in its present position, should have laboriously forced its way through the hard core of the Needle Mountains when it might have turned either to the west or to the east and found softer rocks. Whether the stream is superposed upon the old rocks of the Needle Mountains or has continued its course through them as an antecedent river during their uplift, or has reached its present position solely by headward erosion through the quartzites and crystallines of the Needles to the more readily attacked rocks of the volcanic series, are questions that can not be answered from evidence found within the Silverton quadrangle.

This course of the Animas is comparable to that of the Dolores River, which cuts a deep valley in north-south direction through the domal uplift of the Rico Mountains, with its many intrusive porphyries and stocks of granular rocks, while much softer sediments occur on either side. The La Plata Mountains dome is also bisected in a similar way by the La Plata River, and in that case, at least, headwater erosion has guided the stream, as it does not cut beyond the northern zone of the mountains. The Vallecito River, which cuts almost as deep as the Animas through the eastern half of the Needle Mountains and at its head approaches the northern side of the group, is clearly not an antecedent stream.

GLACIATION.

It is commonly believed by specialists that the recognized glaciation of the Colorado mountain region belongs to the latest main stage of the Glacial epoch known as the "Wisconsin stage." Evidence of more ancient stages has been observed in the Wasatch and Uinta Mountains of Utah, and elsewhere, and it is thought that an interval of great erosion preceded the Wisconsin stage. If this view is correct, it is not improbable that the extensive denudation preceding the known glaciation of the San Juan Mountains was contemporaneous with, or followed the earlier stages of glaciation.

The observed glaciation of the western San Juan Mountains was of the type and extent common in the higher regions of the southern Rocky Mountains. A thick mantle of snow and ice covered the higher levels, and ice streams flowed far down the principal valleys. At its maximum the Animas glacier reached Animas City a few miles above Durango and 40 miles below Silverton, where two parallel terminal moraines cross the valley. The amount of morainal material in the main valley and elsewhere is so small that it must be assumed that most of the mountains were snow covered.

After the maximum development of the ice had passed there was a period during which local glaciers persisted in the heads of lateral valleys. Many of the observable glacial phenomena of this quadrangle belong to this later phase.

Glacial erosion.—The erosive work of the Silverton glaciers does not appear to have been great. It is supposed that at the beginning of the Glacial epoch here recognized a stage in the denudation of the region had been reached in which the principal streams flowed in valleys having nearly even graded sides and many of the smaller tributaries had advanced well on toward maturity. Then came the change, the valleys became beds of great ice streams which, with slow but telling effect, scoured away the loose detritus and renewed the attack upon the solid rocks, with such success that when the ice disappeared the former gently sloping valley sides had been modified and the valleys themselves were U-shaped in crosssection. The Animas, Cunningham, Mineral, and Henson valleys afford examples.

The high mountain divides had meantime, through the operation of other agencies than ice, become sharp ridges or arêtes which looked down on both sides into cirques or amphitheaters whose floors had been scoured by ice and were occupied by lakelets, sometimes lying in solid rock basins, surrounded by sheer precipices hundreds of feet in height. The extreme ruggedness of this circum-glacial topography is still fairly preserved in some localities, but the observer who will in imagination restore the vast amount of detritus visible in many basins to the still precipitous and lofty cliffs from which it plainly came will have a far more vivid and accurate impression of the typical cirque and its environment. It needs to be emphasized that all of the present principal topographic features were developed before the last stage of the Glacial epoch and that the effect of the ice in general was only to modify in a relatively small way the earlier forms. This modification was naturally greater in some places than in others, and the mere fact, significant as it is, that there is no material change in the form of the Animas Valley in its lower portions, above and below the known limit of the ice, need not imply that there was a correspondingly small amount of erosion in the higher mountains near its head. It simply shows very clearly that at the beginning of the Wisconsin stage a topography existed essentially like that of the present day. The most striking change effected by the ice during that stage was due to the carving out the elevated amphitheaters.

Cirques and "hanging valleys."—A glance at the topographic map will show that the higher portions of the Silverton quadrangle are characterized by many excellent examples of the cirques or amphitheaters carved by the "bergschrund" erosion of a local glacier. Attention may be specially called to those under Tower Mountain, the three basins tributary to Arastra Gulch, the small ones high above Cunningham Gulch on the west, and the double amphitheater north of Bear Peak.

Since many of these cirques are at the heads of tributaries of the Animas, the first impression is that they represent that discordant relation between main and lateral valleys which is commonly seen in glaciated mountain regions and which is explained by some physiographers on the theory that a trunk glacier in the main valley had eroded its bed far below the level at which its tributaries once entered it, leaving them as so-called "hanging valleys." The elevated amphitheaters and short valleys bearing a similar relation to the larger valleys of this region are distinctly the product of the local glaciers, belonging to the stage which has not yet entirely passed in the mountains of Colorado. One remnant of ice was observed in the Telluride quadrangle and small glaciers are known at several places in the Front Range, northwest of Denver.

POST-GLACIAL OR RECENT HISTORY.

At the close of the period of active glaciation, which left the rugged glacial and circumglacial topography that has been referred to, the conditions were most favorable for the operation of leveling agencies, which have been steadily at work and have restored portions of the area to the state of comparatively gentle relief which existed prior to the reign of snow and ice. These agencies are those which commonly operate in such districts, but certain of them have for some reason been particularly effective here, producing detrital masses of unusual importance, described and mapped under the designations landslides, rock streams, and torrential fans.

Landslides.—The landslides of the Red Mountain district, which have been described elsewhere, are typical of all of the occurrences of the Silverton region. Similar areas have been found in many parts of the San Juan Mountains in the neighborhood of the Silverton quadrangle, and certain of these have been described in the report on geology of the Rico Mountains, Colorado (Twenty-first Ann. Rept. U. S. Geol. Survey, pt. 2, 1900, pp. 7–167) and in the Telluride folio.

The landslide areas of the Silverton quadrangle are not so large as those in the neighborhood of Telluride, nor has such an enormous amount of material been involved in the individual slips. In the Telluride quadrangle the rocks involved in the landslides have been those of the volcanic series, which rested upon the soft Cretaceous shales. By a motion of the volcanic rocks on the shales, due, perhaps, to saturation with water, great masses and blocks of the overlying rocks slipped down the valley sides. The slides seem to have occurred, in the main, at one distinct period. In the Rico area, however, the slides are individually of much less magnitude than those to the north, and the areas have acquired their present important dimensions through successive slips. This seems to have been essentially the case in the Silverton landslides.

Among the causes which have brought about the landslides of the Telluride and Rico quadrangles, earthquake shocks are supposed to have played the most important part. In the case of the Silverton slides, also, it is almost inconceivable that any other force could have been sufficiently potent to cause such a prodigious fracturing and sliding of solid rocks. The ordinary relations of the rocks, such as the presence of heavy massive flows of andesite upon porous tuffs, etc., were favorable to landslide action in many places throughout the quadrangle, and it is, therefore, difficult to understand why great landslides should have occurred at some points and not at others unless some local cause, such as an earthquake shock, or greater local saturation, or the melting of supporting ice masses, is supposed to have been added to the common structural conditions. That these conditions alone are not sufficient to explain the slides is indicated by many facts. For example, the slide area of Red Mountain No. 2 and Ironton Park embraces extremely altered masses on the eastern and relatively undecomposed flows on the western side. The conditions in the latter area correspond almost exactly to those prevailing in the abrupt cliffs and excessively steep slopes of the Animas Valley, from its head almost to the town of Silverton, where almost no landslides have occurred.

That earthquakes may reasonably be supposed to have caused some of these landslides is evident from the fact that shocks have occurred at recent dates in the Telluride and Red Mountain regions. Some of these have been recorded by H. C. Lay (Trans. Am. Inst. Min. Eng., vol. 31, 1902, pp. 558–567), one of them having been particularly felt in the Yankee Girl, Guston, and other mines, in the heart of the landslide area. In the description of the Red Mountain mines by Mr. Ransome (Bull. U. S. Geol. Survey No. 182) mention is repeatedly made of fresh fractures crossing the ore bodies, evident dislocation of no great extent having occurred in some cases. These facts add force to the idea that earthquake shock has been an important factor in causing the larger landslides of this quadrangle.

Rock streams.—In many of the valley heads or cirques lie extensive accumulations of loose-rock débris, composed for the most part of large, angular blocks ranging from 1 foot to 15 feet in diameter. The form of these deposits is in detail extremely varied, but the majority possess certain common characteristics which make them at once remarkable. Probably masses of the same character occur in many other localities, but they are less sharply defined from other débris heaps and hence, so far as we can ascertain, they have never attracted sufficient attention to be particularly described.

The most striking of these masses, and those to which attention was first directed, closely resemble débris-covered glaciers at the heads of the basins or cirques in which they occur. The surfaces are hummocky and uneven, depressions that strangely simulate crevasses frequently occur, and concentric ridges and depressions are often seen at the end of the accumulations, which are abrupt and have steep faces often rising 100 feet or more above the floor of the cirque. This may be clean or may be covered by a thin, disordered sheet of bowlders and soil. Sometimes on the slopes below there are traces of earlier accumulations of the same character, now completely soil covered and clothed with herbage. Rarely the streams of débris descended from an upper bench in a cirque to a lower one which is otherwise free from débris. All of the accumulations of the sort just described impress one with a sense of motion, looking as if they had flowed as do viscous masses and were still advancing from the head walls of the cirques downward. So noticeable was this that in the field they were spoken of as "rock glaciers" and upon the map receive the name "rock streams." There can be little question that the more typical rock streams derived their materials from the heads of the cirques, as a study of the rocks, as well as the relation of the débris to the rest of the basin, has repeatedly shown.

There are accumulations of another type, in some basins, that do not possess the stream form, but border the bases of cliffs, generally beyond the outer limits of ordinary talus accumulation, the two often being separated by a pronounced trench. These débris piles do not suggest flowage, but they often have the steep outward face and the hummocked, crevassed surfaces of the streams. They never extend far out from the cliffs, and their materials are traceable to the cliffs directly above them. Combinations of these two types are very common. In fact, it is likely that accumulations of the first sort are always more or less modified in their general form by association with the second sort.

The most characteristic examples of rock streams are to be found in the corries or basins tributary to Canyon Creek, as in Richmond Basin near the Camp Bird mine, Pierson Basin, and Silver Basin. Probably the most extensive accumulations are in the Henson Creek drainage, in Schafer, Horseshoe, and Hurricane basins, here intimately associated with talus. Less pronounced occurrences are found in American Basin and Grouse and Burns gulches, while one very beautiful, isolated example is to be seen in the cirque north of Sheep Mountain, in the Pole Creek drainage. The magnitude of these occcurrences is strikingly illustrated by the fact that many of them have been clearly indicated by the contours of the topographic map.

There are several reasons for believing that these deposits, characterized by stream form, are not the result of ordinary talus accumulation. The first and most obvious reason is that the material is too far away from the source of supply. In Pierson Basin and in the cirque north of Sheep Mountain the streams of débris are from one-half to three-fourths of a mile in length. In the last named occurrence the cliffs of Sheep Mountain have been the sole source of supply. The movement of such masses must be accounted for. Again, where two distinct rocks of the bedded volcanic series rest one upon the other in the cliffs back of the débris there may be practically no mingling of the two rocks in the detritus. A striking instance of this is found in Silver Basin, where in the cliffs a rhyolite flow of the Potosi series rests upon tuff and andesite of the Silverton series. At the northern end of the arête between Silver and Pierson basins almost all of the rhyolite has disappeared, only a few pinnacles now remaining. Under this point is a small but very typical deposit of the sort under discussion. It is composed of concentric shells or ridges of large and small bowlders, the outermost ridge consisting entirely of rhyolite débris, while within all is of the Silverton series. The line between the two rocks is very sharp. It is inconceivable that such relations should prevail were the accumulations due only to the conditions usually attending the fall of rock fragments from the cliff face.

The peculiar configuration of the surface of these masses of débris is probably their most striking characteristic to one observing them for the first time, and is totally different from the smooth, even lines of ordinary talus slopes. It may be safely assumed that these deposits are not talus in the ordinary meaning of the word.

The more stream-like of these deposits, from their configuration, from the nature of the materials composing them, and from their relations to the cirques or corries in which they occur, are to be considered as rather unusual types of moraines. They differ from the familiar terminal moraine of the Alps in that they are composed for the most part of moderate-sized angular bowlders, while the fine sands and gravels of the dumping grounds of the Alpine glaciers are present in such small amounts as to be overlooked in many cases. The form of the deposits as a whole is also very unlike that of the typical terminal moraine, as the débris extends from the front quite back to the cliffs at the head of the cirques but is separated from the sides of the basin by a well-defined trench.

The very similar accumulations of rock waste that have been mentioned as bordering the base of cliffs are probably not morainal in the sense that the débris has been deposited by ice. Practically all of these accumulations are at the bases of cliffs that face the north—places most favorable for great banks of snow to form and linger on into the summer. It seems highly probable that this has in fact been the case ever since glacial ice and névé left the cirques. These snowbanks would form highways down which rocks loosened by frost would travel from the cliffs to the floors of the amphitheaters, and the effect would be to deposit waste at a greater distance from the cliffs than ordinary talus, and to protect a zone at the very foot of the cliffs from excessive talus accumulations. The slightly different forms and the varying size that the snowbanks would have from year to year would undoubtedly cause an unequal distribution of the débris, and the uneven, hummocked surface of the deposits would thus be accounted for. During summers ordinary talus would form and in course of time might fill the trench of the protected zone and spread out over the snowbank accumulations, thus giving the impression that the whole mass of débris had fallen in the usual way. The larger rock streams, however, must owe their origin to glaciers; no other agencies could transport such vast quantities of rock waste so far from their sources.

So far, none of the conditions that have been thus supposed to account for the origin of these deposits is in any way unusual. Small glaciers in the Cascade Range of Washington are building moraines under very similar conditions, only the resulting forms are composed of sands and gravels with comparatively few bowlders. These materials are supplied at the "bergschrund," dragged in by the ice near the bottom, and by the shearing of the ice near the front are carried to the surface and dumped on the moraine. The significant features of the rock streams in the San Juan are the remarkable quantity of relatively coarse material composing them, and the fact that the greater part of this must have been carried on the surface of the ice. The problem, then, is to account for the unusual supply of material.

Landslides have been of frequent occurrence in the San Juan Mountains, and are of so much importance as to deserve special mention in this folio, and in their description the conditions which have combined to bring them about have been discussed. That these same conditions prevailed at the period when glacial ice was still in the cirques or corries there can be little doubt. In fact, it must have been the time above all others when the conditions were all exceptionally favorable for landslides. The sapping and undermining of the cliffs of the amphitheaters at the "bergschrund" had oversteepened the cirque walls and when the protection and possible support of the snow and ice had been somewhat lessened by the slowly rising temperature great masses of rock lacking support must have fallen from the cliffs to the surface of the glaciers below. There was probably no great transportation of this material, in the sense that it might have been carried from the lateral valleys to the trunk stream, as the glaciers must have been retreating or dormant, but by their gradual melting they would allow the shattered rock débris to settle slowly to its present resting place on the floors of the cirques. Landslides in recent times, which have not fallen upon ice, have retained with little modification the configuration which they assumed on coming to rest, but this could not be in the case of those falling on the surface of glaciers, for with them not only would the disintegrating action of the frost be unusually active, but the support of the whole mass would be gradually giving way.

In some instances movement of the ice has undoubtedly taken place, but in others the débris has come to its final resting place with little or no transportation by the ice. The uneven surface of the ice, as well as the irregular disintegration of the landslide material, would easily account for the hummocked surface of the rock streams as they are seen to-day, and the very characteristic trench at the sides is to be explained very largely by the protective agency of the lateral snowbanks.

The evident greater age of all sharply defined rock streams as compared with common talus accumulations carries them back to the time of more frequent landslides and, as is brought out in considering the duration of local glaciation, to the time when the ice was restricted to the cirques, the sites of all notable rock streams.

Present conditions.—In the region of the Silverton quadrangle to-day erosion is still actively in progress. The streams are gnawing at the rocks near their heads, and the frost, which occurs nearly every night in the year in the higher portions, is continually splitting off large and small blocks from the cliffs of the still ungraded valley sides. These blocks help to form the great talus slopes in the region or are transported by the streams in times of torrential activity and deposited on the floors of the main valleys as parts of the alluvial fans. Snowslides annually carry with them, in their descent to the gulch or valley bottoms, much rock débris, which is in time taken up and transported still farther by the streams. Undoubtedly in not a few cases snowslides that tear off from the hillsides the timber and soil, when repeated in the same track from year to year, have determined drainage channels at periods of unusual precipitation. These have in a short time assumed the proportions of ravines or gulches, especially when they are cut in loose tuffs or decomposed massive rocks. These very young gulches, such as Governor and Galena Lion, whether or not they are to be referred to snowslides for their origin, are at once noticeable in the field because of the steep slopes, devoid of soil or timber, and the great fans of débris at their mouths, little if any of which has been removed by the main stream. The activity of all erosion by the streams of the Animas drainage is limited by the local base-level of Bakers Park, which has been determined by the hard, resistant quartzites and schists of the Needle Mountains, through which the Animas River is slowly cutting. In the same way, Ironton Park is a local base-level for all of the tributary drainage and is controlled by the quartzites of the Uncompahgre Canyon.

July, 1903.

ECONOMIC GEOLOGY OF THE QUADRANGLE.*

By Frederick Leslie Ransome.

HISTORICAL SKETCH.

Prior to 1860 the area now included in the Silverton quadrangle had been visited by few white men. But in that year a large party of miners, under the leadership of John Baker, penetrated to the little mountain-rimmed "park" where the town of Silverton now stands. They had hoped to find profitable gulch mining, but, overtaken by the winter snows and harassed by the Utes, many of the party perished miserably and the remnant escaped over the mountains after suffering great hardships. For several years the memory of this unfortunate expedition seems to have discouraged attempts to prospect in the neighborhood of Bakers Park. It was not until ten years later that reports of mineral wealth again drew adventurous miners into the San Juan region.

During the seventies the eastern and northeastern portions of the quadrangle were actively prospected, and nearly every lode which has subsequently proved valuable was then located.

In 1881 the remarkable deposits between Red Mountain and Ironton were discovered, and in 1882 and 1883 prospectors swarmed into this new field. The Yankee Girl mine was opened in 1882, and, with the Guston, shipped large quantities of high-grade silver ore for over fourteen years. These two mines alone have probably produced from $6,000,000 to $7,000,000, but much capital has been vainly expended in attempts to find other ore bodies in the vicinity equally large and rich. In 1888 the railroad was extended from Silverton to Ironton, greatly facilitating the marketing of the ore. The Yankee Girl and Guston mines continued working until 1896, but the low price of silver and the increased expense involved in deep workings and in handling the troublesome corrosive waters of these mines, together with the lower grade of the ores in depth, finally compelled them too to shut down.

Prior to the advent of the railroad in Silverton, ores worth less than $100 per ton could seldom be handled with profit; but with the completion of the Silverton branch of the Denver and Rio Grande narrow-gage railroad in July, 1882, the rate of transportation on low-grade ores was much reduced, and many mines hitherto unavailable became productive. Freight charges, at first $16 per ton to Denver or Pueblo, were soon dropped to $12, at which figure they stood for some time. Over 6000 tons of ore were shipped from Silverton during the first six months after the completion of the railroad. It was not until about 1890 that an attempt was made to concentrate low-grade ores. The pioneers in this procedure were the Silver Lake and Sunnyside mines.

With a few notable exceptions, the mines of the Silverton quadrangle produce ores in which silver and lead are the predominant metals. The rapid decline in the value of silver in 1892 and succeeding years resulted in the closing of many mines hitherto productive and in a general decrease of mining activity. At the present time, however, there are signs of a favorable reaction and a marked increase of activity. It is very probable that in the future there will be a great and permanent increase in the productive development of large and persistent ore bodies of low average grade.

Although the first mine worked in the district, the Little Giant, in Arastra Gulch, was a gold producer, for many years prospecting was practically restricted to a search for silver and lead ores. It was apparently owing to this adherence to an established routine that the Una and Gertrude claims, in Imogene Basin, worked twenty years ago for silver and lead, were subsequently abandoned, with no knowledge of the rich gold ore which lay close alongside the argentiferous streak, and which was thrown out as waste. Masses of this rich ore were discovered by Thomas F. Walsh on the Camp Bird claim, and subsequently on the dump of the old workings of the Una and Gertrude, and he purchased the latter in 1896. It is to-day one of the most productive mines in the quadrangle. Gold ores are also extensively mined in the Tomboy and Gold King mines.

Placer mining has never been extensively practiced within the Silverton quadrangle. In former years a little washing was done on the east side of California Mountain, in Picayune Gulch, and in Arastra Gulch, but there are no extensive deposits of auriferous gravels in the district, and the total output from placer mining is insignificant.

PRODUCTION.

Accurate figures from which the total production of the Silverton quadrangle might be computed are not available. The area comprises portions of several counties, and has shipped ore to various smelters. An attempt to ascertain and combine the products of the individual mines within the quadrangle has been only partially successful; but by combining published figures with individual estimates it appears that the total production of the Silverton quadrangle from the beginning of mining activity to the close of 1900 has been at least $35,000,000. The greater part of this has undoubtedly been in silver and lead, but of late years, owing to the activity of the Camp Bird, Tomboy, and Gold King mines, and to the lower price of silver, the value of the gold output has predominated.

METHODS OF MINING AND TREATMENT OF ORES.

The following brief statement of methods may be of use to readers having no practical knowledge of this district or of the modes of procedure followed in it.

Owing to the exceedingly rugged character of the country, the larger mines, with the exception of those in the Red Mountain district, are almost all worked through adit tunnels. Although such adits involve, as a rule, greater initial expenditure, and, in the case of crosscuts, necessitate much "dead work," they have for large mines undoubted advantages in this region over shafts. The levels are usually, although not uniformly, about 100 feet apart, and the ore is commonly worked out by overhand stoping.

