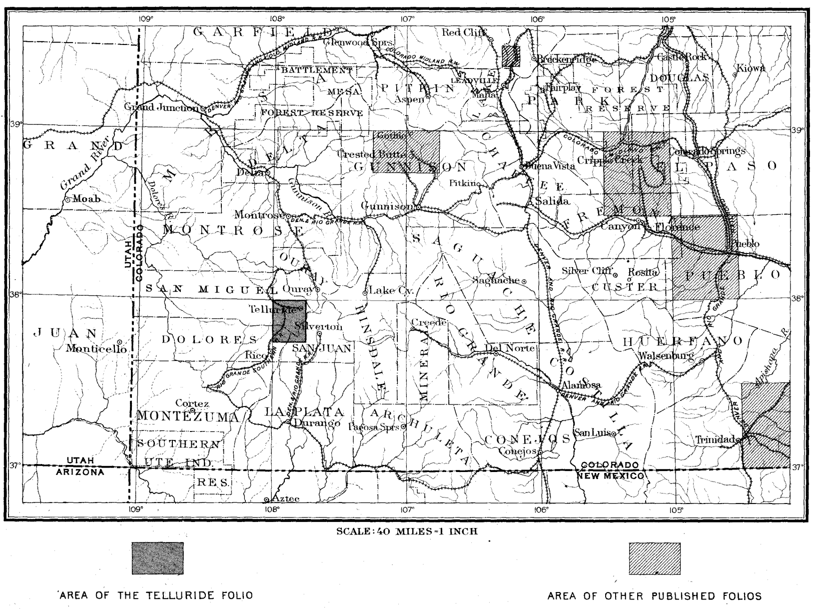
DEPARTMENT OF THE INTERIOR
UNITED STATES GEOLOGICAL SURVEY
CHARLES D. WALCOTT, DIRECTOR

# GEOLOGIC ATLAS
## OF THE
# UNITED STATES

# TELLURIDE FOLIO
## COLORADO

INDEX MAP



SCALE: 40 MILES = 1 INCH

▩ AREA OF THE TELLURIDE FOLIO

▨ AREA OF OTHER PUBLISHED FOLIOS

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FOLIO 57

FIELD EDITION

TELLURIDE

WASHINGTON, D. C.
ENGRAVED AND PRINTED BY THE U. S. GEOLOGICAL SURVEY
GEORGE W. STOSE, EDITOR OF GEOLOGIC MAPS    S. J. KÜBEL, CHIEF ENGRAVER
1899

# EXPLANATION.

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

## THE TOPOGRAPHIC MAP.

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

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

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

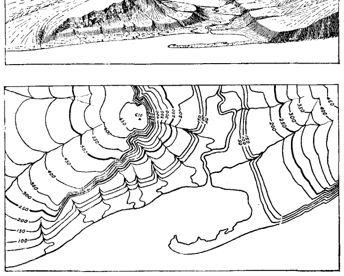


Fig. 1.—Ideal sketch and corresponding contour map.

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

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

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

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

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

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

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

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

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

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

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

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

## THE GEOLOGIC MAP.

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

### KINDS OF ROCKS.

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

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

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

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

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

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

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

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

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

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

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

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

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

### AGES OF ROCKS.

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

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

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

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

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

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

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

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

To distinguish the sedimentary formations of any one period from those of another the patterns for the formations of each period are printed in the appropriate period-color, with the exception of the first (Pleistocene) and the last (Archean). The formations of any one period, excepting the Pleistocene and the Archean, are distinguished from one another by different patterns, made of parallel straight lines. Two tints of the period-color are used: a pale tint (the underprint) is printed evenly over the whole surface representing the period; a dark tint (the overprint) brings out the different patterns representing formations. Each formation is furthermore given a letter-symbol of the period. In the case of a sedimentary formation of uncertain age the pattern is printed on white ground in the color of the period to which the formation is supposed to belong, the letter-symbol of the period being omitted.

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

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

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

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

### THE VARIOUS GEOLOGIC SHEETS.

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

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

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

*Structure-section sheet.*—This sheet exhibits the relations of the formations beneath the surface.

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

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

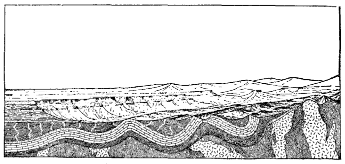


Fig. 2.—Sketch showing a vertical section in the front of the picture, with a landscape beyond.

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

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

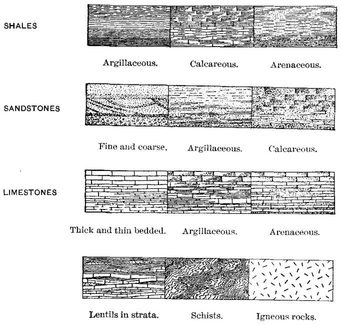


Fig. 3.—Symbols used to represent different kinds of rock.

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

CHARLES D. WALCOTT,
*Director.*

Revised June, 1897.

# DESCRIPTION OF THE TELLURIDE QUADRANGLE.

## INTRODUCTION.

*A general statement of the geography, topography, and geology of the San Juan region of Colorado.*

**Limits of the San Juan region.**

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 are now understood to 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 an extent of nearly 80 miles east and west, and from 25 to 40 miles north and south, and their summits form a great group rather than a range.

**Topography.**

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 Mountains and the group about Rico 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 those about Rico, which may be conveniently called the Rico Mountains, are also disconnected from the San Juan in origin.

The eastern summits of the San Miguel Range—the Mount Wilson group of the Telluride quadrangle—are a portion of the San Juan, cut off by erosion, as shown by the map and text of this folio.

**Precipitation and vegetation.**

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, supporting only a low alpine flora on favored surfaces.

**Economic importance.**

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 have been found in valley bottoms or on lower slopes adjacent to the snow-fed streams from the mountains. With the development of these resources several towns of importance 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.

**Meager knowledge of geology.**

The geological history of the San Juan region is too complex and as yet too imperfectly known to admit of 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 in 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 Telluride quadrangle 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 Eocene, inclusive. Much of this section has now been studied in detail, but definite correlations can not as yet be made between the older formations here seen and the isolated exposures reported from some other parts of the San Juan Mountains.

**The oldest formations.**

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 as belonging to the Archean, but some of them are probably younger than the great series of quartzites exhibited in the Needle Mountains and beneath the volcanics in the canyons of the Uncompahgre above Ouray, which have been referred by Van Hise and Emmons to the pre-Cambrian age of sedimentation—the Algonkian. These latter rocks have suffered great metamorphism and are seen standing on edge or greatly disturbed, and the relations of the isolated exposures to contemporaneous formations elsewhere are quite unknown. These quartzites were called "Metamorphic Paleozoic" upon the Hayden map. Clearly great continental movement followed by enormous erosion preceded the earliest Paleozoic deposits thus far discovered in the region. These latter formations are now exposed in the Animas Valley and near Ouray, and are referred to the Devonian, from fossil evidence. Succeeding the Devonian comes a great series of calcareous sandstones and limestones containing abundant Carboniferous fossils.

**Mesozoic deposits.**

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

In the Rico Mountains a Permo-Carboniferous fauna 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 in the Uncompahgre Valley has not as yet been demonstrated.

Succeeding the red Triassic beds come other formations correlated in general with the fresh-water Jura of other parts of Colorado, and following them comes the Cretaceous section, 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.

**Outline of structure.**

Structurally, the most striking feature in the present attitude of the formations described, from the base of the Devonian upward, is the general southerly or westerly dip away from a point in the west-central part of the San Juan Mountains not far east of the Telluride quadrangle. 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 exists in fact within that territory. But at least one great orographic disturbance not indicated in the Animas section is clearly shown on the northern slopes of the San Juan, and probably also on the southern side, not far east of the Animas River. The red Triassic formations 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 the Los Pinos and Piedra rivers, according to the Hayden map, but no observations appear to have been made on either side of the San Juan Mountains to show the actual position or character of the great overlap which must occur at the base of the La Plata sandstone, or at least below the Dakota Cretaceous.

Other periods of uplift, erosion, or subsidence in Paleozoic or Mesozoic time are indicated by the apparent absence of Cambrian and Silurian sediments, the insignificant development of the lower and middle Carboniferous beds, the local development of the fossiliferous Trias, and the absence of the marine Jura and of recognized equivalents of the great "Lower" Cretaceous section of Texas.

**Post-Cretaceous erosion.**

The geologic structure and constitution of the San Juan Mountains of to-day are mainly the result of the dynamic forces which were intensely active during three great periods of Tertiary time. In the first of these periods the long cycle of upper Cretaceous sedimentation was terminated by a continental uplift of unknown extent, but which may have been very great. The land thus elevated was greatly eroded, and finally subsided, leading to the formation of the early Eocene lakes. Present knowledge does not tell us to what extent the San Juan Mountain area was covered by the Cretaceous sea, 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 the evidence, to be given much more fully further on, that the erosion of the period 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. This nearly plane surface of erosion became, in the region where it is now exposed, the floor of the San Miguel lake, and the sandstones and conglomerates deposited upon it had already attained a thickness of several hundred feet when the great period of volcanic activity began, producing the complex of rocks out of which the present San Juan Mountains are sculptured.

**Volcanic eruptions.**

In the second period the volcanoes 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, covering an area of certainly not less than 15,000 square miles to a depth of many thousand feet in the central portion. This volcanic area has not been studied in detail except in the Telluride quadrangle. The vents from which the lavas came are unknown, and the lavas themselves have been examined only in sufficient degree to show the predominant presence of andesites, with other types ranging in composition from rhyolite to basalt. Penetrating the bedded series are several massive bodies of often coarsely granular rocks, such as gabbro and diorite, 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.

**Tertiary history.**

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. 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 orographic disturbance, the Tertiary history of this region may be summarized as a conflict between volcanic forces, building up by stupendous emissions of lava, and the agencies of erosion, removing the igneous material and carving deep canyons to the very base of the vast lava plateau. The former was most effective in the earliest stages of its activity, 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.

**Measure of erosion accomplished.**

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 examination of the Telluride quadrangle has thrown much light on these great problems. Thus the San Miguel 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. Within the quadrangle the San Miguel conglomerate increases in thickness from 200 feet of bowlder beds on the eastern side to nearly 1000 feet of much finer sediment in Mount Wilson, and upon it, in the latter locality, is a remnant of the San Juan tuff. Both of these formations are also present in Dolores Peak, some 6 miles west of Mount Wilson, but there does not seem to be any possibility of the preservation of either of them at any point farther west.

The amount of Tertiary and recent erosion which has taken place in the Telluride quadrangle from the Dakota plateau to the summit of Mount Wilson is 5250 feet vertically, and a great thickness of still higher volcanics must still be added.

**Present conditions.**

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 San Miguel 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. There are some reasons for thinking that this part of the San Juan is still rising. Much more work must be done before the various movements can be distinguished and given their relative values.

In the resurvey of the San Juan region, now in progress, the Telluride quadrangle was the first one taken up. Most of the field work was done in 1895, with H. S. Gane as regular assistant and E. C. E. Lord as volunteer aid. Before the next field season Mr. Gane was unfortunately obliged to retire from the Survey, on account of impaired health, his place being taken by A. C. Spencer. In 1896 the ore deposits of the quadrangle were studied by C. W. Purington, and the results have been published in the Eighteenth Annual Report of the United States Geological Survey, Part III, pp. 745–850, 1898, with a preliminary edition of the geological map.

## GEOGRAPHY AND PHYSIOGRAPHY.

*An account of the geographic relations of the Telluride quadrangle to the San Juan mountain area, and of the local physical features.*

*General relations.*—The Telluride quadrangle is bounded by meridians 107° 45′ and 108° west longitude, and by parallels 37° 45′ and 38° north latitude, and embraces 235.66 square miles. It lies on the western edge of the great elevated San Juan mountain area, wholly to the west of the Continental Divide. The principal drainage of the quadrangle is by the San Miguel and Dolores rivers, but in the eastern part rise small branches of the Uncompahgre and Animas rivers. By reference to the index map on the cover of this folio the general geographic relations of the quadrangle will be seen, and also the course of traffic communication by means of the Rio Grande Southern Railroad with the main lines of the State. The greater part of the quadrangle is in San Miguel County, while smaller areas fall within Dolores, San Juan, and Ouray counties.

**Mountains, canyons, and plateau.**

*Physical features.*—Situated on the abrupt western border of the San Juan Mountains, the Telluride quadrangle exhibits several distinct classes of topographic forms. Along its eastern side is the bold front of the San Juan Mountains. The western half of the area is chiefly occupied by an undulating plain, which represents the Great Plateau of Colorado and Utah as it abuts against the mountains. In this plain the San Miguel River has cut a canyon which reaches a depth of 1700 feet in the northwestern corner of the area. The plateau and canyon features would doubtless be much more distinctly marked were it not for the intrusive stocks and laccoliths of igneous rock, which cause isolated mountain masses, or small groups, to rise here and there in the plateau area. Some of these outlying mountains represent a geological type occurring in the Henry, Abajo, La Sal, El Late, and Carriso groups of the western plateau country, while the Mount Wilson group, on the western border of the quadrangle, is an isolated remnant of the volcanic complex, and equals the San Juan front in the rugged, precipitous character of its slopes.

**Character of the mountain front.**

*The San Juan front.*—The precipitous front of the San Juan is clearly shown upon the topographic map. It begins near the center of the northern line, swings around the head of the San Miguel Valley above Telluride, thence runs out to the center of the quadrangle at Ophir Loop, and proceeds in an irregular line southerly beyond Grizzly Peak. Nearly all of the indentations in this front have been made by branches of the San Miguel. But this stream has not cut far back at any point, and the high divide, followed by the county line, which traverses the area from north to south, passes eastward into the Silverton quadrangle for only a short distance, around Savage and Ingram basins. On the east of this divide, in the northeastern corner of the quadrangle, is the basin head of Canyon Creek, a tributary of the Uncompahgre River. In the southeastern quarter rise several branches of the Animas River. The crest of this divide remains above 13,000 feet for nearly its entire length in the Telluride quadrangle.

Elevated basins whose floors are above timber line, many of them glacial cirques inclosing beautiful blue lakes, characterize both sides of this divide, as clearly expressed by the map.

*The plateau and canyon area.*—Under this head may be described the country west of the San Juan front, excepting the mountains of igneous rock which have been mentioned. The map brings out very well the undulating character of the plateau above the brink of the San Miguel Canyon. On the western border is represented the contrast of canyon and plain which is so marked over large stretches of country to the westward. Near the mountains the plain is naturally modified by the numerous dikes, sheets, and irregular masses of igneous rock which have prevented the uniform erosion of the Cretaceous shale, often seen where they are absent.

**Types of mountains.**

*Isolated mountains.*—The Mount Wilson group of peaks is only partially included within the quadrangle. It is the eastern and largest of several groups on a general east-west line which together constitute the San Miguel Mountains. These high peaks are due to a great stock of diorite laid bare by erosion of the soft strata penetrated by it.

To the north of the San Miguel River are three mountain masses, Gray Head, Whipple, and Hawn mountains, illustrating the laccolithic type of the plateau country. They are prominent by reason of their comparative isolation. A corresponding mass is Flat Top, on the southern border, south of the Dolores River.

**Origin of names.**

*New names for mountains.*—New names have been given on the map to several prominent summits of the quadrangle for which no local designations were in use at the time of this survey. Of these, Ruffner, Whipple, and Hawn mountains, to the north of the San Miguel, have been named from early scientific explorers of this part of Colorado; Gilpin Peak, south of Mount Sneffels, after the pioneer Governor of the Territory; Mendota Peak, from the noted mine near it; while Gray Head, near Sawpit, Black Face, west of Trout Lake, and Flat Top, on the southern border, possess physical features suggesting the names chosen.

## SEDIMENTARY ROCK FORMATIONS.

*A description of the sedimentary formations represented upon the map by special colors or patterns.*

### ALGONKIAN PERIOD.

*Quartzites of Canyon Creek.*—The small body of upturned quartzites, with an intercalated rhyolite sheet, occurring in Canyon Creek north of Stony Mountain, has been referred to the Algonkian, or oldest sedimentary group of rocks, because it is known, as stated in the introduction, that an immense series of quartzites, schists, slates, etc., does exist beneath the Paleozoic limestones near Ouray, projects up into the volcanic series at several places 5 miles or less to the eastward, and rises to elevations of over 14,000 feet in the Needle Mountains, on the southern border of the San Juan region. It is supposed that the quartzites of Canyon Creek represent a sharp pinnacle of the post-Cretaceous topography which was buried by the great volcanic accumulations of the San Juan.

The quartzites of this area are rather coarse grained, grading into a fine conglomerate. They consist almost entirely of pale, smoky or somewhat clouded quartz grains, with only a small amount of kaolin in the interstices. The beds are massive banks, the bedding being, however, distinct, with variable strikes. The prevalent one seems to be about N. 65° W., and the strata are in places nearly vertical.

**Meaning of occurrence of quartzite.**

These quartzites, if not Algonkian in place, must be supposed to form a block floated up in the gabbro magma of the Mount Sneffels–Stony Mountain eruption. But since the mass projects on one side into the San Juan tuffs, and has but a narrow arm of the gabbro-diorite on the other side, it does not seem possible that a mass of this size can have been floated into this position. Mr. G. E. Kedzie, of Ouray, states that there are other much smaller quartzite masses, which seem to him included in the gabbro of Mount Sneffels, somewhat north of Canyon Creek. The existence of such bodies, however, would not require the same origin for the larger mass of Canyon Creek. The small inclusions might, indeed, be more easily accounted for by the presence of an assumed buried peak of similar rocks.

The rhyolite associated with the quartzites is of a dense, banded, felsitic type, much of it carrying smoky quartz phenocrysts, with some of orthoclase, while plagioclase is lacking. This contrasts strongly with the Potosi rhyolite, which carries plagioclase phenocrysts and is wanting in those of quartz. The rhyolite does not penetrate the San Juan tuffs, and altogether the character of the rhyolite and its association with the quartzites seem to harmonize with the reference of the quartzites to the Algonkian. Dikes of the Potosi rhyolite in this vicinity are glassy, according to Mr. Kedzie.

### JURATRIAS PERIOD.

*Subdivision into three formations.*

**Present divisions compared with those of Hayden Survey.**

*General statement.*—All sedimentary formations of the Telluride quadrangle below the Dakota Cretaceous are included in the Juratrias, excepting only the Algonkian quartzites already described. Three subdivisions are distinguished upon the map, under the names Dolores, La Plata, and McElmo formations. These three formations make up a complex which, upon the Hayden map of Colorado, was also divided into three parts, assigned respectively to the Trias, Jura, and "Lower" Dakota, for the southwestern portion of the State. This complex is represented on the Hayden map as extending up the San Miguel Canyon as far as Big Bear Creek, within the Telluride quadrangle, but the individual formations now recognized are not the same in extent as those of the Hayden geologists.

An accurate correlation of the formations here recognized, and included in the Juratrias, with the Hayden Survey subdivisions of the same complex (see Hayden map and reports by W. H. Holmes and A. C. Peale in annual reports of the Hayden Survey for 1875 and 1876) is at present impossible, because the Hayden classification is based mainly on studies which were most detailed in districts far removed from the San Juan front, while no sections seem to have been made in the quadrangles recently resurveyed. It is known that all these formations change more or less rapidly in lithologic character and thickness from the upturned zone about the western San Juan Mountains toward the great plateau and canyon country of Colorado and Utah. An actual tracing out of these formations, from the apparent shore line in the San Juan to the canyon of the Colorado, is necessary to a correlation of the various subdivisions made by earlier explorers upon observations in localities often hundreds of miles apart.

The three divisions here made in the Juratrias have been established principally on lithologic grounds, and direct evidence of their age is at present very scanty. The lowest of the three divisions, the Dolores formation, contains a few Triassic fossils in its upper portion. Below the fossiliferous horizons occurs a series of reddish grits, sandstones, or conglomerates, in which no fossils have been found. In the Rico quadrangle, adjoining the Telluride on the southwest, an invertebrate fauna has been found in the lower two or three hundred feet of the "Red Beds," which is assigned by G. H. Girty to the Permo-Carboniferous, in the sense of a transition series. The complex of strata characterized by this fauna will be described as the Rico formation. In the absence of fossil evidence, the red strata between the Rico Permo-Carboniferous and the beds containing Triassic remains are grouped with the latter in the Dolores formation.

**The question of age.**

The strata between the Dolores and the Dakota Cretaceous are here referred to the Jurassic portion of the Juratrias, because of stratigraphic position and lithological resemblance to the formations in other parts of Colorado in which vertebrate and invertebrate fossils of asserted Jurassic types occur. No determinable fossils have been found in these beds in the San Juan region. They were called "Lower" Dakota on that part of the Hayden map of southwestern Colorado for which W. H. Holmes and A. C. Peale were responsible, while no divisions were recognized by F. M. Endlich between the "Upper" Carboniferous and the Dakota Cretaceous.

Beds corresponding to those in question were carefully studied by G. H. Eldridge in the Elk Mountains, some 70 miles northeast of Telluride, and were grouped as the Gunnison formation and assigned to the Juratrias (Anthracite-Crested Butte folio, No. 9, Geologic Atlas of the United States, 1894). Fresh-water shells were obtained by Eldridge from a limestone in the lower part of the complex, but no vertebrate remains have as yet been collected from this formation on the Pacific slope in Colorado. A personal knowledge of the Gunnison strata in the Elk Mountains and in parts of the intermediate area leaves no doubt as to the full equivalence of the formations to be described with the series to which the name Gunnison was given by Eldridge.

In stratigraphic position and lithologic character the Gunnison formation seems to be, in part at least, equivalent to the Morrison formation at the eastern base of the Front Range, which embraces the well-known Atlantosaurus beds of Oil Creek, Morrison, and other localities. From their remarkable dinosaurian fauna these latter beds have been referred to the Jura by paleontologists.

Since so little new evidence as to the age of the Gunnison formation has been thus far discovered in the San Juan region, the discussion of that question is reserved for a later section of this text; but it may be said, in passing, that on stratigraphic grounds alone the geologist would be forced to class these beds with the Cretaceous, as has been done by Newberry, Endlich, Holmes, and Peale. This view found expression on the Hayden map by the designation of most of the strata of the Gunnison as "Lower" Dakota, or by the extension of the Dakota to include them.

**Fossils in the Elk Mountains.**

In describing the Gunnison formation of the Crested Butte quadrangle, where its thickness varies from 300 to 450 feet, Eldridge states that "At its base is a heavy white quartzite, 50 to 100 feet thick, usually in a single bed. Above it, in some cases succeeded by other sandstone layers, is a blue limestone containing abundant fresh-water shells of the genera Limnea, Valvata, and Cypris. The remainder of the formation consists of gray, drab, pink, and purple clays and marls, through which run thin intermittent beds of drab limestone." The two parts of the Gunnison thus described have been separated in the course of the present work and named the La Plata sandstone and the McElmo formation. This subdivision of the Gunnison formation, making it a group term in the San Juan region, is required for adequate expression of the local geology, and is further justified by the known development of the individual members of the complex to the westward, in the plateau country.

**Correction of usage in 18th Annual Report.**

In view of the natural division of the Gunnison into two members, Mr. Eldridge acquiesced in a proposition made by the writer to restrict, in future, the name Gunnison to the upper member, and to distinguish the sandstones at the base as the La Plata sandstone. This usage appears on the edition of the Telluride geological map published in the Eighteenth Annual Report of the Survey, Part III, in connection with Mr. Purington's report upon the mining industries of the quadrangle. But it has since been decided that such a procedure is in violation of a Survey rule. Hence, Gunnison is here again used in its original comprehensive sense, and the name McElmo is applied to the upper portion, designated as the Gunnison formation upon the map in the Eighteenth Annual and in the report by Purington.

#### DOLORES FORMATION.

*Definition.*—It is desired to apply the name Dolores to the Triassic strata of southwestern Colorado and of adjacent territory so far as a direct correlation may prove to be practicable. The name has been chosen because of the excellent exposures of typical fossil-bearing strata in the valley of the Dolores River, at present best known in the Rico quadrangle, but probably occurring at many places in lower portions of the valley. The name is now applied to about 2000 feet of generally reddish sandstones, grits, conglomerates, and shales, all highly calcareous, limited below by beds containing Permo-Carboniferous fossils, and above by the La Plata sandstone of the Gunnison formation, of assumed Jurassic age. Vertebrate, invertebrate, and plant remains have been found in the upper part of the formation thus delimited, and upon their evidence the Triassic age of that part of the complex is considered as proved. Whether or not all the beds now associated with the fossiliferous series in the Dolores formation are really of Triassic age remains to be determined by further discoveries. The base of the formation as above defined is not exposed in the Telluride quadrangle, but appears near Rico, a few miles southwest.

*Description of the formation.*—The Dolores formation has in general the characteristics of the widely known "Red Beds" of the Rocky Mountain region. It consists of an alternating series of sandstones, grits, conglomerates, and sandy shales, the latter often grading into earthy limestones. Individual beds of sandstone or conglomerate of uniform texture are seldom more than 25 or 30 feet in thickness, although fine-grained and thinly bedded sandstones with slight textural variations may exceed 100 feet in thickness. Nearly all beds vary greatly in constitution and thickness, so that detailed sections made at points not widely separated can seldom be closely correlated.

**Red color of Dolores formation.**

The reddish color of the series is due partly to pink grains of feldspar in the coarser layers, but chiefly to a ferritic pigment in minute particles. This color is dark or dull red in the lower portion, and a brighter red in the upper part; but white or pale pinkish sandstones appear here and there, and no color distinction can be used over large areas for the subdivision of the formation. While the greater part of the red strata of the region belong to the Dolores formation, it is known that the lower sandstone of the La Plata formation becomes brilliantly colored in places, and the Permo-Carboniferous strata below are also of a more or less distinctly reddish color.

A calcareous cement is present in abundance throughout the Dolores formation, and this constituent increases in amount southward from the Telluride quadrangle, and forms nodular reddish or mottled limestones or marls. In this abundance of carbonate of lime the strata of the Dolores formation resemble the Carboniferous sandstones and conglomerates, and contrast with the quartzose sandstones of the Gunnison formation above.

The strata are chiefly made up of materials derived from granites, gneisses, and the quartzose Algonkian rocks of the San Juan continental area of Triassic time. The finer-grained strata are rich in quartz, and the coarser ones contain much feldspar. The conglomerates are usually rich in pebbles of the dark quartzites and greenish schists of the Algonkian series. By the appearance of limestone pebbles in many strata, especially of upper horizons, the existence of Paleozoic beds in the land area adjacent to the Triassic sea is clearly proved.

**Materials composing Dolores strata.**

*Subdivision of the formation.*—As known between the Animas and San Miguel valleys the Dolores formation may be roughly divided into a lower, coarser-grained part, characterized by conglomerate containing granitic and quartzite pebbles, and an upper, finer-grained portion, with limestone conglomerate, often fossiliferous. This distinction can not be applied throughout the Telluride quadrangle, as the detailed section given below plainly shows. The difference referred to may be seen about Rico, but disappears in most particulars in the valley of Mineral Creek. This speaks for the proximity of the shore line to the eastward.

Along the San Miguel the fine-grained limestone conglomerate, containing teeth of dinosaurs and crocodiles, is a most prominent horizon. It is usually of pinkish color, from 10 to 20 feet thick, forms a projecting ledge, as a rule, and in this quadrangle is the most persistent and most richly fossiliferous stratum of the formation. It has been found convenient to call it the "Saurian conglomerate," by which designation it will often be referred to in this folio.

**The "Saurian conglomerate."**

On Summit Creek, north of the San Miguel River, the Saurian conglomerate occurs about 30 feet below the La Plata sandstone, but this interval increases to nearly 100 feet in the southeastern part of the quadrangle and to 500 feet on the Animas River, in the Durango quadrangle. These upper strata are usually bright red in color, of fine-grained sandstones and calcareous sandy shales, without marked conglomerates. They are similar to the strata seen extending for a few hundred feet below the complex of limestone conglomerates as developed south of the Telluride quadrangle, and are now thought to represent a part of the Dolores formation which has been removed by erosion in the region north of the Telluride quadrangle. The thinning out is apparently due to the unconformity at the base of the La Plata sandstone, which has been referred to.

*Detailed section of the Dolores formation.*—The following section of the Dolores was made by H. S. Gane on the western side of Cataract Creek, a tributary of West Mineral Creek, near the eastern border of the quadrangle. The section was made from the stream bed, at an elevation of 10,000 feet, up to the San Miguel conglomerate near the end of the sharp ridge, at an elevation of about 11,650 feet.

The section reads from above downward. At the top is the San Miguel conglomerate, resting unconformably on the Dolores.

| | | Feet. |
|---|---|---|
| 10. | Bright-red, fine-grained sandstone; quartzose | 32 |
| 9. | Gray limestone conglomerate, with calcareous sandy matrix; pebbles small, seldom exceeding 1 inch in diameter. In matrix abundant remains of a specifically undeterminable Unio | 8 |
| 8. | Alternating sandstone and conglomerate, reddish, with occasional white layers. Pebbles of granite, quartzite, and schist; few of limestone. In two conglomerates of upper part pebbles reach 1 foot in diameter. The sandstones are variably fine or coarse grained. No distinct planes for subdivision of this complex were noted | 910 |
| 7. | Dark-red sandstone with thin mud layers separating beds; limestone fragments rare. | 50 |
| 6. | Coarse reddish sandstone | 50 |
| 5. | Greenish sandy shales characterized by flat or flake-like limestone pebbles, irregularly distributed, usually small or reaching 6 inches in diameter. Upper part more sandy, reddish, with larger limestone flakes | 200 |
| 4. | Thin-bedded sandstone, with conglomerate at top | 75 |
| 3. | Sandstone, shaly sandstone, and conglomerate, alternating | 65 |
| 2. | Conglomerate of large, flat limestone pebbles, which weather out, leaving cavities | 10 |
| 1. | Coarse sandstones and grits, with occasional conglomerate layers. Massive as a whole, and forms cliffs; finer grained near top | 200 |
| | Total | 1600 |

This section is noteworthy for the comparatively coarse grain of the sediments in the upper part, for the presence of large limestone pebbles in so many horizons, particularly in the lower half, and for the occurrence of Unio, not elsewhere known in the San Juan region. About 100 feet of fine-grained sandstone is wanting at the top, with another limestone conglomerate, both of which are found farther up Mineral Creek. The base of the formation probably occurs in the Silverton quadrangle, on the east, not far from Cataract Creek, but it is covered on slopes where it may be expected to appear, and metamorphism through a monzonite stock has also prevented its detection.

**Features of the section.**

From the character of this section it seems unlikely that the strata composing it can be referred to distinctly different epochs. They seem to have been deposited in a littoral zone during one epoch, and the differences seen at other localities seem due to changes in conditions making themselves manifest only at some distance from the shore.

*Fossils of the Dolores formation.*—In 1880 and in 1882 R. C. Hills announced the discovery of vertebrate, invertebrate, and plant remains in the upper strata of this formation at San Miguel, 1½ miles below the present site of Telluride (American Journal of Science, Vol. XIX, 1880, p. 490, and Vol. XXIII, 1882, p. 243). These fossils were submitted by Mr. Hills to experts for determination, but were unfortunately lost before being fully identified. Mr. Hills regarded the abundant teeth found in one stratum as belonging to a crocodile near *Belodon priscus*, and certain fish remains as representing a ganoid similar to *Catopterus gracilis*. A small gasteropod shell and eleven or twelve apparently determinable species of plants were found. The Belodon and Catopterus remains were found in the limestone conglomerate, occurring here about 50 feet below the La Plata sandstone, and the fossil leaves in thin-bedded, reddish, micaceous sandstones not far below the conglomerate.

**Fossils found by R. C. Hills.**

In the course of the present survey the upper conglomerate has been carefully examined for fossils at many places in the Telluride, Rico, La Plata, and Durango quadrangles. It contains most abundantly teeth of Belodon and of a megalosauroid dinosaur, Palæoctonus, according to the identifications of F. A. Lucas. These are Triassic types, species of the latter from Texas having been described by E. D. Cope, and occurring also in the Trias of North Carolina. Further fish remains have not been found. In the Rico and La Plata quadrangles, at one locality in each, in the Saurian conglomerate, a gasteropod shell, poorly preserved, has been found, which, according to T. W. Stanton, belongs to Viviparus or some closely related genus, and it is stated by him that the earliest previous record of this genus is from the Jura.

**Fossils recently discovered.**

While plant stems and indistinct leaves are common at the general horizon at which they were found by Mr. Hills, the only determinable species yet obtained came from the Dolores Valley, a short distance below the Telluride quadrangle, from coarse grit near the Saurian conglomerate. This has been determined by David White as resembling *Pachyphyllum münsteri*, a Triassic plant. A Unio of specifically undeterminable character was found by Mr. Gane in the highest exposed conglomerate of the Cataract Creek section, given above. This is thought by Mr. Stanton to be in all probability one of the forms obtained by Cope on Gallinas Creek, New Mexico.

*Distribution and correlation.*—The Dolores formation has been traced continuously from the Telluride quadrangle to the eastern side of the Animas River, covering much ground mapped as "Upper" Carboniferous by the Hayden geologists. Mr. Hills has observed its fossiliferous portion on the Florida, and it undoubtedly extends eastward until concealed by the overlapping La Plata sandstone somewhere east of the Piedra River. The reddish strata in the Uncompahgre Valley may be confidently assigned to the Dolores, as the Saurian conglomerate was noted by Mr. Gane near Ridgway, a few feet below the La Plata sandstone. The fossiliferous series has not been observed farther north, except on the north side of Grand River near Red Dirt Creek, where it was found by Mr. Hills (Proceedings Colorado Scientific Society, Vol. III, 1890, p. 372). Whether this member of the Dolores was once present over the Dolores Plateau and was removed by erosion before the deposition of the La Plata sandstone, as I am now inclined to believe, or was never formed in that area, as thought by Mr. Hills, is a question for further investigation.

Observations of much value bearing on the distribution of all the formations referred to the Juratrias were made by H. S. Gane in 1897, during a trip down the San Juan Valley to the canyon of the Colorado. On this journey he was able to follow connectedly all the formations recognized in the Telluride quadrangle, from the Dolores to the Dakota, inclusive, and, while changing greatly in development, the limestone conglomerates of the Dolores were found over a large area, bearing the same relation to the lower La Plata sandstone which he had observed in the Telluride quadrangle. At Clay Hill, Utah, a crocodile jaw was found in the Dolores limestone conglomerate, which has been described by F. A. Lucas as belonging to a new genus, having decided Triassic affinities, to which he gave the name *Heterodontosuchus ganei* (American Journal of Science, 4th series, Vol. VI, 1898, p. 399). Poorly preserved shells of Unio, fossil wood, and the usual saurian bones and teeth were noted in the conglomerates. These observations indicate that the Dolores and other lower Mesozoic formations of the San Juan border have a great distribution in the plateau region of Colorado and Utah.

**Observations of H. S. Gane.**

While the Dolores formation, on the southern border of the San Juan region, is covered by later sediments for a long distance, it seems plainly suggested that the Triassic strata on Gallinas Creek, on the western side of the Sierra Madre, New Mexico, from which E. D. Cope obtained crocodilian and dinosaurian remains similar to those of the San Juan region, are to be referred to the Dolores formation. The same is true of the strata of the Abiquiu copper mines of New Mexico, where J. S. Newberry obtained several Triassic plants while on the Macomb exploring expedition.

### LA PLATA FORMATION.

*The name.*—It is proposed to name the lower member of the Gunnison formation after the La Plata Mountains, on account of its prominent and characteristic exposures in the peaks and on the slopes of that mountain group. From the dominant development of white sandstone in the Telluride and other quadrangles, it is there quite appropriate to call this formation the La Plata sandstone, but it is known that the thin limestone of the Telluride area represents a much more extensive series of shales, etc. in some other regions.

*Description.*—In the Telluride quadrangle the La Plata formation consists of two massive sandstone members separated by a thin, dense, bluish or almost black limestone. The total thickness in this quadrangle is seldom more than 100 feet. The distinctive feature of these almost purely quartzose sandstones is their unusually fine and uniform saccharoidal texture, causing them to form very massive banks on canyon walls, although a marked cross bedding is frequently present. These sandstones are here very light gray or white; but this color can not be given as characteristic, since in many places, especially to the south and west, a distinct or even brilliant coloring in varying shades of red or orange has been observed in the lower sandstone. But the contrast with the bright-red strata of the Dolores formation is very striking over large areas.

**Lithologic character of La Plata formation.**

The two sandstone members are usually of similar character, but in the Telluride quadrangle the upper one is sometimes thin bedded and shaly and of much less prominence than the lower. The base of the lower sandstone is, in certain places on the San Miguel, a conglomerate of small pebbles with much sand.

The limestone between sandstones is usually dense, but may be black and thin bedded. It varies in thickness from 6 to 16 feet, being thinnest in the San Miguel Valley and thickest on the southern border of the quadrangle. A thin, shaly limestone appears near the base of the formation in some places, but is probably not thus developed within the Telluride quadrangle. The limestone horizon is important locally, as that of the Sawpit ore deposits.

On the north side of the San Miguel, opposite Bilk Creek, Mr. Spencer found the lower sandstone to have a thickness of 64 feet, the limestone a thickness of 16 feet, and the upper sandstone a thickness of 26 feet. A similar ratio for the three beds way be seen in many exposures.

The upper sandstone layer is succeeded by a highly colored shale, taken as the lowest stratum of the McElmo formation. This shale may be sandy or strongly argillaceous. In color it ranges from chocolate through various shades of red, or it may be greenish. The change from white sandstone to colored shale is commonly abrupt, but is less so on the San Miguel than in most localities.

*Fossil remains.*—No fossils have been found in the La Plata strata of the Telluride quadrangle, but a few miles south of the Twin Sisters some indistinct fish scales and vertebræ were noticed. The specimens of these remains were unfortunately lost. In the Crested Butte quadrangle G. H. Eldridge found many minute shells in the dark limestone, which have been referred to Limnea, Valvata, and Cypris, indicating that the limestone was laid down in fresh water.

**Fossils indicating fresh water.**

### McELMO FORMATION.

*The name.*—The name here proposed for the upper division of the Gunnison is derived from the important branch of the San Juan River which has its source south of the great bend of the Dolores River and runs thence westward for 50 miles, passing the northern base of the El Late Mountains, and for most of its length traversing the arid plain country, the floor of which is the Dakota sandstone. In the main McElmo Valley and in its various side canyons the clays, shales, and sandstones of the upper Gunnison are excellently exposed, and from current reports it appears that vertebrate evidence as to the age of the formation may there be found in abundance. From personal observations of Messrs. Gane and Spencer, as well as from the Hayden reports, the equivalence of the strata here described with those of the McElmo Valley is placed beyond question.

*Description.*—The McElmo formation as developed in the Telluride quadrangle is a variable complex of shales and sandstones, with the latter much more prominent than is commonly the case elsewhere. The thickness of the series varies from 650 to 900 feet. The sandstones are fine grained, quartzose, of yellowish or gray color, and usually soft and crumbling. Some beds are locally massive, are cross bedded, and reach 50 feet in thickness, but shale partings of variable importance subdivide most of the sandstone members. Small flat flakes of green shale are common in many sandstone beds.

The shales are either reddish or greenish, or variegated by a mixture of these two colors. They are seldom pure clay shales, but are commonly both calcareous and sandy. Sandstone layers appear in the shales, and in following the formation along the walls of the San Miguel Canyon a shale stratum may be found to change, within a short distance, to an alternation of sandstone and shale. The reverse change often occurs in the case of sandstone beds.

**Lithologic constitution of McElmo formation.**

The basal member of the McElmo formation is a usually highly colored shale resting on the upper La Plata sandstone, and the upper stratum assigned to it is also a marked shale beneath a massive sandstone, commonly conglomeratic, which is assumed as the base of the Dakota Cretaceous. The appearance of a similar conglomerate in a sandstone bed of the McElmo, about 100 feet below the Dakota, makes the line between the formations difficult to establish in some places.

No fossils have been found in the McElmo formation of the Telluride or adjacent districts.

*Section of the McElmo formation* —The following section of the McElmo was made by Mr. Spencer on the north side of the San Miguel, opposite the mouth of Bilk Creek.

The section reads downward from the overlying Dakota sandstone and conglomerate.

| | | Feet. |
|---|---|---|
| 17. | Shale | 11 |
| 16. | Sandstone, rather fine grained | 22 |
| 15. | Shale, sandy, with many thin layers of fine-grained sandstone | 53 |
| 14. | Sandstone, coarse, grading into conglomerate of quartz and chert pebbles at base | 24 |
| 13. | Shale, dull red or green, with subordinate thin bands of very fine-grained calcareous sandstone | 155 |
| 12. | Sandstone, coarse grained, cross bedded | 48 |
| 11. | Shale | 11 |
| 10. | Sandstone, massive | 16 |
| 9. | Shale, red, with thin sandstone layers | 53 |
| 8. | Sandstone, white | 11 |
| 7. | Shale, red, with thin sandstone layers | 29 |
| 6. | Sandstone, white, cross bedded | 22 |
| 5. | Alternating red shale and gray sandstone | 85 |
| 4. | Sandstone, massive in lower part, but with thin red shale partings above | 80 |
| 3. | Shale, sandy | 32 |
| 2. | Sandstone | 8 |
| 1. | Shale, sandy, chocolate colored in upper part, thin layers of sandstone in upper part | 64 |
| | Total | 724 |

This section is typical of the McElmo formation in the Telluride region, but other sections show many changes in the relative development of sandstone and shale at any given horizon. The conglomerate, number 14 of section, is similar to the Dakota in character, but is very variable in development. Holmes noted the frequent presence of a conglomerate near the top of his "Lower" Dakota in the plateau country to the westward, and sporadic developments of the same in the Morrison beds may be seen in various places at the base of the Front Range.

**Comment upon the section.**

The sandstone strata of the McElmo formation as exhibited in this quadrangle are so similar to those of the La Plata and Dakota formations that it seems highly arbitrary in some places to attach to the boundary planes that have been chosen the great importance that really belongs to them if the formations considered are of the ages that have been assigned to them. The justification of the boundaries adopted is found in the comparatively constant character of the Dakota and the La Plata, above and below, rather than in the McElmo complex itself.

### CRETACEOUS PERIOD.

The formations succeeding the Juratrias in the Telluride quadrangle belong to the great series of the upper Cretaceous, which is so widely distributed through the Rocky Mountain country. Strata which can be correlated with the "Lower" Cretaceous formations of Texas are not known in Colorado, unless the supposed Jurassic formations, the Morrison and the Gunnison, are referred to that period. For reasons given in describing the Gunnison formation, and discussed in greater detail in a later section of this text, they are classed in the Juratrias. This implies that the line between the McElmo and Dakota formations represents a great stratigraphic break.

**Formations belonging to the upper Cretaceous.**

Only two formations of the "Upper" Cretaceous are now found in the Telluride quadrangle—the Dakota sandstone and the Mancos shale. Above these there once existed in this area the full series of higher Cretaceous strata corresponding to that still preserved in the Animas Valley near Durango. The upper formations have here been removed by erosion, partly in the period immediately succeeding the Cretaceous and partly in Tertiary and Recent times.

The Cretaceous section of southwestern Colorado differs so much in lithologic character from that found in other parts of the State that a new scheme for its subdivision into formations is necessary for the appropriate expression of the local geology. Only one of these new formations is found in the Telluride quadrangle, namely, the Mancos shale.

**A general statement of new observations.**

*The Cretaceous section of southwestern Colorado.*—While the full discussion of the Cretaceous section and its subdivision will be presented in the La Plata and Durango folios, now in preparation, a concise summary may be given here. As explained below, the Mancos shale includes equivalents of the Benton, the Niobrara, and a part of the Pierre formation—that is, the Colorado group and a part of the Montana. In the study of the complete section it has been further ascertained that the marine fossils of the Pierre extend up into a large shale series above the coal-bearing sandstone formation which forms the scarp of the Mesa Verde. In the La Plata folio the latter will be called the Mesaverde formation, and the shale above it the Lewis shale, from Fort Lewis, on the La Plata River. In the Durango quadrangle a further subdivision is necessary, distinguishing two heavy sandstone series above the Lewis shale and another shale which separates them. Details of this upper subdivision have not yet been fully determined upon. The Lewis shale is about 2000 feet thick, and is lithologically comparable with the Mancos shale. The Mesaverde formation embraces the coal measures most extensively worked in that region. On the Hayden map it was referred to the Fox Hills.

### DAKOTA FORMATION.

*Description.*—The Dakota is characterized in this region, as commonly in Colorado, by gray or brownish quartzose sandstones, often cross bedded, with a variable conglomerate at or near the base and several shale horizons at intervals. The thickness varies from 100 to 250 feet within the quadrangle.

As compared with other regions the fine basal conglomerate, with its small chert pebbles of white, dark-gray, black, or reddish colors, is especially variable, being absent in some places and unusually coarse and thick in others. The shale members are much more strongly developed than on the eastern slope of the Rocky Mountains. In two of them there is a large amount of carbonaceous matter, which increases to the extent of forming workable coal seams on the Dolores River. In the adjoining plateau country to the west and south coal is commonly found in the Dakota, but seldom exceeds 4 feet in thickness, and is of a quality much inferior to that of the higher Cretaceous horizons developed in the La Plata and Durango quadrangles.

The lower sandstone of the Dakota is especially prominent, not only here but in the plateau region, forming the rim rock, or upper scarp, of thousands of miles of canyons like the canyon of the San Miguel.

Plant remains, in the form of carbonized stems and poorly preserved leaves, are common in the Dakota, but have not been found in sufficient perfection for identification.

*Detailed section.*—The following is a section of the Dakota, made by Mr. Spencer, on the north side of the San Miguel, opposite the mouth of Bilk Creek, above the section of the McElmo formation already given.

The section reads downward from the dark sandy shales of the Mancos formation.

| | | Feet. |
|---|---|---|
| 9. | Sandstone, hard, with quadrangular jointing. | 16 |
| 8. | Sandstone, grading into shale in upper part. | 22 |
| 7. | Shale, black | 16 |
| 6. | Sandstone, massive | 5 |
| 5. | Sandstone, fine grained, lenticular or wavy bedding and thin carbonaceous shale partings | 8 |
| 4. | Shale, black, with 8 inches of coal at base | 8 |
| 3. | Sandstone, thin bedded, with shale partings. | 27 |
| 2. | Shale and thin sandstones, carbonaceous | 5 |
| 1. | Sandstone, coarse grained, rather massive, mainly quartzose, with irregular conglomerate of small quartz and chert pebbles at about 20 feet above bottom | 81 |
| | Total | 188 |

**Comment on the section.**

This section illustrates the general character of the Dakota in the San Miguel Canyon, but the several members here distinguished change much laterally. The heavy sandstone at the base always forms a bold cliff, but in some places shaly layers subdivide it. The bottom of this sandstone is often a conglomerate and generally has a wavy surface of contact with the variegated shale of the McElmo, on which it rests. Irregular shale masses are sometimes included in the basal sandstone.

According to the local development and induration of the higher sandstones, there may be small ledges or scarps above the main one; but where shales are plentiful and the sandstone is soft, the upper part is a broken succession of benches and ledges, often obscured near the top by Mancos shales creeping down from above. Where erosion has removed the upper layers for some distance back from the edge of the canyon it becomes difficult to trace the Dakota-Mancos line with accuracy.

*Local variations of the Dakota.*—Eastward from the point of the section given above the Dakota increases in thickness to about 250 feet, opposite the Keystone placer, on the north side of the river. Eastward the sandstone layers become more massive, and are more indurated, so that the outcrops near Telluride are often very distinct cliffs.

On the southern branches of the San Miguel there is no very marked change in the Dakota, but in the southeastern part of the quadrangle it is only 100 to 125 feet thick. The basal conglomerate is here in places rather coarse and prominent, and is absent in other places. On the Dolores shale bands are strongly developed, and the coal seams are of some economic importance. The lower sandstone is massive, and a sandstone above the coal forms the rim of the canyon.

### MANCOS SHALE.

*Description and name.*—Above the Dakota formation is a dark shale series, of which a thickness of nearly 2000 feet is preserved on the north side of the San Miguel River. In this series no persistent lithologic or paleontologic horizon has been found which could be used for the subdivision of the formation. The shales are dark gray or lead colored, and are nearly always somewhat sandy. Thin calcareous layers become almost limestones in places, and are usually rich in fossils. Sand locally increases to form sandstone, but no limestone or sandstone layer is persistent and prominent enough to be traced far.

About 125 feet above the Dakota is a dark calcareous layer, rich in fossil shells, of which the most abundant is *Gryphæa newberryi*, and 100 feet higher another layer is in this quadrangle characterized by a fossil oyster, *Ostrea congesta*. These layers, developed as thin limestones 1 to 3 inches thick, may often be found, but the fossils of both are of species belonging to the Benton shale of the Colorado group, and do not serve to show the age of the shales above them. At a much higher horizon a few fossil shells, which are referred to species known in the Pierre division of the Montana Cretaceous group, have been found in sandy layers. These sandy layers are very local in development.

Thus it appears that the Cretaceous shale formation of the Telluride quadrangle probably embraces strata belonging to the Benton, Niobrara, and Pierre epochs, but that there are no practicable horizons for the subdivision of the complex in areal mapping. This formation has been traced through the Rico, La Plata, and Durango quadrangles, and adjacent territory, and is found to possess this character as a lithologic unit. It is proposed to call it the Mancos shale, from its characteristic occurrence in the Mancos Valley and about the town of the same name, between the La Plata Mountains and the Mesa Verde.

The Mancos shale covers a large area in the Telluride quadrangle, extending back from the Dakota scarps of the San Miguel and Dolores rivers until overlain by the San Miguel conglomerate or pierced by igneous rocks. It forms smooth-sloped ridges or hills, contrasting with other formations of the region in this respect. Its presence under the Tertiary volcanic series has been favorable to enormous landslides.

**Lists and localities of fossils.**

*Fossils of the Mancos shale.*—Fossiliferous strata which apparently correspond to the Gryphæa and Ostrea layers above mentioned have also been noted at many places in the Rico, La Plata, and Durango quadrangles. They undoubtedly represent the horizon at which Newberry found the same forms "at a thousand points" on the route of the Macomb expedition, in 1859 (Geological Report of the Macomb Expedition, 1876, p. 71). Newberry collected these fossils from many localities in the quadrangles named, and T. W. Stanton has also obtained them from the same district, and from near Mancos (The Colorado Formation: Bulletin U S. Geological Survey No. 106, 1893, p. 32). The complete list of fossils known from these two horizons embraces at present the following forms, as determined by Mr. Stanton: *Gryphæa newberryi* Stanton, *Ostrea lugubris* Conrad, *O. congesta* Conrad, *Inoceramus labiatus* Schlotheim, *I. dimidius* White, *I. fragilis* H. and M., *Baculites gracilis* Shumard, *Scaphites warreni* M. and H., *Prionocyclus macombi* Meek, and *Plicatula* sp. ?. According to Mr. Stanton these forms indicate a horizon well up toward the top of the Benton shale as known in other regions.

Fish teeth and scales also occur with these forms, but are not so abundant as farther east, where Newberry found them so common that he occasionally referred to these strata as the "fish beds."

In loose fragments of sandy strata found on the East Dolores River west of Grizzly Peak Mr. Stanton identified *Anatina* sp. ? and *Turritella* ?. The horizon of these shells was not determined.