As many of the mines are situated above timber line in the high basins, frequently from 2000 to 4000 feet above the main roads, the proper location of the mill and the mode of transportation of the ore and concentrates to the nearest railway are problems which must be solved for each mine. Owing to the scanty and intermittent character of the water supply, it is seldom practicable to mill the ores at the altitude of the adit tunnel. An exception must be made in the case of the Silver Lake mine, where water for the old mill was obtained by pumping from the adjacent lake. But most of the mills are built from a few hundred to several thousand feet below the mines. The primitive method of packing the ore down on backs of burros to the shipping point or to the mill is in use by nearly all the small mines and prospects. But in well-equipped mines, above timber line, the wire-rope tramway performs an office which makes it indispensable in the mining development of so rugged a country.

The ores of the Silverton quadrangle are commercially divisible into shipping ores and milling ores. The former are shipped directly to the smelter as crude ore. They include such high-grade ores as can not be treated economically by simple milling processes and such ores as contain but a small proportion of worthless gangue. The milling ores include such gold ores as can readily be amalgamated or concentrated and those silver-lead ores in which the valuable minerals are associated with considerable quartz or other gangue material. Most large mines produce both grades of ore, but the output of the smaller mines, without mills, is necessarily restricted to crude or shipping ore. Exclusive of the ore from the Revenue tunnel, which really comes from the Telluride quadrangle, the bulk of the crude ore at present shipped from the Silverton quadrangle goes to the American Smelting and Refining Company's smelter at Durango. Heavy lead ores preponderate. The treatment charge varies from $2 to $11, the higher rate being for siliceous or "dry" ores. An extra charge of 50 cents per unit (1 per cent of 1 ton) is made for ores containing over 10 per cent of zinc.

The treatment of milling ores varies considerably with their character. Formerly many lixiviation plants, usually employing some modification of the original Augustin process, were installed in the region for the treatment of argentiferous ores. This process, involving a chloridizing roasting of the ore and subsequent leaching out of the chloride of silver by the use of strong brine, proved successful in treating the ore of the Polar Star mine, about 95 per cent of the silver being saved. In many cases, however, it was a failure, the ores not being adapted to its employment, and it is no longer used. Mechanical concentration, coupled in some cases with amalgamation, has entirely replaced the various chemical processes, and the concentrates thus obtained are shipped to the smelters. The cyanide process is employed on the tailings of the Camp Bird mill working on high-grade gold ore.

The conditions under which the several mines operate differ so widely that it is impossible to assign a definite lower limit to the value of ores that can be profitably extracted. Ores ranging in value from $6 to $12 a ton are perhaps as of low a grade as can be now worked, even on a considerable scale and with modern equipment. For many of the smaller mines, however, this limit must be doubled. The Red Mountain mines were expensive to operate on account of the irregularity in the disposition of their ore bodies, their corrosive waters, and the necessity of pumping and hoisting through shafts. In 1888 the New Guston, then beginning operations on an extensive scale, paid dividends on ore mined at a cost of $53.50 per ton. The lowest annual cost per ton was $9.60 in 1894 on ore worth only $12.80. Location, power, timber, water, kind of country rock, and character and amount of ore form a complex set of factors, which fully accounts for the range in the limiting value between workable and nonworkable ore.

CLASSIFICATION OF THE ORE DEPOSITS.

The ore deposits of the Silverton quadrangle may be conveniently classified and described under three heads: (1) Lodes, (2) stocks or masses, and (3) metasomatic replacements. To the first class belong by far the greater number of the deposits now productive. To the second class belong most of the ore bodies formerly worked in the Red Mountain district, often locally known as "chimneys." In the third class, the least important in this quadrangle, are a few deposits occurring in limestone or in rhyolite.

LODES.

Definition.

The word *fissure*, as used in this folio, means a somewhat extensive fracture in the rocks. A fissure is not necessarily accompanied by recognizable faulting, nor by visible open spaces, nor by mineralization. According to the classical definition of Von Cotta, a *vein* is the filling of a fissure. *Lode* is used throughout this text as a more general term than vein, to designate either a simple filled fissure or a zone of closely spaced fissues with possibly more or less impregnated or replaced country rock. *Lode* thus includes what Von Cotta and Von Groddeck have called *complex veins.*

Lode Fissures.

DISTRIBUTION OF THE ORE-BEARING FISSURES.

Fractures containing ore are widely distributed within the quadrangle, but are larger, more abundant, or richer in metalliferous contents in certain areas than elsewhere. They occur in all the rocks that possess any considerable distribution within the quadrangle, from the pre-Cambrian schist, which constitutes the basement formation of the region, to the latest monzonitic intrusions that cut the Tertiary volcanic series. By far the greater number of the fractures, however, are found in the San Juan tuff and in the Silverton volcanic series. This is apparently due to the fact that these rocks occupy the greater part of the quadrangle rather than to any special determining factor in the rocks themselves.

The existence of local areas of especially pronounced fissuring and mineralization has already been pointed out. Silver Lake Basin may be cited as a center of one such group of fissures. Not only are the fissures within and around this basin exceedingly numerous, but many of them contain large and productive ore bodies. Another area is at Galena Mountain, where the fissures are well exposed and form a remarkable network, but where they are not known to contain ore bodies of much value. As still other centers of conspicuous fissuring may be cited the heads of Treasure and Poughkeepsie gulches, Ross Basin, and Mineral Point. These last four local districts of vigorous fracturing are not distinctly separated, and should perhaps be included together as a single area over which fissuring and subsequent veining has taken place on an extensive scale. Finally, the area embracing Savage, Imogene, and Silver basins, in the northwest corner of the quadrangle, in which are the Virginius and Smuggler-Union mines, may be regarded as part of a very important district of strong ore-bearing fissures, lying chiefly within the Telluride quadrangle.

COORDINATION OF THE FISSURES.

By the coordination of the fissures is meant their arrangement in natural systems, based upon direction, size, persistence, or other features. In the present instance the trends of the principal fractures will first be discussed, and afterward the coordination of minor local groups of fissures occurring in various portions of the quadrangle will be considered.

The most conspicuous fissuring has taken place in a general northeast-southwest direction. The dip of these fissures is usually southeastward at about 75°, but the angles of dip range from 40° to vertical, and a few of the lodes dip northwestward. Perhaps slightly less marked, but economically more important, are numerous strong lodes running in a general northwest-southeast direction. In the southeastern quarter of the quadrangle these usually dip northeastward at angles varying from 50° to 90°. Elsewhere they usually, although not invariably, dip southwestward at high angles.

In addition to the east-west lodes there are several approximately north-south lodes, and if attention were restricted to certain small areas, such as Galena Mountain, it might be advisable to recognize one or both of these directions as characterizing distinct subordinate systems of fractures. Such a grouping, however, while valid for the small area named, is lost where the various directions of all the fissures in the quadrangle are taken into account. The possible number of such subordinate systems then becomes so large as to obliterate the divisions between them. The fissuring of the rocks throughout the quadrangle has been so thorough and has taken place in so many directions that only two of these stand out as dominant. Even these show a certain localization, the northeast-southwest fissures notably predominating in the northeast quarter of the quadrangle and the northwest-southeast fissures being the more persistent in the southeast portion.

Minor systems of fractures in parallel coordination may be well studied on Galena Mountain, a precipitous peak composed chiefly of massive and fragmental latite. The mountain is cut by very numerous fissures, many of them prominently indicated on the surface as lodes or veins. These may be divided into four groups, the members of each group being characterized by approximately the following strikes: (1) N. 45° E., (2) N. and S., (3) N. 25° W., and (4) N. 65° W. In each group are one or more fairly strong lodes accompanied by

*For a fuller treatment of the ore deposits than can be compassed in a folio text the reader is referred to Bull. U. S. Geol. Survey No. 182.

numerous smaller, nearly parallel, fissures, the rock being conspicuously sheeted. These associated fissures are particularly abundant in the N. 25° W. system, as seen on the southern declivity of the mountain, in the vicinity of the Veta Madre mine. They are generally vertical and are rather closely spaced—a foot or less apart. They are usually occupied by small veins which sometimes carry ore minerals, chiefly galena, sphalerite, and chalcopyrite, but which are seldom large or rich enough to be worked.

Another area within which the fissures show striking parallel coordination comprises Treasure Mountain and the head of Placer Gulch. The dominant northeast-southwest fissure system of this portion of the quadrangle is exemplified by a series of strong, persistent lodes, represented by the Sunnyside and Scotia, with a general course of N. 40° E. These fissures dip southwestward at high angles. A second system of shorter, less conspicuous fractures crosses the first series almost at right angles, with a general course of N. 55° W. These fissures are nearly vertical, but the majority of them dip southwestward at high angles. In their trends these fractures belong with the system of northwest-southeast fissures recognized as characteristic of the quadrangle as a whole. Here, however, they are not, as in the Silver Lake Basin, the master fissures, but are short, transverse, relatively unimportant fractures, forming a nearly rectangular network with the strong, continuous, northeast-southwest lodes. A third local system of transverse veins, represented by the Golden Fleece, has a course of N. 75° E., with usually steep southerly dip. Still a fourth set of very prominent lodes is exposed at the head of Placer Gulch, with an average strike of N. 25° E. Their dips are usually steep and easterly. There are several other fissures in this vicinity which do not strictly belong with any of the systems noted. Some of them have a nearly east-west strike, and might, perhaps be grouped together or possibly included with veins of the Golden Fleece system.

In the canyon of the Uncompahgre, north of Abrams Mountain, the thick masses of San Juan breccia and the underlying pre-Cambrian schists and quartzites are cut by numerous and nearly parallel fissures having a general trend of N. 5° W. and an eastward dip of 80° to 85°. These fractures seldom contain prominent veins. A second, less prominent, system of fissures, usually carrying quartz stringers, has a general strike of N. 60° W.

At the head of Porphyry Gulch, near the western border of the quadrangle, the Potosi volcanic series and the underlying Silverton series are traversed by a conspicuous series of nearly vertical fissures striking N. 80° W., which, so far as known, contain no workable ore bodies.

A similar series of fissures is also very prominent in the steep walls of Canyon Creek northeast of the mouth of Richmond Basin. Their general strike is N. 35° W., and they usually dip steeply to the northeast. They belong genetically with the northwest-southeast system of lodes in Silver Lake and Richmond basins, but are unproductive.

On the east side of Ironton Park are several fissures having a general northeast-southwest course and a steep southeasterly dip. Their formation was accompanied by considerable normal faulting.

Sometimes several nearly parallel fissures of considerable extent, containing open spaces ranging from a few inches to a foot or more in width, occur closely spaced within a comparatively narrow zone bounded by less fractured country rock. Such a sheeted zone forms a favorable place for the deposition of ore bodies, and the Camp Bird, Tomboy, and other bodies are chiefly of this type. Coordinate fractures of this simple character, in which the individual fissures maintain their individuality and essential parallelism for long distances, may pass without any line of demarkation into groups of fissures of the linked type, in which the nearly parallel fissures are imbricated and are connected by smaller oblique fractures. This structure is exemplified to some extent in the Tomboy mine, but is not common in the Silverton quadrangle. With a still farther shortening of the principal parallel fissures and an increase in the number and size of the linking fractures the fissure zone becomes a reticulated aggregation of irregular, curved fractures, which, when filled with ore, constitute a stringer lode. Of this class is the North Star (King Solomon) lode. Finally, with yet greater increase in the number and irregularity of the fissuring, this type of fissure zone passes by insensible gradations into a breccia zone, such as a portion, at least, of the Polar Star lode.

Thus far the discussion has dealt with the parallel coordination of fissures into minor systems and with the steps by which such groups of fissures, when confined to rather narrow zones, may pass into other less regular structures commonly associated with the deposition of ore in lodes. It remains to consider another manner in which the fissures of this region are sometimes locally grouped, not in parallel, but in radial, or, perhaps, to speak more accurately, branching, arrangement. This feature is well shown by the lodes of Silver Lake Basin. Another case of conspicuous branching occurs at the head of Placer Gulch, where several lodes having an average strike of N. 25° E. split off from the main Sunnyside lode. The junctions in this case have not been exposed underground, but from the similar character of their filling it is highly probable that these fissures, like those of Silver Lake Basin, were all formed at the same time. Still a third case of branching fissures is that of Lake Como. In this instance, again, the lodes are all similar and appear to have been formed contemporaneously.

RELATION OF FISSURES TO KIND OF COUNTRY ROCK AND TO ROCK STRUCTURE.

It has already been shown that ore-bearing fissures occur in practically all the rocks of the quadrangle. In general, the fissures in the Algonkian rocks are simpler and narrower than those in the volcanic rocks of later age. The fissures cut the schists at various angles with the schistosity, which apparently exercised no influence upon the direction of the fracturing.

The fissures within the various volcanic rocks of the quadrangle have few characteristic differences. The massive lavas and indurated flow-breccias favor comparatively simple fissuring, such as results in fissure veins of moderate size and regularity or in sheeted zones. In the softer tuffs and volcanic breccias the fissuring may be irregular, resulting in stringer or breccia lodes. Irregular fissuring appears to be favored also by alternations of harder and softer members of the nearly horizontal volcanic series, as at the North Star (King Solomon) mine. In this instance the softer rocks are regarded by the miners as the more favorable for ore. According to Purington, in the northeast corner of the Telluride quadrangle the fissures passing from the San Juan formation and massive andesite up into the Potosi rhyolite contain there less ore, and appear to have originally formed with less open space, than in the underlying andesitic rocks. There are no workings in the Silverton quadrangle which afford an opportunity to verify this statement, although the rhyolite of the Potosi series is generally regarded by the miners as unfavorable to ore. Near the head of Porphyry Gulch, however, a vein 10 inches in width carrying galena and sphalerite has been prospected in the Potosi rhyolite.

In the intrusive stocks of monzonite, such as that of Sultan Mountain, the fissures are, as a rule, of regular character and moderate width. They are usually occupied by simple veins. As examples, may be cited the fissures of the North Star, Hercules, and Little Dora veins, in Sultan Mountain, and of the Hamlet, vein near Middleton.

As a rule, local geological structure has had little influence upon the fissuring. The lack of a regular relation between fissures and schistosity has already been pointed out. Contacts between rocks of different kinds and ages also have had little effect upon the fracturing and subsequent veining. This is partly because the contacts are frequently nearly horizontal, while the fissuring is nearly vertical.

Lines of fissuring in this region are occasionally determined by igneous dikes. Thus the Magnolia, a superficially prospected northwest-southeast lode just northeast of Silver Lake, follows for some distance a latite dike about 6 feet wide which curves across the gulch toward Round Mountain. Both this dike and a larger one which crosses it are irregularly fissured and are traversed by poorly mineralized quartz stringers along the greater part of their exposed lengths. A similar occurrence was noted on the south side of Kendall Gulch a mile distant and a little east of south from Kendall Mountain, where a vein 6 inches wide lies on the south side of a nearly east-west andesitic dike. None of these fissures have yet proved to be of economic importance.

DISPLACEMENT OR FAULTING AS AN ACCOMPANIMENT OF THE FISSURING.

In a few lodes only, and those relatively unimportant, are the fissures noticeable faults. The abandoned Molas mine, 3 miles south of Silverton, is on a vein about 2 feet wide which apparently fills a fault fissure. The head of Deer Park Creek is crossed by a nearly north-south fault, with the downthrow on the west side, which is accompanied by some brecciation and veining of the schists along the fracture and by unimportant mineralization.

On the east side of Ironton Park, as shown in the Saratoga and Baltic mines, the formation of a parallel series of approximately northeast-southwest fissures has been accompanied by faulting. These fissures, as a rule, dip steeply to the southeast. The displacement is normal, and the maximum throw, as observed on the Mono vein, can hardly be less than 100 feet. This fissure carries a body of low-grade pyritic ore.

In the northeastern part of the quadrangle there is a broad zone within which is considerable faulting along some of the prominent vein fissures.

Notwithstanding the foregoing exceptions, it remains true that such displacement as occurred in connection with the formation of most of the productive lodes was slight.

The absence of considerable displacement as an accompaniment of the opening of lode fissures is not peculiar to the Silverton quadrangle, but is of common occurrence. In fact, more than moderate faulting in fissures which have formed productive lodes is comparatively rare.

INTERSECTIONS AND RELATIVE AGES OF FISSURES.

In a region where the fractures are so numerous and so diverse in trend intersections are necessarily frequent. But as veins at such points are particularly susceptible to disturbance by later movements of the rocks and to superficial disintegration, the study of these intersections is often difficult. The presence of seams of gouge due to these later or post-mineral movements, and the entrance of oxidizing waters, may so obscure the original relationship at the junction of two fissures as to render a determination of relative age impossible when no conspicuous faulting of one of the fissures has taken place.

In many parts of the Silverton quadrangle intersecting fissures have been formed and filled nearly or quite contemporaneously. This is true of the assemblage of branching fissures worked in the Silver Lake and Iowa mines, and probably true of the Placer Gulch and Lake Como fissures. It is also possible that many of the fissures intersecting nearly at right angles (conjugate fissures) were produced by a single principal stress. In the greater number of instances, however, in which lodes are known to intersect, the exposures are such as leave the actual character of the crossing and the relative ages of the fissures in doubt. They may or may not have been contemporaneously formed.

In three places only were lodes found to be faulted by later transverse vein-filled fissures. The King lode, in Cataract Gulch, 2 miles south of Silverton, with a strike of N. 6° W. and a dip of about 80° to the west, is faulted by a small approximately east-west quartz vein, dipping south at about 50°. By this faulting the northern portion of the King lode is thrown about 12 feet to the west. In the Silver Lake mine the important New York City vein, having an average strike of about N. 20° W. and dipping generally northeastward at about 80°, is cut by a faulting lode, which, where best exposed, is a breccia zone about 6 feet wide, composed of sharply angular fragments of country rock cemented by quartz carrying a little poor ore. This fault fissure strikes apparently about N. 73° E. and dips about 75° to the south. The New York City vein is displaced in the same way and to about the same degree as the King lode. In the Ridgway mine the main lode, with a strike of N. 40° E., is faulted by the Alaska lode, with an average strike of N. 25° W. The fault here is apparently of the same kind as those just described—an offset of the northern portion of the main lode to the west—but the developments in the Ridgway mine were not sufficiently extensive in 1899 to show the relations clearly. While the number of observations is at present too small to serve for the formulation of a general rule for the quadrangle, their agreement suggests that such a rule may be laid down in the future. Even now, in the event that a productive lode in the southeastern portion of the quadrangle should be found, on drifting northward, to be cut off by a more nearly east-west lode with southerly dip, the miner, in the absence of other clues, is not utterly at a loss, but may reasonably hope to regain his ore by crosscutting westward after drifting beyond the interruption.

That, after the original deposition of the important ore bodies, there was at least one period of minor fissuring, followed by fresh deposition of quartz, is shown in many of the lodes of the region. Thus, in the Royal Tiger, the Dives, the Tom Moore, the Sunnyside, the Red Cloud, the Polar Star, and various other mines and prospects the original ore has been fissured or brecciated, and subsequently healed with generally barren or low-grade quartz. In the Tom Moore, the later veinlets are notable in carrying small amounts of native copper in the quartz.

Still younger than any of the fractures hitherto described are numerous fissures, usually noticeable only in mine workings, in which neither quartz nor ore has been deposited. These are the "slips," "gouge seams," or "breaks" of the miners. As these names partly indicate, the fissures are generally filled with a wet, plastic, grayish clay, or gouge, which is, as a rule, merely altered and ground-up country rock, resulting from attrition of the fissure walls. This unctuous gouge, when sharply limited by harder country rock or vein filling, is taken to indicate relative movement of the walls, not necessarily resulting in noticeable displacement. In other words, these fissures are fault planes of greater or less movement, possibly oscillatory. The width of these "post-mineral" fractures, as they are sometimes conveniently called, may vary from a narrow, scarcely noticeable clay seam up to zones 12 feet or more in width, in which the gouge is mingled with masses of shattered country rock, and of which the most notable example is the zone of so-called "broken ground" in the Silver Lake mine.

Thus, briefly to recapitulate, while many of the fissures in the Silverton quadrangle, including some which differ widely in direction, were formed at substantially the same time, there have been later periods of fissuring, also followed by vein deposition. The oldest fissures known have a course somewhat east of north, and appear to have been successively cut by later fissures approaching more and more to an east-west strike. This generalization, however, should not be applied too rigidly, as it is probable that whenever a prominent set of nearly parallel fissures were formed, other fissures intersecting the dominant set at various angles were produced at the same time. Lastly, there has been fissuring not followed, as far as known, by any deposition of quartz or ore in the resulting fractures.

GEOLOGICAL AGE OF THE FISSURES.

Beyond the statement that the ore-bearing fissures of the Silverton quadrangle are of Tertiary and probably of late Tertiary age, it is not possible to fix the exact geological time at which the first considerable fracturing took place. More precise knowledge waits upon a determination of the exact age of the Telluride conglomerate and the San Juan and later volcanic formations. The Telluride formation, which, when present, underlies the volcanic rocks, has been provisionally referred to the Eocene by Cross. It is difficult to conceive that it is older than this, as it has been found by Cross to rest unconformably on the Colorado Cretaceous shales. The Telluride formation and the younger volcanic series have been cut by several great intrusive masses of monzonite, such as the Sultan Mountain stock, which is thus the most recent rock in the quadrangle and can hardly be older than the late Tertiary. Since the lodes occur in the monzonite as well as in other rocks of the area, their formation probably does not antedate the latter part of the Tertiary, and may have extended into the Quaternary.

PROBABLE DEPTH AT WHICH THE PORTIONS OF THE FISSURES NOW EXPOSED WERE ORIGINALLY FORMED.

According to Cross, the maximum thickness of the volcanic rocks in the Telluride quadrangle was, in round numbers, 5000 feet. Owing to the varying thickness of different members of these series in the Silverton quadrangle, no close estimate can be made of the average thickness of the volcanic accumulations over the quadrangle as a whole. It may provisionally be estimated, however, as from 5000 to 6000 feet. As no traces of any extensive later deposits have been found in the San Juan, it may be assumed that this thickness represents practically the total deposition from the beginning of Tertiary time. As most of the lodes worked at the present day occur within the volcanic series, and often from 1000 to 3000 feet above its base, it is evident that the portions of the fractures now accessible must have been formed at geologically moderate depths—that is probably under 6000 feet. When, further, it is remembered that erosion proceeded concurrently with the fissuring and probably made rapid headway during the progress of ore deposition, it appears that many of the deposits must have been formed well within depths frequently reached by mining operations. It might be expected that under these circumstances there would be a recognizable, although probably not very intimate, relationship between the ore as originally deposited and the present topographic surface. The full discussion of this subject, however, brings up questions whose solution properly belongs in another place, and which are treated under the heading "Origin of the lode and stock ores" (page 33).

PERSISTENCE OF THE FISSURES HORIZONTALLY AND IN DEPTH.

Fissures are not of indefinite extent either horizontally or vertically. No fixed limit, however, can be assigned to the length which a given fissure may attain. It depends upon the magnitude of the fissuring stress and upon the relative movement which has taken place between the walls. Great relative movement results in a long fissure, but as profound faulting appears to be usually opposed to the subsequent formation of a lode, there is a certain variable limit beyond which length is to be regarded as an unfavorable factor in the productiveness of a fissure lode. There are, however, certain notable exceptions to the foregoing general rule that should not be ignored. Thus the Merrifield-Ural lode, near Nevada City, Cal., occupies, according to Lindgren, a thrust-fault fissure of probably over 1000 feet throw. In the Silverton quadrangle fissures vary greatly in length. Those having a length of 2 or 3 miles are common, and it is probable that some of the fractures extend continuously for as much as 6 miles. That great length is not necessary for the formation of a productive deposit is shown by such lodes as the Iowa, Stelzner, and East Iowa, which can scarcely be longer than a quarter of a mile, and which die out at their southern ends in small branching fractures. The exact length of a fissure is, of course, rarely determinable, as practical exploitation seldom follows a lode to its total disappearance.

The formation of fractures is limited vertically by that depth below which the rocks are under such pressure that no fissures can form. As the zone of fracture, according to Hoskins and Van Hise, has a depth of about 10,000 meters (33,000 feet), and as fractures may also form in the still deeper zone of combined flowage and fracture, it is plain that this limit will never be reached in mining operations. But many fractures undoubtedly die out long before reaching this ultimate limit. The longer horizontal and the vertical dimensions of the fissures were probably originally nearly the same, and it is not likely that the present depth of any fissure very greatly exceeds its length. The depth will at least be roughly proportional to length. But the depth to which fissures extend is rarely actually determined, as the value of the ore body nearly always falls below the limit of profitable working long before the fissure itself disappears. That many of the smaller fissures die out at moderate depths is a well-attested fact. In the Silverton quadrangle, where mining development is as yet restricted to moderate or slight depths, no well-authenticated case is yet known of the dying out in depth of a fissure which carried workable ore at a higher level. The ore may change in character, or may disappear, as in the North Star (King Solomon) mine, but the fissure still continues to an unknown depth.

In such instances as the last many considerations enter into the question whether it is advisable to follow the pinched fissure in the hope of finding new ore bodies. The first step in such an investigation is to determine whether the pinch is merely a local constriction or whether it signifies the final diminution of the lode. This can be decided only by a careful consideration of the length and strength of the fissure as exposed above, of the possible faulting which accompanied its formation, and of the behavior of the fissure in those portions already mined. If the length of the croppings is several times the depth attained, if the fissure is usually strong, if it has been opened by faulting, and if it has been found subject to local pinches above, it may safely be concluded that it will persist and open out again with increased depth. But equally important is the question of the character of ore that may be found below, even if the fissure continue, for, as will be fully shown later on, the ore contents of a given fissure are not constant at all depths, either in kind or in value. Lastly, in connection with these factors must be considered the costs involved in mining the ore from an increased depth.

The foregoing relates to simple fissures. Lodes in general exhibit similar characteristics, but their persistence will in the main be greater than that of a simple fissure. They are subject to the same general laws as the individual fractures of which they are composed.

ORIGIN OF THE FISSURES.

The attempt to explain the origin of so complex a network of fissures as occurs in the Silverton quadrangle presents many difficulties. No explanation that can now be proposed is to be regarded as complete or as free from several necessary assumptions. Our knowledge of the degree of homogeneity of the various rock masses under strain, of the depth at which the fissures were originally formed and of their exact extent, direction, and distribution, of the geological conditions at the time of fissuring, and of other essential data is far too fragmentary to permit rigid analysis leading to irrefutable results.

The hypothesis that the dominant northeast-southwest and northwest-southeast fissures were formed by compressive stress acting in a nearly north-south direction seems open to fewer serious objections than any other that has been devised. Since there is no known source of such stress exterior to the quadrangle and the region immediately adjacent, it is thought probable that the stresses were generated chiefly within the quadrangle, by slight vertical movements following the enormous transfer, in Tertiary time, of volcanic material from an intratelluric to a superficial position, and that the surrounding country merely acted as a relatively passive buttress against which the thrust was directed. In other words, it is believed that the stresses were due principally to local gravitative readjustment. Some genetic connection between volcanism and the subsequent fissuring, mineralization, and veining can scarcely be doubted, as these phenomena rapidly diminish in intensity away from the volcanic district of the San Juan Mountains.

In addition to the principal stress outlined, there were doubtless minor stresses set up in many directions at various times, some contemporaneous with the principal north-south stress and others earlier or later, frequently leading to the production of minor local fissure systems. These also were probably in part compressive tangential thrusts, and it is the existence of these widely differing directions of effective stress that furnishes one of the strongest arguments against seeking sources for the latter outside of the region. It is exceedingly improbable that stresses which were to find their most energetic expression in the fissuring of the area itself should have been initiated at various widely separated points in the relatively undisturbed regions inclosing the volcanic area.

Structures of the Lodes.

The larger structural features of the lodes depend mainly upon the character of the fissures in which they were deposited. Where the original fracture was a simple dislocation, the resulting lode is a fissure vein. Most of the lodes of the Silverton quadrangle are of this character—nearly vertical plates of gangue and ore confined between definite walls. They sometimes show local irregularities and may divide into numerous branching stringers (stringer lodes) at their edges, but in the essential character of their workable portions they are veins, in the original sense of Von Cotta. Such are the veins of the Empire group on Sultan Mountain, the New York City, Stelzner, Royal, and Iowa veins of Silver Lake Basin, the Green Mountain vein, most of the veins of Galena Mountain, the Hamlet vein, and many of the lodes in the northeast portion of the quadrangle. The width of the workable veins usually varies from a few inches up to 10 or 12 feet. Lodes of greater width than this are rarely simple veins, although some of those near Sunnyside Basin, from 30 to 50 feet wide, appear to have filled simple open fissures. A width of 2 or 3 feet is perhaps a rough characteristic average of the productive veins of the Silverton region. The vein filling usually fits snugly to the fissure walls and is frequently adherent to them—"frozen," as the miners say. In many cases, however, there has been sufficient movement along the fissure to cause the ore to part readily from one or both walls, and sometimes there is a gouge or selvage present. This is rarely thick or extensive. Fissures sometimes contract, or pinch, and the vein then becomes much reduced in width and may be entirely absent.

As a rule the country rock adjoining the veins is not strikingly altered and retains practically the original form of the fractured surfaces. In some veins in rhyolite, however, there has been replacement of the rock by ore, as may be seen in the Tom Moore mine.

Veins of the simple type described are connected by many transitional forms with lodes occupying closely spaced sheeted zones and consisting really of several parallel veins. Such are the small lodes of the Micky Breen and the important lodes of the Camp Bird and Tomboy mines. In both the Camp Bird and Tomboy, however, the parallel veining resulting from sheeting of the country rock is associated with the less regular linked-vein structure, in which the lode is composed of nearly parallel or slightly diverging veins connected by irregular linking stringers and with the yet more irregular stringer-lode structure, in which the lode consists of a mass of stringers without noticeable parallelism. In these mines the more regular structure is usually found with the gold ore, which is separated from the hanging wall by a little gouge, and the more irregular structures characterize the foot-wall portion of the lode, which carries a low-grade galena ore.

The stringer-lode structure is perhaps best exemplified in the North Star (King Solomon) lode, in portions of the Royal Tiger and of the Pride of the West lodes, in the upper part of the Forest lode, and in the Alabama lode.

Breccia lodes—that is, lodes in which the ore and gangue originally filled the spaces in a zone of brecciated country rock—are not common. The only deposit seen which is characterized chiefly by this structure is that of the Silver Queen mine on Bear Creek, near the northern edge of the quadrangle. Here the pay streak, from 3 to 6 feet wide, lies in a brecciated zone about 12 feet wide in the San Juan formation. The Polar Star and Red Cloud lodes also were in part deposited in brecciated zones.

The Ores of the Lodes.

MINERALOGY OF THE ORES.

GANGUE MINERALS.

Under this head are included those mineral constituents of the lodes which make up the matrix of the metallic ore minerals or are intimately associated with these.

In the brief notes describing the physical properties of the minerals, the aim has been to give those features of color, form, etc., which will enable one to recognize the minerals as they occur in this quadrangle. The same minerals occurring in other regions may differ in the properties named.

Quartz.—SiO_2. Rhombohedral. Massive, or in hexagonal prisms terminated by rhombohedrons. Usually white or colorless. Hardness, 7. Specific gravity, 2.6.

This, as a rule, has the usual character of vein quartz. It varies from semi-opaque, milk-white varieties to those which are vitreous and transparent. In the Camp Bird and Tomboy lodes the latter carry free gold, usually in minute particles. The quartz of the veins is generally massive, and in thin section under the microscope is seen to be composed of interlocking grains with incomplete crystal boundaries. A radial arrangement of the imperfectly formed crystals was noted in the Dives, Magnet, Camp Bird, and Tomboy mines. The quartz of the Silver Lake lodes frequently incloses chlorite, which gives a green color, usually regarded as an indication of good ore. In some of the lodes the presence of minute included crystals and grains of galena, sphalerite, tetrahedrite, argentite, various sulphobismuthites, and other ore minerals results in a dark-clouded quartz in which the ore minerals are not recognizable with the naked eye. Such is the richest ore of the Ridgway mine.

In addition to quartz of the foregoing character, which has crystallized in open spaces, there occurs within and adjacent to many of the lodes, and especially in connection with the stocks of the Red Mountain district, a much more finely crystalline quartz, sometimes resembling a fine-grained quartzite, which has resulted from a partial or complete replacement of country rock by silica. As seen in thin sections under the microscope, this quartz is associated with sericite or kaolin, and sometimes with alunite, in a cryptocrystalline mosaic. Such a mosaic often reveals the outlines of the former crystals of feldspar, which have been metasomatically replaced.

As vein filling, with other gangue minerals and ore, quartz occurs in nearly all the productive lodes of the quadrangle, but the relative amount of quartz and ore minerals varies widely between the highly siliceous gold ore of the Tomboy, showing to the eye insignificant mineralization, to the coarsely crystalline, heavy lead ore of the Royal Tiger and Iowa mines. In a few of the lodes occurring in rhyolite, vein quartz may be practically absent. It did not occur to any considerable extent with the ore stocks of the Red Mountain district, where the quartz is chiefly the result of metasomatic replacement of the country rock.

Barite.—$BaSO_4$. Orthorhombic. Massive, or in groups of diverging tabular crystals. Cleaves perfectly in three directions. White. Transparent to opaque. Hardness, 3. Specific gravity, 4.5; whence common name "heavy spar."

This is not nearly so important a gangue mineral in the Silverton quadrangle as quartz, but it occurs massive with the latter mineral in the veins in the Sultan Mountain monzonite mass; in the Royal Tiger, Melville, and probably other lodes in Silver Lake Basin; as a heavy vein in the Dives and Potomac claims; in the veins of Galena Mountain, where it has sometimes been replaced by pseudomorphous quartz; and in the Bonanza, Alaska, Tempest, Alabama, Old Lout, and other lodes in Poughkeepsie Gulch. It was found in the stocks of the Red Mountain district in close association with the argentiferous copper ores. It also occurs in the Zuñi mine, on Anvil Mountain, embedded in kaolinite, and with zunyite in guitermanite. Where occurring in lodes, the barite is commonly associated with gray copper (tetrahedrite). In the Mastodon claim on the Sunnyside lode, barite forms with quartz a finely crystalline aggregate which constitutes the gangue of a highly argentiferous lead sulphobismuthite.

Calcite.—$CaCO_3$. Rhombohedral. Commonly massive or in rhombohedrons, scalenohedrons, or prisms. Cleaves perfectly in three directions, affording rhombohedrons. White. Transparent to opaque. Hardness, 3. Specific gravity, 2.71. Effervesces freely with cold dilute acid.

Calcite is less abundant than barite in the productive lodes, but is nearly always present in small amount, particularly in small vugs and in minute veinlets cutting the ore. As the principal filling of mineralized veins it was noted in the Oneida, a prospect at the head of American Basin, where it carries sphalerite with a little pyrite, chalcopyrite, and galena, and at the Yellow Jacket claim on Bear Creek, on the northern edge of the quadrangle, where also it contains abundant sphalerite. As an important gangue constituent it was noted in some of the copper-bearing lodes north of Henson Creek. In the Camp Bird mine it is fairly abundant, filling vugs and spaces in the quartz left by comb structure. As a microscopic constituent calcite is found almost invariably in the wall rocks near the lodes, except where the rock has been silicified, in small amount with rhodonite and rhodochrosite in the so-called "pink spar" (chiefly rhodonite) of the Sunnyside and other mines, and with fluorite and quartz in a pale-green cryptocrystalline aggregate accompanying and forming part of the rich streak in the Camp Bird lode.

As limestone, impure massive calcite occurs at several points in the quadrangle, and on the east side of Sultan Mountain and at the Saratoga mine in Ironton Park is directly associated with deposits of ore.

Dolomite.—$CaMg(CO_3)_2$. Rhombohedral. Usually massive or in curved rhombohedra. Cleavage like calcite. White or brownish. Milky to opaque. Hardness, 3.5. Specific gravity, 2.88. Effervesces with cold dilute acid only when finely powdered.

This mineral is not abundant or important in connection with the ore deposits, but occurs as a microscopic constituent with rhodonite and rhodochrosite.

Rhodochrosite.—$MnCO_3$. Rhombohedral. Massive or in small rhombohedra in vugs. Cleavage like calcite. Usually some shade of pink. Hardness, 3.5 to 4.5. Specific gravity, 3.5. Effervesces freely in powdered form with dilute acid.

Occurs abundantly in massive form as gangue in the Titusville lode, in small amounts in the veins of the Empire group on Sultan Mountain, and in most of the lodes in the northeast quarter of the quadrangle, where it may usually be observed as minute rhombohedral crystals lining small vugs. In small quantity it always present in the veins containing rhodonite. In the Golden Fleece vein it forms, with quartz, the gangue of the rich free-gold ore, and also occurs in small amount in the Camp Bird lode. It is found in beautifully colored rhombohedral crystals in the Grizzly Bear mine, on Bear Creek, just within the northern boundary of the quadrangle.

Kaolinite.—$H_4Al_2Si_2O_9$. Monoclinic. Massive, or in a loose powder consisting of microscopic crystalline scales. White. Hardness, 2 to 2.5. Specific gravity, 2.6. Can be scratched with the finger nail. Smooth to the touch.

This mineral occurs in very pure form in the National Belle mine as a snow-white powder, made up of minute crystalline scales. As seen in the upper workings in 1899 it fills fissures in the country rock or spaces among the fragments of brecciated zones near the ore bodies.

As an original constituent accompanying the ores, kaolin is abundant in the stock deposits of the Red Mountain district. This is usually a firm, compact variety, intimately associated with pyrite.

In the Zuñi mine, on Anvil Mountain, compact kaolinite is abundant and is directly associated with pyrite, barite, and small nests of enargite to form the lower exposed portion of the ore body. The pyrite is often beautifully crystallized in slightly modified octahedra, which are thickly embedded in the white kaolinite.

As a soft white powder kaolinite occurs with the gold quartz of the Tomboy and Camp Bird mines.

As an alteration product of the wall rock, more particularly of the feldspathic constituents, kaolinite is extremely common; but it is often impossible, without a chemical analysis, to distinguish it from sericite.

Fluorite.—CaF_2. Isometric. Massive, or in variously modified cubes and octahedra. Cleaves in four directions, forming octahedra. Colorless, or pale green or lilac. Hardness, 4. Specific gravity, 3.1.

Pale-green fluorspar is abundant on some of the dumps of the Aspen mine, but was not seen in place. In massive condition it forms a vein on the north side of Picayune Gulch, near its mouth, and occurs in a prospect near the Mountain Queen mine, in California Gulch, and in another prospect just east of Lake Como. It was also noted in the dump of the upper tunnel of the Micky Breen mine. Well crystallized with quartz, fluorite occurs in a prospect just north of the Old Lout mine, and in the Indiana tunnel in Gray Copper Gulch. In the Sunnyside lode, fluorspar, usually of a lilac tint, accompanies the best ore. Pale-green fluorite occurs with calcite in the quartz of the Tomboy lode and as a microscopic constituent in some of the rich Camp Bird ore. It probably occurs also in visible masses in portions of the latter lode, although none was seen at the time of visiting the mine. It is abundant in the Morning vein of the Japan mine, and in the Empire-Victoria vein with hübnerite. This latter association, however, is much more strikingly shown on the Adams claim, near Gladstone. On the whole it is not a common gangue mineral in this quadrangle, and when not too abundant is frequently associated with free gold.

Rhodonite.—$MnSiO_3$. Triclinic. Found only in cryptocrystalline massive form in the Silverton quadrangle. Color, rose-pink, fading and then turning black on exposure to the weather. Hardness, 5.5 to 6.5. Specific gravity, 3.5.

The silicate of manganese, comprising much of the so-called "pink spar" of the miners, occurs in many of the larger lodes of the northeast quarter of the quadrangle as a fine-grained pink material, very hard and tough, forming partitions between the ore-bearing portions of the lodes, as elsewhere described. It is a conspicuous and abundant constituent in the Sunnyside lode, in the neighboring lodes in Placer Gulch, and on Treasure Mountain, particularly in the dominant northeast fissures, and occurs much less abundantly in other lodes of the northeast quadrant. It is also found in the Saratoga mine, near Ironton, where it has partly replaced limestone.

Zunyite.—$(Al(OH,F,Cl)_2)_6Al_2Si_3O_{12}$. A very basic orthosilicate of aluminum. Isometric, tetrahedral. Colorless. Hardness, 7. Specific gravity, 2.8.

This mineral, which was first described and named by Hillebrand, from the Zuñi mine, occurs only in the Zuñi and one or two adjacent prospects on Anvil Mountain. It forms small tetrahedral crystals up to 5 millimeters (three-sixteenths of an inch) in diameter, embedded in guitermanite or its oxidation product, lead sulphate, and associated with pyrite, enargite, bournonite, kaolin, and barite.

Although of much scientific interest, the mineral at present has no economic importance.

Other minerals.—Sericite, epidote, chlorite, and zircon occur in some of the ores, often merely as microscopic constituents. In the mines of Silver Lake Basin chlorite, with the usual green color and minute radially foliated structure, forms nests in the vein quartz. The spots of chlorite are commonly regarded as an indication of good ore. It is abundant also in ore from the Silver King tunnel, on Mill Creek, and in vein quartz carrying pyrite in the Barstow mine. Sericite is often associated with kaolinite in ores formed by partial replacement of rhyolite and related potash-bearing rocks. A little chalcedony was noted in the Camp Bird ore. Alunite, although found in the National Belle mine and as an alteration product in some of the volcanic rocks of the Red Mountain Range, has not been noted as a true gangue mineral. Gypsum occurs occasionally as small crystals in vugs of the Red Mountain ores.

ORE MINERALS.

Under this head are included minerals generally mined as ores, together with some compounds of the heavy metals not of commercial value in this region. Unless otherwise stated, these minerals are characterized by a metallic luster.

Pyrite.—Iron disulphide, FeS_2. Isometric, pyritohedral. Massive, granular, or in pentagonal dodecahedrons (pyritohedrons), octahedrons, or cubes, or in combinations of these forms. Pale brass-yellow. Hardness, 6. Specific gravity, 5.

The isometric sulphide of iron is common in all the ores of the district, and impregnates to a varying extent all of the country rock in the vicinity of the ore bodies. In some cases this impregnation has involved huge masses of rock, as in the Red Mountain Range, which owes its color to the oxidation of the disseminated pyrite. Large bodies of pyrite, formed in part by replacement of country rock, are known to exist in the lower workings of many of the abandoned mines of the Red Mountain district. Other large masses of crumbling granular texture occur near Ironton, in the Saratoga and Baltic mines, in great part replacing limestone. Pyrite, in beautiful octahedra embedded in kaolin, is abundant in the Zuñi mine, on Anvil Mountain. As a rule the pyrite, when occurring in large bodies with little or no quartz, is not of sufficient value to pay for working. When, however, as in the Henrietta mine, it is associated with a considerable amount of chalcopyrite, it can sometimes be mined at a profit. Associated with true vein quartz, especially when the latter carries some free gold, the pyrite itself is usually sufficiently auriferous to repay treatment. In the Tomboy and Camp Bird mines the amount of gold in the pyrite is less than that occurring free in the quartz. In the Gold King, however, the reverse is true. A large part of the gold in the Silver Lake mine occurs in pyrite.

Pyrite in radially fibrous spherules was noted in the dumps of the Red Cloud and Old Lout mines, and also as small stalactites in cavities in the Genesee-Vanderbilt ore body. It also forms radial spherules embedded in calcite at the Yellow Jacket claim, on Bear Creek near the northern edge of the quadrangle.