A sandy ledge in the shales at 11,500 feet, on the slope south of Mount Wilson, contains poorly preserved specimens of *Inoceramus cripsii* var. *barabini* Morton ?, *Synocyclonema rigida* M. and H., and *Baculites* sp. ? (either *B. ovatus* or *compressus*). These forms belong to the Pierre division of the Montana group, according to Mr. Stanton, and give the only fossil evidence thus far secured in the Telluride quadrangle as to the age of the upper Mancos shale. But in the La Plata quadrangle Mr. Spencer found a number of characteristic Pierre shells in the shale, especially near Thompson Park, and at several horizons. Among them Mr. Stanton has identified *Inoceramus undabundus* M. and H. ?, *I. cripsii* var. *barabini* Morton, *Baculites asper* Morton ?, *Leda* sp. ?, *Mactra* sp. ?, *Arca* sp. ?, *Ptychoceras* or *Hamites* sp. ?, and *Scaphites* sp. ?.

## EOCENE PERIOD.

Normal sedimentary deposits of apparently Tertiary age are represented in the Telluride quadrangle by the San Miguel formation only. This has been assigned to the Eocene, because of the great unconformity at its base and because it underlies the volcanic complex of the San Juan, which is thought to be of Eocene age in the portions here developed.

### SAN MIGUEL FORMATION.

**Formation first observed by R. C. Hills.**

*Recognition and naming of formation.*—Beneath the bedded volcanic series all through the Telluride quadrangle, and in portions of the Silverton quadrangle on the east, occurs a coarse conglomerate resting unconformably on Mesozoic and Paleozoic formations. The first recorded observations of this conglomerate were made by R. C. Hills, who referred to it in addresses delivered before the Colorado Scientific Society in 1888 and in 1890 (Proceedings Colorado Scientific Society, Vol. III, pp. 174 and 407). Mr. Hills noticed this formation in the typical exposures of the San Miguel Valley near Telluride, and on Canyon Creek above Ouray. The name San Miguel was proposed by the writer for this formation in a communication presented to the Colorado Scientific Society, September 7, 1896 (Proceedings Colorado Scientific Society, Vol. V, p. 235), from the locality mentioned, where it was first recognized in exposures displaying its character and relationships most perfectly.

*Description of the formation.*—The San Miguel beds vary in thickness from 200 to about 1000 feet. In the eastern part of the quadrangle, where thinnest, they are uncommonly coarse and massive conglomerates, containing round bowlders from 2 feet down to 1 inch in diameter, embedded in pinkish sand or gravel. The beds are very variable in texture, however, and change, within short distances, from coarse conglomerate to grits and sandstones with a few pebbles. As the formation increases in thickness westward the average texture becomes finer, and sandy layers even predominate locally. In Mount Wilson, where the complex is 1000 feet thick, very fine-grained sandstones and sandy shales are largely developed.

**Materials of the conglomerate.**

The pebbles and bowlders of the San Miguel conglomerate represent many rocks—granite, gneiss, greenish schists of several varieties, white, gray, and bluish quartzites, limestone, red sandstone, and an igneous rock of prominent porphyritic structure being common. The matrix is a gravel or sand of quartz and other hard minerals derived from the same rocks that furnished the pebbles.

The composition of the conglomerate varies somewhat from place to place, but all through the eastern part of the Telluride quadrangle it may be noticed that limestone and red sandstone are much more abundant in the lower half of the formation, while the ratio of bluish quartzites and dense greenish schists increases upward. Changes both in texture and in materials occur so rapidly from place to place as to show that strong shore currents must have played an important part in distributing the sand, gravel, and pebbles.

In general appearance this formation is light pink or gray in color, and massive, forming distinct cliffs, and, by contrast with the dark tuff above, it becomes one of the most striking features of the precipitous San Juan front. From a point like Sunshine Mountain the San Miguel formation can be clearly distinguished beneath the volcanic formations, from Ruffner Mountain on the north to Grizzly Peak on the south, excepting only where it is obscured by landslide areas or cut by the diorite-monzonite stock of Ophir Needles and Yellow Mountain. The view in fig. 1, on the Illustrations sheets, shows this contrast in the cliffs north of the San Miguel River. In the greater part of the quadrangle the cliff-making part played by the formation, as illustrated here, is particularly due to the presence below it of the Cretaceous shales; but in nearly all places it is sufficiently different from the underlying formation, either in texture or in stratigraphic position, to form a distinct ledge.

*Details of constitution.*—The fine exposures of the San Miguel conglomerate on Cataract Creek and on Lime Creek near the eastern boundary of the Telluride quadrangle are only 3 miles from the eastern slope of Sultan Mountain, which lies directly east, in the Silverton quadrangle, where it is now known that the formation is only a few feet thick. From Sultan Mountain to Mount Wilson is a distance of 18 miles, within which the formation increases from less than 50 feet to about 1000 feet in thickness. Hence the variations in character of the San Miguel within this quadrangle are of much significance.

**Local variations and characters.**

On Cataract Creek, and opposite to it on Lime Creek, the San Miguel conglomerate is reddish in color and massive in bedding, and huge blocks have fallen from the overhanging ledge, nearly 200 feet in height, into the gulch below. The lower 100 feet of the beds is rich in limestone pebbles, with an unusual number of red sandstone and shale fragments, often not well rounded. The limestones are of various shades, dark gray prevailing, with some of white, gray, bluish, and pinkish color; some are sandy, and some contain black chert fragments. Some contain Carboniferous and others Devonian fossils. Schists and quartzites predominate in the upper 100 feet of the conglomerate, and the bowlders are larger than those below.

Around the head of Mineral Creek the San Miguel is about 300 feet thick on an average. On the west side of the Twin Sisters the lower part is shaly, and contains many fragments of the dark Mancos shale, on which it here rests. This corresponds to observations in other localities—that the lower few feet of the formation often contains much worked-over débris of the sedimentary formation immediately below. On the eastern slope of Rolling Mountain a very marked, fine, shaly band occurs near the middle of the formation.

On Howard Fork the San Miguel conglomerate is not so well exposed as elsewhere, owing to the bleaching and decomposition it has undergone in this highly mineralized area, and also to the unusually fine grain of the formation as a whole. It occurs, in almost its customary coarseness and distinctness, as a conglomerate at the head of Swamp Creek, and from there can be traced, as indicated on the map, on both sides of Howard Fork until it is cut by the igneous stock below Ophir; but at many points it is so fine grained and bleached that unless the unconformity at its base is clearly shown, one might easily mistake the San Miguel for some of the Dolores grits.

On Bear Creek the lower part of the conglomerate is very coarse in many places, bowlders more than 2 feet in diameter being present. While limestone pebbles occur in these lower layers, quartzites of white, gray, pink, or bluish colors are much more common, with many schists and few pebbles of granite or gneiss.

From the head of the San Miguel Valley above Telluride to Ruffner Mountain the formation is generally of finer texture than on Bear Creek, the pebbles seldom exceeding 6 inches in diameter, while in many exposures the strata are chiefly sand stones and grits, with a few pebbles irregularly scattered through them. Quartzites of various colors are most abundant here, and porphyries of several types are unusually numerous among the pebbles. These igneous rocks are not of the volcanic series to be described, and their sources are as yet unknown. In Campbell Peak and on Deep Creek the San Miguel formation is much bleached, but its exposures on Mill Creek and at many points to the east are highly characteristic.

**Increase in thickness westward.**

In the mountain northwest of Grizzly Peak the San Miguel is about 500 feet in thickness, and increases to 700 feet toward Sheep Mountain. The lower strata are, as a rule, fine-grained buff and reddish sandstones, with thin layers of conglomerate. There are many thin mud layers exhibiting trail markings and apparent shrinkage cracks. Search for fossils in these beds was fruitless. In the conglomerates, which are nearly all of small pebbles, limestone is very abundant, varying from black, through shades of gray, to almost pure white. Rapid lateral variation in texture of beds is characteristic of the series here. Near the top of the formation in this region is a very light-gray layer 30 to 40 feet in thickness, composed mainly of quartz sand and quartzite pebbles, which is conspicuous from distant points of view.

On the western slope of Sheep Mountain the San Miguel is nearly 700 feet in thickness, and consists of variable grits and sandstones, with thin conglomerate layers all through the series. The light-colored layer near the top is a coarser conglomerate than most of the beds below. The gradual decrease in thickness of the formation from this point along the north slope of the mountain to the west base of Vermilion Peak, where it is less than 400 feet thick, can be most plainly seen from points like San Bernardo Mountain.

In the mountains between Trout Lake and Mount Wilson the San Miguel formation is mainly a loose and friable grit or sandstone series, exhibiting conglomeratic development here and there all through the complex. At Mount Wilson the maximum observed thickness of the formation was found on the south side. The formation is here a succession of fine conglomerates, grits, sandstones, sandy shales, calcareous shales, sandy limestones, and dark, or even black, shales. The layers of homogeneous constitution are seldom more than 10 feet thick, and the fine-grained sediments vary rapidly from one development to another. Thin shale layers may separate conglomerate beds. All the finer-grained strata are likely to show curved impressions like fucoidal markings or like trails or burrows. No fossils of any kind could be found. The conglomerates show many kinds of rocks represented among the pebbles, but quartzites predominate.

In the vicinity of the Mount Wilson stock the finer-grained strata are often so hardened that recognition of the formation is difficult unless the conglomerate layers are found.

**Details of the unconformity below the San Miguel.**

*Stratigraphic relations.*—The great unconformity at the base of the San Miguel formation, which has been already alluded to, is shown on the geological map, and it may be clearly seen as present on the north side of the San Miguel River, between Iron Mountain and Marshall Creek, by an observer stationed at any good point of view on the south of that valley. The general westerly dip of the underlying formations and the low easterly dip of the San Miguel beds bring out this angular unconformity most distinctly. In Ruffner Mountain nearly 2000 feet in thickness of the dark Mancos shales are present below the San Miguel conglomerate. Following southeasterly along the base of the San Miguel, it is found that the shales thin out and finally disappear on Butcher Creek, and that in succession the Dakota, McElmo, and La Plata formations are cut off, so that between Marshall and Ingram creeks the San Miguel comes to rest on the red beds of the Dolores formation. At no known point directly east of this locality has erosion cut down sufficiently to reveal the San Miguel beds, if present, beneath the volcanics. In the southeastern portion of the quadrangle the unconformity is shown in equal degree between Sheep Mountain and the quadrangle boundary on Lime Creek, though the outcrops are not continuous, owing to the monzonite stock of Grizzly Peak. East of this point, however, the unconformity is shown for 3 miles farther, to Sultan Mountain, near Silverton, where the upper Carboniferous beds appear under the conglomerate, here only 30 to 50 feet thick. It may be that the shore line here indicated marks the eastern limit reached by the formation on the south side of the San Juan Mountains, but this generalization will not be warranted until the region east of the Needle Mountains has been examined.

**Importance of the unconformity.**

Whether or not the lower Carboniferous and the Devonian strata are ever found in actual unconformable contact with the San Miguel formation, it is plain that they, too, must have been affected by the great uplift at the close of the Cretaceous, and that they were exposed in the land mass adjacent to the San Miguel lake. Limestone and quartzite conglomerate pebbles derived from Devonian strata occur in the conglomerate of the San Miguel. The unconformity at the base of the San Miguel formation is, therefore, one of the most striking and important ones known in the Rocky Mountain region, and testifies to an uplift of unknown extent, followed by stupendous erosion in the interval between the close of the Laramie Cretaceous and the subsidence by which the San Miguel lake was created.

Above the San Miguel beds of the Telluride quadrangle come, with apparent conformity, the stratified tuffs of the San Juan formation. The abrupt change in constitution marks the dividing line very clearly, as will be brought out in describing the latter formation.

The actual contact of the San Miguel formation in unconformable relation to the beds below may be seen in many places. The most striking points are where the white La Plata sandstone disappears and the pink San Miguel comes in contact with the much darker red Dolores sandstones or conglomerates. One can put his finger on the spot where this contact occurs on the east side of Bear Creek, and it can be located with great precision at almost every other point where it is represented upon the map. The exposures on Lime Creek and on the north side of the San Miguel are especially favorable for examination by any one who wishes to follow this unconformity for considerable distances.

## IGNEOUS ROCK FORMATIONS.

*A description of the igneous masses represented upon the map, occurring either as surface lavas, as fragmental material, or as the filling of fissures or other conduits penetrating the sedimentary rocks.*

The igneous rocks of the Telluride quadrangle belong in large part to the great series which form the San Juan Mountains, and these naturally fall into two geologic groups of somewhat different characteristics, namely, the bedded volcanic series of surface flows and fragmental material, and the stocks, or irregular cross-cutting masses, which penetrate the former. In the sedimentary beds beneath the volcanic series are other rocks intruded in the form of laccoliths and sheets. These are more closely related in general character to the rocks of similar masses in the La Plata and other isolated mountain groups of the plateau country than to the rocks of the San Juan. There are, besides the above classes, a large number of small dikes and a few peculiar igneous bodies having obscure relations. The rocks will be described in the general groups outlined above.

**Hayden Survey names.**

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 originated by F. M. Endlich and defined 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" have thus far been 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 variety of andesites, diorite, monzonite, gabbro, and several porphyries were obtained by him in areas mapped as "trachoreite."

In the San Miguel, La Plata, and other outlying mountains, the Hayden map classifies the igneous rocks as "porphyritic trachyte (hornblendic)." These are mainly areas of intrusive porphyries, of the diorite or monzonite families. But in extending this designation to cover the andesitic tuffs and the stock diorite of the Mount Wilson group, a more serious error of classification was committed. This, like many other discrepancies of the Hayden map, arose from adjusting the observations of two geologists in the border zone between their areas of field work.

### BEDDED VOLCANIC SERIES.

### SAN JUAN FORMATION.

**Basal member of the volcanic series.**

*Geologic relations.*—The basal member of the bedded volcanic series building up the plateau, of which the present San Juan Mountains are a remnant, is represented in the Telluride quadrangle by a complex of more or less clearly stratified beds, which may be called tuff, breccia, or agglomerate, according to the texture presented in various layers. The beds here lie conformably upon the San Miguel formation, and while nearly all the materials are of volcanic origin, the bedding of the lower part at least seems due, throughout this quadrangle, to the action of water in the San Miguel lake of the period at which the eruptions began. The rock fragments are exclusively of andesite, so far as observed, and it is believed that the beds are the product of the first great explosive eruption in the San Juan area. For this bedded fragmental series, laid down before the eruptions of rhyolite, the name San Juan formation was proposed at the same time that the San Miguel conglomerate was named (Proceedings Colorado Scientific Society, Vol. V, p. 226).

The San Juan tuff, breccia, etc., may be considered as a pyroclastic formation which passes uninterruptedly from regions like the Telluride quadrangle, where the materials were in part at least stratified by water, to adjacent land areas, where a subaerial bedding may be locally well marked, or where the arrangement may be chaotic near the explosive vents. A similar transition is undoubtedly represented in the vertical section, the lower beds having been waterlaid, while a filling up and forcing back of the water would lead to a bedding of the upper portion entirely due to subaerial agencies.

*Description.*—The San Juan formation of the Telluride quadrangle is a series of horizontal tuffs, agglomerates, and breccias, composed of andesitic débris and reaching a maximum thickness of about 2000 feet. It lies unconformably on the San Miguel beds, and the line between the formations is sharp only in the abrupt change from light-colored quartz and feldspar sand to dark volcanic material.

For 100 or 200 feet above its base the formation is here a fine-grained, well-bedded dark tuff; that is, a stratified volcanic sand or gravel in which granitic sand and a few pebbles of Algonkian quartzites are locally found in quite subordinate amount near the base. This lower zone of dark tuff is prominent in the San Miguel Valley.

**A bedded fragmental volcanic formation.**

Above this dark tuff comes a succession of more or less clearly stratified tuff, agglomerate, or breccia beds. The bedding is always distinct where cliff faces of some size can be seen, but may not be evident within some of the thicker bands if examined in detail only. Several views presented on the Illustrations sheets show the bedding as present in large exposures. Tuff layers of even grain appear at intervals throughout the formation, but by the admixture of larger fragments in varying degree, most beds become intermediate between tuff and agglomerate—a confused mingling of blocks of various sizes. Beds which may properly be called breccia, because made up of angular fragments without a considerable amount of fine-grained matrix, occur here and there, and probably become more important to the eastward.

In general it appears that the beds are coarser and more chaotic in texture near the eastern boundary, but local modifications are often found which deviate from this rule. The nearly horizontal bedding also continues unchanged over the quadrangle. Thus, change neither in texture nor in attitude of the beds indicates near approach to the vicinity of the volcanic vents from which the materials came.

**Details of constitution.**

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, but of many different textures and details of structure.

In the fine tuffs the small angular grains clearly belong to many types of andesite. Some are finely vesicular or fluidal; a glassy base may be suspected in some cases; but the large majority are either of microcrystalline groundmasses of very fine grain or cryptocrystalline. The larger fragments are of the same types as those in the tuffs, and are similar to the hornblende- or pyroxene-andesites occurring in flows to be described. No basalt particles have been seen in the San Juan tuffs. The usual state of decomposition in which the rock particles are found makes any special petrographical description unsatisfactory. Some of the dark tuffs of the lower horizons contain much more granitic sand than the megascopic appearance suggests. Much of this sand is of microcline granites.

Such andesitic beds are usually dark bluish gray, but this color is seldom found in the Telluride quadrangle. They are commonly purplish or dull reddish brown all through the district, the matrix and the larger fragments being often of different tones, emphasizing the texture, which might otherwise be obscured by the secondary coloring. These colors produce very dull and somber effects in the mountains where the exposures are most extensive.

**Colors developed through decomposition.**

In the areas of greatest mineralization the San Juan tuffs, etc., like other formations, have been extensively impregnated by minute particles of pyrite. The staining of the tuffs by hydrous oxide of iron, resulting from the decomposition of this pyrite, often causes brilliant yellow or red colors, but this is not peculiar to the San Juan formation, being, indeed, most striking in the rhyolite flows of the higher peaks.

The tuffs, breccias, and agglomerates of this series have been somewhat indurated by the calcite and other substances resulting from the circulation of waters through them, and in consequence form very rugged slopes, as shown in the views on the Illustrations sheets and discussed somewhat in detail later on.

**Thickness.**

The thickness of the series varies from 2000 feet near Telluride to a few hundred feet at the Lizard Head. There is also a marked thinning of the formation southward, so that on West Mineral Creek only about 400 feet of fragmental beds have been assigned to the San Juan formation. But the line separating it from the Intermediate series above was not very clearly established at this locality. The variation in thickness is probably due in large degree to erosion in the interval preceding the eruptions of the Intermediate series.

From the several textures and the somewhat varying mineral composition of the andesite fragments seen in the tuffs, etc., it would appear that the explosive eruption which has been assumed must have destroyed an earlier volcanic mountain built up of lavas represented by these fragments. If this be true, the San Juan formation seen in this region does not actually mark the beginning of the volcanic cycle, but no observations thus far made indicate the site of the volcano destroyed.

### INTERMEDIATE SERIES.

The andesitic tuffs, agglomerates, etc., of the San Juan epoch are overlain in the Telluride quadrangle by a series of rocks of characters indicating such a different phase of volcanic activity that it is desirable to distinguish them upon the map and in discussion. This series is termed the Intermediate series, as expressing both the observed position of the rocks, between the San Juan tuffs and the Potosi rhyolite series above, and also the transitional nature of the epoch of eruption, from one of exclusively andesitic products to one of rhyolite flows and tuffs. In general the series consists of alternating rhyolite and andesite flows, with tuffs of varying constitution below, between, and above them, grading into a breccia, mainly of andesite, and in this particular resembling the San Juan, although commonly more chaotic in arrangement. The series changes in character so rapidly that the description must proceed according to local development.

**The first lava flow recognized.**

*The lower andesite flow.*—In the northeastern part of the quadrangle the series consists largely of lava flows of both augite-andesite and rhyolite. The most prominent member here is the massive flow of augite-andesite which is so prominent in Marshall Basin at the general level of the Mendota mine. This is 600 feet in thickness in some places, but thins out to the northward, and on the south slope of Dallas Peak it is reduced to a discontinuous lava sheet 30 feet or less in thickness, and on the southeast ridge of Campbell Peak its westernmost observed outcrop is a ledge of lava 4 feet high, largely vesicular.

The rock of this flow is augite-andesite, with a small amount of probable hypersthene, represented by decomposition products. So far as determined the plagioclase phenocrysts are labradorite. They are often full of glass inclusions, and exceed the pyroxenes in amount. The groundmass is of the typical microlitic form common in andesites. In some specimens there is or has been a scanty glass base, but in most cases the mass seems holocrystalline. Fluidal structure is often seen.

*Rhyolites of the Intermediate series.*—In the ridge between Campbell and Dallas peaks the thin andesite sheet seems to be all that can be referred to the Intermediate series, but on the ridge north of Park Basin there appear some thin rhyolite flows, of black or dull-reddish, glassy appearance, associated with thin tuffs, and all about Marshall Basin and the head of the San Miguel rhyolite flows or tuffs occur below the main andesite flow. To the south of Ingram Creek the series changes in character, and is much more prominently tuffaceous or breccia-like; both the andesite and the rhyolite flows are less marked as such.

**The peculiar rock at the base of the series.**

The base of the series in the central eastern part of the quadrangle appears to be a peculiar, unevenly lamellar rhyolite of gray, red, or greenish color, characterized by flat blotches, half an inch or less across, of dull-red or green color, as a rule. These are very prominent on the surface of lamination, and cause a streaked appearance at right angles to it. The blotches are either pressed-out vesicles or mud flakes, and the rock is a devitrified rhyolite (aporhyolite). This blotchy rock was found at the base of the Intermediate series at many places between U. S. Grant Peak and Marshall Basin. It is only a few feet thick and grades into reddish banded rocks of a dense matrix, holding numerous small angular fragments of andesite or dull-reddish rhyolite. These pass into apparent tuffs of rather indistinct character, many of which were found to be flow breccia—that is, a rhyolite flow holding so many fragments of andesite that the fluidal matrix becomes quite inconspicuous and can not be seen with the naked eye. The true nature of these rocks was not recognized in the field, and, indeed, the base of the series was not determined for many localities until the specimens were microscopically studied.

Microscopical examination of the rhyolites of the Intermediate series shows them to have been partly glassy, in most cases with strongly developed fluidal structures. Devitrification is very common, and many of the rocks are properly termed aporhyolite, as expressing their present condition.

The dark rhyolite-vitrophyre of Park Basin has a brown, stringy glass, which exhibits the beginning of devitrification in the usual manner, proceeding from perlitic cracks. A dull-red rock results when the ferritic particles have become hydrated and devitrification has become more pronounced. The feldspar phenocrysts are nearly all plagioclase, and when determinable have been found to be labradorite ($Ab_1 An_1$), as in the other forms of rhyolite occurring in this region.

**Petrographic details.**

The aporhyolite of the "blotchy type" above referred to exhibits, under the microscope, a peculiar microbreccia structure, apparent by the sharp interruption of fluidal structure shown by the strings and films of ferritic particles, though the fragments seem to have been welded together again. This structure appears to have been produced by shocks while the mass was in a stiff, viscous condition. Perlitic fissures furnish the points of attack by the agents of devitrification, as in the vitrophyre. The "blotches" are apparently vesicles pressed out very flat in the flowing of the lava and filled by secondary substances, such as chlorite and calcite, in exceedingly fine particles.

Above the blotchy aporhyolite occurs more massive flow-breccia having some evidence of devitrification, generally rather obscure, and containing, as the name indicates, a large number of angular fragments, of both andesite and rhyolite. As the number of these fragments increases, the character of the rock becomes less and less distinct to the unaided eye. In some cases a very subordinate amount of a felsitic fluidal base is seen in thin sections, but so obscured by limonite and other alteration products that the interpretation of these masses as rhyolitic flow-breccia is based on the observed gradation to the unquestionable rhyolite with a few fragments rather than on determination of the character of the base. No andesitic flow-breccias have been observed.

### POTOSI RHYOLITE SERIES.

The uppermost member of the volcanic series is a succession of rhyolite flows and tuffs, the former greatly predominating, with andesitic ash particles either included in the flows or mingled with rhyolite in the tuffs. One thin augite-andesite flow occurs between much thicker rhyolite sheets, in the northeastern part of the quadrangle, but the epoch of these eruptions was plainly one in which the andesitic extrusions had become comparatively insignificant.

**Subdivision of the series.**

Three divisions of the series are noticeable. At the base is a coarse-grained tuff or flow-breccia; above that comes the principal division, including the important flows which are the cause of much of the rugged topography of the higher mountains and ridges; the uppermost member, appearing only in the northeastern section of the quadrangle, is a succession of thin flows and tuffs, making much gentler slopes and presenting a marked reddish color, due to the andesitic ash in the tuffs.

The greatest observed thickness of the Potosi series is over 1000 feet, as developed in Gilpin Peak and corresponding summits. In Potosi Peak, whence the name is derived, situated as shown in fig. 7 of the Illustrations sheets, there is apparently still more.

*The lower tuff and flow-breccia.*—The basal member of the Potosi series is a gray or light-reddish massive band, seeming in many places like a coarse gravel bed. It is variable in thickness, ranging from a few feet to more than 100 feet, and is clearly distinguishable from the darker flow-breccia or tuff-agglomerate of the Intermediate series below and from the lamellar flows above.

The gravel-like beds consist predominantly of angular fragments of gray porphyritic rhyolite, with variable amounts of reddish felsitic rhyolite and darker andesites. The matrix is finer dust of rhyolite, and when this is present in large amount the tuff appears like a massive rock, for there is not much bedding distinguishable within the band.

The fragmental character is most evident near the bottom of the band, and in several sections a massive flow with many inclusions—a flow-breccia—follows without any clearly defined line of separation; in fact, some specimens collected to represent supposed gravelly tuff were found on microscopical examination to be flow-breccia; so that it is not known how much of the lower member of the Potosi series is actually fragmental rock.

**Tuff grades into flow-breccia.**

This band of gravelly tuff and flow-breccia forms massive outcrops of rather rounded outlines, and often marks the floor of a bench above which rise the banded flows. It is well shown in the region from Campbell Peak to the head of Bridal Veil Basin. The tuffs appear to be best developed in Mill Creek and in the region westward, while flow-breccia is very prominent in Marshall Basin and southward. In the mountain south of Howard Fork a thinner but still very distinct layer of this material appears beneath the banded flows.