Tetrahedrite (gray copper).—Sulphantimonite and sulpharsenite of copper. The composition of tetrahedrite proper is $4Cu_2S.Sb_2S_3$, corresponding to 52.1 per cent of copper. For tennantite, the arsenical variety, it is $4Cu_2S.As_2S_3$, corresponding to 57.5 per cent of copper. These two varieties are connected by various intermediate compounds. Isometric, tetrahedral; commonly massive. Color, gray. Streak, brownish or reddish. Hardness, 3 to 4.5. Specific gravity, 4.4 to 5.1.

This mineral rivals galena in this region in importance and abundance as an ore constituent. Its high percentage of copper, and the fact that it often carries a large amount of silver, which replaces part of the copper, gives it its value. Most of the varieties contain both arsenic and antimony, but antimony predominates, especially in the highly argentiferous variety sometimes known as freibergite (the typical freibergite from Freiberg contains over 30 per cent of silver), which is usually of a lighter gray than ordinary tetrahedrite. Moderately argentiferous tetrahedrite occurs in the North Star, Belcher, Empire, Little Dora, and other lodes on Sultan Mountain, in the Aspen mine on Hazelton Mountain, and in the Royal Tiger and other mines in Silver Lake Basin, associated with galena, chalcopyrite, sphalerite, pyrite, quartz, and barite. An antimonial variety rich in silver, probably freibergite, constituted the principal ore of the North Star (King Solomon) mine. Tetrahedrite has been found in the Pride of the West, Philadelphia, and Highland Mary mines, in Cunningham Gulch, and usually constituted the richest ore. It occurs in most of the lodes of Picayune and California gulches, in the Tom Moore lode, in the Micky Breen, Poughkeepsie, Bonanza, and other mines in Poughkeepsie Gulch, and in many other mines and prospects in various parts of the quadrangle. In some, such as the North Star (King Solomon), Tom Moore, and Micky Breen, it is the principal constituent of ore bodies of some size and continuity, but in others, especially in those lodes carrying much galena, the tetrahedrite often occurs as bunches in the other ore. A little lead may sometimes replace part of the copper, as was found to be the case with a tetrahedrite carrying both arsenic and antimony, from the Black Diamond claim, on California Mountain. Tetrahedrite was present also in the ores of the Yankee Girl, Silver Bell, and other Red Mountain mines.

Enargite.—Sulpharsenate of copper, $3Cu_2S.As_2S_5$. Contains 48.3 per cent of copper. Orthorhombic. One perfect cleavage. Grayish black to iron black. Hardness, 3. Brittle. Specific gravity, 4.4.

Enargite is of frequent occurrence in the ores of the Red Mountain Range. It was found abundantly in the Zuñi and Congress mines, and formed the principal ore of the National Belle. Handsome clusters of prismatic crystals incrusted with malachite and quartz have come from the now inaccessible workings of this mine.

The enargite of the Zuñi mine is said to have carried over 200 ounces of silver per ton. In the National Belle it was probably of much lower grade.

Chalcocite.—Cuprous sulphide, Cu_2S, corresponding to 79.8 per cent of copper. Orthorhombic, commonly massive. Blackish lead-gray. Hardness, 2.5 to 3. Specific gravity, 5.5 to 5.8.

Stromeyerite.—Sulphide of silver and copper, $(AgCu_2)S$. Form and physical properties like chalcocite, except slightly higher specific gravity—6.1 to 6.3.

These two closely related species do not always admit of sharp distinction. Stromeyerite may be regarded as chalcocite in which about half of the copper is replaced by silver. Chalcocite is itself a valuable ore mineral on account of its high percentage of copper, but stromeyerite, which may contain over 50 per cent of silver, is particularly valuable. The two minerals are probably connected by intermediate varieties.

Chalcocite, more or less argentiferous, was noted on the dump of the Frank Hough mine, and bornite in the Silver Link and J. J. Crooke. Stromeyerite is reported to have been formerly an abundant ore in the Yankee Girl and Guston mines, where it occurred at a depth of less than 600 feet, between galena above and bornite below. One lot of 6 tons of this rich ore from the Yankee Girl contained over 5300 ounces of silver per ton, while one small lot from the sixth level of the Guston is stated to have contained 15,000 ounces of silver per ton, which corresponds roughly to the percentage of silver in pure stromeyerite.

Some of the richest ore in the New York City lode, in the Silver Lake mine, contains small quantities of a black amorphous copper sulphide, probably chalcocite.

Bornite.—Sulphide of copper and iron, $3Cu_2S.Fe_2S_3$. Contains 55.5 per cent of copper. Isometric. Commonly massive. Copper-red or pinchbeck-brown on fresh fracture, but soon becomes iridescent from tarnish, whence the name "peacock ore." Hardness, 3. Brittle. Specific gravity, 4.9 to 5.4.

This mineral, often highly argentiferous by the replacement of a portion of the copper by silver, was a very important constituent of the large ore bodies formerly worked in the Red Mountain district. It formed large, solid masses in the Yankee Girl and Guston mines, associated with barite, the crystals of the latter being often embedded in the bornite. It was found also in the Genesee-Vanderbilt mine. It is usually intimately associated with chalcocite and chalcopyrite. With quartz it occurs in bunches in the Silver Link mine and also in the J. J. Crooke, associated with chalcocite.

Chalcopyrite (yellow copper).—Sulphide of copper and iron, $Cu_2S.Fe_2S_3$, corresponding to 34.5 per cent of copper. Tetragonal, sphenoidal. Commonly massive. Brass-yellow. Hardness, 3.5 to 4. Brittle. Specific gravity, 4.1 to 4.3.

This is a common ore mineral throughout the quadrangle, and is sometimes auriferous, as in the Sound Democrat, or argentiferous (carrying also a little gold), as in the Yankee Girl, Guston, National Belle, and other Red Mountain mines, and in the Guadaloupe mine on Abrams Mountain. It is very abundant in the Titusville mine, in the New York City lode of the Silver Lake mine, and in the Hamlet mine. Associated with pyrite, it forms the ore of the Henrietta mine, and with tetrahedrite much of the ore of the Tom Moore lode. It is always present in ores carrying galena, sphalerite, and pyrite, although the amount varies widely in different ore bodies. In the Saratoga mine it occurs with pyrite and galena, replacing limestone.

Galena.—Lead sulphide, PbS. Isometric. Rarely showing external crystal form, but characterized by its perfect cubic cleavage. Lead-gray. Hardness, 2.5. Specific gravity, 7.5.

This very important ore mineral, which when pure contains 86.6 per cent of lead, occurs in nearly every ore deposit in the quadrangle, although in extremely varying amounts. In the lodes of the Silver Lake Basin and vicinity it forms coarsely crystalline masses, associated with quartz, sphalerite, chalcopyrite, pyrite, and sometimes barite and tetrahedrite. Such coarsely crystalline varieties carry in this region relatively low silver values. In other lodes, in Maggie, Picayune, and Placer gulches, and around Mineral Point, the galena is sometimes so minutely crystallized as to give merely a dark color to the quartz in which it is inclosed. This finely crystalline galena is often, but not invariably, highly argentiferous, as in the Sound Democrat mine in Placer Gulch.

Sphalerite (*zinc blende*).—Zinc sulphide, ZnS. Isometric, massive, and tetrahedral. In variously modified tetrahedral forms. Perfect dodecahedral cleavage. Luster resinous. Color, various shades of yellow or orange to dark brown or black. Hardness, 3.3 to 4. Specific gravity, 4.0.

This is a very common mineral in this region and always accompanies galena. It is not, however, worked as an ore of zinc, and its presence in the ore often involves additional cost in concentrating and smelting. The light-yellow varieties, commonly termed "rosin zinc" by the miners, are often associated with native gold. An orange or red sphalerite is common in the ores of the Red Mountain Range. In the Yellow Jacket, a prospect on Bear Creek near the northern edge of the quadrangle, sphalerite occurs abundantly as cylindrical aggregates of radial structure, in a gangue of calcite.

Bournonite.—Sulphantimonite of lead and copper, $3(PbCu_2)S.Sb_2S_3$. Orthorhombic. Steel-gray, lead-gray, or black. Hardness, 2.5 to 3. Rather brittle. Specific gravity, 5.8.

A lead-copper sulphantimonarsenite, probably bournonite with some arsenic replacing the antimony, occurs at the Zuñi mine in small vertically striated prisms with pyrite and zunyite.

Zinkenite.—Sulphantimonite of lead, $PbS.Sb_2S_3$. Orthorhombic, but chiefly massive. Steel-gray. Hardness, 3 to 3.5. Specific gravity, 5.3.

Described and analyzed by Hillebrand from the Brobdignag claim, where it is said to occur sparingly with barite. None could be seen in 1899 or 1900.

Guitermanite.—Sulpharsenite of lead, $3PbS.As_2S_3$. Massive, compact. Bluish gray. Hardness, 3. Specific gravity, 5.9.

This mineral, with zunyite, was first described and named by Hillebrand, and occurs, so far as known, only in the Zuñi and adjacent claims. It always incloses the minute, sparkling tetrahedrons of zunyite, and is intimately associated with pyrite, enargite, kaolin, and barite. It alters superficially to anglesite. As it contains about 66 per cent of lead, and probably some silver, it is a valuable ore.

Stibnite.—Antimony sulphide, Sb_2S_3. Orthorhombic. Usually in clusters of radiating prisms. Perfect cleavage in one direction. Lead-gray. Hardness, 2. Specific gravity, 4.5.

A single specimen of this mineral was seen, which was stated on reliable authority to have come from the North Star mine on Sultan Mountain. It is readily distinguished by its lustrous cleavage surfaces and softness, being easily scratched with the finger nail.

Polybasite.—Sulphantimonite of silver, $9AgS.Sb_2S_3$, with part of silver replaced by copper and part of antimony by arsenic. Orthorhombic. In characteristic, short, six-sided tabular prisms, with triangular striations and beveled edges. Iron-black. Hardness, 2 to 3. Specific gravity, 6.1.

This rich silver ore is known to have been present in the upper workings of the Yankee Girl, and probably in other mines of the Red Mountain district. Well-crystallized specimens from this region are preserved in the museum of the Bureau of Mines, Denver, and in various private cabinets.

Proustite (*ruby silver*.)—Sulpharsenite of silver, $3Ag_2S.As_2S_3$, corresponding to 65.4 per cent of silver. Rhombohedral, hemimorphic. Luster, adamantine. Transparent to translucent. Color, scarlet-vermilion, but somewhat masked by brilliant luster. Hardness, 2.25. Brittle. Specific gravity, 5.5 to 5.6.

Few of the ores now mined show this mineral, although it was seen in the Ben Butler mine, associated with galena and perhaps argentite. It is also known in the Ridgway mine and has been reported on good authority from the Red Cloud, Polar Star, Mammoth, Annie Wood, Palmetto, and Wheel of Fortune mines. It is known to have occurred in the Yankee Girl, and a specimen was seen which was said to have come from the Genesee-Vanderbilt mine. It characterizes the upper portions of argentiferous ore bodies and is not known at depths over a few hundred feet.

Bismuthinite.—Sulphide of bismuth, Bi_2S_3. Orthorhombic. One perfect cleavage. Lead-gray. Hardness, 2. Somewhat sectile. Specific gravity, 6.5.

This sulphide of bismuth occurs in slender prismatic crystals, with specularite, in quartz at the Neigold claim, on the south slope of Galena Mountain.

Argentite.—Silver sulphide (Ag_2S), containing 87.1 per cent silver. Isometric. Blackish lead-gray. Hardness, 2 to 2.5. Sectile. Specific gravity, 7.3.

This valuable ore of silver, which is readily distinguished by the ease with which it can be cut with a knife without breaking or splintering, is not abundant in the Silverton quadrangle. It was distinctly recognized only at the Ridgway mine, where, curiously enough, it is called "brittle silver." Here it constitutes the richest ore, and is evidently one of the most recently formed of all the ore minerals, as it occurs characteristically in vugs, incrusting or filling the interstices between the quartz crystals. It probably occurs also in the Gold Nugget and other prospects in Maggie Gulch, and is said to have constituted a large part of the rich ore formerly extracted from the Polar Star mine on Engineer Mountain, and from the Palmetto mine on American Flat.

Molybdenite.—Molybdenum disulphide, MoS_2. Probably hexagonal. Occurs in scales with eminent basal cleavage, or compact. Laminæ flexible, but not elastic. Lead-gray. Leaves a bluish-gray mark on paper. Feel, greasy. Hardness, 1 to 1.5.

This mineral occurs in the Sunnyside Extension mine, where it has been mistaken for graphite. Here it frequently contains free gold.

Hematite (*specularite*).—Ferric oxide, Fe_2O_3. Rhombohedral. Lamellar or in thin scales. Color, steel-gray or iron-black. Streak, cherry-red or reddish-brown. Hardness, 5.5 to 6.5, but often apparently much softer on account of its scaly structure. Specific gravity, 5.2.

The variety of hematite known as specular iron is frequently found in small quantities in the lodes. It is present for example, in the Crown Point lode on Sultan Mountain, in the Little Giant lode, in the Neigold claims on Galena Mountain, and in the Daniel Webster prospect in Maggie Gulch. In all cases observed it is a vein mineral inclosed in quartz. It is of no economic importance, but is frequently mistaken for more valuable minerals—in one case for "brittle silver." It is easily recognized by its scaly structure, brittleness, and red color when crushed.

Sulphobismuthites.—These include cosalite ($2PbS.Bi_2S_3$), galenobismuthite ($PbS.Bi_2S_3$), alaskaite ($(PbAg_2)S.Bi_2S_3$), beegerite ($6PbS.Bi_2S_3$), kobellite ($2PbS.(Bi,Sb)_2S_3$), and possibly other species.

Sulphobismuthites of lead, carrying usually considerable silver and sometimes a little copper, are of frequent occurrence, particularly in the northern half of the quadrangle. As most of the above-named minerals resemble one another very closely in physical properties and as a rule are massive, their specific identification is impossible without a quantitative chemical analysis in each case. Nor is this method often available, for these sulphobismuthites are usually so intimately associated with other ore minerals that pure material suitable for chemical analysis can not be obtained. They are nearly all lead-gray in color, with hardness varying from 2.5 to 4.

The argentiferous galenobismuthite named by Koenig *alaskaite* is abundant in the Alaska mine and in the Acapulco claim adjoining it on the east.

Cosalite from the Yankee Girl mine, with part of the lead replaced by silver, has been analyzed by Low, and the mineral probably occurs in other mines in the vicinity. It has been reported also from the Alaska mine. Kobellite has been analyzed and described by Keller from the Silver Bell mine, and beegerite, from Poughkeepsie Gulch, by Koenig. The naming and identification of these species from the Silverton quadrangle rests upon chemical analysis of massive, more or less impure material, and these results have not yet been confirmed by any investigation of crystal forms.

In the course of the present investigation sulphobismuthites have been found in many of the ores, but never with external crystal form nor in such amount or purity as would warrant complete chemical analyses, whereby alone they can be specifically determined.

At the Barstow mine the richest ore is a bright lead-gray mineral, of hardness 3 to 3.5 and specific gravity 7.04 at 30° C. (Hillebrand). It shows indistinct crystal forms, suggestive of isometric symmetry, and is very intimately intergrown with pyrite.

The purest material that could be picked out proved to be a mixture of a lead sulphobismuthite, probably beegerite, with pyrite and a telluride which is perhaps an auriferous hessite.

In the Sunnyside Extension mine a sulphobismuthite of lead and silver, showing no distinct crystal form, is intimately associated with molybdenite and free gold in an ore containing quartz, barite, sphalerite, pyrite, and galena. In the Mastodon, which adjoins the Sunnyside Extension on the north, an argentiferous sulphobismuthite of lead showing indistinct prismatic crystallization is so finely disseminated in quartz as to give the latter a dark, clouded appearance.

In the Custer claim on California Mountain an argentiferous lead, sulphobismuthite, forms the richest ore, and similar bismuthiferous compounds occur in the ores of the Sound Democrat and Silver Queen mines in Placer Gulch.

A lead-copper sulphobismuthite, probably argentiferous, occurs in small, ragged prisms, frequently forming star-like radial clusters, in quartz with pyrite at the Uncompahgre Chief, near Mineral Point.

At the Silver Bell mine, between Ironton and Red Mountain, the richest ore was a massive argentiferous lead sulphobismuthite carrying up to 1000 ounces of silver per ton. Massive argentiferous lead sulphobismuthites, of probably more than one species (one of them cupriferous), occurred in the Genesee-Vanderbilt ores, intimately associated with barite and pyrite. A massive lead sulphobismuthite (with perhaps a little copper) has been found in the Silver Queen mine on Bear Creek. In the Neigold group of claims on Galena Mountain a lead sulphobismuthite, carrying a little silver and perhaps some copper, is present as small, indistinct prisms and specks in quartz with pyrite, specularite, and bismuthite. Lastly, it is known that rich bismuthiferous ores, probably argentiferous lead sulphobismuthites, were formerly mined in the Old Lout and Poughkeepsie mines, and are probably present in varying amounts in most of the lodes of Poughkeepsie Gulch.

Tellurides.—The occurrence of tellurides of gold or silver has been noted at only four localities within the quadrangle, and at each of these in small amounts only. In some of the rich ore of Camp Bird mine a little tellurium, probably in the form of a telluride, has been detected chemically by Dr. W. F. Hillebrand, although no tellurium mineral has been recognized. In the Barstow mine small amounts of an unknown telluride are intimately associated with an argentiferous lead sulphobismuthite and pyrite. Its presence can be detected only by chemical means. At the Silver Ledge mine a small amount of a telluride resembling calaverite was found, with free gold in a single small pocket. At the Magnet mine telluride of silver, probably hessite, is, intimately associated with argentiferous galena and a little free gold in a quartz gangue.

Gold.—Isometric, but rarely showing crystal form. Usually in irregular hackly particles. Gold-yellow. Hardness, 2.5 to 3. Very malleable and ductile. Specific gravity, 15.6 to 19.3.

Free or native gold forms arborescent sheets in quartz and rhodonite in the Golden Fleece vein. In the Sunnyside Extension mine it has been found scattered through masses of spongy quartz, as implanted crystals on the faces of the quartz crystals in vugs, and embedded in yellow sphalerite and molybdenite. It is also sometimes present in the ores of the Sound Democrat and Silver Queen mines of Placer Gulch. In the Sunnyside mine it is intimately associated with quartz, rhodonite, fluorite, yellow sphalerite, and galena, and has been found embedded in the latter. In the Camp Bird it is inclosed as small particles with galena, sphalerite, pyrite, chalcopyrite, and traces of some telluride, in quartz and fluorite. In the Tomboy it is found with pyrite in quartz, but only rarely in visible particles. Visible particles are also met with in bunches in the quartz in the Gold King mine. In the mines of the Silver Lake Basin free gold is very rarely seen, and only one specimen has been noted in the Royal Tiger.

One small bunch of free gold, associated with a telluride (probably calaverite), has been found in the Silver Ledge mine. Rich pockets of free gold are reported to have been mined in early days in the Whale and Argentina lodes in Savage Basin, and it was the free gold of the Little Giant in Arastra Gulch which in the early seventies first called attention to the San Juan region.

Silver.—Isometric. Commonly filiform (wire silver). Silver white, but sometimes black through tarnish. Hardness, 2.5 to 3. Ductile and malleable. Specific gravity, 10.1 to 11.1.

Native silver is very rarely seen in the ores worked at the present day. But in the form of wire silver it was formerly found in the Pride of the West, Aspen, Ben Franklin, and Sunnyside Extension mines. It occurs occasionally in the Aspen and in the Antiperiodic mines, and, as small hackly particles and plates solidly embedded in limestone (probably Devonian), on the Fairview claim on Sultan Mountain. It is probably in all cases of secondary origin, resulting from the oxidation of other silver minerals.

Copper.—Isometric. Occurs in irregular plates and branching forms. Copper-red. Ductile and malleable. Hardness, 2.5 to 3. Specific gravity, 8.8 to 8.9.

Found in small amounts in the Royal Tiger, Tom Moore, and Sunnyside Extension mines. It is confined, as far as known, to the superficial portions of the lodes and is of later formation than the bulk of the ore. In Tom Moore it occurs in a stringer of quartz which contains small crystals of hübnerite and cuts the ore.

Hübnerite.—Tungstate of manganese, $MnWO_4$, usually with some iron. Monoclinic. One perfect cleavage. Usually in bladed prisms; often radial. Brownish red to black. Luster, submetallic or metallic-adamantine. Hardness, 5 to 5.5.

This mineral is rather widely distributed over the Silverton quadrangle as a vein mineral associated with quartz and fluorite. It is most abundant in the Adams lode on Bonita Mountain, where it forms conspicuous radial clusters of brownish-red crystals embedded in quartz and pale-green fluorite. It is also found in a quartz lode in Dry Gulch, but in smaller crystals. In the Tom Moore lode it was noted as minute brown prisms in quartz. On Sultan Mountain it has been obtained from the North Star mine, and occurs in moderate abundance in the Empire-Victoria lode. The mineral from the last-named locality is very nearly black and probably contains considerable iron, thus approaching wolframite in composition. It is embedded in quartz and pale-green fluorite.

This mineral, if found in sufficient quantities, would be valuable as an ore of tungsten. It is doubtful, however, whether any of the above-mentioned deposits contain it in sufficient abundance to render possible its commercial extraction.

PRODUCTS OF SUPERFICIAL DECOMPOSITION.

Owing to the vigorous erosion of the Silverton region, oxidized ores have seldom accumulated to great depth. Small amounts of the carbonates of copper—malachite, and azurite—and the carbonate of lead—cerussite—can be found in the croppings of most of the lodes, and cerussite was mined to some extent from the upper levels of the Silver Lake mine. Anglesite, or sulphate of lead, also occurred near the surface in the Silver Lake and Whale lodes and formed an important part of the ore body of the Zuñi mine, where it resulted from the oxidation of guitermanite. Anglesite, resulting from the oxidation of galena and often containing kernels of the sulphide, occurs in the Anaconda mine about three-fourths of a mile south of Cinnamon Pass, whence four or five carloads, carrying 55 per cent of lead and 14 to 18 ounces of silver per ton, have been shipped. In the Saratoga mine the greater part of the ore has been mined comparatively near the surface, and consisted of a soft mass of ferruginous clay carrying carbonate of lead and silver, probably native or as chloride,

Partial oxidation sometimes extends to depths of several hundred feet. The partial oxidation of the Tomboy and Camp Bird lodes at considerable depth, and the deposition within them of black oxide of manganese, are apparently due to fracturing of the original lode filling, which allowed the downward seepage of oxidizing waters.