The flow-breccia contains plagioclase and alkali feldspar phenocrysts, usually broken and much altered, a very few biotite leaves, and a groundmass generally much obscured by decomposition. In the freshest rocks examined microscopically fluidal structures are very distinct through curling bands of ferritic globulites. A very rude spherulitic structure appears in some cases, but is so obscured by limonite flakes and other decomposition products that its character is not plain. Evidently there was a considerable amount of glassy base in most of the rocks studied, but devitrification, producing a very fine cryptocrystalline mass, doubtless of quartz and alkali feldspar, has often entirely replaced the vitreous base. Proofs of the former glass are found in the perlitic fissures traversing the cryptocrystalline mass, and in occasional remnants of glass.

**Microscopic details.**

The included rhyolite fragments are similar to the varieties observed in the Intermediate series, and the andesitic particles are like those of the San Juan tuffs.

*The heavy-banded flows.*—The chief member of the Potosi series consists of two or three flows of a banded rhyolite of characteristic features. These flows, generally from 100 to 200 feet in thickness, are separated by thin tuff, or, as in one case, by a flow of andesite. Vertical columnar structure is marked within each sheet, and the steep cliffs or jagged ridges caused by this jointing are most prominent features of the high divide at the head of the San Miguel drainage. Benches or horizontal lines, visible for long distances, mark the zones between the flows. These characteristics are to be seen in several figures of the Illustrations sheets.

The rhyolite of these flows is usually a light-gray rock, very clearly laminated in process of flowing, and containing numerous crystals of both plagioclase and alkali feldspars, with a little biotite in thin leaves. No quartz crystals have been noticed. Usually there is a contrast between dull-gray bands and those of white or earthy-gray shade, each less than a centimeter in thickness. Where this banding is most conspicuous the feldspar crystals are less distinct. But in some places, especially in contact zones, the groundmass of the rhyolite is more homogeneous in appearance, and then the large crystals become very prominent. A fluidal structure is evident in the wavy curves of the banding, and especially if the rock contains many angular inclusions of rhyolite and andesite, like those of the flow-breccia, as is often the case. This rock splits easily into thin plates parallel to the banding.

Under the microscope a most delicate and striking fluidal structure is common in the rock of these flows. It is expressed by the curling and twisting of strings or films of dark ferritic globulites. The thin wavy bands between these dark lines are either glassy, with some irregular trichites, or rudely spherulitic, in the freshest specimens. More commonly, however, obscure devitrification has set in, from perlitic cracks in some cases, and much of the rock is to be designated aporhyolite-porphyry.

The feldspar phenocrysts of these rhyolites are seldom fresh, but it is clear that, as in all other varieties of the bedded series, a plagioclase—probably labradorite ($Ab_1\ An_1$)—and several forms of alkali feldspar are present. Biotite has been commonly resorbed, with usual products.

The banded or streaked appearance is due to alternation of layers, drawn out by motion of the lava, in which slightly different structures or degrees of crystallization may be noted. In the dull-gray bands there is commonly a coarser development of the ferritic constituent, in distinct grains or trichites of magnetite, and spherulitic crystallization is commonly coarser, if developed at all. This corresponds to observations in many well-known acid lavas of much fresher condition, such as those of the Yellowstone Park.

**Details of constitution.**

The chemical composition of these rhyolites is assumed to be represented in a general way by the analysis of the vitrophyre, given below. None of the gray rhyolites here under discussion was fresh enough to warrant quantitative analysis.

*The upper division.*—Above the heavy-banded flows just described occurs a complex of thin flows and reddish tuff layers, of which about 400 feet is preserved in Gilpin Peak. The original thickness of this series is not known, and it is not preserved at all south of Telluride Peak.

In general this succession of thin flows resembles the earliest rhyolites of the Intermediate series. There are reddish and pinkish lamellar varieties, and some black glassy flows with numerous white feldspar crystals, a typical rhyolite-vitrophyre, exactly like that on the ridge north of Park Basin, at the base of the Intermediate series. A chemical analysis of this rock is given below.

**Alternating flows and tuffs.**

The upper flows are reddish rhyolite-porphyries, and contain rather more feldspar and biotite than the lower rocks. Dull, felsitic, streaked, brown or gray bands, containing few crystals and showing flow structure, are numerous. Andesitic inclusions occur to some extent in all flows, and in the thin, variable tuff layers between flows there is sometimes a considerable admixture of andesite. The series as a whole has more or less reddish color, making it conspicuous at long distances.

These rocks exhibit microstructures and stages of devitrification, when examined microscopically, similar to those of lower flows. Some bands are rudely spherulitic, others are partly glassy. One black vitrophyre from the ridge east of the pass between Marshall and Virginius basins was so nearly fresh that a quantitative chemical analysis of it was made by H. N. Stokes, with the following result:

*Analysis of black vitrophyre from ridge east of pass between Marshall and Virginius basins.*

| | | | |
|---|---|---|---|
| $SiO_2$ | 64.72 | $MgO$ | 0.50 |
| $TiO_2$ | 0.43 | $K_2O$ | 1.82 |
| $Al_2O_3$ | 14.18 | $Na_2O$ | 3.88 |
| $Fe_2O_3$ | 1.58 | $P_2O_5$ | 0.08 |
| $FeO$ | 0.40 | $H_2O$ below 110° C. | 2.68 |
| $CaO$ | 2.62 | $H_2O$ above 110° C. | 6.82 |
| $BaO$ | 0.28 | | |
| $SrO$ | 0.21 | Total | 100.20 |

Traces of $MnO$, $CO_2$, $S$, $SO_3$, and $Cl$.

This analysis is vitiated to some extent by minute inclusions of andesitic ash, but serves to show that this rock is not a typical rhyolite, and explains the phenocrysts of lime-soda feldspar. As these phenocrysts characterize the whole series of Potosi rocks, and as the black vitrophyre of the lower division is quite indistinguishable from the one analyzed, the composition given above may be assumed as representative of the banded rhyolites as well. The rocks are rather intermediate between rhyolite and dacite, and may, perhaps, be considered as highly siliceous lavas in the series of which some forms richer in the ferromagnesian silicates have been termed latite by F. L. Ransome. It is not thought wise to introduce at this time a new name for the rock.

**Systematic position of the rock.**

## INTRUSIVE SERIES.

### STOCK ROCKS.

The great cross-cutting masses of the Telluride quadrangle are petrographically complex, and it is impossible either to represent the known complexity upon the map or to express it in legend names for the rocks of the larger bodies. While some of the existing complication is apparently due to several eruptions of somewhat different magmas within certain stocks, a still larger part is due to gradual transitions in the composition of the rock from place to place. The designations of the map merely express the predominant rock characters in the larger masses, as explained in detail below.

*General characters.*—The rocks of these stocks are mostly granular, with a local tendency to porphyritic structure in the large masses and in dikes or arms extending out into the surrounding rocks. They are usually rather fine grained, but coarse facies occur in most of the larger stocks.

The variation in composition, partly expressed in the names on the map, is gradual in many places, as in the Ophir Needles and at Mount Wilson; but rather abrupt changes at other places seem to indicate dikes. The rocks as a group are made up of the minerals plagioclase, orthoclase, and quartz on the one hand, and the dark silicates augite, hypersthene, hornblende, and biotite on the other. According to the ratio of these minerals to one another, the rock assumes from place to place the characters of the various types to which distinct names are given. The principal groups will now be described.

**Variation in constitution.**

*Monzonite.*—The largest stock of the district—that of Grizzly Peak, Rolling Mountain, and San Miguel Peak—is made up more prevailingly of a single rock type than any other of the corresponding masses. This type is pinkish gray, rather fine grained, with orthoclase, plagioclase, and quartz as the most abundant constituents, and with several ferromagnesian minerals—biotite, augite, hypersthene, and hornblende—also variably prominent. Each of the light-colored constituents is equal to the total of the dark minerals in much of the rock. The plagioclase is chiefly referable to labradorite ($Ab_1\ An_1$), and is nearly equal in importance to orthoclase. The latter has a pinkish color, while the plagioclase is white. Quartz is not very noticeable to the unaided eye, but is shown by the microscope to be an important element. Biotite and augite are more persistently developed throughout the mass than the other dark constituents.

**General description.**

A rather peculiar mottling is seen in much of this monzonite, caused by a tendency of the white plagioclase and the darker minerals to segregate in spots, leaving the quartz and orthoclase to form a more continuous matrix of a pink color. Occasionally a part of the orthoclase develops in large grains or rude crystals, making a porphyritic phase of the rock.

Under the microscope it is found that augite, hornblende, and biotite are often intergrown as primary contemporaneous constituents. Both augite and hornblende are of very pale-green color, and the biotite is light brown. Hypersthene is not so abundant as the other constituents. There is very little magnetite, apatite, or other accessory minerals.

**Petrographic details.**

Allanite occurs sporadically in the usual prisms. Ordinarily quartz and orthoclase are in separate grains, but occasionally they appear in micrographic intergrowth.

A fresh specimen of the prevalent facies of the stock, from near the lake northwest of San Miguel Peak, was subjected to quantitative analysis by H. N. Stokes, with the following results:

*Analysis of monzonite from near lake northwest of San Miguel Peak.*

| | | | |
|---|---|---|---|
| $SiO_2$ | 65.70 | $K_2O$ | 4.62 |
| $TiO_2$ | 0.72 | $Na_2O$ | 3.62 |
| $Al_2O_3$ | 15.31 | $P_2O_5$ | 0.33 |
| $Fe_2O_3$ | 2.54 | $SO_3$ | 0.12 |
| $FeO$ | 1.62 | $Cl$ | 0.03 |
| $CaO$ | 2.56 | $H_2O$ below 110° C. | 0.17 |
| $BaO$ | 0.12 | $H_2O$ above 110° C. | 0.42 |
| $SrO$ | 0.03 | | |
| $MgO$ | 1.62 | Total | 99.53 |

Sp. gr. 2.720 at 34° C. Traces of $Li_2O$ and $MnO$.

The observed ratio of constituents and the above analysis show that this rock is intermediate between granite and quartz-diorite, and it therefore comes within the group to which Brögger has given the name monzonite, a term used in the folios of the Survey as coordinate with diorite, granite, etc. This particular type belongs with the quartz-bearing monzonites, not far from the modification to which the name banatite has been given.

**Relation to banatite.**

Variations from this type observable in this stock consist, on the one hand, in an increase in the amount of quartz and orthoclase, producing as an extreme form a granitic facies, which is also somewhat porphyritic through the development of orthoclase phenocrysts. This facies is very local, and the monzonite-granite intermediate rocks are also rare. On the other hand, dioritic facies, either rich or poor in quartz, have been noticed, but all tend toward monzonite by the presence of considerable orthoclase. Aplitic bands traverse the monzonite in some places.

At several places near the edges of the monzonite stock a white porphyry was found by Messrs. Gane and Lord as an apparent dike in the monzonite. This rock, which was not mapped, may be referred to here as probably one of the complementary dike forms associated with the monzonite magma. The porphyry has a largely predominant, very fine-grained, light-gray groundmass, in which are embedded small feldspar phenocrysts of less than 2 millimeters diameter, with thin biotite leaves. Seen with a hand lens the groundmass appears distinctly granular in some specimens and felsitic in others.

**Complementary dikes associated with the monzonite.**

The microscope shows the groundmass to consist principally of dusty orthoclase grains, with some quartz and a considerable amount of green hornblende. There is a very little magnetite, titanite, and zircon. The feldspar phenocrysts are oligoclase and, probably, alkali feldspar, both very much obscured in the sections examined. This rock may be called a granite-porphyry or a quartz-syenite-porphyry.

The rock in a measure complementary to the above in composition is an augite-mica-syenite—a narrow dike in monzonite. It consists of orthoclase, largely in grains as much as 1 centimeter in diameter, filled with pale-green augite prisms, red-brown biotite leaves, and magnetite grains. Apatite needles are numerous, and a little quartz is present. The cleavage planes of the large orthoclase grains, interrupted by the many minute inclusions, illustrate the poikilitic structure beautifully.

*Diorite-monzonite.*—This compound name has been applied upon the map to the rocks of the Mount Wilson and Ophir Needles stocks, of the connecting arm between them, and of the irregular Black Face mass. The name expresses the fact that the greater part of the rock in question is intermediate between diorite and monzonite, in that soda-lime feldspar—plagioclase—predominates, while potash feldspar—orthoclase—is also prominent. There is also great variation in the amounts of quartz and of the dark silicates and magnetite, so that the observed extremes are granite and gabbro.

In the Mount Wilson stock the prevailing rock is diorite, tending toward monzonite through the presence of considerable orthoclase, but quartz-bearing monzonite and granite occur locally.

In the mass of Yellow Mountain and Ophir Needles a quartz-monzonite is very conspicuous, and probably exceeds the dioritic facies in amount. But the most basic modification of this eruption is found in the Ophir Needles, especially in the upper part of the mountain. Here gabbro rich in the dark silicates occurs, either in the fine-grained dike-like bodies or in more irregular areas grading into other facies less abruptly.

**Variable constitution of these rocks.**

The structure of these rocks varies, but by far the greater part is moderately fine and even grained. Coarsely granular development is local. But while the stock parts are generally granular, the sheet-like connection and the Black Face intrusion are more or less distinctly porphyritic. The groundmass in these portions is much less in amount than the phenocrysts, but occasionally a few large orthoclase crystals develop and make the structure pronounced. Such a growth of orthoclase may also occur locally, even in the large stock of the Mount Wilson group.

The transitions observed between the many structural and mineralogical varieties occurring in the rock masses here under consideration are, as a rule, so gradual that the several facies can not be regarded as of distinctly different periods of eruption, the later ones cutting the older in dike form. It seems more in accordance with observation to assume that the magma injected into these stocks was not homogeneous in composition, and that much of the existing variation in the rocks is due to original variation in the magma. There is no apparent regular relation of changes in composition to form of the masses, suggesting a differentiation within the magma after eruption. An exception to this statement may be presented in the Black Face mass, where orthoclase and quartz are frequently found in vein-like or irregular areas, often intergrown as graphic granite, but yet showing zones of transition into diorite-monzonite of subordinate porphyritic structure. These appear to be due to segregations of magma rich in potash and silica, and are not limited to any particular portions of the exposed rock.

A full discussion of the character of the numerous rock facies occurring in the stocks of Mount Wilson and Ophir Needles will be possible only after much more extensive field study than was permissible in connection with the present work. Other stocks of this and adjacent quadrangles should also be included in the discussion. But some details may here be given as an aid to the understanding of these remarkable rock masses.

The minerals entering into the constitution of these rocks are the same as those found in the monzonite. Plagioclase is commonly labradorite, of composition $Ab_1\ An_1$, as determined by the Michel Lévy method, which is particularly applicable here because of the common association of the Carlsbad and albitic twinning in the same crystals. Varieties richer in the anorthite molecule occur in some of the gabbro facies, and andesine appears in some of the monzonites.

The alkali feldspar is apparently always orthoclase, doubtless with some soda in it. Augite is the most important of the ferromagnesian silicates, but hypersthene is usually present in all but the highly feldspathic members of the series. It is of moderate pleochroism, and is often altered in the common manner. Intergrowths of hypersthene, augite, and biotite are common. Hornblende appears as a primary element in the strongly dioritic facies only. As uralite it replaces augite or hypersthene in altered phases.

**Petrographic details.**

The porphyritic structure occasionally seen never becomes comparable to that so characteristic of laccolithic intrusions. The contrast between groundmass and phenocrysts is never so sharp as in the latter masses, and transitions in size between the groundmass grains and the larger crystals are usual.

A megapoikilitic structure is often noticeable in the diorite-monzonite facies, especially in zones between monzonite and gabbro, as in the Ophir Needles.

The transition in chemical composition which would be expressed by a series of chemical analyses is so obvious from the mineral constitution that no such series has been considered necessary. But one of the dark gabbroic facies of the Ophir Needles is so common both here and in the Stony Mountain–Mount Sneffels stock, that a very fresh specimen was analyzed by H. N. Stokes, yielding the following result:

*Analysis of diorite-monzonite from Ophir Needles stock.*

| | | | |
|---|---|---|---|
| $SiO_2$ | 56.93 | $MgO$ | 3.30 |
| $TiO_2$ | 1.03 | $K_2O$ | 2.58 |
| $Al_2O_3$ | 17.03 | $Na_2O$ | 3.19 |
| $Fe_2O_3$ | 3.67 | $P_2O_5$ | 0.44 |
| $FeO$ | 4.54 | $H_2O$ below 110° C. | 0.13 |
| $MnO$ | 0.10 | $H_2O$ above 110° C. | 0.45 |
| $CaO$ | 6.51 | | |
| $BaO$ | 0.08 | Total | 100.04 |
| $SrO$ | 0.06 | | |

Sp. gr. 2.860 at 33° C.

The rock of this analysis is dark gray, fine and even grained, and megascopically almost aphanitic. Labradorite is its principal constituent, with considerable amounts of hypersthene, augite, and biotite, in order of importance. These are all somewhat irregular in form, the prismatic hypersthene being more nearly automorphic than the others All three are intergrown in some grains. Orthoclase and quartz are present in very subordinate amounts, but serve to connect this rock with the dominant types of the region.

The analysis is to be compared with analyses of similar rocks from Stony Mountain and Mount Sneffels, given below.

*Inclusions in the diorite-porphyry at Ophir Loop.*—Both railroad cuttings at the Ophir Loop show the diorite-monzonite at that locality to be characterized by numerous inclusions of many varieties of rocks. The inclusions are most abundant at the level of the lower railroad cutting, where for nearly half a mile the diorite-porphyry is so crowded with them that they make up more than half the mass. This line of the railroad is within about 50 feet of the lower contact of the igneous mass, which is, however, not exposed. Apparently this is about the point at which the sheet-like arm extending westward toward Mount Wilson leaves the main stock of the Ophir Needles. No reason is apparent for the concentration here of such an enormous number of inclusions. Occasional inclusions are found in Yellow Mountain, and in the arm forming the cliff shown in fig. 12 of the Illustrations sheets.

Fig. 13 shows a small section of the cliff on the lower railroad cutting and gives a fair idea of the number and relations of the inclusions. In size these included masses vary from the common diameter of 1 or 2 feet to 15 feet. They are angular or subangular, and a very rude horizontal arrangement is visible in large exposures. The inclosing rock is a fine-grained, hornblendic diorite-porphyry, showing distinct fluidal structure winding about the inclusions. Fig. 14 shows one of the blocks blasted from the cliff, the fine-grained porphyry, holding the inclusions, contrasting with the darker or coarser-grained inclusions.

**Description of the occurrence,**

The inclusions of the Ophir Loop exposures present great variety in composition and structure, but in both of these respects there is so complete gradation represented, even in the comparatively small portion of the mass here visible, that the question of their origin becomes of great importance. The striking fact is that many of the inclusions are practically coarse-grained diorite, and that gradation seems to exist toward masses which are nearly pure segregations of each of the constituent minerals of the diorite. Further, nearly every mineral aggregation is found, both in granular and in banded forms. The study of the great number of transition forms present makes it seem highly probable that all these rocks are most intimately connected in origin, and when the variations within the mass of the Ophir Needles stock are borne in mind, the association of the inclusions with the igneous rock inclosing them has an apparent significance which is of great theoretical importance in connection with the general problem of the origin of igneous rock varieties. The inference seems most natural that this diorite-monzonite magma and these inclusions have a common source, and that the great variations in chemical and mineralogical composition found in each have resulted from the processes of "magmatic differentiation," the nature of which is, unfortunately, as yet a matter of hypothesis. Words can hardly give an adequate conception of the strong evidence in favor of this conclusion afforded by the phenomena visible at Ophir Loop, and an extended discussion is out of place in this folio text, but short descriptions of the main rock varieties occurring among those inclusions will be given below.

**Large series of rocks found as inclusions.**

The rock inclusions of Ophir Loop, so far as represented by the specimens collected, may be grouped as in the following descriptions. It is to be kept in mind, however, that many more varieties are undoubtedly present, making the complex one of almost perfect gradation from all extremes toward the average rock, which is of the general composition of a diorite.

**List of rocks observed as inclusions.**

(*a*) *Labradorite rock.*—A white granular mass of labradorite, with a little orthoclase, no magnetite, no quartz, no hornblende, or other primary ferromagnesian silicate. Small specks of epidote and chlorite may be decomposition or infiltration products.

(*b*) *Aplitic granite-porphyry.*—Variable large pink orthoclase phenocrysts and some smaller ones of quartz lie in a fine-grained groundmass of orthoclase and quartz. A few minute augite grains and specks of magnetite are present. Plagioclase not identified.

(*c*) *Granite.*—Of rude gneissoid structure, consisting chiefly of pink orthoclase and quartz, with a very little chlorite and epidote. The rock is unevenly granular and of rather coarse grain. A little plagioclase is present, and one crystal of allanite was seen in the thin section.

(*d*) *Gneiss.*—A banded rock in which certain bands 2 or 3 inches wide consist almost wholly of pink orthoclase, with a little quartz; others have some white plagioclase, and still others are variably dark by the admixture of green augite.

(*e*) *Mica-granite-gneiss.*—A thinly banded but evenly granular rock, with much quartz and orthoclase, and some plagioclase and chlorite. The latter is derived chiefly from biotite, of which small fresh leaves are found included in quartz, and partly from augite. The distribution of the former dark mineral in thin layers causes the banded appearance.

(*f*) *Gneissic rocks,* with broad or narrow alternating bands of dark-green color, rich in augite, and others nearly free from any dark silicate and rich in feldspar and quartz. Veins of feldspar and quartz cut the dark bands. All the banded rocks exhibit contorted folding in some bowlders, but no shearing or lamellar schistose structure is shown.

(*g*) *Hornblende-diorite,* seeming coarse grained at first glance, composed chiefly of hornblende and feldspar sharply separated into aggregates of small grains. These aggregates are more or less connected, but seem to be in distinct areas on many fracture faces. Now one, now the other, is the more continuous, and there is much variation in the relative amounts of hornblende and feldspar in different inclusions. In some fragments a tendency of the aggregates to draw out into wavy lenticular form is visible. Occasionally totally irregular variation in composition appears, each of the elements forming massive rock either grading into the other or being bounded by a rather sharp line. Fig. 14 shows several of the structures and phases of variation exhibited in these singular rocks.

The microscope shows that magnetite and biotite are common associates of the hornblende, which is of the common green variety, and that orthoclase is variably mingled with the predominant labradorite in the feldspathic portions. No evidence appears that these structures were of mechanical origin after the consolidation of the mass.

(*h*) *Diorite rich in magnetite.*—A massive, rather coarse-grained rock, consisting mainly of hornblende in stout prisms several millimeters in diameter, labradorite in compound grains or stout prisms, and magnetite in large amount included in both silicates, almost obscuring the labradorite megascopically, and making the mass notably heavier than the pure amphibolites. A little biotite and chlorite are seen in thin sections.

(*i*) *Banded augite, hornblende, or biotite rocks.*—Under this head are included a whole series of rocks of rude schistose or gneissic structure, in which the three dark silicates predominate, either alone or in association, with a lesser amount of feldspar, a large part of which is labradorite with some apparent orthoclase. Much of the feldspar is unstriated, and generally occurs in small round grains. Titanite and magnetite vary greatly in amount. The banding comes entirely from the alternating abundance of dark silicates and feldspar. Nearly all are granular. The biotite-rich rocks seem like biotite-schists, but have much augite, hornblende, and feldspar associated. One schistose-looking biotite rock has strongly pleochroic hypersthene in narrow irregular zones about magnetite grains and intergrown with the biotite.

(*j*) *Hornblende rocks.*—There is a great variety of massive and schistose rocks made up almost entirely of hornblende, with small amounts of augite, feldspar, and magnetite. Some have small, long prisms of hornblende, and in these a decided schistose structure is developed. Others consist of large hornblende prisms, sometimes an inch long and half an inch thick, irregularly grouped, with small grains of other minerals crowded into the angular interstitial spaces. Many of these inclusions are similar to the hornblendic inclusions often found in massive diorite.

*Gabbro-diorite.*—This term is applied upon the map to the stock rock of Stony Mountain and Mount Sneffels and of a number of small cross-cutting bodies. The compound name indicates primarily that much of the rock is intermediate between gabbro and diorite, and also that there is a transition from gabbro to diorite.

The principal rock of Stony Mountain, as seen at its summit and down the eastern slope, is a dark, coarse- or medium-grained gabbro, composed chiefly of a plagioclase rich in lime, with abundant hypersthene and diallage-augite. Even in this rock there is some orthoclase and quartz, while in some phases of the rocks here included there is a considerable amount of these two minerals, and a transition develops toward the rock called monzonite.

**General description.**

In Mount Sneffels, so far as the mass is now known, gabbroitic phases are predominant, partly coarse grained, but with large amounts of the fine-grained, almost aphanitic type seen in the Ophir Needles, of which an analysis has been already given. A dark gabbro-porphyry occurring in dikes is very prominent on the southwest side of the mountain and at the pass on the south. This porphyry is characterized by thin plates of plagioclase in more or less marked parallel arrangement. They appear dark themselves, from the great number of dusty inclusions they carry and because they lie in a dark aphanitic groundmass of the other minerals common in these rocks.

The lighter-colored fine-grained rocks of the connecting arm between Stony Mountain and Mount Sneffels, and the rocks of the smaller stocks and dikes mapped as gabbro-diorite, are less rich in the dark silicates than the gabbro proper. Their plagioclase is like that of the diorite-monzonites, and they have some orthoclase and quartz. Usually these rocks are fine grained in texture and gray in color, and hornblende is sometimes the most distinct constituent. They have the general habit of diorite.

In the more basic rocks of this series (as in the gabbro-porphyry of Mount Sneffels) plagioclase as rich in lime as bytownite may be found, but the most common variety is labradorite of $Ab_1$ $An_1$, the same that occurs in many of the monzonites. This feldspar forms a large part certainly of the plagioclase in the gabbro of the summit of Stony Mountain. This persistence of one variety of plagioclase through such a series of rocks makes impossible a satisfactory subdivision of the series on the basis of that component, and it appears that the criterion for the distinction between gabbro and diorite lies here in the quantitative relation of the ferromagnesian silicates to the feldspathic element. The character of the soda-lime feldspar is ordinarily found to vary in harmony with this ratio, but certainly does not do so in these rocks.

**Petrographic details.**

The labradorite, hypersthene, and diallage of the summit rock of Stony Mountain possess the characters common in gabbros; but the diallage parting is not commonly found in even more basic forms than that. When the plagioclase is richer in lime than $Ab_1$ $An_1$ it usually has some peculiar habit and is ordinarily very full of glass and globular augite inclusions, as in the gabbro-porphyry. Magnetite seldom becomes strongly developed in these rocks, and, aside from apatite and titanite, accessory constituents are very rare.

The gabbro of the summit of Stony Mountain has the following composition, as determined by analysis made several years ago by L. G. Eakins:

*Analysis of gabbro from Stony Mountain.*

| | | | |
|---|---|---|---|
| $SiO_2$ | 52.05 | $K_2O$ | 1.61 |
| $Al_2O_3$ | 17.96 | $Na_2O$ | 2.99 |
| $Fe_2O_3$ | 4.09 | $H_2O$ | 0.97 |
| FeO | 6.33 | $P_2O_5$ | 0.31 |
| MnO | 0.43 | | |
| CaO | 8.64 | Total | 100.41 |
| MgO | 5.03 | | |

Sp. gr., 2.891 at 13.5° C.

The fresh gabbro-porphyry of the pass south of Mount Sneffels was analyzed by H. N. Stokes, with the following result:

*Analysis of gabbro-porphyry from pass south of Mount Sneffels.*

| | | | |
|---|---|---|---|
| $SiO_2$ | 47.32 | MgO | 5.69 |
| $TiO_2$ | 1.50 | $K_2O$ | 2.02 |
| $Al_2O_3$ | 16.71 | $Na_2O$ | 2.70 |
| $Fe_2O_3$ | 6.92 | $P_2O_5$ | 0.96 |
| FeO | 5.94 | $SO_3$ | 0.19 |
| MnO | 0.08 | $H_2O$ below 110° C. | 0.24 |
| CaO | 8.51 | $H_2O$ above 110° C. | 1.04 |
| BaO | 0.07 | | |
| SrO | 0.06 | Total | 99.95 |

Sp. gr., 2.949 at 26.5° C.

### LACCOLITHIC ROCKS.

Among the igneous rocks of the Telluride quadrangle are certain varieties which have been intruded into the sedimentary complex in the form of laccoliths, lifting up the strata above them. These rocks here differ sufficiently from the stock rocks in structure to be distinguished very readily. Two varieties have been indicated upon the map.

*Diorite-porphyry.*—The rocks forming the large bodies of Gray Head, Whipple, and Hawn mountains, Flat Top, and numerous thin sheets adjacent, have been designated diorite-porphyry. They contain phenocrysts or distinct crystals of a soda-lime feldspar (andesine or labradorite), hornblende, biotite, and occasionally augite, in a gray groundmass of orthoclase, plagioclase, and quartz. The crystals are never very large. In the laccolithic masses the groundmass is so coarse and the crystals are so small that the porphyritic structure is rather subordinate, but appears distinctly when thin sections of the rocks are studied under the microscope. In the thin adjacent sheets the groundmass is very fine grained, and hence contrasts with the phenocrysts embedded in it.

**Porphyritic structure subordinate.**

The mineralogic composition of these rocks does not vary greatly. Quartz is not very abundant in any of them and is nearly lacking in the rock of Flat Top. Orthoclase is always so subordinate that no decided approach to monzonite-porphyry can be found.

*Granite-porphyry.*—Above Ophir occurs a porphyry body, cut in two by Howard Fork, which is in some respects analogous to a laccolith, although somewhat irregular in its relations to the inclosing sedimentaries. This rock is called a granite-porphyry. It contains pink orthoclase crystals, some of which are half an inch long, and many smaller ones of white oligoclase, quartz, green hornblende, and brown mica, which lie in a groundmass consisting chiefly of orthoclase and quartz. The large orthoclase crystals especially characterize this rock.

### DIKE ROCKS.

Under the general name "Basic dikes" a number of dark dike rocks have been represented on the map. These dikes are younger than any other igneous masses of the region, and several varieties occur which will be specially described.

**The youngest igneous rocks.**

*Pyroxene-andesite.*—By far the majority of all the observed dikes are of a pyroxene-andesite very similar in composition to the rock of the flows in the Intermediate series, but dense in texture and usually quite aphanitic. These dikes prevail in the eastern portion of the quadrangle, all of those represented on the map in that section belonging to this type. The small dikes in the vicinity of Sawpit, not shown on the map, belong in this group, as do the dikes about the Lizard Head and the one shown on the ridge south of Mount Wilson.

A few inconspicuous dikes in Campbell Peak and Ruffner Mountain are hornblendic.

*Plagioclase-basalt.*—The dike at the mouth of Big Bear Creek is a very simple normal basalt, having abundant fresh olivine crystals and a holocrystalline groundmass consisting of augite, olivine, labradorite, magnetite, and a little biotite.

*Augite-minette.*—In the ridge running southeast from Gladstone Peak, in the Mount Wilson group, are two narrow dikes of a dense, dark, almost black rock, cutting Cretaceous strata. These contain abundant augite and brown biotite, with a few decomposed olivine crystals, in a smoky-brown glassy base with cryptocrystalline spots. It is believed that this glassy base must be rich in potash and that the rock belongs with the minettes on account of the prevailing character of similar dikes in adjacent districts.

*Vogesite.*—On the ridge running east from Gladstone Peak and in Bilk Basin are narrow dikes of an ash-gray rock with black semivitreous contact zones. The center of the larger dikes contains much augite and dark-brown hornblende, with some olivine, in a colorless base, which consists largely of delicate interlocking, branching crystals of orthoclase. The contact zones are dark glass with augite crystals alone.

*Augite-camptonite.*—The small lenticular plug to which Black Face owes its name is composed of a dense black rock in which the naked eye can detect only a few minute particles of feldspar and dark grains of augite. The microscope shows much augite, brown hornblende, plagioclase in microlites, orthoclase in irregular grains, and a dust of magnetite. The chemical composition of this rock is very nearly the same as that above given for the gabbro of the Ophir Needles.

### MISCELLANEOUS IGNEOUS ROCKS.

*Rhyolite.*—Two occurrences of rhyolite shown upon the map can not be assigned to the Potosi series. One of these is represented by two small plugs near the railroad line southwest of Trout Lake. This rock is a dark-gray, dense felsite, with a few small decomposed feldspar crystals and reddish-brown mica leaves. The mass of the rock is finely granular and cryptocrystalline, and is possibly a devitrification product, though no definite proofs of this origin have been observed. In the plug nearest Trout Lake a breccia occupies most of the space, but is cut by arms of the same rock in massive form.

Interbedded with the Algonkian quartzites of the small exposure in Canyon Creek occurs a banded rhyolite, very different in its habit from the flows of the Potosi series. This rock is felsitic, gray or pinkish, delicately banded and then nearly free from phenocrysts, or it may exhibit many sanidine and smoky quartz crystals and be less distinctly banded. The dense portion exhibits under the microscope much quartz and a cryptocrystalline granular part, which is probably mainly orthoclase. No biotite or other dark constituent now remains.

**Algonkian rhyolite.**

*Andesite.*—Capping Diamond Hill, east of Big Bear Creek, is a thin sheet of a much decomposed rock, in certain portions of which are many small cavities containing perfectly clear crystals of quartz, whence the local name of the hill. The rock is so highly impregnated with calcite and chlorite, and all its constituents are so much altered, that its original character is uncertain, although it is designated andesite upon the map. It may be an intrusive sheet of porphyry, but, if so, it has undergone alteration in a manner not elsewhere observed among the intrusive sheets.

## DESCRIPTIVE GEOLOGY.

*A description of the quadrangle, showing the distribution and local characteristics of the rock formations and their influence in producing the existing physical features under the agencies of erosion.*

### OUTLINE SKETCH.

The Telluride quadrangle affords a striking instance of the dependence of physiography upon geology. The strongly contrasting physical features of the area, which have already been mentioned, are most intimately related to contrasting geologic features. The mountains and valleys are the result of long-continued erosion of a part of the San Juan volcanic plateau and of the older formations beneath it; and it is possible ble to recognize the relation between many of the physical features and the character and mode of occurrence of the different rock masses which have been described. These facts lead to a natural subdivision of the quadrangle for descriptive purposes.

**The mountain area.**

The eastern half of the quadrangle belongs to the San Juan mountain complex of to-day. The bold mountain front exhibits most clearly the bedded volcanic series which makes up a large part of the mountains to the eastward. Penetrating these volcanics are great stocks and smaller bodies of granular igneous rocks, known also in other parts of the San Juan region. The mountain front is imposing, but the deep dissection to which the interior of the San Juan Plateau has been subjected is well illustrated by the eastward drainage of Canyon, Mineral, and Lime creeks, and in the valleys of these streams the relations of the volcanic rocks to the underlying sedimentary formations are well exposed.

**The plain area.**

The western half of the quadrangle is an undulating plain, interrupted at several places by isolated mountains or groups of peaks. Viewed in its broader relationships this plain is the eastern limit of a great plateau country covering thousands of square miles to the westward, the floor of which is the Dakota sandstone with local remnants of the Mancos shales upon it; and the San Miguel Canyon is a type of the gorges cut by many streams of the Colorado Plateau into the sandstone and shale series beneath the Dakota. In the walls of this canyon one may study the details of sculpturing produced by the erosion of horizontal rock beds of varying constitution.

Viewing the plain area from a more local standpoint, it presents the record as to the extent of erosion below the floor of the San Juan volcanics, and the isolated mountains become of prime interest, since in the Mount Wilson group and in the summits east of it is the proof that the San Juan volcanic complex and the underlying San Miguel formation once extended for an unknown distance beyond the Telluride quadrangle to the west. The mountains of the Wilson group exhibit the rugged forms caused by a great stock from which the surrounding beds have been largely removed.

In Gray Head, Whipple and Hawn mountains, and Flat Top are shown excellent illustrations of the mountain forms resulting where large igneous masses of the intrusive laccolithic type have been laid bare by the removal of the inclosing sediments and have themselves been sculptured in bold relief.

The area thus exhibits, on one hand, the structure of the San Juan Mountains and of isolated outliers once connected with them, and on the other the sedimentary plateau and the laccolithic type of mountain which in several areas modifies the monotony of the great plateau country.

### THE SAN JUAN MOUNTAIN FRONT.

**An area of bedded volcanic and cross-cutting stocks.**

As represented on the geological map, the entire western front of the mountains, from Ruffner Mountain to Grizzly Peak, is formed by the bedded volcanic series of andesitic and rhyolitic rocks which have been described, excepting only the salient points at Ophir Needles and Grizzly Peak, where two large and massive stocks appear, causing a rugged topography very different from that found elsewhere along the front. Except for the small stock at Stony Mountain and a few lesser intrusions, the bedded volcanics extend eastward beyond the limits of the quadrangle, producing the same general features of mountain and valley observable on the actual front. Beyond Ruffner Mountain the bedded series extends but a few miles northwest, to Mears Peak, and then swings rapidly eastward, while for 20 miles east of Grizzly Peak there are no remnants of the volcanic series south of the parallel forming the southern boundary of the Telluride quadrangle. It is literally the southwestern front of the San Juan Mountains which is here presented.

**Description of fig. 1.**

*North side of the San Miguel River.*—The general character of the mountains facing the San Miguel Valley between Ruffner Mountain and Telluride can best be described with reference to views reproduced on the Illustrations sheets. Fig. 1 represents the mountain face as seen from the ridge between Mill and Butcher creeks, looking northwest. In the foreground is the rolling plateau of Mancos shales, covered here and there by detrital material swept down from the mountains. The light band of cliffs next above the shales is of the pale-reddish San Miguel conglomerate, here about 300 feet thick. Succeeding that comes the San Juan tuff-conglomerate, fully 1500 feet thick, stratified as perfectly as the San Miguel in its lower portion, but of contrasting dark color, as is well shown in the figure. The San Juan reaches to the horizontal ledge near the top of the dark point on the right, and to the little scarp below the main cliffs of Campbell Peak, near the center of the picture. This little scarp is caused by a 4-foot sheet of augite-andesite, all that here represents the Intermediate series. The more rugged upper part of Campbell Peak and the higher peak on the right are due to the massive rhyolite flows of the Potosi series.

The view in fig. 1 shows that, rugged as are the mountains to-day, they were much more precipitous at a time not very remote. The great talus slope which extends from near the summit of Campbell Peak down to the Cretaceous shales has almost covered the scarp of the lower San Juan tuff and the San Miguel formation. The glacial cirque in front of the peak, at the head of Eder Creek, has now no solid rock exposures anywhere near its floor, and all the high basins are in a similar condition. But the mountains north of the San Miguel are particularly characterized by these débris slopes, on account of the decomposed state of the rocks, causing them to split into small angular pieces under the influence of frost. In many places the altered rocks are bleached or heavily iron stained and the color contrasts are often striking.

**Mountain sculpture shown in figs. 2 and 3.**

Fig. 2 shows the sculpturing of the same mountains as seen from the south side of the San Miguel, about 2 miles below Telluride, looking somewhat east of north. The ledges of Dakota sandstone in the foreground are on the north bank of the river, the valley bottom not coming into the view. Back of the rolling shale slopes appear the cliffs of the San Miguel conglomerate, cut by Eder Creek. On the left is the long talus slope seen in fig. 1, leading up to the andesite ledge of Campbell Peak. The higher mountains of the ridge between Campbell and Dallas peaks exhibit the general bedding of the Potosi rhyolite series, and, so far as it is exposed, of the San Juan tuff. In several places may be seen the rounded pinnacles of the San Juan, nearly buried under the talus, and in fig. 3 is represented a characteristic bit of detail of this kind. The view is from timber line on Campbell Peak, looking across Eder Creek at a group of these turreted forms of cliff erosion, and beyond them to the massive cliffs of the Potosi series, just west of Dallas Peak. A small ledge midway in the cliff represents the horizon of a thin andesite sheet separating the heavier rhyolite flows. The rhyolite débris fallen upon this ledge often conceals the andesite and causes a lighter band. One of the narrow and somewhat irregular andesite dikes common in this vicinity is shown cutting the tuffs on the left.

In Iron Mountain the tuffs about the summit are heavily iron stained, but on the lower slopes they are bleached and much hardened near the gabbro-diorite dike shown on the map. On the east branch of Deep Creek the same general development of the volcanic series is found, with very brilliant yellow and reddish coloring in places.

**Ruffner Mountain, fig. 4.**

Ruffner Mountain, the summit of which is beyond the quadrangle line, is especially rugged, by reason of the number of andesite dikes penetrating the San Juan tuffs, and particularly through the induration of both sedimentary and igneous beds adjacent to the broad gabbro-diorite dike on its southwestern slope. The San Miguel conglomerate and the Mancos shales below it are very well exposed on the western side, the latter in almost continuous outcrops for 1500 feet, down nearly to Deep Creek. On the southwest ridge of the mountain is a small irregular stock of gabbro-diorite cutting horizontal shales, which are greatly metamorphosed near it. This mass is like a number of others found in the volcanic area. Fig. 4 shows this stock as seen from the south side of east Deep Creek. The lower limit of the outcrop is shown and on either side appear ledges of hardened shale.

*Marshall Basin and the head of the San Miguel.*—Between Mill and Marshall creeks the westerly dip of the Mesozoic formations, combined with a gentler eastern dip of the San Miguel conglomerate, brings the latter down to rest on the La Plata sandstone at a level only a few hundred feet higher than the valley lake bed above Telluride. Within this distance Butcher and Cornet creeks and Owl and Royal gulches descend rapidly from the mountain crest of Potosi rhyolite across the Intermediate series, the San Juan tuffs and agglomerates, and the San Miguel conglomerate, each stream bed in turn showing the latter in unconformity upon various older strata. A waterfall or cascade occurs in each as it crosses the San Miguel ledge.

**Bridal Veil Basin.**

From the extreme eastern limit of the lake beds above Telluride the somber cliffs of the San Juan formation rise with startling abruptness on the north, east, and south. From the mouth of Bridal Veil Creek to the end of the ridge between Ingram and Savage basins, known as Telluride Peak, there is a rise of 3000 feet within one mile. Ingram Creek descends in a cascade for more than 1000 feet, and Bridal Veil fall, over the San Miguel ledge, is over 300 feet in height. The character of the country may be seen in fig. 5 (Illustrations sheets). This view is from a point well up in Bridal Veil Basin, looking directly north. In the center are the wonderful buttressed cliffs between Marshall and Ingram creeks, formed by the San Juan tuffs and agglomerates. From the lowest point visible to a level several hundred feet above timber line all belongs to that formation. This view illustrates the distinct bedding throughout the formation as well as the massive effect of the whole in cliff exposures.

In the left-hand portion of the view is seen the zigzag trail to Marshall Basin, from about the point where it crosses to the western side of the stream up to a level beyond the buildings at the mouth of the Bullion tunnel. A little higher a section of the wagon road in the basin may be seen, but the mines on the Smuggler vein are hidden. The Intermediate series of flows and tuffs occupies a zone running through the amphitheaters and shoulders, separating them. The lowest cliff, facing Marshall Basin and nearly surrounded by talus, is formed by the augite-andesite flow near the base of the series, here some 600 feet in thickness. This sheet thins out southward, toward the point of view, and the flows become much subordinate to tuffs and agglomerates. The columnar jointing of the rhyolites of the Potosi series and the general rugged character of the crest of the divide between Marshall Basin and Canyon Creek are clearly shown.

In and about Marshall Basin the character of the Intermediate series can be studied to good advantage. On the western ridge, opposite the Smuggler workings, the flows of dark glassy rhyolite are very distinct, and the principal augite-andesite flow has its maximum development here, causing the projecting shoulders which separate the minor basins between Marshall and Savage basins. Directly west of the Mendota, on the trail to the head of Cornet Creek, the base of the Potosi series is very well exposed, and below it, in a hollow of the andesite sheet, occurs a considerable thickness of tuff of the Intermediate series.

*Head of Canyon Creek.*—In the northeastern corner of the Telluride quadrangle is the head of Canyon Creek, which enters the Uncompahgre at Ouray. It is separated from the drainage of the San Miguel by the high divide formed of the Potosi rhyolite series, seen in fig. 5. On the northeast is the corresponding crest, extending from Potosi Peak to Mount Sneffels. In the center of the basin rises Stony Mountain, due to a small gabbro stock connected with that of Mount Sneffels. The geology of this basin will be described with reference to three views given on the Illustrations sheets.

**Description of the view in fig. 6.**

Fig. 6 is from a photograph taken from Stony Mountain looking south at the ridge separating the Virginius branch of Canyon Creek from Marshall Basin. At the foot of the middle cliffs are the Virginius mine buildings, and below them are those of the Terrible mine. The trail to Marshall Basin passes through the little windy gap above the Virginius. This view is well adapted to show the nature of the details commonly found in the horizon of the Potosi series, which extends from the Virginius buildings to the crest of the ridge. The main cliff-making flows of the series are distinctly shown, separated by a narrow débris-covered bench, at the horizon of a thin andesite flow. This line can be seen for miles, as appears from the views given in figs. 2 and 5. The columnar structure in these sheets is due partly to shrinkage cracks and partly to fissure systems, which traverse all the formations. The rounded summits of the divide are caused by the more easily disintegrating, thin, glassy flows and purplish tuffs of rhyolite belonging to the highest member of the volcanic series thus far examined. Where this upper series has been removed the narrow serrated crest becomes impassable. Its character appears above the Virginius mine and in St. Sophia Ridge, north of Mendota Peak. A larger thickness of the upper tuffs and flows appears in Gilpin Peak and other summits above the 13,200-foot level.

At the horizon of the Virginius mine, in the center of the view, appears a line between the basal tuff of the Potosi series and the darker tuffs of the Intermediate series, which are locally exposed in several outcrops, though commonly concealed by talus. The San Juan tuffs are seldom well exposed in the upper parts of Canyon Creek, owing to the great amount of débris from the higher zones. The smooth slopes of the middle ground, seen in fig. 6, are yearly swept by terrific snowslides, some of which have been attended by loss of life in the immediate vicinity of the Virginius and Terrible mines.

**Potosi Peak.**

Fig. 7 is a view from a small bench south of Stony Mountain looking down to the forks of Canyon Creek below the Trust Ruby mine and showing the almost unbroken slope of Potosi Peak, 3000 feet in height. In the left foreground is a projecting spur of the Stony Mountain stock. The volcanic series of Potosi Peak has not been examined in detail, but it is known that glassy rhyolite flows have here a greater development than at any point in the Telluride quadrangle.

**Stony Mountain.**

The massive forms produced by the stock of Stony Mountain contrast markedly with those resulting from the erosion of the bedded volcanics. The stock forms the angle between the forks of Canyon Creek, and presents rough cliffs of massive, irregularly jointed rock on all sides except the west, where a narrow divide but little lower than the summit connects it with the main ridge. The gabbro mass extends across the north branch of the creek, penetrating the San Juan tuffs and so metamorphosing them that the line between the rocks can be traced only with great difficulty, even in the bare glacial surfaces or ledges of the creek bottom. Arms of the gabbro-diorite run into the tuffs east of the Yankee Boy mine and as narrow dikes reach far up the slope of the ridge from Potosi Peak. Much of the detail on this slope is too complex for representation upon the map.

**Old buried peak of Algonkian quartzites.**

The small mass of Algonkian quartzites and rhyolite at the north base of Stony Mountain is of much interest, especially if it is, as represented in the map and sections, a peak of the old mountains covered by the San Juan tuffs. The outcrops are not very favorable to a study of the mass, for all about them the tuffs are highly metamorphosed, arms of the gabbro-diorite partly inclose them, and all rocks have here been mineralized, then bleached out, and are in addition so crushed and fractured that in and near the creek bed they break up into minute angular pieces on exposed surfaces, so that recognition of the original rock character by the naked eye is sometimes impossible. The laminated rhyolite is distinct in the creek bed, and so is the narrow quartzite ledge on the east of it, while parts of the larger quartzite area west of the rhyolite are beautifully exposed on a smooth glaciated surface.

**Mount Sneffels.**

Between the quartzite area and Mount Sneffels a widening band of rather fine-grained gabbro-diorite can be traced to the cliffs of the peak, though many details of its contact are concealed by talus. The extreme western head of Canyon Creek, under Mount Sneffels, and the mountain itself, are shown in fig. 8, a reproduction of a photograph taken from Stony Mountain. This view exhibits the character of the mountains, due to the massive stocks of granular rock penetrating the bedded volcanics of the San Juan Mountains. Unfortunately it has been impossible to examine this mass except on the ridge leading to the pass on the left, and it is not known how extensive the stock may be on the north. It is possible, moreover, that indurated tuffs take some part in the very summit or on the right-hand point of the mass. The view shows the great amount of talus in the basin south of Mount Sneffels.

**The "Great Amphitheater."**

To the west of the saddle between Gilpin Peak and Mount Sneffels rises a fork of Dallas Creek, in a basin called the "Great Amphitheater" on the Hayden map. Only the upper slopes come within the Telluride quadrangle, and they exhibit the bedded volcanic series which has been described as appearing on the southern side of the crest between Gilpin and Campbell peaks. This is one of the elevated glacial basins the origin of which was ascribed by F. M. Endlich to a sinking of the floor for more than 2000 feet (Annual Report of the Hayden Survey for 1874, p. 206). No evidence of such subsidence was cited by Endlich, and it seems, in fact, that this amphitheater was formed by the same agents of erosion that produced all the other basins of the region. Several small blue lakes are found in the various branches of this basin. That it was once filled by snow and névé fields feeding a glacier below is directly suggested by an actual remnant of névé ice lying at an elevation of about 12,500 feet, directly under the sharp ridge east of Dallas Peak.

*Area between Telluride and Howard Fork.*—The greater part of the mountain area lying between the main or Telluride branch of the San Miguel and Howard Fork is made up of the San Juan tuff breccia or agglomerate, penetrated by a few narrow dikes of pyroxene-andesite and seamed by mineral veins, some of which can be seen miles away. The basins at the heads of the main streams and their tributaries are either high up in the San Juan series or in the overlying rocks. As shown by the topographic sheet, the fall of the streams from these basins is often very rapid, while between them occur many broken precipices a thousand feet or more in height. These great faces of dull red, purple, or brownish tuff, etc., are monotonous in detail and need no special description. In Mr. Purington's paper in the Eighteenth Annual Report, Part III (1898), are several views illustrating the character of this rugged district as seen from different points of view on the north. Bear Creek has cut deep into the red Dolores sandstones, and the unconformable relations of the San Miguel conglomerate are here very plain.

**Development of the Intermediate series.**

From the base of the Intermediate series to the summits of the mountains there is much more variety to the formations. The Intermediate series increases in thickness and changes in character from Ingram Basin southward. The andesite flows and the vitreous rhyolites are much less distinct here, while flow breccias and tuffs composed of both rocks become more prominent. Some of the upper agglomerate bands are locally coarse and chaotic in arrangement. In the mountains west of Bridal Veil Basin the tuff-agglomerates of this series are very similar to the San Juan, and the absence of prominent rhyolite or andesite flows in some places makes the field recognition of horizons uncertain. But the "blotchy aporhyolite" which has been described can be traced through all this section as an unfailing criterion for determining the base of the Intermediate series.

**The Potosi series.**

The base of the Potosi series is well marked through the mountains east of Bridal Veil Basin by the contrast between the dark andesitic beds and the lighter-colored rhyolite-tuff. But on the west side and at the head of the basin the bleaching or discoloration to which the rocks have been subjected makes the line much less plain. The lower member of the Potosi series here is often a fine-grained flow-breccia, distinguishable from the entirely fragmental bed of other localities only on microscopical examination. Above this bed, which is of variable thickness, though always considerable, come two heavy laminated rhyolite flows like those of the northeastern part. They are separated by a thin band of dark-red or almost purplish tuffs and by thin flows of rhyolite. These tuffs may be at the horizon occupied by the thin andesite flow in the mountains above Marshall Basin, or may correspond to the upper purple bands of Gilpin Peak. In the latter case one of the lower flows of the northeastern district has disappeared and a higher one has come in. This development of the Potosi series is very plain in the crest from Waterloo Peak, at the head of Grays Basin, to Lookout Peak.