STRUCTURE OF THE LODE ORES.

MEGASCOPICAL STRUCTURES.

Six kinds of structure have been recognized in the lode ores of the Silverton quadrangle:

1. *Massive structure.*—The quartz, galena, sphalerite, chalcopyrite, pyrite, and other minerals are all crystallized irregularly in the fissures without external crystal form and without definite arrangement. As a rule the constituent minerals appear to have crystallized practically simultaneously.

This structure is exceedingly common and is the characteristic one of the quadrangle. It is typically exhibited by the ores of the Silver Lake, Royal, Stelzner, New York City, Iowa, and East Iowa lodes of the Silver Lake Basin. The quartz sometimes incloses empty spaces, either as minute interstices between interlocking quartz prisms or as small vugs lined with quartz crystals. Occasionally, instead of being perfectly massive, the ore shows indistinct traces of the structure next to be described. The two are connected by intermediate forms.

2. *Banded structure by deposition.*—The ore and gangue minerals have been deposited in parallel sheets, distinguishable from each other by the fact that they contain the constituent vein-forming minerals in different proportions.

This is far less common than the preceding, but it is found in many small and unproductive veins and in some of the more important lodes, such as the Gold King, where the pyrite has been deposited in bands alternating with white quartz. On the large scale it is perhaps exemplified in the Sunnyside lode, where the ore streaks, themselves of massive structure, consisting of galena, sphalerite, chalcopyrite, pyrite, tetrahedrite, and free gold in a gangue of quartz, rhodonite, and a little fluorite, are separated by plates or lenses of relatively barren rhodonite.

Another form of original banding is that exhibited by the rich gold ore of the Camp Bird mine, in which sphalerite, galena, and free gold are concentrated in intricately curved and very narrow sheets in a quartz, calcite, and fluorite gangue.

In the Tom Moore mine the pay streak frequently consists of chalcopyrite in the middle with tetrahedrite on each side, the latter fading off into the altered country rock.

3. *Brecciated structure.*—Ore formed at an earlier period of deposition has been broken into angular fragments by renewed movement along the fissure, and cemented by fresh deposition of the ore or gangue.

Ore so shattered as to come under this head has not been noted as a conspicuous feature of any important deposit, although some brecciation can often be detected. The structure is best exemplified by material from the dump of the Red Cloud mine, in which an original deposit of radially fibrous pyrite has been broken up and is held together by a younger accumulation of vein quartz carrying a little sphalerite and galena, and also by vein filling from the Polar Star and Palmetto mines.

4. *Cellular structure.*—The quartz or other vein material has crystallized as a mass of irregularly intersecting septa, leaving numerous drusy cavities separated by relatively thin walls.

This is not a structure characterizing any important ore deposit, and was not seen in place. The structure is best exemplified by fragments on the dump of the Pride of Syracuse mine and on an upper dump of the Empire group, Sultan Mountain. In the latter case the septa are composed chiefly of sphalerite and galena, and the cells are lined with drusy quartz and in some cases filled with rhodochrosite. Beautiful little crystals of amber-colored sphalerite and of tetrahedrite were observed in some of the cells, implanted upon quartz.

5. *Spherulitic structure.*—The vein quartz has crystallized in prisms, often imperfectly formed, which show a marked tendency to cluster in radial fashion about local centers of crystallization.

A rough spherulitic crystallization was noted in the gold quartz of the Tomboy mine and, in connection with banding, in the Camp Bird lode. It is also a notable feature of the North Star lode, where worked in the Dives mine, and of the Magnet lode. The quartz in this case has often grown radially outward from kernels of tetrahedrite. Less conspicuous radial structure was noted in the Silver Queen at the head of Placer Gulch.

AREAL DISTRIBUTION OF THE LODE ORES.

The various mineralogical and structural types of ore are not distributed at random over the quadrangle, but a portion of the area is often characterized by ore of a certain kind. These areal subdivisions are not sharply bounded, and it sometimes happens that in a district in which a certain type of ore prevails there will occur ores that are more characteristic of some other part of the quadrangle. But, notwithstanding these transitions and exceptions, the localization of ore types is a striking feature of the region.

The lodes traversing the monzonite of Sultan Mountain are usually filled with rather coarsely crystalline vein filling, carrying galena, tetrahedrite, and chalcopyrite, with some sphalerite and pyrite, in a gangue of quartz and barite. Their chief value is in silver. The most productive of these lodes has been the North Star, which produced an ore carrying about 40 per cent lead and 70 ounces of silver. This lode is in monzonite, but mineralogically similar ore is found in the King lode in pre-Cambrian schists, said to carry about 0.1 ounce of gold, 55 ounces of silver, and 15 per cent of lead. The ore of the Empire group of veins is similar in character.

Southeast of Silverton, in the vicinity of Deer Park, are numerous mineralized fissures cutting the schists and granites, and in some cases the overlying San Juan tuff. These are occupied, as a rule, by quartz veins carrying pyrite, and a little galena, sphalerite, and chalcopyrite, with small pockets of free gold. Compared with most of the lodes in the quadrangle these veins are not heavily mineralized and are not extensively mined.

The lodes of Silver Lake Basin are characterized by coarse, massive structure and are heavily mineralized. Galena often exceeds in amount all other constituents of the vein filling, and lead is an important factor in the output. Sphalerite and chalcopyrite accompany the coarsely crystalline galena, and there is usually some pyrite present. The gangue is quartz, often containing chlorite. Tetrahedrite occurs sporadically in many of these lodes, and barite was noted in the Royal Tiger workings. These are generally low-grade concentrating ores, averaging from $8 to $15 per ton. Free gold is rarely seen, but the gold tenor in some of the lodes amounts to 2 or 3 ounces per ton. In the Silver Lake mine about half the value of the output is from the gold; the remainder being in silver, lead, and copper. The other mines contain less gold, and the Royal Tiger mine depends chiefly upon its lead. Most of the ore of Hazelton Mountain appears to have been of the general type just outlined. A thousand tons from the Aspen mine is said to have produced 110 ounces of silver per ton and 60 per cent lead, although the average tenor was less than this. An exception of the sort referred to at the beginning of this section is afforded by the Little Giant lode, on the north side of Arastra Gulch, which produced a free-gold ore.

In Maggie Gulch the greater number of the lodes contain siliceous ores, of which that of the Ridgway mine may be taken as the general type. In these ores the quartz is finely crystalline and the ore minerals occur as minute dark specks, which when abundant, give the gangue a dark, clouded appearance. In the Ridgway, the only mine working these ores on a commercial scale, the ore particles are chiefly argentite. But in other veins they are galena, and apparently not always very argentiferous. Ores similar to those of Maggie Gulch occur at various points in the northeastern part of the quadrangle, particularly in the vicinity of Mineral Point.

In Sunnyside Basin and at the head of Placer Gulch the ores are commonly of moderately coarse crystallization and carry abundant galena, sphalerite, and chalcopyrite. They are almost invariably associated with abundant rhodonite. Of low grade as a whole, they sometimes contain bunches of rich ore which, in the Sunnyside Extension mine, carried, in carload lots, as much as 74 ounces of gold per ton, mostly free. The ore of the Sunnyside mine is typical of this district.

In Poughkeepsie Gulch the ores somewhat resemble those of the Sunnyside Basin and of Mineral Point, but their most characteristic feature is the occurrence of the lead and silver in some combination with bismuth, usually as an argentiferous sulphobismuthite of lead. The ore of the Alaska mine is a well-known example.

In the extreme northeast corner of the quadrangle many of the prospects and some of the mines formerly worked contain argentiferous copper ores, usually chalcocite or bornite, with some galena and chalcopyrite.

The Red Mountain Range, embracing the region bounded by Cement, Gray Copper, and Mineral creeks, is characterized by the predominance of the stock deposits and their peculiar ores, which will be described later.

Lastly, in the northwest corner of the quadrangle, ores carrying much galena, and recalling in some of their features those of Silver Lake Basin, are associated with gold ores such as those of the Camp Bird and Tomboy mines.

The distribution of ore types as briefly sketched in the foregoing paragraphs is purely areal and is not dependent upon kind of country rock or direction of fissuring. Finally, emphasis should again be laid upon the fact that there is much overlapping and intermingling of types, and that ores of many kinds may occur in any given area. Free-gold ores, in particular, may be expected to occur in any part of the quadrangle.

DISTRIBUTION OF THE ORES WITHIN THE LODES.

Lodes are seldom equally rich in all portions. Those parts of a lode or vein which are sufficiently large and rich to be worked are known as pay shoots or ore shoots. A pay shoot is not susceptible of exact delimitation. Its size and shape depend to some extent on fluctuations in the metal market (unless purely a gold ore) and on variations in the operating expenses of the mine.

In most of the workable veins and simple lodes, such as those of Sultan Mountain and Silver Lake Basin, pay ore is usually, although not invariably, found wherever the fissure is wide enough to hold an ore body. This appears to be particularly true of the New York City, Stelzner, Royal, and Iowa veins. A partial exception to this is found in the impoverishment of the radial lodes, such as the New York City and Stelzner, near their junction with the Silver Lake lode, which is itself of lower grade, and in occasional spots where the lodes retain their width but are of too low grade to work. The pay shoots of these lodes also grow longer with depth, which is apparently due to the increasing length of the fissures as determined by the dip of the Silver Lake lode. In the Silver Lake lode the pay ore is found in bunches of varying size; but as these bunches usually occur wherever the filling of the fissure is wide and firm they probably do not constitute a marked exception to the foregoing general rule. In the Royal Tiger mine not enough work has been done to reveal the shape and extent of the ore body. In the North Star mine, on Little Giant Mountain, the ore occurred irregularly in a stringer lode, but the old stope maps show the pay shoot as a whole to have been about 700 feet in length on the levels and to have pitched to the southeast. Other small ore bodies were found farther in the mountain, to the northwest. In the Sunnyside and Sunnyside Extension mines the pay shoots are lenticular bodies 30 or 40 feet in length, lying on either the hanging or foot wall side of the lode, or between plates of rhodonite. Owing to the lack of maps, the exact size, and shapes of these ore bodies are not known.

In the Silver Queen mine, on Bear Creek, the ore occurs in three separate pay shoots, pitching south and separated by from 12 to 15 feet of lean quartz. The northern pay shoot consists of low-grade chalcopyrite, with subordinate galena and tetrahedrite. The middle ore body is rich in an argentiferous sulphobismuthite of lead associated with galena, but changes to chalcopyrite above the tunnel level. The south pay shoot is almost wholly galena. The development of this mine is very superficial and the three pay shoots may, with more extensive working, be found to be portions of one ore body.

In the Camp Bird mine the pay shoots, so far as known, appear to be coextensive with the lode, disappearing only where the fissures locally contract to a mere crack. What is known as the west pay shoot is about 1200 feet in length, and others occur along the lode, separated by pinches. The pay shoots are stated to be increasing in length with depth. As previously pointed out, the auriferous portion of the lode lies next the hanging wall, with a silver-lead streak near the foot wall.

In the Tomboy, also, the pay shoots, as indicated by the stopes, are long, and are practically identical with the lode itself, disappearing only where the latter pinches. It is beyond question that in this mine the best ore occurs in quartz which has been crushed. The solid, unbroken, unstained quartz is invariably of somewhat lower grade. As in the Camp Bird, the auriferous ore is next the hanging wall, a silver-lead streak lying near the foot wall.

From large, regular pay shoots, such as are found in the New York City, Camp Bird, and Tomboy lodes, all gradations may be found through smaller, more irregular ore bodies down to the occasional small pockets of rich ore encountered in some of the lodes of Deer Park and Maggie Gulch.

The changes which take place in pay shoots with depth are exceedingly important in mining operations. Unlike the auriferous lodes of California, which rarely show any progressive or regular change in the character of their ores even to depths of 2500 feet, the pay shoots of the Silverton quadrangle are inconstant.

In this region the pay shoots that contain chiefly ores of lead, silver, and copper may change in mineralogical character and in value within very moderate depths. But while galena in one case has been succeeded by tetrahedrite and in another case partly by sphalerite, in other lodes containing silver-lead ore, tetrahedrite (Royal Tiger and Buckeye mines) and sphalerite (Iowa lode) have been more abundant in the upper than in the lower workings. Thus the known facts do not justify a general statement that galena passes into gray copper in depth, or vice versa. The occurrence of abundant argentiferous galena and tetrahedrite in the Virginius lode at the Revenue Tunnel level, over 2000 feet below the croppings, and of galena in the deepest workings on the New York City lode, indicate that both tetrahedrite and galena may occur abundantly and retain their values at far greater depths than were reached in the Aspen, North Star, and other mines of the Silverton quadrangle, in which the pay shoots are reported to have diminished in value or to have disappeared entirely. As applied to the lodes, therefore, the often-heard dictum that galena and tetrahedrite "do not go down" is based on insufficient premises in so far as it relates to the depths ordinarily reached in mining.

With regard to the rich silver ores argentite and proustite, the known facts, incomplete as they are, seem to warrant the conclusion that these minerals occur in the upper portions of the lodes only, and do not extend to great depths, probably rarely over 500 feet in this region. This is in general accord with observations in other districts where these and other rich silver minerals occur. The vertical range of the argentiferous sulphobismuthites of lead occurring in the Silverton region is not known, but there are indications that they do not extend to great depths.

The free-gold ores have not been worked to a sufficient extent in the Silverton quadrangle to furnish reliable data as to their possible changes in value with depth. The indications, however, are in favor of a tenor that is varying but on the whole more nearly constant with greater depths than is the tenor of silver-lead ores.

RELATION OF ORES TO KIND OF COUNTRY ROCK.

So far as known, the influence of the country rock upon the deposition of the lode ores in the Silverton quadrangle is slight. Extensive ore bodies occur in monzonite, in the Silverton volcanic series and in the San Juan tuff. Although none are worked in the pre-Cambrian rocks, there is no indication that, given a suitable fissure, ores would not be deposited as readily in these as in other rocks. The influence of the wall rock upon ore deposition appears to be limited to favoring impregnation and replacement in the deposition of ores in some of the rhyolitic and latitic flow breccias and tuffs. This, however, is a phenomenon relating to the form of the deposit and to the subject of the alteration of the wall rocks rather than to the character of the ores.

ALTERATION OF THE LODE ORES.

As erosion in this high region is effected by mechanical disintegration rather than by secular decay, the oxidation of the ores is not very extensive and is sometimes negligible. In the North Star mine, on Little Giant Mountain, oxidized ore, consisting chiefly of anglesite, is reported to have extended to a depth of 200 feet. Ordinarily, however, complete oxidation is very superficial, although traces may be found at much greater depths than 200 feet. Carbonate and sulphate of lead and carbonates of copper, often associated with the unaltered sulphides, occur in the croppings of most of the lodes carrying galena and tetrahedrite or chalcopyrite. In the Silver Lake mine sulphate and carbonate of lead occurred abundantly in the highest level with unoxidized ore. At the level below, however, the secondary ores were unimportant. There is usually no sharp line separating an upper zone of oxidation from the sulphide ores. The decomposition of the original ore minerals penetrates irregularly downward wherever oxidizing waters find opportunity to descend and the level of permanent water often lies far below the oxidized portion of the lode. In the Tomboy and Camp Bird mines black oxide of manganese occurs in the deepest workings and usually indicates good ore. In these mines the oxide appears to be associated with post-mineral fracturing and crushing and to have been deposited later than the bulk of the ore. In the New York City lode of the Silver Lake mine a sooty, amorphous sulphide of copper accompanies pyrite, chalcopyrite, galena, and sphalerite. This is probably of secondary origin, and, although not a product of ordinary oxidation, is due to water percolating downward from the zone of weathering.

VALUE OF THE LODE ORES.

The lode ores of the Silverton quadrangle are generally of low grade and require careful mining and milling to yield profitable returns. They range in value from about $6 to several thousand dollars per ton. The extremely high values, however, are for ores carrying free gold and occurring only in small amounts in pockets in otherwise low-grade lodes, or in very small veins, such as the Golden Fleece. From the Sunnyside Extension mine, however, ore was obtained in carload lots carrying $1500 per ton in gold alone. In Silver Lake Basin the ores vary from $8 to $70 per ton, according to the proportion of lead, silver, or gold which they contain. The ore from the Iowa mine averages $12 per ton, although in places it contains from 2 to 3 ounces of gold, thus giving higher returns. The general average of the Silver Lake mine is probably higher, as half the value of output is in gold. The ore of the Royal Tiger is, on the other hand, lower, the product being chiefly lead. The North Star mine, on Sultan Mountain, in 1882 produced large quantities of ore carrying, according to the Mint reports, 40 per cent of lead and 70 per cent of silver. At the commercial values for that year this means an ore of about $120 per ton, gross value, or, at present prices, about $72 per ton. The Aspen mine is said to have produced one lot of 1000 tons of ore containing 110 ounces of silver and 60 per cent of lead, which at present prices would correspond to about $110 per ton. The average value of the ore from this mine was, however, probably less than half this. The shipping ore from the Ridgway mine, containing finely disseminated argentite, is reported to average $110 per ton, of which about 3 ounces is in gold and the rest in silver. The free-gold ore of the Tomboy mine averages about $20 per ton, of which $19 is in gold. The most uniformly rich ore now worked in quantity in the quadrangle is undoubtedly the gold ore of the Camp Bird. This is all milled, and averages from $40 to $200 per ton. The gold ore of the Gold King mine is generally of low grade and can be worked as economically as any in the quadrangle.

THE STOCKS OR MASSES.

DEFINITION AND GENERAL DESCRIPTION.

Stocks are irregular bodies of ore possessing distinct boundaries. They differ from veins or lodes in the absence of a characteristic tabular form, and from impregnations in being fairly solid masses of ore with definite limits.

The stocks of the Silverton quadrangle are nearly vertical, cylindrical, lenticular or spindle-shaped bodies of almost solid ore, surrounded by an envelope of much-altered, partly silicified country rock, which is usually impregnated with pyrite. Neighboring ore bodies are commonly connected by fissures filled with gouge or kaolin. The sizes of the individual ore bodies vary greatly. In plan, lengths of 40 or 50 feet and widths of 10 to 15 feet appear to have been not uncommon. Accurate sections of stocks are not now available, but individual ore bodies were followed in many cases through several levels, and therefore had vertical dimensions of several hundred feet. Although sometimes nearly circular, the ore bodies generally show an elongated or elliptical plan, the longer axis of which usually lies more nearly north and south than east and west. The direction of the longer axis is not, however, constant for all depths.

The ore bodies, particularly in the deeper workings, are usually found within nearly vertical zones of fractured, altered country rock, locally known as "ore breaks."

DISTRIBUTION.

The stocks do not occur in all portions of the quadrangle, but are limited to a small, well-defined area, which includes the crest and western slope of the Red Mountain Range. This district is bounded on the northeast by Gray Copper Creek, on the northwest by Red and Red Mountain creeks, on the west and south by Mineral Creek, and on the east, with one or two exceptions near Red Mountain No. 3, by the ridge crest extending from Anvil Mountain northward to Red Mountain No. 3 and thence northeastward to the saddle at the head of Gray Copper Gulch. The area thus outlined has certain characteristic features, apparent to the most unobservant eye. There is scarcely an exposure of rock within it which has not been bleached, silicified, or otherwise altered, and the whole has been thickly impregnated with fine crystals of pyrite. The iron originally contained in this pyrite, through weathering and oxidation, has given to the Red Mountain Range the beautiful coloring for which the region is noted, blending from the deepest red, through vermilion and orange tints, to the most delicate yellow and gray.

The greater part of the deposits, and all the more important ones, are closely grouped in the northwestern part of this area, in a belt less than a mile wide and about 4 miles long, extending from Ironton to a point about a mile south of Red Mountain village.

Although no continuous fissures or veins can be detected on the surface, the St. Paul, Congress, Senate, Hudson, Enterprise, Charter Oak, Genesee-Vanderbilt, Yankee Girl, Robinson, Guston, White Cloud, and Silver Bell mines all lie close to a straight line bearing about N. 21° E. The National Belle, Paymaster, and Grand Prize mines, and a host of less-noted claims, are apparently irregularly disposed on both sides of this line.

South of the vicinity of Red Mountain the stock deposits are scattered and have not proved of much value. The only one which has produced ore in important amounts is that of the Zuñi mine, on Anvil Mountain, which, however, is interesting chiefly as the source of the minerals guitermanite and zunyite.

ORIGIN OF THE SPACES NOW FILLED WITH ORE.

The ore spaces were formed primarily by complex, intersecting fissuring, and were enlarged both by solution and by metasomatic replacement. The dominant fissuring strikes between 20° and 30° east of north and is well shown along two principal zones. But there was also much minor fracturing in other directions. At the intersections of the fissures the country rock was usually brecciated and furnished channels for ascending currents of warm or hot mineral-bearing waters which effected pronounced hydrothermal metamorphism. That such waters could enlarge the irregular conduits through which they circulated, either prior to or during the deposition of the ore, seems likely when the shape of the ore spaces and the extent to which the rocks in their vicinity have been altered are considered. Not only was the fissuring locally complex, but the ascending thermal waters had more chemical activity than elsewhere within the quadrangle, so that they enlarged zones or aggregations of fractures into ore spaces and metamorphosed the country rock to an extent not elsewhere observed in this region. The cause of this local intensity of chemical and physical activity is not known, although it is probable that the circulating intratelluric waters were here hotter and more copious than elsewhere. Some indication of the latter is afforded by the abundant strongly mineralized springs which issue from the surface in this district at the present day. There is, moreover, some geological grounds for believing that the Red Mountain region was formerly a center of local volcanic activity.