The separation of the Potosi series into several massive bands with crumbling material between them causes a marked development of benches and ledges in the basins under the higher points. This is very noticeable from Lookout Peak northeast. On these benches are numerous lakelets of clear blue water, which add much to the beauty of the landscape. At the head of Bridal Veil Basin several of these ponds occur very near the base of the Potosi series.

From Lookout Peak westward to Silver Mountain the mountain crest is very narrow and jagged, presenting forms similar to those found in the mountains north of Telluride. A view of Silver Mountain and the spur toward Gold Hill, as seen from the west, is given in fig. 10. It will be noticed that the San Juan slopes are partially talus covered, while the higher levels occupied by the Potosi series are more rugged, with a serrate crest above them, as in other regions already described.

In this ridge the rocks are either bleached or highly colored, and are so much fissured that, particularly on the southern face, great talus slopes descend almost unbroken from the summits to the valley bottom of Howard Fork.

**View from the head of Howard Fork.**

*Howard Fork and the mountains about it.*—Howard Fork of Lake Fork of the San Miguel River has excavated a deep, broad basin in the front of the mountains, from which it flows through a narrow v-shaped gorge cut in the diorite-monzonite stock. A general view of this valley is given in fig. 9, a reproduction of a photograph taken from the ridge north of South Lookout Peak, looking nearly west. On the right hand is seen a portion of the valley bottom, with the busy little mining town of Ophir appearing just over the monumental forms of the foreground. On both sides of the town are steep débris slopes, rising almost to the top of Silver Mountain on the north, while the positions of Waterfall Gulch and Swamp Canyon are indicated beyond or in front of the smooth ridge characterized by areas of fallen timber, seeming like piles of jackstraws at this distance.

Below Ophir the v-shaped gorge is outlined against the dark spruce-covered eastern base of Sunshine Mountain, lying beyond Lake Fork. From this point the line of Yellow Mountain may be traced in its projection against the summits beyond Lake Fork, which culminate in the lofty peaks of the Mount Wilson group in the middle background.

**Talus slopes and rock coloration.**

Howard Fork has cut deep into the sedimentary formations below the volcanic series, but, while the unconformity below the San Miguel conglomerate is well exposed at some points in Swamp Canyon and in Waterfall Gulch, the geology of the lower slopes is greatly obscured by the great talus slopes, the metamorphism adjacent to the diorite-monzonite stock, and the general decomposition of some large areas. Especially on the north side of the valley have the rocks been highly mineralized, not only in the vicinity of the numerous ore veins, but generally, by a thorough impregnation of the rocks by iron pyrites in minute particles. The leaching out of this pyrite and of the original iron-bearing constituents of the andesites has left the rocks either bleached or stained yellow and red, often in most vivid hues. Other processes of decomposition have likewise gone on in the permeation of the rocks by solvent waters, and many types are now recognizable with great difficulty or not at all.

**Iron springs.**

The iron extracted from the rocks has been again deposited on the lower slopes, either as a cement for the mantle of débris, making a hard resistant shell of dark breccia materal, or, where springs have long issued, in considerable masses of brown iron ore, or bog ore. At a point about one mile above Ophir is situated one of the strongest of these iron springs (see map), which has built up a cone of iron sinter holding a beautiful pool of limpid blue water. This cone has the characteristics of those formed about the hot springs of the Yellowstone Park and other districts. The mass of ore deposited at this cone and on the slope below it is of such purity and extent that it is now being used in large amounts as a flux in the smelter at Durango. The iron cap resulting from the cementing of débris is to be noted at many points on Howard Fork and also on the east of Ophir Pass, in the drainage of Mineral Creek.

The Dolores formation is best exposed in Waterfall and Swamp creeks, and in the ravine west of the Badger mine, on the north side of the river. But the hardened, bleached, and fissured rocks seen in the locality last named and in the lower part of Waterfall Creek can scarcely be recognized as belonging to the Dolores, except by their relation to the white band of La Plata on the slope of Yellow Mountain. The red color of the Dolores strata appears, however, in the upper parts of Waterfall and Swamp creeks.

**Exposures of sedimentary formations.**

The San Miguel conglomerate is scarcely recognizable along the north side of Howard Fork, being greatly altered in appearance by the decomposition of the limestone and granitic pebbles and the general bleaching out which all formations have here undergone. But in the southern tributaries it is again well developed. In Swamp Canyon the limestone pebbles have frequently been partially replaced by iron oxide in the outer shell, while the interior may have been dissolved, leaving a cavity.

**Development of the volcanic series.**

The San Juan and Intermediate series are here developed much as in Bridal Veil Basin, but the latter varies much in thickness. In the Ophir Pass divide and in the Lookout Peaks on either side, this series has its greatest known thickness and contains several augite- and hornblende-bearing andesite flows of limited lateral extent. Westward the Intermediate series thins out rapidly, owing partly to an increase in the thickness of the San Juan tuffs, etc., in Yellow Mountain, and partly to removal by erosion in the interval preceding the eruption of the Potosi series. The blotchy aporhyolite at the base of the Intermediate series was found both east and west of U. S. Grant Peak, but was not identified in the ridge between Yellow Mountain and Pilot Knob. Certain remnants on the former seem to be of andesite flows, but the basal tuff of the Potosi series rests on an irregular surface of San Juan tuff on the ridge at the head of Roger Gulch.

The Potosi rhyolite series is present in a thin remnant from U. S. Grant Peak to Pilot Knob, causing the usual impassable sawtooth crest where the lower massive flow remains, and rounded forms in the horizon of the basal tuff or flow-breccia. The decreased prominence of the Potosi series is chiefly due to a gradual rise southward of the floor upon which it rests, amounting to about 400 feet between North Lookout Peak and U. S. Grant Peak.

**Granite-porphyry mass.**

The granite-porphyry areas in the valley above Ophir doubtless belong to one irregularly intruded mass having a general lenticular cross section. The representation of these areas is somewhat generalized, as the contacts are seldom clearly exposed. No other occurrence of this rock has been noted within the quadrangle. The structure of the porphyry is that ordinarily characterizing laccolithic bodies.

At the head of Swamp Canyon, below Ophir Pass, and high up on the north side of the valley east of Staatsburg Gulch are several dikes or small stocks of gabbro-diorite, which form projecting outcrops similar to the one on Ruffner Mountain, illustrated in fig. 4. Those near Staatsburg Gulch are very prominent as seen from the valley. These masses are doubtless arms connected at some depth with the larger stock of Ophir Needles.

**The diorite-monzonite stock.**

The great cross-cutting body of variable constitution through which Howard Fork has cut a deep and narrow gorge is one of the most remarkable igneous masses of the quadrangle and deserves far closer study than could be given to it. The petrographical complexity here found has been already alluded to. The irregularities of its contacts are in small measure shown by the map. The northern portion, causing the craggy ridge known as the Ophir Needles, is shown in figs. 9 and 10. In the latter the bedding of the San Miguel formation should be visible between the jagged crest and the strip of snow-covered talus. The contact is nearly vertical, with many minor irregularities, and the stratified rocks are so hardened near it as to form unusually bold cliffs. A bit of detail along the contact line between the stock and the sedimentaries, from the San Miguel down, is shown in fig. 11, a view from near Ophir station looking northeast. The light-colored San Miguel beds, which lie almost horizontal on the left-hand face of the mountain, are seen to be split apart directly under the summit by a blunt wedge of the stock rock, turning up the higher strata at a steep angle, while the lower ones are cut off sharply by the nearly vertical contact, which can be followed from that point down the ridge. Below the San Miguel the hardened Mancos shales appear, and at the base of the slope is seen the white Dakota sandstone, both of these steeply upturned by a fold older than the San Miguel, whose strata are not affected by it. This contact is typical of those ordinarily found about the great stocks of the quadrangle, though lateral arms of varying form and extent are sometimes seen, as particularly illustrated in this stock.

The diorite-monzonite mass forms the northwestern end of Yellow Mountain and sends off a large irregular dike, in which are some of the workings of the Montezuma and adjacent mines. There are doubtless other offshoots of this mass, not represented upon the map, for the recognition of small arms in the metamorphosed sediments is often difficult and requires more detailed examination than could be given to any portion of the area. Mr. Purington reports that a broad dike of dioritic rock was cut in the Badger (?) tunnel. If this dike is exposed on the surface it escaped detection, but it is presumably an arm from the Ophir Needles.

**Western offshoot from the stock.**

The diorite-monzonite extends westward across Lake Fork of the San Miguel, penetrating the Cretaceous in three directions. The two arms at the eastern and northern bases of San Bernardo Mountain are found with crumpled and hardened shale about them, few contacts being clearly shown, on account of the wooded slopes or the soft shale débris from above. The representation is, therefore, somewhat diagrammatic on the map. The northern arm, however, is seen in the cliff exposures north of Wilson Creek for nearly 2 miles as an apparently regular sheet immediately below the Dakota sandstone. The cliff formed by this mass is shown in fig. 12, a view from near Ophir station, on the railroad. The almost vertical cliff is 800 feet high in places. The Dakota sandstone is at the top of the cliff, and McElmo beds are exposed in the small railroad cutting seen near the center of the view. The actual base of the eruptive rock is concealed by talus.

At a point nearly opposite Ames the mass cuts rather abruptly across the Dakota and runs westward to the north slope of Sunshine Mountain, where it unites with a branch of the Mount Wilson stock, the minimum thickness of the sheet-like body at this point being about 100 feet. The regularity of the intrusive body in the cliff of fig. 12 is thus very local. The rock is not present on the eastern side of the river, and on Wilson Creek it again cuts up across the Dakota into the Mancos shales.

At the base of the lobe of this mass, between Howard and Lake forks, on the lower railroad grade of the loop, is the place, referred to in the description of the diorite-monzonite, at which it is filled with rounded inclusions of many kinds, as illustrated by figs. 13 and 14.

Directly opposite this point a thin, sheet-like arm lies on top of the Dakota sandstone for a distance of about one mile.

**High peaks of this projection.**

*Southwestern promontory of the San Juan.*—From Pilot Knob to a point a little south of Grizzly Peak the formations of the volcanic series extend connectedly as a high and rugged promontory of the San Juan Mountains. Along the irregular and extremely rugged crest of this promontory rise Pilot Knob, Golden Horn, Vermilion, Fuller, and Beattie peaks, all capped by the rhyolite flows of the Potosi series, giving them the character already described and illustrated for other points to the north. Beyond Beattie Peak the divide passes into the great monzonite stock within which are the summits of Rolling Mountain, San Miguel Peak, and Grizzly Peak. All of these but Beattie Peak exceed 13,500 feet in elevation, and the lowest pass in this range, traversed by the trail between Lake Fork and Mineral Creek, is above 12,000 feet.

**Description of fig. 15.**

The abrupt western face of Pilot Knob is well shown in fig. 15, which is a view from the rhyolite knob at the head of the landslide between Ground Hog and Leslie gulches. On the left is a building at the mouth of a tunnel on the Sulphuret No. 2 claim. San Juan tuff and agglomerate, of more nearly homogeneous character than usual, forms the entire cliff to a level just below the smooth saddle. The cliff at the top of Pilot Knob is due to a rhyolite flow, and below it is a series of thinner flows and rhyolitic tuffs, with a thin band of the Intermediate series, which was not very clearly distinguishable from the San Juan tuff in this neighborhood. Nearly all of these summits in the Potosi rhyolite series are brilliantly colored, as is indicated by the names Vermilion Peak and Golden Horn.

On the east of this serrate range lies Ice Lake Basin, holding a dozen beautiful blue glacial lakelets, most of which are near the 12,500-foot level and lie upon the tuffs, etc., of the Intermediate series, if the distinction here drawn upon the basis of an augite-andesite flow is correct.

**Variations in the San Miguel formation.**

On the east and west of the monzonite stock are three isolated areas of the bedded volcanic complex. The one on the west, from San Miguel Peak to Sheep Mountain, is most beautifully exposed in the cliffs on all sides. The chief interest here attaches to the San Miguel formation, which visibly thickens from about 400 feet on Lake Fork to 700 feet at the west side of Sheep Mountain, indicating a change in character as distance from the shore line increases, and preparing one to recognize the thin-bedded fine-grained strata of Mount Wilson as the formation which on Lime Creek and elsewhere is a coarse conglomerate. Above the San Miguel are the monotonous dark-gray slopes of the San Juan tuffs, etc., with possible remnants of the Intermediate and Potosi series in the highest points. The brilliant coloring of the sharp knobs west of San Miguel Peak suggests the presence of the rhyolite, but these points were not visited. Between Sheep Mountain and Grizzly Peak the San Miguel is well exposed, and the San Juan tuff caps the unnamed summit northwest of the latter peak.

Rolling Mountain is cut in two by the nearly vertical contact between monzonite and the bedded volcanics. Here there is great decomposition of all rocks, and huge talus slopes obscure the contacts at many places. A branch of Mineral Creek between Rolling Mountain and the Twin Sisters has cut below the level of the San Miguel conglomerate, thus completing the isolation of the area of bedded volcanics extending eastward on the south side of Mineral Creek as far as Sultan Mountain near Silverton.

**The monzonite stock.**

The monzonite stock of this promontory has been deeply scored at the head waters of three distinct streams, and at the head of Cascade Creek there is a wide amphitheater whose floor is nearly 1000 feet below the normal level of the San Miguel conglomerate. The contacts of this great mass are, as shown by the map, very steeply cross cutting, except on the north of Grizzly Peak, where a wedge of the stratified rocks is upturned by the monzonite and given an irregular northwesterly dip. These amphitheaters are no doubt glacial cirques, but polished rock faces are now rare, owing to the disintegration of the rock in outcrops, or the enormous talus and slide accumulations which conceal them.

*The eastern drainage areas.*—From Three Needles to Grizzly Peak the southeastern slope of the high mountain divide is drained by tributaries of the Animas River, but the streams to the north of the South Fork of Mineral Creek have not cut to the base of the San Juan tuffs within the Telluride quadrangle. In Paradise Basin the andesitic tuffs, etc., are greatly decomposed and heavily iron stained, so that horizons can be traced with difficulty. A small gabbro-diorite stock on the divide south of this basin is prominent by reason of its projecting crags.

**South Fork of Mineral Creek.**

In the south branch of Mineral Creek the relations of the San Miguel to the Mesozoic formations are especially clear on account of variable dips of the latter, in which the San Miguel does not take part. Above Bandora a thin remnant of the Mancos shales appears under the conglomerate, and one going down this stream crosses the Dakota, McElmo, La Plata, and Dolores formations in order. The formations are much hardened adjacent to the monzonite stock, but farther down the slopes the strata have their normal constitution to about the boundary of the quadrangle. Here they have been greatly affected by the monzonite stock of Bear Peak, in the Silverton quadrangle, and are also much decomposed by thermal waters. It is probable that the base of the Dolores formation is but little below the quadrangle line. The structure of the sedimentary formations here will be described in a later section. The prevalent southwesterly dip is indicated by the outcrop of the La Plata sandstone.

On the trail leading to Ice Lake Basin and west of the stream from Clear Lake is a small but noteworthy landslide block, in which are represented the Dolores, San Miguel, and San Juan formations, now dipping at about 20° northward. This block has a diameter of about 300 feet and is much broken, though the relations of the formations are plain. The point from which this block came is evident in the cliff above.

The head of Lime Creek affords excellent opportunities to study the San Miguel formation as to its constitution and its unconformable relations to the Mesozoic series. The Saurian conglomerate of the Dolores is also very well exposed in a persistent ledge around the head of the gulch and in the ridge just south of the quadrangle line.

## LANDSLIDE AREAS ON THE FACE OF THE MOUNTAINS.

**Landslides of Pleistocene age.**

*General occurrence.*—At the western base of the San Juan front, in the Telluride quadrangle, are several areas within which the rock formations normally occurring far above on the mountain are found in very irregular and confused relations to one another. From the size of these areas and the fault-like boundaries seen in certain places, especially along the upper borders, they would naturally be explained as due to ordinary structural faults of some remote geologic epoch. But from internal evidence of various kinds, and from the limited extent and the form of the areas, they are considered as having been caused by gigantic landslides in Pleistocene time. The unusual scale of the phenomena exhibited gives these landslide areas an exceptional interest and makes them worthy of rather extended discussion.

**Landslides elsewhere in the San Juan.**

Since the survey of the Telluride quadrangle was completed landslides have been noted in other districts, and it is probable that this phenomenon has been of common occurrence in the San Juan Mountains. It is stated by Endlich that "Numerous places may be found in the volcanic section where large masses of rock have fallen down, at times for several thousand feet, and are now lying immediately below the perpendicular cliff that their falling produced" (Annual Report of Hayden Survey for 1874, p. 194). While some of the instances here included by Endlich may be basins of erosion, like the "Great Amphitheater" near Mount Sneffels, it is altogether probable that others observed by him are directly comparable with the landslides of the Telluride quadrangle.

**Present conditions.**

**Past conditions.**

*Conditions favorable to landslides.*—It is evident, from the present rugged topography of the San Juan front, as illustrated in this folio, and from the character of the rock formations present, that natural conditions very favorable to landslides still exist in the Telluride quadrangle. The great complex of volcanic rocks, mainly fragmental and highly permeable to water, from rain or melting snows, is underlain by the equally porous San Miguel conglomerate, and the whole rests upon the sandy Mancos shale. Numerous fissures also penetrate the rocks, affording channels for percolating waters to reach the shale horizon. It seems inevitable, then, that each spring the shales below the San Miguel conglomerate must be softened and rendered somewhat plastic by the waters which have found their way down through the porous rocks above. That under these conditions landslides of greater or lesser magnitude should yearly occur at many projecting points of the San Juan front seems quite natural. That huge masses like some of those to be described should have been detached en masse in this way seems to require the assumption that somewhat exceptional conditions prevailed at the time of their fall. The fact appears to be that the topography of early Pleistocene time was bolder even than that of to-day, and it is quite natural to assume that this region may have experienced earthquake shocks of considerable severity in times past, one effect of which must have been to cause landslides of more than ordinary magnitude. From the superficial slipping combined with extensive shattering of the rocks, as observed about Rico, it seems necessary to assume that violent earthquakes have occurred in that region, only a few miles distant from the large slide areas of the Telluride quadrangle. The conditions which now exist or which may reasonably be supposed to have existed in this region are considered competent to explain the areas under discussion as due to landslide action.

**Classification of evidences.**

*Evidence of sliding observed.*—The internal evidence offered by the areas themselves as to their origin may be briefly discussed: 1. The rock formations at the surface in these areas occur in the mountains near by at much higher levels and must have come to their present position by structural faulting or surface slipping. This dislocation is more than 2000 feet in some places. 2. The areas are so circumscribed that structural faults can not explain them unless the dislocation was the sinking of a block without disturbance of adjacent country — a phenomenon not easily accounted for. 3. At the Currency mine, within one of the landslide areas, Mancos shale was found under 190 feet of San Juan and San Miguel material, showing that this area is not a faulted block. 4. In many places the formations of the supposed slide areas dip at 30° or more toward the adjacent cliff of the mountain front, the recognized normal attitude of slide blocks to the mass from which they have been detached. 5. The rocks within the separate areas are greatly shattered and present abnormal and confused relations at many points. 6. The topography of the larger landslide areas is extremely peculiar, with many knolls and rounded hills among which the drainage channels wind in irregular course, and there are numerous sinks and pools without surface outlet. 7. At the Currency mine and at a few other points there is evidence that sliding is still in progress within the area. 8. Small slide blocks adjacent to the larger areas are of unquestionable origin, and exhibit many features in common with the larger ones.

**Breaking-up of landslide blocks.**

The smaller slide blocks are often seen in process of disintegration, in the course of which they must eventually form talus heaps indistinguishable from those of slower accumulation. Certain talus masses are surely of this origin. By the existing gradation in size down to masses less than 100 feet in length a transition to the ordinary talus accumulation is evident. Where a detached block, in sliding down the slope, maintains in some degree the normal attitude of the bedded formations its origin can be recognized. But a similar mass may break into several smaller fragments by the shock of the fall, and appear to be the result of numerous separate falls.

**Landslides at various times.**

*Age of the slides.*—The age of the larger landslides of the Telluride quadrangle is not definitely known in relation to other phenomena of Pleistocene time, but while they seem to be the oldest of the slides now recognizable the landslide period must be considered as extending down to the present time. That similar phenomena played an important rôle during the whole period of erosion since the shales were first exposed below cliffs of the San Miguel formation and the volcanic series can hardly be doubted. The landslides in question occurred after the mountain front had reached its present position, but while the upper members of the volcanic complex were much more prominently developed in the peaks and ridges above that front. That fact bears on the recent erosion of the region, and indicates that the physiography of the San Juan Mountains was much bolder and that the summits were higher at the time of these landslides than they are at the present day.

It is difficult to determine whether the glacier which left the moraine still visible on the east side of Lake Fork was older than the large landslide east of it. The map shows the slide in contact with the moraine and crossing its southern end, as if more recent. This is believed to be the actual relationship of the two phenomena, but it is possible that the part crossing the end of the moraine is a more recent slide than the part above the moraine to the north. The moraine has been so nearly destroyed and the secondary slides are so numerous that the primary relations of the two phenomena can not be clearly demonstrated at this day.

The several landslide areas will now be described in some detail.

*Landslide east of Trout Lake.*—From Trout Lake almost to the crest of the Yellow Mountain ridge, about 3000 feet above the lake, and extending for nearly 3 miles along the slope, is a landslide area exhibiting in great clearness the various evidences of its origin. It is probable that the lake owes its origin to the dam of slide material at its lower end, now almost entirely eroded away. The outline of this area upon the map is accurate for only the upper part, at its contact with the cliff of San Juan tuff and agglomerate, seen in fig. 15. The lower line is obscured on the surface by both grass and forest growth and by the numerous small blocks of slide material which have become detached from the original slide mass and have disintegrated into a confused talus-like mingling of huge bowlders.

**Description of fig. 16.**

Fig. 16 is from a photograph showing the uppermost part of this slide mass resting against the cliff of San Juan tuff and agglomerate. The point of view is the little saddle between the heads of Leslie and Ground Hog gulches, looking north toward Yellow Mountain, whose summits are seen in the center of the view. On the right hand is the cliff of bedded tuff, etc., continuous with that seen in fig. 15. On the southwest or left-hand face of Yellow Mountain is seen a similar cliff, of the same formation. But this cliff is interrupted in the center of the view by a shoulder of very different character. In its upper part this shoulder is largely grassed over, with huge débris blocks scattered about and several outcrops of light-gray rock forming knoll-like projections. Below appears a distinct ledge or cliff, with straggling timber-line spruces struggling for a foothold. All of this shoulder seen in the view is made up of the Potosi series, and in all the distinct outcrops the lamination dips toward the east or northeast at variable angles, often exceeding 30°. The apex of this rhyolite mass is very near the crest of the main ridge on the right, just under a little knob, visible on the sky-line of fig. 15, which is made up of the tuff-like flow-breccia at the very base of the Potosi series. This apparently rests on the San Juan tuff, the Intermediate series being absent at this point, so that there is now no lamellar rhyolite, such as that of the shoulder described, on the ridge above it. The base of the rhyolite in Ground Hog Gulch is 1000 feet below the apex of the mass, and under it comes San Juan tuff, etc., as in the normal section. On the ridge north of the gulch the rhyolite comes several hundred feet lower, but rises again to 11,700 feet on the divide between Roger and Minnie gulches. These variations are in general accompanied by changes in dip and strike of the rhyolite bands, but not always. Fracture planes marking lines of dislocation traverse the mass in several directions. One of these is indicated upon the map.

On the ridge north of Roger Gulch a massive flow of pyroxene-andesite appears beneath the rhyolite and is taken to mean that the Intermediate series is present in a thin remnant, as expressed on the map. Below the line of rhyolite and Intermediate andesite is a broken, wooded country, with numerous knobs or huge blocks of San Juan tuff, etc., and occasional ones of rhyolite. The structure in these exposures is very variable, in no two being quite alike, and the conclusion is that they are not outcrops of rock in normal relation to the rhyolite above.

**Formations exposed in the slide.**

The only line of outcrops affording a good idea of the composition of this area is in Ground Hog Gulch. Here, at about 10,800 feet, the San Miguel conglomerate is found resting on Mancos shales, both exhibiting an eastward dip of nearly 45°. The outcrops are very distinct and the San Miguel is almost continuously exposed in a thickness of between 200 and 300 feet. The shales below it are crushed and are not exposed except very near the San Miguel. Below and on either side the wooded slopes were carefully searched in vain for further exposures on this general horizon. The San Juan tuffs, etc., are exposed in several places between the San Miguel and the rhyolite above, but there is manifestly not room for the entire section of these beds present in the cliff face of Yellow Mountain, or in that seen in fig. 16.

**Landslide topography.**

From Trout Lake up to the rhyolite or andesite flow the area traversed by Roger and Minnie creeks is very irregular in its topography, with many hillocks and short ridges covered by aspens, with sink holes on the upper side of many of them and drainage ravines winding intricately around among them. In the frontispiece to Mr. Purington's paper in the Eighteenth Annual Report this topography is illustrated, as seen from San Bernardo Mountain. Below the 10,400-foot level large blocks of San Miguel conglomerate are numerous, and surfaces of considerable extent show only débris of this formation, but perhaps still lower may be found an area equally characterized by the San Juan tuff. The larger knolls may have ledge-like outcrops, showing that either the San Juan or the San Miguel formation is present in mass, but the dips vary, and in the strike of a ledge of one of these are knolls exhibiting the other rocks. No outcrops of shale could be found down to the level of Trout Lake.

**Adjacent slide blocks.**

On the ridge running west from Yellow Mountain a small block of the San Miguel has dropped a distance somewhat less than the thickness of the formation. It is much fissured and will surely be precipitated down the steep slope at no distant day. A few hundred feet below that a similar block of the San Miguel rests on the Mancos shales, marking an earlier slide, and in the valley of Lake Fork is an area, shown by the map, within which is a jumble of large and small fragments of the San Miguel conglomerate, thought to represent a slide block in an advanced state of disintegration.

The lower border of the large slide area east of Trout Lake is indicated on the map by a line showing the lower limit of a confused mass of San Juan and San Miguel materials which continuously conceal the Mancos shales. From the nature of the case this line can be drawn with only approximate exactness. Spots of débris occur in places below it, and the grassy or wooded slopes above it may in some places be underlain by shale. It is supposed that the shales beneath the San Miguel in Ground Hog Gulch belong to the landslide mass, on account of their dip.

The southern boundary of this mass as represented on the map is possibly incorrect. The line may be in Leslie Gulch instead of in Poverty Gulch, as drawn. Observations of sufficient detail to determine this point were not made.

Reviewing the evidence of this area, it seems that a great slide has taken place, and either at the time it occurred or subsequently the block has been much broken up, so that only the general relations of the various parts can now be made out. The base of the rhyolite series in Ground Hog Gulch is 1000 feet vertically below its normal place on the ridge above, but the base of the San Miguel is only 200 or 300 feet lower than the level it occupies to the north or south of the landslide block. This discrepancy is partly accounted for by the increasing dip of the lower part of the dislocated complex, but a larger factor in this case is probably the grinding up and disappearance from the section of much of the San Juan tuff, a result of the complex fracturing which the slide block as a whole has undergone.

*Landslide area northwest of Silver Mountain.*—The largest landslide area of the Telluride quadrangle, embracing about 10 square miles and shown on the map, extends from Lake Fork near Ames nearly to the Telluride branch of the San Miguel. Its upper limit is along the slopes of Silver Mountain, Bald Mountain, and Gold Hill, and its lower border is in general about 1500 feet below, except at the southern end, where the slide material comes quite down to the stream of Lake Fork, more than 2500 feet below the upper line as it crosses Turkey Creek.

The topography within this area is that most naturally characteristic of a surface made up of landslide blocks. In fig. 10 is illustrated the configuration of the southern part of the landslide mass as seen from the western side of Lake Fork, looking toward Silver Mountain. There are a great number of knolls, longitudinal ridges, or benches, the majority of which have steep outer slopes, with trenches, or depressions, often containing a stagnant pool, back of them, on the mountain side, and the drainage is extremely irregular.

**Observations in this area.**

While this area is large it exhibits relatively few exposures in which the attitude of the bedded formations there present can be clearly seen. On the upper limit, north of Ophir Needles, a small slide block of San Juan tuff, etc., interrupts the San Miguel ledge between the levels 10,500 and 11,000 feet. In this block the tuffs strike somewhat west of north and dip 21° easterly. This seems to have been a recent slide of the lower few hundred feet of the San Juan formation. The trail from the Gold King road to Ophir Loop passes at the base of this slide block, over a bench on which there is a small lake. At about this level to the north is a much more extensive bench with two ponds, which are shown upon the map. These benches are typical of many in this slide area, having a steep outer slope in which the crushed San Juan tuff does not form a distinct ledge outcrop, though its presence is plain.

From the south branch of Turkey Creek around Bald Mountain to Prospect Creek the slide line is not sharply indicated, except that above it are seen nearly continuous outcrops of the San Juan tuff in normal position and below it the confused landslide topography begins. On the west slope of Gold Hill, however, lateral ridges, with a trench back of them, are found in several places near the cliffs of the San Juan. In some of these ridges the outcrops show the San Juan tuff dipping at various decided angles toward Gold Hill. One of these is below the point where the normal cliff of the San Miguel formation reappears.

Rhyolitic débris is scattered over the upper part of the slide area, but was not found in mass, as east of Trout Lake. San Juan tuff and agglomerate forms most of the knolls and benches down to a level somewhat below 10,500 feet. In several outcrops below the Gold King road dips of as much as 60°, generally somewhat north of east, were observed.

The most regular element in the composition of this area seems to be the presence of the San Miguel formation in a broad band extending from Prospect Creek to Turkey Creek. The lower line of the slide and the line between the San Miguel and San Juan formations can be pretty clearly made out within this space. Mr. Spencer noted several outcrops of the San Miguel having strikes between N. 15° W. and N. 20° W., with dips of 45° to 60° easterly.

South of the south branch of Turkey Creek no regular relation between San Juan and San Miguel outcrops can be made out. Above the Currency mine is a knoll of San Miguel conglomerate with irregular eastward dip, the reddish western face being visible miles away. This is the oval mass represented upon the map. All around it is débris of the San Juan tuff.

**The Currency mine.**

The Currency mine (No. 30 on Economic sheet), a little below this exposure, has a shaft 200 feet deep sunk through San Juan and San Miguel formations to the Mancos shales. By an unfortunate error on the Economic sheet the Currency shaft has been placed north of the boundary of the landslide. It belongs within the landslide area, immediately below the knoll of the San Miguel conglomerate. This shaft was sunk on an ore-bearing vein which was traced down to the Mancos shale, though much fractured and dislocated. Drifts from the shaft and various surface workings have shown the broken-up character of the San Juan formation about this point and have furnished evidence of slipping still in progress. Thus tunnels running nearly parallel to the general slope of the country in the vicinity exhibit a crushing of the timbers, especially on the upper or mountain side. The Currency shaft could not be kept vertical, the bottom moving down the slope and with a twist indicating some undulation in the shale surface upon which the sliding mass rests. A short distance from the Currency shaft a prospect tunnel in broken-up San Juan material was run into an older tunnel whose timbers were all crushed together, the entrance to this old working having been entirely obliterated by recent sliding. Mancos shale was also found here, much nearer the surface than in the Currency shaft.

**The Currency ore body.**

The attempts to find a continuous ore body in the Currency mine resulted in the discovery of sufficient ore in small stringers and disconnected masses to induce the erection of a steam hoisting plant and other mine machinery, but the total irregularity in dislocation and the cumulative evidence that the whole mass was slide material caused the abandonment of further exploration. There are some indications of secondary deposition of ore on the shale contact, but the thoroughly crushed condition of vein and rock matter and the likelihood of some ore being dragged into the zones of movement make positive statements on this point unwarrantable.

Material representing the San Miguel conglomerate, much broken up, occupied some 15 feet above the shale in the Currency shaft. In some levels and tunnels a greater thickness was found, but in both this and the San Juan tuffs, etc., the normal bedded structure could seldom be made out, and the innumerable fracture planes running in all directions plainly showed the cause of the existing conditions. It seems probable that the Currency mine is in a slide block which may have originally been much more solid than at present, and that secondary sliding has increased the dislocation upon the fractures produced in the fall, and perhaps created new ones.

Below the Currency mine the confused mingling of San Juan, San Miguel, and Mancos shale extends down to Lake Fork. At one point the wagon road close by the stream passes over the loose black shale 500 feet below the Dakota ledge, over which it has been pushed by the sliding mass of the other formations. This shale and that of other exposures higher on the slope is thought to belong to the great furrow of this soft material which must have been thrown up by the plowing force of the original slide.

There is much landslide material in disconnected masses on the slope west of Ophir Needles, and the southern border for the landslide mass, as shown on the map, is thus a necessary generalization.

**A compound landslide.**

From the extent and observed structure of this, the largest landslide area of the Telluride quadrangle, it is supposed to be the product of several slides from the mountain face, which were perhaps contemporaneous or nearly so, and that ever since the primary slide there has been continual slipping of minor masses within the area. The disintegration of the whole mass is going on, under the active operation of a geological agent of no mean importance in such a region.

**Rocks exposed.**

*Landslide at west base of Sheep Mountain.*—The map shows a small landslide area just below the cliff of the San Miguel formation on the west slope of Sheep Mountain. In this mass Potosi rhyolite flows and tuffs, the San Juan tuff, etc., and some coarser agglomerate referred to the Intermediate series, have been distinguished and represented upon the map in their proper colors. The main part of this mass is Potosi rhyolite, of two lamellar flows, with the usual flow-breccia below them. Under this rhyolite comes some very much crushed San Juan tuff in a thin band less than 200 feet thick at its maximum. Bowlders and pebbles of quartzites and granite found at its base in a few spots indicate a disintegrated layer of the San Miguel conglomerate. Across the southern end of the rhyolite flows runs a cross fracture, beyond which a chaotic agglomerate of pyroxene-andesite appears, seeming to belong to the Intermediate member of the volcanic complex. The lower boundary of this mass is obscure, in a heavy growth of spruce forest, but shale exposures at several points and the smooth character of the slopes below indicate that the map is here nearly correct.

The laminated rhyolite flows dip toward Sheep Mountain, but not regularly, since cross fractures plainly show the mass to be much broken up. On the west face of Sheep Mountain above this slide is a depression drained by two shallow ravines, shown on the map, and one can not avoid the conclusion that the depression marks the place from which the slide block came. If the original mass included much of the San Juan, that material was so ground up by friction that little of it now remains.

This block shows that at the time of its fall the Potosi series extended out along the crest from San Miguel Peak to Sheep Mountain. It is not now present at the extremity of Sheep Mountain, and only small remnants may be still found in the points above 13,500 feet near San Miguel Peak. Much less erosion has been necessary to remove this rock from Sheep Mountain than must have taken place on the Yellow Mountain–Pilot Knob ridge.

*Other landslide masses.*—Other landslides besides those above described have undoubtedly taken place at many localities along the San Juan front, but they are either so small or have become so disintegrated in course of time that they can not be represented on the map. One point where small masses have been detached and have broken into smaller blocks in their fall is on the unnamed mountain northwest of Grizzly Peak. Here are several pinnacled projections in the zone of the San Miguel formation, already detached by crevasses from the mountain and slightly dislocated, which must ere long fall or slide en masse down the steep shale slope beneath.

It is quite probable that small slides, more or less broken up, exist on the north slope of Sheep Mountain and to the north of the San Miguel River, on the rounded slope below the cliffs seen in fig. 1.

### THE MOUNT WILSON GROUP AND ADJACENT SUMMITS.

**Relations to the San Juan complex.**

It has been stated above that the San Miguel formation and some of the overlying volcanic rocks have been found in the Mount Wilson group and adjacent summits. The geological map expresses the observed distribution of formations, demonstrating at once that the Mount Wilson group is geologically an outlier of the San Juan Mountains, isolated by the deep erosion of the San Miguel and Dolores rivers. A glance at the map will show the almost complete correspondence in constitution between the mountains under discussion and the southwestern promontory of the San Juan ending in Grizzly Peak. In each area a great stock of granular rock is partly surrounded by remnants of the San Miguel formation and of the overlying bedded volcanics. In the one case connection with the main mass of the San Juan still exists; in the other the isolation is complete.

**Black Face.**

*Summits west of Trout Lake.*—To the west of Trout Lake is a long, curving ridge with an abrupt face on the southern and southeastern sides and with great talus streams extending far out over the lower shale slopes. This ridge is due to a great irregular injection of gabbro-diorite in Mancos shale. Just under its summit on the south side a dense, dark igneous rock allied to camptonite penetrates the gabbro-diorite in an irregular small stock or plug. Its vertical cliffs contrast strongly with the gray mass of the mountain and form so prominent a feature as seen from the south that the hitherto nameless elevation has been called Black Face. This mass of gabbro-diorite is plainly to be considered as an arm of the Yellow Mountain stock, but the contacts are seldom visible. At the north end, above San Bernardo, the shales are seen in a ravine, and are much contorted and baked near the intrusive mass. The shales may also be seen above the mass, dipping northwesterly from the summit of Black Face and easterly from the hill south of the Lizard Head. On the southeast side of the latter hill the lower contact is also seen, and on the northwest a thin branch in sheet form is present in the shales. At the end toward the Lizard Head the mass comes in contact with the San Miguel conglomerate and sends off a narrow dike into it. At several places in this dark-gray gabbro-diorite are coarse-grained veins or small segregations rich in orthoclase and quartz, often intergrown in the form of graphic granite.

**San Bernardo and Sunshine mountains.**

The first trace of the San Miguel conglomerate west of Lake Fork is in San Bernardo Mountain, which is capped by a remnant of that formation some 400 feet in thickness, its base being about 500 feet higher than on the west slope of Yellow Mountain. West of San Bernardo Mountain Wilson Creek has cut down 1200 feet into the soft Mancos shales. On its western side rises a high ridge, at the northern end of which is Sunshine Mountain and at the southern end the singular monolith called the Lizard Head. In this ridge the San Miguel formation has a variable development. Under the summit of Sunshine Mountain the formation has a thickness of nearly 1000 feet, while at the southern base of the Lizard Head the San Juan tuffs come down to less than 200 feet of the Mancos shales. This seems explainable only as due to erosion, and indicates that the San Juan tuffs were not deposited at this point in such perfect continuity with the San Miguel beds as they appear to have been elsewhere.

**The Lizard Head.**

A thin remnant of rhyolitic flow-breccia and mixed tuffs of the Intermediate series occurs on the ridge about the Lizard Head. The latter is a column with nearly vertical walls on all sides, rising nearly 300 feet above its platform. Its summit is inaccessible, and the reason for its preservation is not evident. At the base it is a bedded mass of andesitic breccia, which might belong to the Intermediate series, and a horizontal banding is visible far up on its walls, although a vertical fissuring renders this obscure in many places. It is possible that there is here a rounded or oval neck of massive rock, like some of the basic dikes of the vicinity, which has indurated the surrounding tuffs, so that the core is concealed by a shell of this character.

**Remnants of bedded formations.**

*The Mount Wilson group.*—On the northern and southern sides of the Mount Wilson group the San Miguel formation occurs in its maximum known thickness of about 1000 feet, with much thinner remnants of the San Juan tuffs above. The character of the San Miguel may be especially well studied on the ridge south of the summit of Mount Wilson. The base is commonly very distinct in contrast to the Mancos shales, even where the latter are much indurated. The San Juan tuffs are not preserved in characteristic condition, being greatly decomposed and iron stained, but the microscope leaves no doubt as to the nature of the tuffs.

The high peaks of the Mount Wilson group are all within the irregular diorite-monzonite stock, which has been deeply scored by the head waters of several streams. The various peaks and narrow, serrate connecting divides present the extremely precipitous and rugged forms characteristic of the dissected stocks. These summits are the highest remaining in the Telluride quadrangle; several exceed 14,000 feet in height above sea level, the point known as Mount Wilson having the altitude of 14,250 feet.

**Rugged character of the group.**

As these mountains stand isolated they present a particularly striking appearance in contrast to the gentle slopes of Mancos shales about them. Fig. 17 is intended to give some idea of the rugged grandeur of this alpine group as seen after one of the light snowfalls of early autumn from the valley of the East Dolores, at the eastern base of Flat Top. On the left hand is a ridge of San Miguel and San Juan beds, the stratification being apparent through the snow. The view also shows the extremely jagged forms of Mount Wilson and of Gladstone and Wilson peaks.

Another view of these summits is given in fig. 18, from the point of Dakota sandstone directly north of San Miguel. In this view Wilson Peak becomes most prominent. To the left of it are Magpie and Bilk basins. In the distance, on the right hand, are the peaks of the Dolores group; on the left hand, Sunshine Mountain and the Lizard Head. Even at this distance of 10 miles or more one can clearly distinguish the bedded San Miguel formation from the massive stock which cuts it, but much of this contrast has been lost in the reproduction.

### LACCOLITHIC MOUNTAINS.

The remaining mountain masses of the Telluride quadrangle show by their structure and the character of the igneous rocks in them that they are not geologically connected with the San Juan Mountains in origin, but represent instead the laccolithic type of the plateau country to the westward.

**Structure.**

*Flat Top.*—Near the southwestern corner of the quadrangle is the mountain mass called Flat Top, caused by a thick body of gray diorite-porphyry. The porphyry rests on the Dakota sandstone, as may be seen at many points, and has a small remnant of baked and somewhat bleached Mancos shales on its summit. As shown by the map, the Flat Top porphyry is 1200 feet thick under the summit, but its thickness decreases so rapidly to the northeast that an apparent sheet, 100 feet or less thick, represents it on the opposite side of the narrow East Dolores Valley, while to the west and northwest no trace of it appears on the edge of the plateau. It is easy to understand how the overlying shales must have been domed up over this mass, and the body seems from the map to be almost a typical laccolith. But the porphyry extends from Flat Top for 3 miles southeastward to Hermosa Peak, in the Engineer Mountain quadrangle, occupying, so far as now known, this same horizon at the base of the Mancos shales. The mass is, therefore, not symmetrical, but differs in no other respect from the laccolith as originally defined by Gilbert.

Several thin sheets of dense gray porphyry appear in the Mancos shales to the northeast of Flat Top, which are considered as offshoots from the laccolith. Enormous talus slopes obscure the lower contact in many places, especially on the Barlow Creek side.

**A dissected laccolith.**

*Gray Head.*—In the northwestern part of the quadrangle are three intrusive masses of the same variety of diorite-porphyry that occurs in Flat Top. One of these is the resistant rock of the mountain called Gray Head, the summit of which is 3500 feet above the river at Sawpit. The general plane of intrusion of this mass is also the upper surface of the Dakota sandstone, although on the southern side some shales come between the porphyry and the sandstone, as indicated upon the map. Mancos shales rise to the summit of the mountain on the east, with a general eastward dip of about 30°. They are soft and friable except in the immediate contact zone, a few feet in thickness, where they are hardened and somewhat bleached. The Gray Head mass extended but a short distance beyond the quadrangle line on the north, being now cut off by a steep curving gulch, which enters the San Miguel at Sawpit. The approximately dome-shaped form which this laccolith must have possessed is shown by the fact that it did not extend far enough to the southwest, northwest, or north to reach the opposite side of the canyons, the rim rock of which is the Dakota sandstone, with the Mancos shale resting on it. The maximum vertical thickness of the porphyry mass was more than 2000 feet, for the present summit, upon which the shales have an easterly dip, rises to that elevation above the horizontal Dakota sandstone of the canyon wall. The apex of the dome was somewhat to the west of the summit. The rock presents an extremely rugged face, with many cliffs and gray crags on all sides where it is exposed. The Mancos shales are much crushed and contorted about the blunt ending of the porphyry on the south, and are mainly concealed under large talus slopes on the north.

**A laccolith in Mancos shales.**

*Whipple and Hawn mountains.*—East of Gray Head occurs a larger body of the same type of porphyry. There are two distinct summits of this mass, named respectively Whipple and Hawn mountains, after early explorers in this region, while a large basin has been excavated between them, at the head of Willow Creek. Mancos shales are found on the summit of Whipple Mountain in almost horizontal position, and extend down the north face with a northerly dip, connecting with the shales surrounding the mass, thus limiting, at a short distance beyond the quadrangle line, the two porphyry lobes represented on the map. While it is plain that the contacts of the porphyry about the present mountain must be with Mancos shales, the exact nature of the lower line was not found at any point, owing to the great talus heaps at the base of the precipitous slopes, and this talus extends so far out over the shale that the structure of the latter is not evident near the mass. This body of diorite-porphyry is regarded as a laccolith intruded into the soft Mancos shales, its principal mass, at least, lying at some distance above the Dakota sandstone. The shales on the summit of Whipple Mountain are more than 2000 feet above the base of the massive porphyry cliffs on the southern ridge.

**Relation of laccoliths.**

*Other intrusive masses.*—Between the two large porphyry laccoliths above described occurs a smaller one of the same rock, exposed by the erosion of Summit Creek. This body lies on the Dakota, with a wedge-like arm in shales at the eastern end of the outcrop. There can be no doubt as to the connection of these three laccoliths in some manner, but the soft and crumpled shales above them do not preserve the structure due to the intrusions with sufficient clearness to indicate where the connection takes place. It is assumed in section AB of the Structure Section sheet that it is north of the line of that section. Numerous small tongues of dense porphyry occur in the shales all about these masses, assuming sheet, dike, or irregular shapes, and a few of them could be mapped. Near the Last Dollar claim, on the ridge northeast of Gray Head, and also farther north, are some dikes and sheets of diorite-porphyry in the Mancos shales, which exhibit the porphyritic structure to perfection by the strong contrast existing between the uniform gray groundmass and the plagioclase and hornblende crystals embedded in it. Several small sheets and dikes on Deep Creek are supposed to be offshoots from the mass of Hawn Mountain.

### THE CRETACEOUS PLATEAU AND ITS VALLEYS.

**The Dolores Plateau modified.**

*Relations to the mountains.*—From the western base of the San Juan Mountains in the Telluride quadrangle a gently undulating plateau extends due west for 120 miles to the brink of the Colorado Canyon. This plateau is immediately underlain by the Dakota sandstone over large areas, but toward the mountains variable thicknesses of the Mancos shales locally remain upon the sandstone. The western portion of the plateau, the Great Sage Plain, is interrupted in this east-and-west line only by the small laccolithic group of the Abajo or Blue Mountains, in Utah. The eastern portion, the Dolores Plateau, would certainly have developed to abut abruptly against the San Juan front were it not for the igneous intrusions of the San Miguel Mountains. Of these, the western summits, Lone Cone, Dolores Peak, and some lower elevations, are certainly in large part of laccolithic origin, as described by W. H. Holmes, analogous to the smaller masses, Flat Top, Gray Head, and others of the Telluride quadrangle. The Mount Wilson group, geographically belonging to the San Miguel Mountains, has been shown to be geologically an isolated outlier of the San Juan volcanic area. All these elevations are locally of much prominence, but they are dwarfed by comparison with the broad expanse of the plateau from which they rise.

The level borders of the San Miguel and Dolores canyons in the Telluride quadrangle are distinctly the eastern limits of the Dolores Plateau. Between 1500 and 2000 feet above this plateau level is the old plain of post-Cretaceous erosion, which upon subsidence became in this region the floor of the San Miguel lake. From Ruffner Mountain to Sheep Mountain the slopes of the zone between these plains are mainly occupied by the Mancos shales, and the lower part of the mountain front thus presents the rounded forms normal to the degraded slopes of such material.

Fig. 18 presents a view of the Dolores Plateau in its relation to mountain and canyon, as developed in the San Miguel drainage area of the Telluride quadrangle. The view is looking southwest from the top of the Dakota sandstone ledge north of San Miguel, at an elevation of about 10,200 feet, here less than 300 feet below the base of the San Miguel conglomerate. The scene is, then, nearly equivalent to that which would fall under the eye of an observer looking down upon the Dolores Plateau from the level of the post-Cretaceous plain of erosion.

**Description and illustration of the relations.**

The Dakota sandstone descends rapidly from the point of view to the general level of the table-land, as illustrated by the map. In the foreground is the alluvial floor of the San Miguel Valley below Telluride, and along the edge of the plateau beyond it runs the Dakota, covered in most places here by glacial or slide material, but exposed in a distinct ledge near Lawson's ranch, on the left hand.

The level middleground, with its grazing land or cultivated fields, belongs to the table-land between Bilk Creek and Lake Fork or to the area east of the latter, above Vance Junction, a veritable bit of the Dolores Plateau, continuous from this point down the San Miguel Valley. The canyons of the streams cutting it are but indistinctly outlined in the view by strips of aspens, or by the white lines of the Dakota ledge on their farther rims. The undulating wooded ridges which rise on the left hand to Bald Mountain and Gold Hill, and in the distance to Sunshine Mountain or Wilson Peak, are characteristic of the intermediate country lying between the base of the San Miguel formation and the plateau level. In fig. 17 the southeastern slopes of Mount Wilson, of the same character, are well shown.

Between Bilk and Big Bear creeks is a prominent hill capped by a very much decomposed igneous rock whose original character is much obscured. It has numerous small rounded cavities containing very clear quartz crystals having polished faces and sharp angles. Some of these crystals have weathered out and can be picked up. The name Diamond Hill, locally in use for this hill, was doubtless suggested by these clear crystals.

*The San Miguel Valley.*—The Dolores Plateau is traversed by several important streams, two of which have their extreme eastern head waters within the Telluride quadrangle. Of these the San Miguel River is locally the more important, and the deeper parts of its canyon for 10 miles above Sawpit are in many respects typical of thousands of miles of canyon valleys traversing the arid plateau region to the westward.

**A typical canyon.**

At Sawpit the San Miguel Canyon is 1700 feet deep, from the plateau level to the stream bed, and it is more than 1000 feet in depth at the mouth of Bilk Creek. The Dakota sandstone is at once the rim rock of the canyon and the floor of the plateau. It frequently presents an almost vertical cliff for its entire thickness, varying from 100 to 250 feet, but the shaly layers more commonly cause slight benches. Below the Dakota comes the series of alternating sandstones and shales of the McElmo formation, forming a corresponding succession of rock ledges and débris-covered slopes. Many sandstone ledges overhang the soft, friable shales beneath them.

The La Plata sandstone is sure to form a notable horizon along the canyon walls by reason of its more massive sandstones and its usually distinct white color, contrasting strongly with the red Dolores strata below. But the lower portion of the La Plata is itself sometimes highly colored in shades of orange or red; ordinarily, however, different from those of the Dolores beds. The thin bituminous limestone separating the massive sandstones is prominent in many exposures about Sawpit. Within the Dolores formation the red sandstones and conglomerates cause very rugged topography, the latter bands being commonly most prominent. In this canyon the principal ledge of Saurian conglomerate is less than 100 feet below the La Plata sandstone and is almost continuously distinguishable for the entire length of the canyon.

**Dike features.**

The narrow dikes of basalt or other dark igneous rocks which cut the canyon walls in the vicinity of Sawpit and at the mouth of Big Bear Creek are striking features. The one running from Newmire up to the plateau level is characterized by a regular vertical and horizontal jointing, parallel and at right angles to the walls. The magma of this dike has also hardened the shales and sandstones in contact with it. The combined effect of these two conditions is to produce a cleft in the cliff face, due to the removal of the joint blocks of the dike, the indurated contact zones of sedimentary rock standing out as walls, in places 30 or 40 feet high and only 10 to 15 feet thick, themselves resembling the more common outcrop of dikes in such strata. This dike is of plagioclase-basalt. The narrow dikes near Sawpit are visible for long distances as projecting ribs cutting the sandstones.