There has probably been fracturing of the rocks, or at least movement along existing fissures, since the ore bodies were formed, but there are not at present facilities for studying the relation of the older to the later fissures.

ORES OF THE STOCKS.

CHARACTER AND STRUCTURE OF THE ORE.

It is very difficult, in the present condition of the mines, to give a satisfactory account of the mineralogy and structure of the ores of the stocks. The chief difference between them and the ores of the lodes is that the stock ores form nearly solid masses, with very little gangue. The presence of enargite, moreover, is apparently peculiar to the stock deposits, the mineral not being known in the lodes. It does not, however, occur in all of the stocks. The common ore minerals of the latter are galena, sphalerite, tetrahedrite, enargite, chalcocite (stromeyerite), bornite, chalcopyrite, and pyrite. While the galena ore of the upper levels is argentiferous, the highest silver values occur with the copper-bearing minerals, especially with the chalcocite, bornite, and chalcopyrite. These three ore minerals are almost invariably accompanied by pyrite. In the richer parts of the ore bodies the pyrite is subordinate, and is found chiefly in the outer portions of the stocks. But in the poorer ores the argentiferous copper minerals occur as nodular bunches in masses of low-grade pyrite carrying up to 5 per cent of copper, a little silver, usually less than 10 ounces per ton, and a fraction of an ounce of gold. The pyrite usually forms a rather fine-grained and sometimes crumbling aggregate, but in the Zuñi mine occurs in beautifully sharp octahedra embedded in white kaolin. Bismuthiferous ores of silver and lead occur in some of the ore bodies, notably in the Silver Bell and Genesee-Vanderbilt. Specimens from the latter mine contain a bright lead-gray mineral having the physical properties of cosalite, which chemical tests show to be slightly argentiferous sulphobismuthite of lead containing a little copper. Cosalite occurs also in the Yankee Girl. The rare mineral, kobellite, a sulphantimonite of lead with bismuth partly replacing the antimony, was found in the Silver Bell mine and carried from 3 to 4 per cent of silver. The only other known occurrence of this mineral is at Hvena, Sweden. The rich silver ores proustite and polybasite occur in the Yankee Girl, Genesee-Vanderbilt, and probably other mines of this district. Tennantite is reported from the National Belle mine. Zinkenite has been described by Hillebrand from the Brobdignag claim, a now abandoned prospect in the Red Mountain Range near Chattanooga. Guitermanite and zunyite are found in the Zuñi ore body and in a few adjacent prospects. Zunyite forms small sparkling, colorless tetrahedrons embedded in the massive, bluish lead-gray guitermanite. Barite is apparently always present in the ores of stock deposits. It often occurs as isolated crystals or crystalline masses embedded in the argentiferous bornite of the Guston and Yankee Girl mines, and these inclosed masses occasionally carry free gold. In the Zuñi it is intimately associated with pyrite and kaolin. The latter mineral is associated with the ores of all the Red Mountain mines, sometimes occurring in the ore or serving as a matrix to pyrite, as in the Zuñi, but is present more abundantly in fissures in the wall rock and as a direct product of the alteration of the latter.

Although the common structure of the principal ore bodies is that of a solid and massive aggregate, yet there is evidence that vugs or cavities sometimes occur in the unoxidized ores. Stalactites of pyrite, having the radial structure usually considered as characteristic of marcasite, were seen, which were said to have come from caves in the Genesee-Vanderbilt. Specimens of enargite from the National Belle mine, preserved in various cabinets, show a free development of clusters of radial prisms of enargite, such as could only have formed in open spaces. The well-crystallized specimens of polybasite which have come from the Red Mountain district were also probably formed in vugs.

CHANGES IN THE ORE WITH DEPTH.

As indicated in the preceding section, the ores of some of the stocks are partially oxidized down to the ground-water surface. This secondary alteration is particularly noticeable in the National Belle mine, and to some extent in the Genesee-Vanderbilt mine, but is less conspicuous in the Yankee Girl, Guston, and other mines, whose ore bodies outcrop nearer to Red Creek. The oxidation has no unusual features, and consists chiefly in the transformation of galena to carbonate and sulphate of lead, with removal of more soluble constituents, reduction in the bulk of the ores, and the consequent formation of caves. Even when, as in the National Belle, the ore of the deeper workings is chiefly enargite, the oxidized ores nearer the surface are largely composed of lead compounds. This result is probably less a consequence of any peculiar process of oxidation than of the relative disposition of the sulphide or unoxidized ores prior to weathering.

In spite of some diversity shown by the different ore bodies, there is after all remarkable uniformity in the change at very moderate depths—usually less than 300 feet—from an ore consisting chiefly of argentiferous galena to highly argentiferous silver-copper ores, and then a gradual diminution of value downward through the increasing proportion of low-grade pyrite in the ore bodies. These changes are best recorded in the Yankee Girl, Guston, and Silver Bell mines. There are certain exceptions to what may be regarded as the normal or complete sequence. Thus the Congress ore body, from the croppings downward, consists chiefly of enargite, with some bunches of galena. That the enargite at greater depth will gradually give place to iron pyrite, with diminishing amounts of chalcopyrite, can scarcely be doubted in the light of what is known of other deposits of this district. In the National Belle, enargite—in this case of low grade—was found near the surface, but the oxidized ore in the siliceous knoll which forms the croppings was derived chiefly from galena, while below the third level practically no pay ore was found. Explorations on the fourth level resulted only in the finding of small bunches of good ore and masses of crumbling iron pyrite carrying less than 0.1 ounce of gold and about 5 ounces of silver per ton, with from 1 to 3 per cent of copper.

Chalcopyrite appears usually to have been good ore. It contains, theoretically, 34.5 per cent of copper, and in the Red Mountain district carries silver and gold; but its appearance in great quantity is apparently a precursor of the ultimate change to ores carrying chiefly the low-grade iron pyrite.

Although there is on the whole a general change from argentiferous lead ores to argentiferous and auriferous copper ores, and finally to slightly argentiferous and auriferous pyrite, yet the progression is overlapping and irregular in detail. Pyrite and chalcopyrite occur at practically all depths, and galena in small bunches is sometimes found far below the point at which it ceases to be the principal ore.

VALUE OF THE ORES.

The ores of the stocks, like those of the lodes, vary widely in value. In 1883, 3000 tons of ore extracted from the Yankee Girl averaged nearly $150 per ton. A lot of 10 tons from the richest stopes of the same mine carried 3270 ounces of silver per ton and 29 per cent of copper, corresponding to an average value of about $3,000 per ton. Much richer ore than this was found in small quantities in the Yankee Girl and Guston. The average sales value of the ore of the Guston was $91.81 per ton for a period of eight years. The highest annual average was $363.25 per ton, and the lowest $10.70. These are the prices for which the ore was sold to the smelters. Values based directly upon metallic contents, without reference to cost of treatment, would be higher. The highest annual average represents the ore from the rich stopes above the seventh level. The lowest corresponds to the low-grade pyritic ore of the deeper levels. The richest ore recorded from this district was taken in 1891 from the Guston at a depth of 378 feet. It carried 15,000 ounces of silver and 3 ounces of gold per ton, and was worth at the current price of silver $14,880.

The ore of the Genesee-Vanderbilt was of much lower grade than that of the Yankee Girl, Guston, and Silver Bell. Its gross value for any one year probably never averaged more than $40 per ton. No records, however, are available for the ore taken out prior to 1893, when the price of silver stood higher. The ore of the National Belle was also of low grade, but its average value is not known.

MINERAL WATERS ASSOCIATED WITH THE ORE DEPOSITS.

Probably all the waters met with in the mines of the Silverton quadrangle now accesible are meteoric waters variously modified by the materials through which they have passed in their indirect descent from the surface. The abundance of these waters varies much in different mines, and fluctuates with the seasons. In the Gold King mine scarcely a drop of water reaches the lower levels. Many other mines, such as the Silver Peak and Iowa, which are moderately wet in summer, become nearly dry in winter, owing to the freezing of the ground near the surface. No noticeable spring of ascending mineralized water issues from the ore deposits now being worked. The descent of meteoric water through masses of pyrite and other ore minerals is often sufficient, however, to give it a strong acid reaction and render it highly ferruginous.

In the Red Mountain district the troublesome acid character of the mine water was notorious. In spite of its abundance, however, it is not improbable that this, too, was meteoric water which had become strongly charged with sulphuric acid by its oxidizing passage through the adjacent bodies of pyrite and through the masses of altered pyritized country rock which surround the ore.

Strongly ferruginous springs are abundant within the drainage of Cement Creek and in the upper basin of Red Mountain Creek. When their waters are brought in contact with the atmosphere the iron is oxidized and is deposited near the spring as a mound or apron of limonite, or it accumulates as bog iron in the swampy ground along these creeks. Such springs, with their accompanying deposits, may be seen near Burro Bridge, also just below Chattanooga, and near the village of Red Mountain. A spring of the same general character issues from the hillside about 150 feet above the Guston mine, and has deposited a large apron of limonite. At present the water flows from a tunnel which was run into the limonite, and has cemented the dump of the tunnel into a firm, ferruginous mass. There is no definite evidence connecting the ferruginous springs of this region directly with the original processes of ore deposition, nor is it necessary to assume that their waters have come from deep-seated sources. The mine waters of the Yankee Girl and Guston are said to have carried much copper in acid solution. This is to be expected wherever surface waters carrying oxygen percolate through pyrite and chalcopyrite.

METAMORPHISM IN CONNECTION WITH ORE DEPOSITION.

The metamorphism or change which has been effected through the agency of the mineral-bearing solutions (hydrothermal metamorphism) in the rocks adjacent to the ore bodies differs markedly in degree, and to a less extent in character, in different portions of the quadrangle.

The mode of alteration is in general by *metasomatism* (literally change of body), which signifies the process by which a mineral, through chemical reactions, undergoes a partial or complete change in its chemical constitution. Rocks or aggregates of minerals are "metasomatic" if any or all of the constituent minerals have undergone such changes.

In Silver Lake Basin the simple fissure veins which there predominate, carrying galena, sphalerite, chalcopyrite, pyrite, and sometimes tetrahedrite, in a gangue of quartz with frequently some barite, are not accompanied by any very evident or striking alteration of the immediate wall rock.

The rocks in which the ore deposits of Silver Lake Basin occur are chiefly latitic breccias. In the neighborhood of the mines these breccias have been generally altered to an unknown depth. The alteration involves the change of feldspar to sericite, calcite, and quartz; of augite to calcite and chlorite; and of biotite to chlorite, sericite, and rutile. Although this metamorphism is probably connected with the ore deposition, it is so general that its connection with the deposition of ore in any given fissure can not be recognized. It appears to have been effected by water charged with carbon dioxide or carbonates. The change in the rocks is propylitic in nature, and should be distinguished from ordinary weathering, with which it is often confused. Close to the veins, usually within a few inches, and in small horses of country rock within the veins, metamorphism of a different kind frequently occurs. Here calcite and chlorite have diminished in amount or are wholly absent, and quartz and sericite constitute the bulk of the rock. This alteration, which plainly emanates from the individual fissure, differs from the more general metamorphism less in kind than in the relative proportions of calcite and chlorite on the one side and of quartz and sericite on the other. This usually inconspicuous and very local alteration of the wall rock to quartz and sericite is rather common within the quadrangle, especially near lodes in the latitic rocks of the Silverton series or in the andesitic San Juan tuff. It occurs in pronounced degree in the Ridgway mine, which produces an argentite ore. It is the usual alteration seen in the mines of Savage Basin, Sultan Mountain (in monzonite), and in many other lodes where metamorphism of the country rock other than that of propylitic character is not a conspicuous phenomenon, and where no special microscopical study of wall rock was made.

Kaolinite was not identified in the altered wall rocks of Silver Lake Basin, but in the Dives mine (on the North Star lode) it apparently occurs with sericite and quartz. Metamorphism in connection with the Dives ore body is similar to that just described in detail for the Silver Lake mines; but in its greater intensity, in the presence of kaolinite, and in the more evident silicification of portions of the wall rock it is intermediate in character between that metamorphism and the kind next to be described.

The metamorphism associated with the ore deposits of Engineer Mountain and of the Red Mountain district is different from that just discussed. As the ore of Engineer Mountain occurs in lodes in andesite and that of the Red Mountain district is prevailingly in stocks in andesitic breccia, and as the metamorphism presents some phases of difference in the two modes of occurrence, they will be separately treated.

The Polar Star lode, which has produced some rich silver ore carrying argentite and proustite, may be considered as a type of the Engineer Mountain deposits.

The characteristic features of the Polar Star metamorphism are (1) its limitation to the immediate vicinity of the lode, (2) the removal of at least 2 per cent of the substance of the rock, including all of the magnesia and carbon dioxide, nearly all of the alkalies and lime, and much of the iron, (3) the addition of silica, water, alumina, and sulphur, and (4) the formation of a secondary aggregate chiefly of quartz, kaolinite, pyrite, diaspore, and sericite.

The depth to which this alteration extends is not known. The specimens studied evidently came from the deepest workings, probably over 500 feet from the surface.

The metasomatic alteration of the rocks of the Red Mountain Range is not limited to the immediate vicinity of known ore bodies, but it is so widespread as to be a serious embarrassment to the geologist intent upon unraveling the relations of the various igneous rocks involved.

As a rule, the metamorphosed rocks, where not superficially stained by iron oxide, are nearly white. Frequently traces of original structure, such as outlines of feldspar phenocrysts or of breccia fragments, can be recognized, but not uncommonly these, too, have vanished, and the rock has become a white granular aggregate resembling a fine-grained quartzite. Of such origin and character is most of the so-called "quartz" of the Red Mountain mines, which forms the siliceous knobs in which many of the ore bodies outcrop.

The notable features of the alteration are the introduction of silica, water, and sulphur, the total removal of iron (except that combined with sulphur to form pyrite), magnesia and carbon dioxide, and the almost entire abstraction of lime and alkalies. The occasional formation of diaspore brings this alteration close to that described at the Polar Star mine, the original rocks in both cases being of similar chemical composition, while the addition of silica and the formation of kaolin, usually without sericite, is characteristic of the Red Mountain mines.

This is a very different alteration from that normally brought about by waters carrying alkaline carbonates, which tend to form sericite and carbonates in the wall rock. It is believed to be due to acid waters.

The conspicuous metamorphism of the Red Mountain region has involved rocks of various kinds, reducing them all to light-colored secondary aggregates of similar appearance. Andesites, latites, monzonite-porphyry, and rhyolite have been altered to products which often give little indication of the nature of the original rock. But in many portions of the quadrangle the rhyolitic rocks show certain characteristic phases of metamorphism in connection with ore deposition which seem to merit special notice. This rock, when acted upon by ore-bearing solutions, is particularly susceptible to recrystallization into secondary aggregates of quartz and sericite, quartz and kaolin, or quartz, sericite, and kaolin. As a rule such metasomatic alteration is accompanied by partial replacement of the rock by ore, as may be seen in the Tom Moore or Silver Ledge mines.

PARAGENESIS OF THE LODE AND STOCK ORES.

By *paragenesis* is here meant the association of the various ore and gangue minerals with special reference to the order and mode of their formation.

Beyond the common and well-known derivation of certain secondary minerals in the zone of oxidation, as, for example, anglesite or lead sulphate from galena, the directly observable paragenesis of the ores offers few points which can be embodied in any general statement of regular association. As a rule the ore minerals which are found together in any deposit have formed contemporaneously, and a definite and constant succession of different ore minerals can rarely be recognized. In the Tom Moore lode chalcopyrite formed after tetrahedrite. The same relation exists in the Dives lode, where masses of tetrahedrite are surrounded by envelopes of chalcopyrite from which radiate still younger quartz crystals. But in many other lodes tetrahedrite and chalcopyrite occur in such relations as to indicate contemporaneous crystallization. In the Empire-Victoria lode, on Sultan Mountain, hübnerite and fluorite have formed since the ore was deposited. Native copper is always of later origin than the sulphide ores with which it is associated. Native silver was seen only in detached specimens of ore, but it occurs characteristically in the upper portions of the deposits and is undoubtedly of secondary origin. Quartz of at least two generations is common, as shown by the relatively barren stringers of this mineral, which traverse the ore of many deposits.

Free gold is usually embedded in quartz and is associated with pyrite or chalcopyrite. In the Sunnyside, Sunnyside Extension, and Camp Bird mines it is also associated with fluorite and pale-yellow sphalerite. Some specimens from the Sunnyside Extension mine show crystals of gold implanted on quartz.

Unfortunately there are few opportunities for studying the occurrence of proustite and argentite in the Silverton quadrangle. In the Ridgway mine much of the argentite is implanted on, or wedged between, the quartz crystals of small vugs, and was the last mineral to crystallize. It is the universal experience in the Silverton district that argentite, proustite, and polybasite are comparatively superficial ores. The data at hand do not fix the depth at which these rich argentiferous minerals change to low-grade ore, but the indications are that it is less than 1000 feet, although it is well known that in other regions some of them extend to greater depths. It is probable that in the Silverton region proustite, argentite, and polybasite are secondary and indicate a zone of enrichment.

The downward change from galena through richly argentiferous copper ores to chalcopyrite and pyrite, which is characteristic of many of the Red Mountain mines, though a case of paragenesis on a large scale, will be discussed in the following section, on the origin of ores. The origin of the rhodonite, which is so abundant in many of the lodes of the northern half of the quadrangle, and its exact relation to the quartz and ore which accompany it, constitute a puzzling problem, for which no satisfactory solution has been found. Such a solution must account for the large lenticular masses of rhodonite, carrying a few specks of low-grade ore and dividing the ore bodies longitudinally into two or more parts, and for the stringers of rhodonite in the ore. In the Saratoga mine rhodonite has formed by metasomatic replacement of limestone. It is possible that in such lodes as the Sunnyside the large, solid masses of rhodonite within the vein may be metasomatically altered horses of country rock. Rhodonite has undoubtedly been deposited also in open fissures as a true vein mineral.

ORIGIN OF THE LODE AND STOCK ORES.

That the ores of the Silverton quadrangle were deposited from aqueous solution needs no special demonstration. They were precipitated partly in open spaces, and partly as metasomatic replacements. Their deposition was accompanied by chemical and mineralogical changes in the adjacent country rock, producing effects which in the majority of cases diminish rapidly in intensity with increasing distance from the fissure walls. So far as known, the deposition of ore within the fissures was not affected by differences in character of the wall rock. It is believed that the facts presented in the descriptive portions of this folio indicate an initial primary deposition by ascending mineralized waters. It is not known from what particular rocks the ores were extracted nor at what depth most of the solution took place.

That the process of ore deposition was directly connected with volcanism can scarcely be doubted. The most obvious aspects of this connection are threefold: (1) The mechanical formation of the fissures; (2) the accession of the heat, whereby the chemical activity of underground water was intensified; and (3) the accumulation of vast masses of igneous rock from which, at some depth, the constituents of the ore minerals were probably in part derived. It is possible that there should be included here also the evolution of carbon dioxide, sulphydric acid, and other volatile substances, as active solvent and chemical agents.

Nearly all aqueous solutions that occur in nature may, under suitable conditions of heat and pressure, act as solvents and carriers of the heavy metals and their sulphides. Some solutions are undoubtedly more efficient than others under like conditions, but where so many unknown elements, such as temperature, pressure, relative masses of solvent and dissolved substance, and duration of the process, enter into the problem, it is rarely possible to arrive at even approximate quantitative results.

As the lode and stock ores were deposited from solutions, it follows that the chemical action of these solutions on the wall rocks offers a very important mode of attacking the problem of their chemical character. The nature of this metasomatic alteration has been indicated and it is concluded that the solutions producing it were chemically different in different portions of the quadrangle. The very slight development of carbonates in connection with some lodes, and their entire absence in others, indicate that carbon dioxide or alkaline carbonates were not abundant in the mineralizing waters, although probably not wholly absent in the case of deposits such as those of Silver Lake Basin. The silicification associated with the Red Mountain deposits, the removal of most of the bases, including in some cases part of the alumina, and the addition of sulphur and water, indicate the action of acid waters, probably containing free sulphuric acid. But water containing sulphuric acid and ferric sulphate is known in the Red Mountain region to-day, not as ascending thermal water, but (in part at least) as descending water, which owes its acidity to the oxidation of iron pyrite. The capacity of this water to effect changes in the country rock is beyond doubt. It is likely, therefore, that much of the alteration in the Red Mountain area is the final result of the action of different solutions on the rock at different times.

Ore deposits that show an orderly vertical succession from rich sulphides near the ground-water level to poor sulphides at greater depth are usually the product of two concentrations—a concentration by ascending waters and a further concentration by descending waters. These two processes may go on at the same time, or they may operate successively. The facts observable in the Red Mountain region point to the original deposition of bodies consisting chiefly of pyrite carrying a little gold, silver, and copper. The lead may have originally been sparingly deposited as galena with the pyrite. It is into such low-grade auriferous and argentiferous pyrite, carrying 2 or 3 per cent of copper and containing an occasional bunch of galena, that the rich ore bodies graded in the Guston, National Belle, Silver Bell, and Yankee Girl mines.

Subsequently, as the surface of the region was reduced by erosion, descending waters, which found ready passage through the fissured and mineralized rocks of the region and through the upper portions of the lean primary ore bodies, effected a second concentration, which produced the rich ore formerly mined. These descending waters are known to have been heavily laden with the sulphates of iron and copper and other salts resulting from oxidation of the upper portions of the ore bodies. As they penetrated downward they probably acted upon the low-grade pyritic ore, replacing part of the iron sulphide by sulphides of copper and silver.

The hypothesis of secondary enrichment, which affords the most satisfactory explanation of some of the peculiar features of the Red Mountain deposits, has, if its application is correct, important consequences. It indicates that the rich ores formerly mined have a lower limit which is probably less than 1000 feet in depth. While small bodies of rich ore may occur deeper than this, it is probably not worth while to prospect for them when once the depth has been reached at which the ore is practically all low-grade pyrite. On the other hand, as some pyrite occurs at all depths, and as the vertical limits of the zones of enrichment are necessarily irregular and overlapping, it is unwise to suspend operations merely because the ore falls off locally in value and becomes pyritic.

When we pass from the Red Mountain stock deposits to the lodes occurring in other portions of the quadrangle, the evidence of secondary enrichment is less easily read. It seems probable that the rich silver minerals, such as polybasite, proustite, and argentite, are the result of secondary enrichment. In the San Juan region, however, the steps of the alteration of lower-grade ores into those rich in silver can not be traced. The evidence of secondary origin is that these rich minerals occur largely in vugs, and that in several cases they pass at moderate depths into low-grade ores. These features, however, do not in themselves preclude the idea that the minerals are primary and were formed by original deposition in a zone where ascending and descending waters mingled.

In the Tomboy mine the undoubted association of the richest gold ore with shattering and movement in the lode, accompanied by some oxidation far below the level of general weathering, is suggestive of secondary enrichment. In the Silver Lake mine it is reported that rich bunches of ore are associated with secondary or "post-mineral" fissuring, which, if true, is also indicative of some secondary enrichment below the zone of oxidation.

THE GROUND WATER.

In many mining regions the depth of the ground-water surface is a matter of much importance, as by it are frequently determined questions of mine drainage and the depth at which oxidized ore changes to unoxidized ore. In the Silverton region, however, erosion has proceeded with such celerity relative to processes of oxidation and weathering that the change is largely independent of the depth of the ground water.

In most hilly regions the upper surface of the ground water is a subdued copy of the topographic relief. In the exceedingly rugged and much fissured Silverton area, however, the ground-water surface is very much less accentuated than the topography. Not only is the water tapped and drained by the deep ravines, but its level is modified by the tunnels run into the mountains, sometimes several thousand feet below the crests of the ridges. Under these conditions it is often impossible to predict at what depth the ground-water surface will be reached in mining operations.

Tunnels driven from the floors of the high basins do not, as a rule, encounter permanent ground water. Those run below the basins, such as the Unity tunnel, or from the bottoms of the deeper ravines, such as the Highland Mary tunnel in Cunningham Gulch, the Bonanza tunnel near Animas Forks, the Old Lout tunnel in Poughkeepsie Gulch, the Revenue tunnel, the North Star tunnel on Sultan Mountain, and the Empire tunnel near Silverton, usually tap the ground water and artificially lower its surface within the overlying rock. In the shafts of the Red Mountain district permanent water is found at depths varying from 50 to 200 feet below the surface, dependent upon the location of the shaft and the seasonal fluctuations of the ground-water surface, which sometimes exceed 50 feet. In the Red Mountain district the ground-water surface is highest in spring or early summer.

REPLACEMENT DEPOSITS.

Between certain replacement deposits and the metasomatic impregnations frequently accompanying fissure veins or stocks no sharp distinction can be made. Whether the deposit shall be classed as a vein or as a replacement deposit may depend merely upon the quantitative relation between the ore found within the walls of the fissure and that occurring in disseminated particles or in larger masses in the metasomatic country rock. The Red Mountain stocks undoubtedly owe their form partly to metasomatic replacement, and might almost as well be described under this head. Ore-bearing fissures traversing rhyolitic rocks are in this region frequently accompanied by notable replacement of the wall rock by ore. But there are a few deposits where replacement is so conspicuous a feature and where so small a part of the ore occurs within distinct fissure walls that but little doubt need arise as to their proper classification. They are, however, neither abundant nor relatively important in the Silverton quadrangle.

Direct replacement of limestone by ore occurs in the Ouray limestone on the eastern side of Ironton Park. At the Saratoga mine the ore, consisting in its unoxidized state of pyrite, chalcopyrite, and galena, with perhaps a little argentite, has irregularly replaced the upper part of this limestone. The ore-bearing solutions have been active chiefly along the contact between the limestone and the overlying San Juan tuff. A little Telluride conglomerate, consisting largely of limestone pebbles, outcrops near the adit of the mine, between the limestone and the overlying volcanic series. It has been silicified and probably partly replaced by ore, but was not recognized in the main workings. The ore is sometimes associated with rhodonite, which has also replaced the limestone and often incloses residual kernels of the latter. The ore was probably deposited by solutions rising through one or more northeast-southwest fissures, although no direct connection of the ore with any of the fissures could be made out. In the Baltic mine a similar but lower-grade ore occurs, also as a replacement of the upper portion of the same bed of limestone. This ore, however, is directly connected with an ore body filling a fault fissure (the Mono vein). In the Maud S. claim, which is part of the Baltic group, some argentiferous copper ore occurs in bunches in the same limestone alongside a fault fissure. The direct connection between the replacement ore bodies of the Baltic group and a system of northeast-southwest fault fissures strongly suggests that a similar connection does or did exist in the case of the Saratoga ore body.

In the southern portion of the quadrangle the Ouray limestone at the east base of Sultan Mountain carries disseminated particles of native silver on the Fairview claim, and in an undeveloped prospect near the King mine a body of chalcopyrite occurs partly in a fissure and partly as a replacement of the limestone near the fissure. The ore replaces the underside of the limestone, and rests upon the Elbert formation.

The facility with which the rhyolitic rocks of this region become metasomatically replaced by ore has already been noted. In most cases such replacement is a minor accompaniment of the deposition of ore in fissures. But at the Silver Ledge mine replacement is the dominant mode of occurrence. The ore, consisting of galena and sphalerite, occurs along a zone of fracturing and faulting which trends N. 20° E. These fractures contain crushed country rock and ore, and there has evidently been movement along them since the ore was deposited. The principal ore bodies, however, are not within the fissures, but occur as irregular replacements of the rhyolite which forms their walls. Some bodies of ore have been followed into the country rock for 30 or 40 feet from the main fissures. The replacement is sometimes complete, resulting in solid masses of ore. More often the ore is disseminated, in which case there is no definite boundary to the ore body, and only so much of it is removed as can be profitably worked.

The deposition of the ore has been accompanied by complete local recrystallization of the rhyolite to a nearly white, minutely crystalline aggregate of sericite, kaolin, and quartz, with generally a little rutile and occasionally a small amount of calcite. The proportions of the three principal constituents vary, some facies of the rock consisting chiefly of sericite and kaolin, while others are largely sericite and quartz.

MISCELLANEOUS MINERAL RESOURCES.

Compared with the extraction of gold, silver, copper, and lead, all other mineral operations in the quadrangle are insignificant. At present no deposit is worked for zinc, but sphalerite ores are abundant. As a rule, ore bodies showing much sphalerite with subordinate galena have been little prospected, on account of the smelter penalty attaching to an excess of zinc in ores smelted for other metals. But with the increasing demand for zinc ores it is likely that some of the sphalerite lodes may be worked for this metal.

The occurrence of hübnerite (tungstate of manganese and iron) on Cement Creek has aroused expectations of the profitable exploitation of the deposits. The mineral is easily separated from its gangue, but it is doubtful whether it occurs in deposits of sufficient size to justify extensive operations.

Bog iron ore occurs in the swampy ground along Mineral Creek and in Ironton Park as a deposit from iron-bearing springs. It was formerly used in Silverton as a flux in smelting, but has at present no market.

Limestone occurs at several points in the peripheral portions of the quadrangle, and has been burned near Silverton to supply local demand.

Building stone is not in much request. Particularly good stone might be quarried from the monzonite of Sultan Mountain were there any demand for a building material involving so much labor in its production.

May, 1901.

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

TOPOGRAPHY

COLORADO
SILVERTON QUADRANGLE

LEGEND

RELIEF
(printed in brown)

Figures *(showing heights above mean sea level instrumentally determined)*

Contours *(showing height above sea, horizontal form, and steepness of slope of the surface)*

Depression contours

DRAINAGE
(printed in blue)

Streams

Intermittent streams

Ditches

Lakes and ponds

CULTURE
(printed in black)

Roads and buildings

Trails

Railroads

County lines

Triangulation stations

Bench marks

E.M. Douglas, Geographer in charge.
Control by Frank Tweedy.
Topography by W.M. Beaman and Arthur Stiles.
Surveyed in 1895 and 1900-1901.

APPROXIMATE MEAN DECLINATION 1901.

Scale $\frac{1}{62500}$

Miles

Kilometers

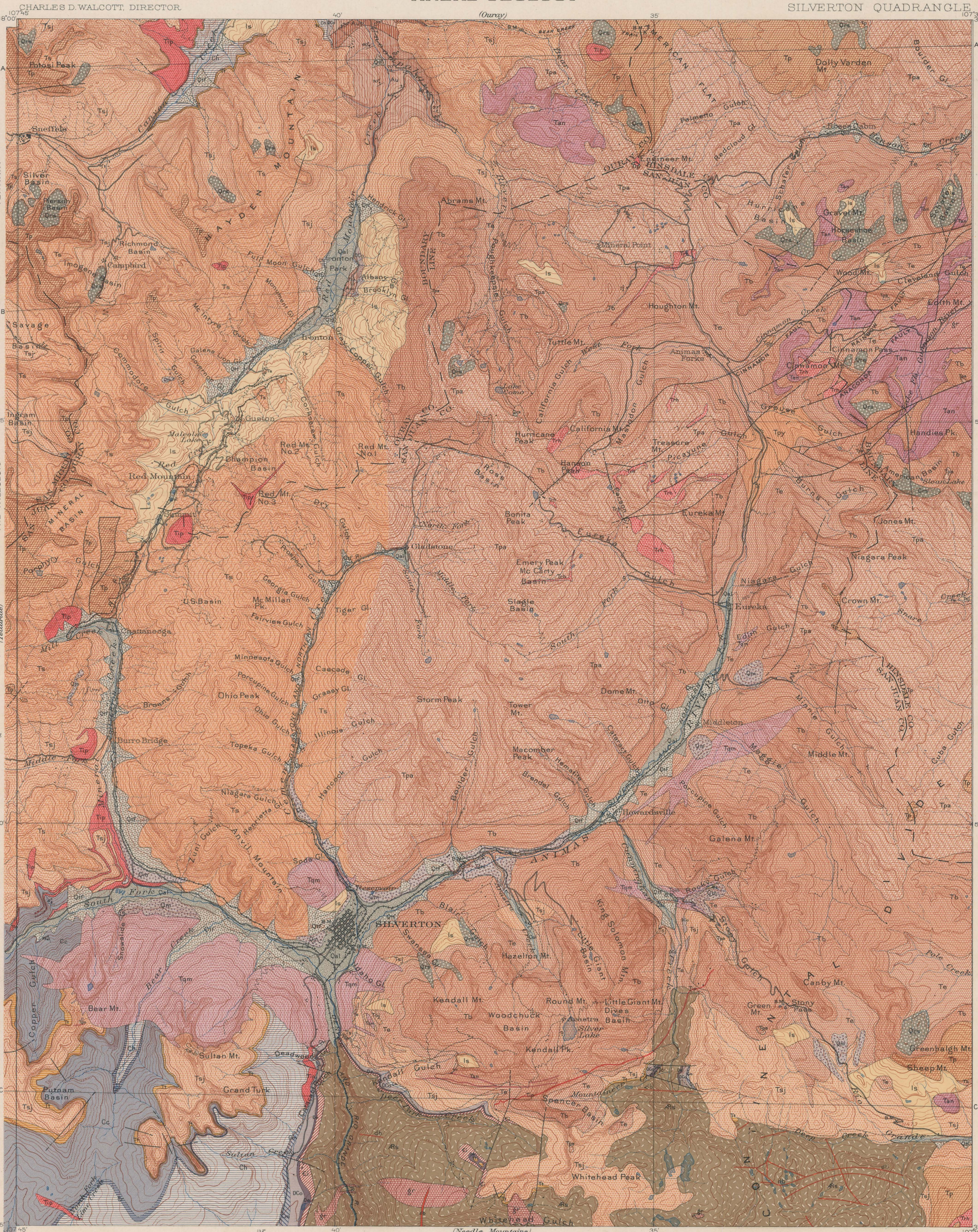
Contour interval 100 feet.
Datum is mean sea level.
Projection based on U.S.C. and G. Survey data of 1900.
Projection of Telluride sheet based on earlier data.

Edition of June 1904.

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

AREAL GEOLOGY

COLORADO
SILVERTON QUADRANGLE



LEGEND

IGNEOUS ROCKS (continued)

Silverton volcanic series

- **Tpa** — Pyroxene-andesite (*bearing augite and hypersthene; flows, tuffs, and dikes*)
- **Tb** — Burns latite (*containing hornblende, biotite, and augite; dikes, flows, and tuffs*)
- **Te** — Eureka rhyolite (*mainly flows and dikes of flow-breccia; some tuffs*)
- **Tpy** — Picayune andesite (*augite bearing; massive and breccia*)
- **Ts** — Silverton volcanic series undifferentiated (*andesite and rhyolite flow-breccia, in flows, tuffs, and breccia*)
- **Tsj** — San Juan tuff (*bedded tuff and breccia or agglomerate of andesitic material*)

TERTIARY

- **db** — Diabase (*cuts schist and granite*)
- **gr** — Granite (*dikes and large irregular masses cutting schist*)

PRE-PALEOZOIC

Known faults (*doubtful location indicated by dashes*)

Concealed faults (*covered by younger deposits*)

Sections

A — A
B — B
C — C

20° *Strike and dip of stratified rocks*

LEGEND

- **ls** — Landslides

SEDIMENTARY ROCKS

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

- **Qal** — Alluvium (*sands and soils of valleys*)
- **Qtf** — Torrential fans (*accumulations of loose material at the mouths of ravines and gulches*)
- **Qrs** — Rock streams (*talus-like masses which have moved on their rock bases and simulate glaciers in form*)
- **Qm** — Moraines (*bowlders, gravel, and sand*)

QUATERNARY

Eocene?

- **Tt** — Telluride conglomerate (*bowlders of granite, schist, quartzite, and limestone*)

TERTIARY

UNCONFORMITY

Permian?

- **Cc** — Cutler formation (*sandstone, grit, conglomerate, and some calcareous shale; prevailing color red*)

Pennsylvanian

- **Cr** — Rico formation (*sandstone, limestone, and shale, of red or gray color; fossiliferous*)
- **Ch** — Hermosa formation (*sandstone, shale, and limestone, of grayish color; fossiliferous*)
- **Cm** — Molas formation (*red, calcareous, sandy shale, with thin fossiliferous limestone; many chert pebbles in lower part*)

CARBONIFEROUS

UNCONFORMITY

- **DCo** — Ouray limestone (*white or light-pink, saccharoidal limestone, with a few quartzite layers; fossiliferous*)
- **De** — Elbert formation (*calcareous shale, thin limestone, and quartzite; characterized by casts of salt crystals*)

DEVONIAN

UNCONFORMITY

- **Ci** — Ignacio quartzite (*thin-bedded, gray or pink, wavy quartzite, with trail markings on shaly partings*)

CAMBRIAN?

UNCONFORMITY

- **Au / Aus** — Uncompahgre formation (*massive, white or gray quartzite, locally conglomeratic, with dark slate or shale bands, Aus*)

ALGONKIAN

METAMORPHIC ROCKS OF UNKNOWN ORIGIN

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

- **Ʀs** — Schist and gneiss (*finely foliated rocks of varying character, dark gray in color*)

ARCHEAN?

IGNEOUS ROCKS

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

- **Tqm** — Quartz-monzonite (*stocks and dikes*)
- **Tip** — Intrusive porphyries (*dikes, small stocks, laccoliths, and irregular masses*)
- **Trh** — Intrusive rhyolite (*dikes and sheets*)
- **Tan** — Intrusive andesite (*dikes, small stocks, and sheets of andesite or latite*)
- **Tp** — Potosi volcanic series (*flows and tuffs of quartz-latite and rhyolite*)

TERTIARY

Legend is continued on the left margin.

E. M. Douglas, Geographer in charge.
Control by Frank Tweedy.
Topography by W. M. Beaman and Arthur Stiles.
Surveyed in 1895 and 1900-1901.

TRUE NORTH — MAGNETIC NORTH 13½°
APPROXIMATE MEAN DECLINATION 1902.

Scale $\frac{1}{62500}$

1 ½ 0 1 2 3 4 Miles

1 ½ 0 1 2 3 4 5 Kilometers

Contour interval 100 feet.

Datum is mean sea level.
Projection based on U.S.C. and G. Survey data of 1900.
Projection of Telluride sheet based on earlier data.

Edition of Nov. 1904

Areal Geology by Whitman Cross, Ernest Howe, and A. C. Spencer.
Assisted by J. Morgan Clements, G. W. Stose, and R. D. George.
Surveyed in 1899, 1900, and 1901.

U.S. GEOLOGICAL SURVEY
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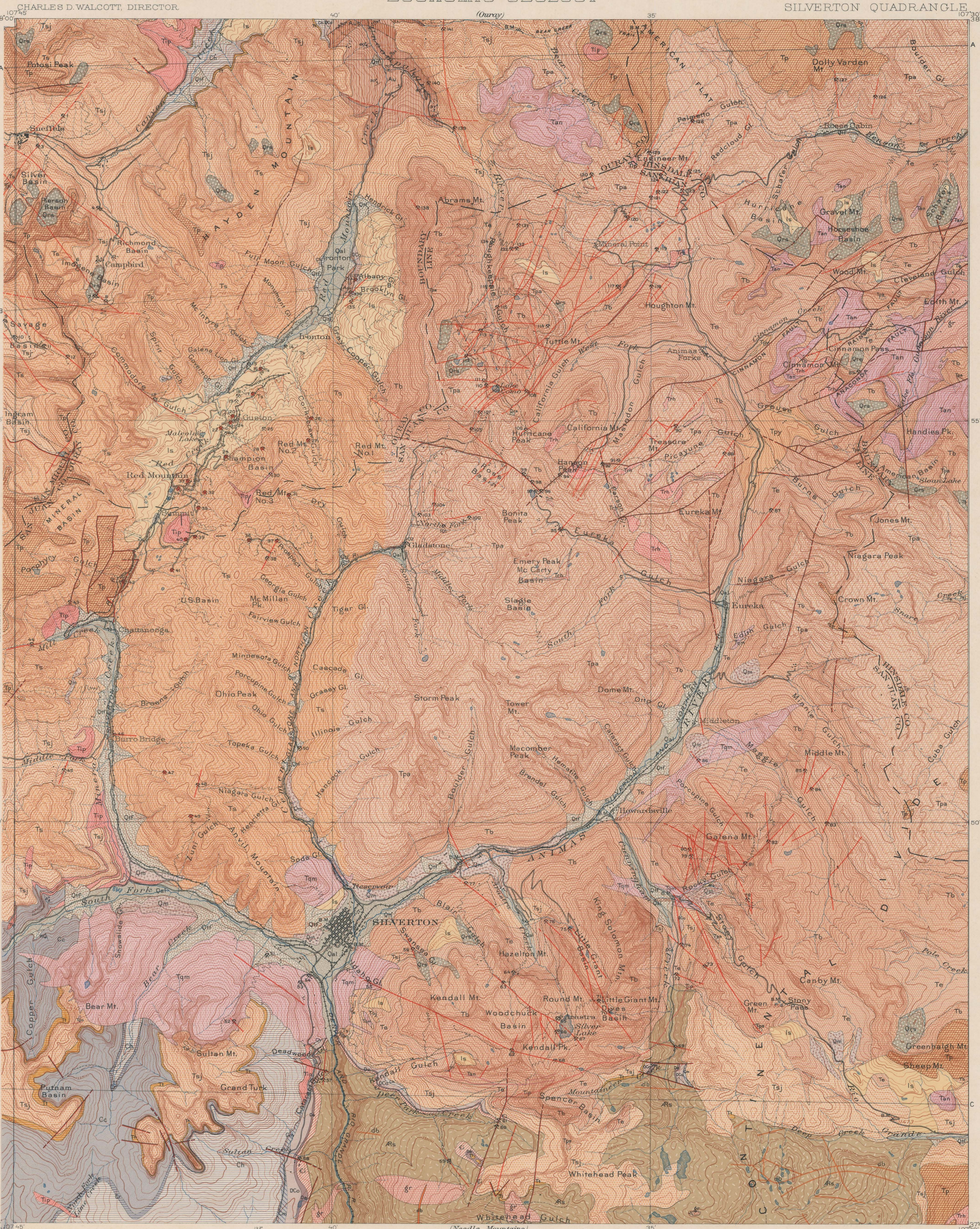
ECONOMIC GEOLOGY

COLORADO
SILVERTON QUADRANGLE



LEGEND

IGNEOUS ROCKS
(continued)

Silverton volcanic series — TERTIARY

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- **gr** Granite *(dikes and large irregular masses cutting schist)*

Known faults *(doubtful location indicated by dashes)*

Concealed faults *(covered by younger deposits)*

Sections

20° *Strike and dip of stratified rocks*

Mines and prospects

Lodes carrying ores of gold, silver, and lead. (owing to their prevalent mineralization, faults are also indicated as lodes even when not obviously accompanied by ore)

Stocks and replacement ore bodies

Note: The lodes shown were plotted in the field on the topographic base of 1895. The transfer in the office of these lodes to the topography as revised in 1901 has possibly introduced some inaccuracies.

Mine names, represented on the map by numbers, are printed on the back of this sheet.

LEGEND

- **ls** Landslides

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

QUATERNARY

- **Qal** Alluvium *(sands and soils of valleys)*
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TERTIARY — *Eocene?*

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METAMORPHIC ROCKS OF UNKNOWN ORIGIN
(Areas of metamorphic rocks of unknown origin are shown by patterns of short dashes)

ARCHEAN?

- **Ars** Schist and gneiss *(finely foliated rocks of varying character, dark gray in color)*

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

TERTIARY

- **Tqm** Quartz-monzonite *(stocks and dikes)*
- **Tip** Intrusive porphyries *(dikes, small stocks, laccoliths, and irregular masses)*
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Economic Geology by F. L. Ransome.
Surveyed in 1899 and 1900.

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

STRUCTURE SECTIONS

COLORADO
SILVERTON QUADRANGLE

E. M. Douglas, Geographer in charge.
Control by Frank Tweedy.
Topography by W. M. Beaman and Arthur Stiles.
Surveyed in 1895 and 1900-1901.

TRUE NORTH
MAGNETIC NORTH
APPROXIMATE MEAN DECLINATION 1902.

Scale $\frac{1}{62500}$

1 ½ 0 1 2 3 4 Miles

1 ½ 0 1 2 3 4 5 Kilometers

Projection based on U.S.C. and G. Survey data of 1900.
Projection of Telluride sheet based on earlier data.

Edition of Feb. 1905.

Areal Geology by Whitman Cross, Ernest Howe, and A. C. Spencer.
Assisted by J. Morgan Clements, G. W. Stose, and R. D. George.
Surveyed in 1899, 1900, and 1901.

LEGEND

SHEET SYMBOL / SECTION SYMBOL

Is — **Landslides**

SEDIMENTARY ROCKS

SHEET SYMBOL / SECTION SYMBOL

QUATERNARY

Qal — **Alluvium** *(sands and soils of valleys)*

Qtf — **Torrential fans** *(accumulations of loose material at the mouths of ravines and gulches)*

Qrs — **Rock streams** *(talus-like masses which have moved on their rock bases and simulate glaciers in form)*

Qm — **Moraines** *(bowlders, gravel, and sand)*

TERTIARY — *Eocene?*

Tt — **Telluride conglomerate** *(bowlders of granite, schist, quartzite, and limestone)*

UNCONFORMITY

CARBONIFEROUS — *Permian?*

Cc — **Cutler formation** *(sandstone, grit, conglomerate, and some calcareous shale; prevailing color red)*

CARBONIFEROUS — *Pennsylvanian*

Cr — **Rico formation** *(sandstone, limestone, and shale, of red or gray color; fossiliferous)*

Ch — **Hermosa formation** *(sandstone, shale, and limestone, of grayish color; fossiliferous)*

Cm — **Molas formation** *(red, calcareous, sandy shale, with thin fossiliferous limestone; many chert pebbles in lower part)*

UNCONFORMITY

DEVONIAN

DCo / DCe — **Ouray limestone** *(white or light-pink, saccharoidal limestone, with a few quartzite layers; fossiliferous)*

De — *Combined with Ouray limestone on sections* — **Elbert formation** *(calcareous shale, thin limestone, and quartzite; characterized by casts of salt crystals)*

UNCONFORMITY

CAMBRIAN?

€i — **Ignacio quartzite** *(thin-bedded, gray or pink, wavy quartzite, with trail markings on shaly partings)*

UNCONFORMITY

ALGONKIAN

Aus / Au — **Uncompahgre formation** *(massive, white or gray quartzite, locally conglomeratic, with dark slate or shale bands, Aus)*

METAMORPHIC ROCKS OF UNKNOWN ORIGIN

SHEET SYMBOL / SECTION SYMBOL

ARCHEAN?

Ærs — **Schist and gneiss** *(finely foliated rocks of varying character, dark gray in color)*

IGNEOUS ROCKS

SHEET SYMBOL / SECTION SYMBOL

TERTIARY

Tqm — **Quartz-monzonite** *(stocks and dikes)*

Tip — **Intrusive porphyries** *(dikes, small stocks, laccoliths, and irregular masses)*

Trh — **Intrusive rhyolite** *(dikes and sheets)*

Tan — **Intrusive andesite** *(dikes, small stocks, and sheets of andesite or latite)*

Tp — **Potosi volcanic series** *(flows and tuffs of quartz-latite and rhyolite)*

Legend is continued on the left margin.

LEGEND

IGNEOUS ROCKS *(continued)*

SHEET SYMBOL / SECTION SYMBOL

TERTIARY — *Silverton volcanic series*

Tpa — **Pyroxene-andesite** *(bearing augite and hypersthene; flows, tuffs, and dikes)*

Tb — **Burns latite** *(containing hornblende, biotite, and augite; dikes, flows, and tuffs)*

Te — **Eureka rhyolite** *(mainly flows and dikes of flow-breccia; some tuffs)*

Tpy — **Picayune andesite** *(augite bearing; massive and breccia)*

Ts — **Silverton volcanic series undifferentiated** *(andesite and rhyolite flow-breccia, in flows, tuffs, and breccia)*

Tsj — **San Juan tuff** *(bedded tuff and breccia or agglomerate of andesitic material)*

PRE-PALEOZOIC

db — **Diabase** *(cuts schist and granite)*

gr — **Granite** *(dikes and large irregular masses cutting schist)*

Known faults *(doubtful location indicated by dashes)*

Concealed faults *(covered by younger deposits)*

20° *Strike and dip of stratified rocks*

NAMES OF MINES.

Location indicated on the map by numbers.

NUMERICAL LIST.

1. Bimetallist.
2. Revenue Tunnel.
3. Wheel of Fortune.
4. U. S. Depository.
5. Camp Bird (main adit).
6. Hidden Treasure.
7. Camp Bird (upper adit).
8. Hancock.
9. Japan.
10. Tomboy (main adit).
11. Tomboy (upper tunnel).
12. North Chicago.
13. Barstow.
14. Little Candies.
15 Meldrum Tunnel.
16. Silver Bell.
17. Paymaster.
18. American Girl.
19. White Cloud.
20. Guston.
21. Hammond Tunnel.
22. Yankee Girl.
23. Robinson.
24. Scotch Girl.
25. Grand Prize.
26. Midnight.
27. Carbonate King.
28. Alexandra.
29. Genesee-Vanderbilt.
30. Summit.
31. Webster.
32. Charter Oak.
33. National Belle.
34. Lake (Red Mountain).
35. Hudson.
36. Galena Queen.
37. Mineral King.
38. Henrietta.
39. Carbon Lake.
40. Congress.
41. St. Paul.
42. Silver Ledge.
43. Silver King.
44. Silver Crown.
45. Bonner.
46. Magnet.
47. Brobdignad.
48. Irene.
49. Zuni.
50. Yukon Tunnel.
51. North Star.
52. Belcher (Sultan Mountain).
53. Montezuma.
54. Empire Tunnel.
55. Idaho.
56. Lackawanna.
57. King.
58. Molas.
59. Mabel.
60. Montana.
61. Little Ray.
62. Titusville.
63. Nevada.
64. Unity Tunnel.
65. Silver Lake.
66. Iowa.
67. Royal Tiger.
68. Buckeye
69. Highland Mary.
70. Dives.
71. North Star (King Solomon).
72. Green Mountain.
73. Philadelphia.
74. Pride of the West.
75. Big Giant.
76. Little Giant.
77. Aspen.
78. Antiperiodic.
79. Veta Madre.
80. Neigold.
81. Big Ten.
82. Ridgway.
83. Little Maud.
84. Dewey.
85. Gold Nugget.
86. Hamlet.
87. Tom Moore.
88. Toltec.
89. Anaconda.
90. Scotia and Golden Fleece.
91. Sound Democrat.
92. Silver Queen (Placer Gulch).
93. Mastodon.
94. Sunnyside Extension.
95. Ben Franklin.
96. Sunnyside.
97. Belle Creole.
98. Lake.
99. George Washington.
100. Gold King (and Sampson).
101. American.
102. Gold King (lowest tunnel).
103. Red and Bonita.
104. Adams.
105. Queen Anne.
106. Mountain Queen.
107. Columbia.
108. Belcher (Poughkeepsie Gulch).
109. Bonanza.
110. Red Rogers.
111. Seven-Thirty.
112. Alaska.
113. Saxon and Amador.
114. Tempest.
115. Poughkeepsie.
116. Alabama.
117. Red Cloud.
118. Early Bird.
119. Butler.
120. San Juan Chief.
121. Mammoth.
122. Annie Wood.
123. Pride of Syracuse.
124. Polar Star.
125. Mohawk.
126. J. J. Crooke.
127. Dolly Varden.
128. Palmetto.
129. Frank Hough.
130. Sunset.
131. Maid of the Mist.
132. Forest.
133. Old Lout.
134. Old Lout Tunnel.
135. J. I. C.
136. Baltic Group (Mono).
137. Saratoga.
138. Guadaloupe.
139. Micky Breen.
140. Silver Link.
141. Silver Queen (Bear Creek).

ALPHABETICAL LIST.

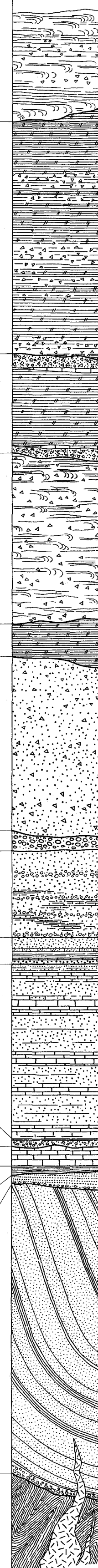
Adams, 104.
Alabama, 116.
Alaska, 112.
Alexandra, 28.
American, 101.
American Girl, 18.
Anaconda, 89.
Annie Wood, 122.
Antiperiodic, 78.
Aspen, 77.
Baltic Group (Mono), 136.
Barstow, 13.
Belcher (Sultan Mountain), 52.
Belcher (Poughkeepsie Gulch). 108.
Belle Creole, 97.
Ben Franklin, 95.
Big Giant, 75.
Big Ten, 81.
Bimetallist, 1.
Bonanza, 109.
Bonner, 45.
Brobdignad, 47.
Buckeye, 68.
Butler, 119.
Camp Bird (main adit), 5.
Camp Bird (upper adit), 7.
Carbonate King, 27.
Carbon Lake, 39.
Charter Oak, 32.
Columbia, 107.
Congress, 40.
Dewey, 84.
Dives, 70.
Dolly Varden, 127.
Early Bird, 118.
Empire Tunnel, 54.
Forest, 132.
Frank Hough, 129.
Galena Queen, 36.
Genesee-Vanderbilt, 29.
George Washington, 99.
Gold King (and Sampson), 100.
Gold King (lowest tunnel), 102.
Gold Nugget, 85.
Grand Prize, 25.
Green Mountain, 72.
Guadaloupe, 138.
Guston, 20.
Hamlet, 86.
Hammond Tunnel, 21.
Hancock, 8.
Henrietta, 38.
Hidden Treasure, 6.
Highland Mary, 69.
Hudson, 35.
Idaho, 55.
Iowa, 66.
Irene, 48.
Japan, 9.
J. J. Crooke, 126.
J. I. C., 135.
King, 57.
Lackawanna, 56.
Lake, 98.
Lake (Red Mountain), 34.
Little Candies, 14.
Little Giant, 76.
Little Maud, 83.
Little Ray, 61.
Mabel, 59.
Magnet, 46.
Maid of the Mist, 131.
Mammoth, 121.
Mastodon, 93.
Meldrum Tunnel, 15.
Micky Breen, 139.
Midnight, 26.
Mineral King, 37.
Mohawk, 125.
Molas, 58.
Montana, 60.
Montezuma, 53.
Mountain Queen, 106.
National Belle, 33.
Neigold, 80.
Nevada, 63.
North Chicago, 12.
North Star, 51.
North Star (King Solomon), 71.
Old Lout, 133.
Old Lout Tunnel, 134.
Palmetto, 128.
Paymaster, 17.
Philadelphia, 73.
Polar Star, 124.
Poughkeepsie, 115.
Pride of Syracuse, 123.
Pride of the West, 74.
Queen Anne, 105.
Red and Bonita, 103.
Red Cloud, 117.
Red Rogers, 110.
Revenue Tunnel, 2.
Ridgway, 82.
Robinson, 23.
Royal Tiger, 67.
St. Paul, 41.
San Juan Chief, 120.
Saratoga, 137.
Saxon and Amador, 113.
Scotch Girl, 24.
Scotia and Golden Fleece, 90.
Seven-Thirty, 111.
Silver Bell, 16.
Silver Crown, 44.
Silver King, 43.
Silver Lake, 65.
Silver Ledge, 42.
Silver Link, 140.
Silver Queen (Placer Gulch), 92.
Silver Queen (Bear Creek), 141.
Sound Democrat, 91.
Summit, 30.
Sunnyside, 96.
Sunnyside Extension, 94.
Sunset, 130.
Tempest, 114.
Titusville, 62.
Toltec, 88.
Tomboy (main adit), 10.
Tomboy (upper tunnel), 11.
Tom Moore, 87.
Unity Tunnel, 64.
U. S. Depository, 4.
Veta Madre, 79.
Webster, 31.
Wheel of Fortune, 3.
White Cloud, 19.
Yankee Girl, 22.
Yukon Tunnel, 50.
Zuni, 49.

COLUMNAR SECTION

GENERALIZED SECTION FOR THE SILVERTON QUADRANGLE.

SCALE: 1 INCH=1000 FEET.

System.	Formation Name.	Symbol.	Thickness in Feet.	Character and Distribution of Formations.
TERTIARY	Potosi volcanic series.	Tp	1250	An alternation of rhyolite and quartz-latite flows and tuffs, the flows predominating near the base. Some of the thin upper flows seen in Potosi Peak are glassy. A thin augite-andesite sheet occurs in the lower portion. Thirteen hundred feet is the maximum thickness preserved in the quadrangle.
	UNCONFORMITY			
	Silverton volcanic series. Pyroxene-andesite.	Tpa	100–3000	A succession of andesite flows and tuffs, also dikes, characterized by the presence of both augite and hypersthene. Forms the upper member of the Silverton series and has its greatest known development in the central part of the Silverton quadrangle.
	UNCONFORMITY			
	Silverton volcanic series. Burns latite.	Tb	1200	A succession of flows, tuffs, and breccias, and dikes of dark hornblendic quartz-bearing latite, of andesitic habit. Several varieties, of local distribution, have been observed.
	UNCONFORMITY			
	Silverton volcanic series. Eureka rhyolite.	Te	1800	Massive flows, dikes, and well-bedded tuffs, the former greatly predominating. The flow rock is characterized by so many small fragments of rhyolite of various textures and of andesitic rocks that the term flow-breccia is inappropriate. Belongs to the Silverton series.
	UNCONFORMITY			
	Silverton volcanic series. Picayune andesite.	Tpy	500	Augite-andesite occurring in tuff, breccia, or agglomerate, and massive flows. The earliest known member of the Silverton series. Imperfectly exposed. Base not known.
	UNCONFORMITY			
	San Juan tuff.	Tsj	100–2000	Almost exclusively of andesitic débris. Near the base it is a well-stratified tuff, but becomes coarser and less distinctly bedded in its upper portion. Fossils are not known. The beds vary greatly in thickness, owing both to primary causes and to the erosion preceding the eruptions of the Silverton series. The maximum thickness observed in the Silverton quadrangle is adjacent to Canyon Creek.
	UNCONFORMITY			
	Telluride conglomerate.	Tt	0–200	A coarse conglomerate containing pebbles and bowlders of schist, granite, and quartzite with some limestone and the harder sediments of the Paleozoic formation. Thickens westward until it becomes a series of conglomerates, grits, sandstones, and shales, nearly 1000 feet in thickness.
	UNCONFORMITY			
CARBONIFEROUS — PERMIAN?	Cutler formation.	Cc	1000+	A complex of bright-red sandstones and lighter red or pinkish grits and conglomerates alternating with sandy shales and earthy or sandy limestones of varying shades of red.
CARBONIFEROUS — PENNSYLVANIAN	Rico formation.	Cr	300	Dark reddish-brown sandstone and pink grits, with intercalated greenish or reddish shale and sandy, fossiliferous limestone.
CARBONIFEROUS — PENNSYLVANIAN	Hermosa formation.	Ch	2000	A series of limestones, grits, sandstones, and shales, of variable distribution and development. Limestone in thick massive beds predominates in the middle and upper parts of the section, the lower portion being mainly sandstone and shale with a few limestone layers. Numerous invertebrate fossils occur in shale and limestone.
CARBONIFEROUS — PENNSYLVANIAN	Molas formation.	Cm	75	Red calcareous shale and sandstone with chert, limestone, and quartzite pebbles and thin fossiliferous limestone lenses. The chert and limestone pebbles often contain fossils from the Mississippian portion of the Ouray limestone; the limestone lenses carry Pennsylvanian species.
	UNCONFORMITY			
MISS'P'N	Ouray limestone.	DCo	200+	Pale-yellow to buff compact limestone; lower third shaly, with thin quartzites; abundant fossils indicate Devonian age of lower two-thirds and Mississippian age of upper part.
DEV.	Elbert formation.	De	25–100	Thin limestone and sandstone, and calcareous shale containing casts of salt crystals. Contains fragmentary fish remains locally in Needle Mountains, demonstrating Devonian age.
	UNCONFORMITY			
CAMB.	Ignacio quartzite.	Ci	0–200	Quartzite, massive and conglomeratic in the lower part, thin bedded with shale or sandy partings in the medial zone, succeeded by more massive quartzite. Light gray, pink, or yellow predominates. One shell, *Obolus* sp?, has been found near the middle of the formation.
	UNCONFORMITY			
ALGONKIAN	Uncompahgre formation.	Au	8000+	Massive white or smoky quartzite and dark slate, with a few members in which those rocks alternate in thinner layers. No fossils have been found.
ARCHEAN?	Schist and gneiss.	Æs		Schist and gneiss, of dark and light colors, often in alternating bands. Intruded by granite and cut by basic dikes, many of which have been mashed.



WHITMAN CROSS,
ERNEST HOWE,
Geologists.

ILLUSTRATIONS

FIG. 1.—VIEW FROM SNOWDON PEAK NORTH TOWARD SILVERTON.

In the center lies Molas Lake, underlain by Ouray limestone. On the deforested slope to the left are ledges of Carboniferous limestone. Above these rise Grand Turk and other mountains of San Juan tuff. To the right of the lake is the line of Animas Canyon, with Kendall Mountain beyond

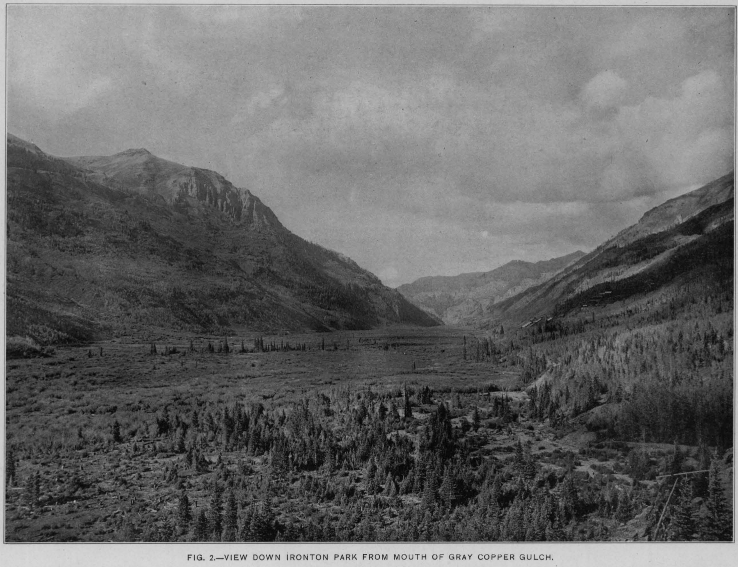


FIG. 2.—VIEW DOWN IRONTON PARK FROM MOUTH OF GRAY COPPER GULCH.

The nearly level park extends for 1½ miles from view point. On the right are Saratoga mill and mine buildings, where Algonkian quartzites and overlying Paleozoic beds appear. On the left is fan of Full Moon Gulch, with Carboniferous sandstone at the road level on either side. Above, on Hayden Mountain, appear characteristic cliffs of San Juan tuff.

FIG. 3.—TALUS PILES IN EASTERN BRANCH OF HORSESHOE BASIN.

Shows relation of talus and cliff where a snow bank against foot of cliff is supposed to have aided in the accumulation of débris at some distance from cliff. This mass grades into rock stream at its upper end.

FIG. 4.—ROCK STREAM IN SILVER BASIN.

Shows sharp definition of stream and indicates its great volume as compared with talus piles below right-hand cliffs. These cliffs of Potosi lavas are similar in material and height to those whence the material of the rock stream came.

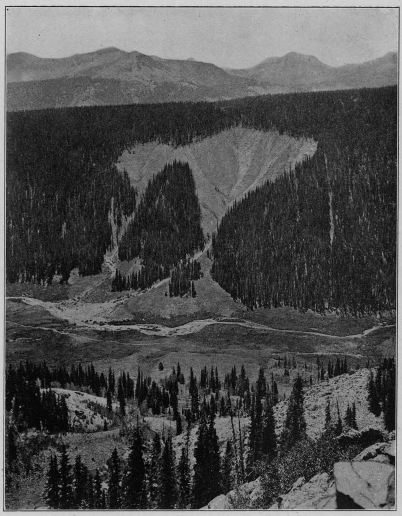


FIG. 5.—TORRENTIAL FANS ON SOUTH SIDE OF RIO GRANDE BELOW DEEP CREEK, FROM SLOPE OF SHEEP MOUNTAIN.

Ravines cutting into forested hillside of San Juan tuff are depositing most of their detritus in torrential fans below.

FIG. 6.—LANDSLIDE SURFACE BELOW RED MOUNTAIN NO. 2, FROM FAN AT MOUTH OF GALENA LION GULCH.

Shows multitude of small slide blocks. This slide area extends across ridge from Red Mountain No. 2 into Corkscrew Gulch. On the left is the knoll above Paymaster mine. In the foreground are White Cloud and American Girl mines.

FIG. 7.—LANDSLIDE AREA OF RED MOUNTAIN CREEK NEAR ROBINSON AND GUSTON MINES.

View is up creek from knoll north of Robinson mine, in foreground. All is landslide area but the distant cliffs. On the right the blocks are larger and of comparatively fresh rock. On the left the blocks are small and much disintegrated. A small knob of silicified rock appears beside Robinson shaft.

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112	Bisbee	Arizona	25
113	Huron	South Dakota	25
114	De Smet	South Dakota	25
115	Kittanning	Pennsylvania	25
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