The more important southern tributaries of the San Miguel — Big Bear and Bilk creeks and Lake Fork — flow in their lower courses in canyons repeating in miniature the features of the larger gorge. About the forks of Big Bear Creek are several faults crossing the stream and the adjacent plateau. These are very noticeable at many points on the walls where the Dakota ledge is dislocated, but they are not sufficient in displacement to change materially the relation of canyon to plateau.

**Lake Fork.**

Lake Fork of the San Miguel flows in a canyon decreasing in depth upstream as far as the junction with Howard Fork. The western side of this shallow canyon has the usual rim of Dakota sandstone until the intrusive arm of diorite-monzonite shown in fig. 12 adds nearly 1000 feet to the height of the wall at this point. On the eastern side the glacial gravels extend from Turkey Creek southward until the arm of the landslide mass below the Currency mine is encountered, which sweeps quite down to the stream bed, replacing the normal canyon wall by the irregular, uneven slope shown in part in fig. 10.

The bed of Lake Fork rises rapidly across the diorite-monzonite, and on its southern side, at San Bernardo, is in the Mancos shales. It is probable that the Dakota is very near the surface at San Bernardo, and it can not be very deeply buried at Trout Lake or on the flat divide of hay lands about Lizard Head station. The true dips of the crumbling shale can not be definitely made out in this vicinity, but the position of the Dakota below can be inferred from the lenticular exposure of its upper strata about 2 miles southeast of Trout Lake and from the level of its appearance on the Dolores drainage to the southwest.

*The Dolores Valley.*—The East Dolores River, from Barlow Creek upward, flows in a valley of the same general character as that of the San Miguel. The Dakota forms the bounding ledge between the plateau and canyon, and the Flat Top porphyry mass adds locally to the depth of the canyon, as does the Gray Head mass at Sawpit to the San Miguel Canyon.

Below Barlow Creek the influence of the dome uplift of the Rico Mountains is felt, and the stream cuts rapidly into the Dolores formation.

## GENERAL GEOLOGY.

*A discussion of the general problems respecting the geological history of the region presented by the facts observed in the Telluride quadrangle.*

The Introduction to this text gave some idea of the scope of the geologic problems presented in the San Juan region and of the scanty basis for their discussion afforded by our present knowledge. The survey of the Telluride quadrangle has brought to light many lines of evidence which, when followed out through adjoining districts, will lead to a much better understanding of the complicated geologic history of the San Juan. Naturally the correct interpretation of much of this evidence must depend on future investigation, but a brief discussion of the observed facts will be given, in order that the reader may obtain a better idea of the geologic development of this particular area and also a conception of the broader significance of the local geology, as it is at present understood.

### THE PRE-DEVONIAN CONTINENT.

The fundamental element in the geologic structure of the San Juan Mountains concerning which we have any considerable knowledge at the present time is the continental mass, composed largely of Algonkian quartzites, with granites, gneisses, and schists, some of which are probably Archean, against and around which sedimentary formations were deposited during many periods of Paleozoic and Mesozoic times. This land mass has doubtless varied in size in different periods, but facts have not yet been discovered to prove that it has ever been entirely submerged beneath the sea level. Yet it is also true that the shore lines of the various surrounding formations have not been determined with accuracy.

**Algonkian quartzite in Canyon Creek.**

The only evidence afforded by the Telluride quadrangle concerning this old continent mass is that of the isolated exposure of quartzite in Canyon Creek north of Stony Mountain. This proves that the Algonkian quartzites are present in this vicinity, and they are doubtless continuous, beneath the younger formations, with the quartzites of the lower part of Canyon Creek, near Ouray, where they are overlain by Devonian limestone. Since the oldest strata found resting upon the Algonkian quartzites of the San Juan are probably of Devonian age, it must be inferred that a land mass existed here during Silurian and Cambrian times.

### MESOZOIC HISTORY.

No Paleozoic formations are exposed within the Telluride quadrangle, but it must be assumed that they are present beneath the Dolores formation, since they appear within a few miles to the southwest about Rico, to the southeast in Lime and Mineral creeks, and to the northeast in Canyon Creek.

**Shore line near this quadrangle.**

*The Dolores epoch.*—The Dolores formation of this quadrangle is coarser grained than in the Rico, La Plata, or Durango quadrangles. Its characteristic limestone conglomerates prove that in the adjacent land areas older limestones were exposed, and the greater number of conglomerate layers and the large size of the pebbles in the easternmost section examined, that of Cataract Creek, seems to indicate approach to the shore line in that direction. The conglomerates frequently contain a large amount of quartzite and greenish schists derived from the Algonkian complex, together with granite and gneiss. All these facts lead to the conclusion that during the Dolores period a land mass existed not far east of the Telluride quadrangle, composed of essentially the same formations now found in the Needle Mountains.

*Relations between the Dolores and La Plata formations.*—It has already been explained that a great overlap unconformity, demontrating elevation, erosion, and subsidence, separates the La Plata sandstone from the Dolores formation on the northern and southern slopes of the San Juan. Little evidence bearing upon this problem has been observed within the Telluride quadrangle. The varying thickness of Dolores strata occurring between the La Plata sandstone and the uppermost Saurian conglomerate, increasing from 30 feet in the San Miguel Valley to several hundred feet in the La Plata Mountains, may represent a gradual transgression of the La Plata outward from a zone of more marked unconformity near the San Juan continent of Dolores time. But this transgression is so gradual that the thickening might easily be due to original conditions of deposition of the Dolores sandstone.

**An important stratigraphic break possible.**

No satisfactory fossil evidence has been found to prove the age of the Gunnison formation. But it is clear from the lithologic character of the sandstones of both the La Plata and the McElmo division that the conditions of sedimentation during those epochs were very similar to those prevailing while the Dakota sandstones were being laid down. Especially noteworthy in this connection seems the presence of a peculiar fine-grained conglomerate both in the McElmo and in the Dakota formation. The small pebbles are largely of chert or dense siliceous rocks, white, dark gray, pink, or red in color, and many of them appear to represent silicified limestones. The origin of these materials is unknown, but they speak for similar land conditions in the two epochs of sedimentation. Yet, if the McElmo be of Jurassic age, the long period included in the "Lower" Cretaceous must have separated them.

There is no known reason to suppose that the full "Upper" Cretaceous section was not deposited in the Telluride and adjacent areas in a similar development to that now seen on the Animas River near Durango. In that section the total thickness of the "Upper" Cretaceous, from the Dakota to the Laramie, inclusive, is about 6200 feet.

The San Juan shore line during the "Upper" Cretaceous may have been far east of that which existed during the Dolores period. Indeed, the sediments of the former may have entirely covered the area of the present San Juan Mountains, so far as any definite evidence now known indicates.

### POST-CRETACEOUS UPLIFT AND EROSION.

**Great importance of the uplift.**

*Nature and extent of uplift.*—The evidence which has been found in the Telluride quadrangle as to the great uplift which brought to an end the long period of continuous Cretaceous sedimentation, and the enormous erosion which followed that uplift, is so plainly shown by the geological map and has been so frequently referred to in the details of local geology that little more need be said in this place. The upturning of the Mesozoic formations is seen about Telluride and Ophir, in the South Fork of Mineral Creek, and in Lime Creek. In the adjacent Silverton quadrangle the Carboniferous and Devonian strata are also upturned. While several earlier periods of orographic movement are supposed to have taken place in this region, and there have certainly been later uplifts, it seems clear that the present attitude of all the Paleozoic and Mesozoic formations in the western part of the San Juan Mountains is mainly due to the great post-Cretaceous uplift.

The broad structure resulting from this uplift was a general dip north, west, and south, away from the western center of the San Juan mountain area. This is apparent from the structure of the Telluride quadrangle, but it also appears that there were subordinate folds or wrinkles in this area, the extent of which can not now be fully made out.

*Erosion following uplift.*—The measure of the erosion following the great uplift is found in the unconformity at the base of the San Miguel conglomerate, for the region occupied by that formation. On the supposition, scarcely questionable, that the entire "Upper" Cretaceous section was present in this area at the time of uplift, about 7000 feet of strata were removed above the spot where Ingram and Bridal Veil creeks now unite. A glance at the map shows, moreover, that the surface upon which the San Miguel was deposited was a gently undulating plain, and although elaborate discussion of the subject at this time would be premature, it must be pointed out that, while the San Miguel formation is doubtless limited in extent, the Hayden map represents the entire volcanic complex of the San Juan as resting upon a surface which is in a broad way the continuation of that beneath the San Miguel in the Telluride quadrangle. The quartzite and granite peaks of the Needle Mountains rise above this level, and on their northwestern side is a known shore line for the San Miguel formation, but it is quite possible that these beds reappear beneath the andesitic tuffs southeast of the Needle Mountains. In any case it is demonstrated that the period of uplift and erosion before the deposition of the San Miguel conglomerate was one of great importance. The extent of its influence is at present unknown, though it must be assumed to have been far reaching.

**Plain on which the San Miguel rests.**

That a general subsidence led to the formation of the San Miguel lake is a most natural supposition, but little evidence indicating the amount of that movement is as yet available.

### PROBLEMS OF THE SAN MIGUEL FORMATION.

The San Miguel beds occupy a position of great importance in relation both to the events which preceded and those which followed their deposition. Could the age of the San Miguel be closely determined a valuable contribution to our knowledge of the orographic history of the Rocky Mountains would be made, and at the same time the epoch in which the volcanic eruptions of the San Juan began would be fixed. But no fossils have been discovered in the San Miguel beds, although careful search was made in the fine-grained strata at many points. Only some carbonized plant stems and trail-like markings in mud layers were seen.

*Age of the formation.*—The only direct evidence as to the age of the San Miguel formation now known comes from its position upon the plain of erosion above discussed and beneath the volcanic complex of the San Juan. According to R. C. Hills, the later eruptions of the main San Juan series were "involved in the disturbances which produced the San Luis Park depression and the final upheaval of the Sangre de Cristo Range." This uplift is called by Hills the "post-Bridger, for the reason that it terminated the period of Eocene sedimentation in the Huerfano Basin, where the uppermost beds are paleontologically referable to this age" (Orographic and structural features of Rocky Mountain geology: Proc. Colo. Sci. Soc., Vol. III, pp. 407, 408). In the address just cited (p. 407) Hills remarks that the San Miguel conglomerate, which he had observed near Telluride, "belongs, presumably, to post-Laramie or early Eocene times;" and in the original description of the formation the present writer called attention to the analogy in composition and general relations between the San Miguel and the Arapahoe formation of the Denver Basin.

**Post-Laramie or Eocene ?.**

*Correlation.*—To suggest a correlation of the San Miguel and Arapahoe formations is to suggest further that the San Juan tuffs of the Telluride quadrangle correspond in age, as they do in composition, with the Denver beds, and thus is raised the whole broad question as to the relations between the physical history of the Rocky Mountain region and the changes that took place in animal and plant life during the time interval between the period of the uppermost conformable Cretaceous formation, the Laramie, and the lowest recognized Eocene formation, the Puerco. The Arapahoe and Denver beds contain a rich fossil flora and a fauna of wonderful vertebrate forms, the evidence of which has inclined many paleontologists to group these formations with the Laramie Cretaceous in spite of the great orographic movement which preceded them. For a full presentation of this question the reader is referred to the discussion, by the writer, of the age of the Arapahoe and Denver formations, in the Survey monograph upon the geology of the Denver Basin (Monographs U. S. Geological Survey, Vol. XXVII, Geology of the Denver Basin in Colorado, 1896, pp. 206–252).

**Relation of San Miguel to Arapahoe formation.**

The necessity for considering this correlation in spite of the lack of known fossils in the San Miguel or San Juan formations arises from the presence of the andesitic tuffs known as the Animas formation between the Laramie and the Puerco, near Durango. It is but natural to assume that the material of these beds was derived from the San Juan Mountains, but they contain a fossil flora similar to that of the Denver beds, and if they are really to be correlated with the San Juan tuffs of the Telluride quadrangle, the San Miguel formation must be older and would then correspond with the Arapahoe formation. The Animas beds now appear in seeming conformity with the Laramie in the only places where they have been seen in contact, and no possible equivalent of the San Miguel formation has been found south of the outcrop shown in the Telluride quadrangle.

The only hope for a solution of the problems involved lies in determining the age of the San Miguel or the San Juan formation, or in finding proof of the relation between the Animas beds and the volcanic series of the San Juan Mountains, which are petrographically so similar. The only region in which this can be reasonably looked for lies to the east of the Animas River, near the point where the San Juan River issues from the mountains.

**Rocks of the land mass.**

*The land mass adjacent to the San Miguel lake.*—The San Miguel conglomerate is of much importance for the evidence it bears as to the character of the San Juan land mass during the epoch of its deposition. The nature of the pebbles in its strata testifies to the proximity of a land area made up of quartzites and schists, granite, and gneiss, like the Needle Mountains of to-day, and probably these mountains are a remnant of that land mass. Strata of Paleozoic and lower Mesozoic age, upturned around the mass of older rocks, must have furnished the red sandstones, the limestones, and some of the quartzites occurring in the San Miguel. The decreasing amount of these materials in the upper beds is testimony of the wearing away of these formations. There must have been some large porphyry body exposed in the land area, as there are many pebbles scattered throughout the conglomerate layers. This rock is unlike any of the dioritic or monzonitic porphyries forming the intrusive sheets or laccoliths in the sedimentary series of this region, and it is probably of much greater age.

### THE VOLCANIC SERIES.

The bedded volcanic rocks of the Telluride quadrangle bear witness to the character and magnitude of the San Juan volcanic outbursts during a considerable portion, at least, of the period of activity. Until much more extended examinations have been made even the outline of this volcanic history can not be sketched, but it is of interest to consider the evidence presented by the formations that have been described.

**A fragmental deposit due to explosive eruptions.**

*The San Juan formation.*—The first evidence of the San Juan volcano thus far discovered is contained in the tuffs, agglomerates, and breccias of the San Juan formation. From their characteristics, which have already been given, these materials are thought to be the product of explosive eruptions at one or more centers situated some little distance east of the Telluride area. It is supposed that these materials received their stratified arrangement in part in the waters of the San Miguel lake, but that, as they overlapped the shores of that body of water, a similar structure was produced by subaerial agencies alone. Two thousand feet of this stratified formation is preserved in the Telluride quadrangle, and this amount was doubtless exceeded in proximity to the vents.

Mr. Hills speaks of this agglomerate, etc., as an "outflow of breccia," implying a molten matrix or some unusual form of eruption from the depths. No evidence of a molten base holding the fragments has been observed in the beds here called the San Juan tuffs, etc., though in the Intermediate series a rhyolitic magma has locally caught up great numbers of andesitic and rhyolitic fragments.

**Probable earlier eruptions.**

The San Juan formation contains andesite of several varieties and of many textural phases, and the most natural supposition as to its origin appears to be that it is the result of explosive outbursts of great violence, by which a volcanic cone, or perhaps several cones, formed in the earliest stages of the eruptions in the San Juan region, were largely destroyed and lavas in fragments of various sizes were showered upon the surrounding country for many miles around. This occurrence would be of the same order as the explosions which in recent years have been witnessed at Krakatoa, in the Straits of Sunda, and at the volcano of Bandaisan, in Japan. There is great similarity in composition and in structure between the bedded series under discussion and certain members of the volcanic complex of the Yellowstone National Park, but in the latter case evidence of slow accumulation is found in the succession of fossil forests destroyed and buried by the andesitic tuffs and breccias.

*The Intermediate series.*—The alternating series of andesitic and rhyolitic lavas included in this group serves to show that at a certain time a change took place in the character of the volcanic products. Lavas of rhyolitic composition were erupted for the first time, but alternated with andesitic outpourings in a manner to suggest that different vents must have been emitting different materials at the same time.

The Intermediate series has a much more variable development than the San Juan, as now seen. It is thickest near Ophir Pass, and extends as far west as the Lizard Head.

*The Potosi rhyolite series.*—The uppermost member of the volcanic complex in this quadrangle is composed almost wholly of rhyolite, and indicates an important epoch, in which andesitic eruptions had practically ceased. There is no means of knowing how fully the flows and tuffs seen in the Telluride quadrangle represent the whole series of eruptions in this epoch, but it must be assumed that there were still higher flows or tuff layers, now completely removed from the highest peaks of the region.

**Rhyolite representative of a distinct epoch.**

As with the lower members of the local sequence, the Potosi flows and tuffs are so nearly horizontal and cover so much space that no inference of value can be drawn as to their source or extent in other parts of the San Juan. Dikes of glassy rhyolite are said to occur in Potosi Peak, but that these fissures were the channels of eruption for the thick flows of the same mountain does not seem possible.

*Dike eruptions.*—The three bedded members of the volcanic succession are cut by narrow dikes of pyroxene-andesite, especially in the northeastern portion of the quadrangle. These dikes cut every other rock in their paths, but there is no certain evidence that the andesitic dikes belong to the same period of eruption as the basic dikes associated with the diorite-monzonite stock of the Mount Wilson group. From the uniform character of the andesite dikes in the eastern portion of the quadrangle it seems probable that they belong to some late epoch of activity in the cycle of the San Juan volcano not otherwise represented in this area.

**Dikes belonging to a late epoch.**

*Period of waning volcanic energy.*—When the entire San Juan region has been studied many phenomena will undoubtedly be observed which must be explained as belonging to the later phases of activity commonly noted in volcanic districts, such as local eruptions of peculiar lavas, solfataric and fumarole action, hot springs, etc. The Telluride quadrangle, however, seems sufficiently removed from the real centers of volcanic action to make it a matter of some doubt as to how far the agencies which have produced changes in the rocks, or have deposited secondary minerals in them, may be considered truly volcanic agencies. Decomposition of the fragmental and of some of the massive rocks has taken place, but this would be a natural result of the percolation of surface waters.

### LACCOLITHIC INTRUSIONS.

The laccoliths of the Telluride quadrangle, together with the small sheets and dikes near them and the granite-porphyry mass of Howard Fork, are thought to have been intruded after the surface eruptions of the bedded volcanics, but before the stock intrusions. The granite-porphyry mass penetrating the San Juan tuffs affords direct evidence of this fact, and the presence of Mancos shales on the summit of Whipple Mountain seems to give inferential testimony in the same direction. It does not seem probable that these shales would have been preserved at this point, 600 or 700 feet above the plain of erosion upon which the San Miguel beds rest in Ruffner Mountain, if the planation of the region took place after the intrusion of the diorite-porphyry.

**Relation of laccoliths to volcanic succession.**

The inference that the laccoliths are older than the stock eruptions is based upon the relation of sheets and stocks of similar rocks in the Rico and La Plata mountains. In both of these districts diorite- and monzonite-porphyries are cut by diorite stocks. In the Telluride quadrangle no evidence bearing upon this point was observed.

### STOCK ERUPTIONS.

The large stocks of the Telluride district present a number of interesting problems. The form of the masses and their clearly exposed relations to the sedimentary formations and the bedded volcanic series show that the stocks now seen represent the filling of immense conduits which penetrated to the highest levels now existing in this part of the San Juan, and which, it must be assumed, ascended to the surface of the time of eruption. If they did extend to the surface, lavas must have issued from them, and they are thus volcanic channels, but no evidence has been found indicating that they are the throats of explosive volcanoes, such as those from which the great fragmental masses of the San Juan were derived.

**Relations to other eruptions.**

The rocks of these stocks are mainly granular in structure and are often rather coarse grained, as in the case of the Stony Mountain gabbro. It has been a belief among petrologists that such structures could result from the consolidation of igneous magmas only at great depths — depths measured by at least several thousand feet. To assume that the rocks now seen in the summits of Mount Wilson, Mount Sneffels, and other high peaks were consolidated at even 3000 or 4000 feet below the surface is to add to the volcanic complex of the San Juan an enormous amount of material. But unless it is supposed that these granular rocks were formed very near the old surface they must be considered as giving clear evidence of a former extent of the volcanic pile of the San Juan, beside which its present dimensions become insignificant; and whether the visible monzonites, diorites, or gabbros formed at 1000 or 10,000 feet below the surface, it is plain that the typical porphyries of the region, including the Rico and La Plata mountains, consolidated at the same or greater depths; so that the belief, finding most positive expression in the German school of petrography, that great depth is essential to the formation of granular structure in large igneous masses, while the porphyritic structure belongs to higher zones in the earth's crust, is clearly contrary to the facts here revealed.

**Importance of stock rocks in history of San Juan.**

The petrographic complexity of some of these stocks is worthy of much more detailed examination than could be given it in this work. The one exhibiting the greatest variation is that of the Ophir Needles, while a considerable diversity of rock varieties was also noted in Mount Sneffels and in Mount Wilson. Most of the changes in composition appear gradual and are not explainable as due to distinct eruptions of different magmas. In some cases sharp contacts were found. No regular relation between the variation and the form of the stock was observed. Some stocks, as that of Grizzly Peak and Rolling Mountain, are nearly homogeneous in mineral composition throughout. No fragmental material like agglomerate occurs in these stocks, and they are not centers from which dikes radiate. These facts do not allow of the supposition that repeated eruptions of different magmas took place in any one of these conduits to a degree which can permit the idea that they are possibly throats of typical volcanoes.

### RELATIONS BETWEEN THREE TYPES OF ERUPTION.

Three very different phases of eruptive activity seem to be illustrated in the Telluride quadrangle. The products of eruption do not vary essentially in chemical composition; at least some of the stock diorites, laccolithic porphyries, and surface andesites correspond closely in chemical composition. But if all are derived from the same source of molten material, as might be inferred from this chemical composition, it appears that the eruptions took place under different physical conditions; that the forces impelling the eruptions were of different kinds, or of greatly varying intensity if of the same kind. It is not intended to discuss this problem at length in this place, for it is hoped that light may be shed upon the connection between these several types of eruption through the investigations of other portions of the San Juan. But the form which the problem takes as presented in this quadrangle will be briefly stated.

**Problems as to igneous rocks.**

The question may be expressed in general terms as follows: Were the magmas of the intrusive laccoliths, the stocks, and the effusive flows of the Telluride quadrangle derived from the same subterranean source and impelled to or toward the surface by volcanic forces of the same origin, or were they derived from different levels and impelled by forces differing somewhat in kind? The laccoliths are similar to thousands of porphyry masses scattered through Colorado and the adjacent plateau country of Utah, Arizona, and New Mexico, in regions where no evidence now remaining suggests that surface volcanic eruptions ever took place. The stocks of this region are conduits, so near the old surface that they seem to represent channels through which lavas were quietly poured out. But exactly similar stocks are present in the Rico, La Plata, and Elk mountains, and probably in other mountain groups of the Great Plateau. It thus becomes questionable whether the association of these intrusive masses with the surface volcanics of the San Juan is evidence that they are products of eruptive activity about one great center, or whether they are really independent of the typical volcanic manifestations of the San Juan.

### TERTIARY AND RECENT OROGRAPHIC MOVEMENTS.

*The general problem.*—The area of the San Juan Mountains seems to have been a land mass from the time that the San Miguel lake was filled up by the great series of volcanic rocks. As no sedimentary beds exist by which the earth movements of Tertiary time can be differentiated within the mountain district, a detailed study of the whole region is necessary before any definite statements can be made as to the various movements of uplift or subsidence by which the San Juan district has been affected. That the area is now one of the most elevated in the United States, and that a vast amount of denudation has already been accomplished, are the two great facts which testify to the magnitude of the combined disturbances since the beginning of the volcanic eruptions. The San Juan area has, moreover, been uplifted as a great continental mass, and not by axial folds like those of some of the Rocky Mountain ranges of Colorado.

**Orographic history not yet fully determined.**

The Hayden map shows a lake-bed deposit in the valley of the Rio Grande above Wagon Wheel Gap, bearing the symbol of the Green River Eocene, but the reports give no information as to the grounds for assigning the beds to that age. On the southern flanks of the San Juan the Puerco and Wasatch divisions of the Eocene are present in the drainage area of the San Juan River, and they are to some extent upturned nearest the mountains. Since they do not come in contact with the volcanic formations of the San Juan the influence upon the latter of the movement affecting these Eocene deposits can not be determined.

The discussions of orographic movements in the Rocky Mountains by S. F. Emmons (Bulletin Geological Society of America, Vol. I, 1890, pp. 245–286) and R. C. Hills, (Proceedings Colorado Scientific Society, Vol. III, 1890, pp. 362–458) present valuable generalizations as to the succession of movements recognized at various places, but in their application to the San Juan mountain region proper the conclusions are necessarily largely speculative. The unconformity at the base of the San Miguel shows that much of the upturning of the Mesozoic beds adjacent to the mountains, which, as seen on the Animas River, might be considered as the same movement that affects the Puerco, is really in large degree post-Cretaceous, unless the San Miguel and the volcanic series are all of much later date than is now believed.

*Tilting of the volcanic complex.*—In the Telluride quadrangle the two definite structural phenomena referable to Tertiary movements are the tilting of the whole bedded volcanic series, with the San Miguel at their base, and the faulting by which all formations seem to be affected. In the main valley of the San Miguel the conglomerate of that name descends more than 1000 feet in the distance of 8 miles between Iron Mountain and Ingram Creek. This is due to a gentle eastward inclination of the strata. In the central portion of the quadrangle a northeasterly dip of a very few degrees prevails, with many local irregularities due to the large igneous intrusions. In the southeastern corner of the quadrangle the base of the San Miguel is 2000 feet higher than at Ingram Creek, and the strike is nearly east and west. Local undulations, such as those in the Twin Sisters and in the ridge south of Rolling Mountain, are found here and there.

**One definite movement recognized.**

This general northeasterly dip of the San Miguel and overlying volcanic formations has, no doubt, had an important and perhaps predominant influence in determining the broad features of the dissection of the San Juan volcanic plateau by erosion, at least in its western portion.

*Faults and fissure systems.*—The faults observed to cut the volcanic series are of small dislocation, trend in various directions, and display no system. Some of them are ore-bearing veins, and possibly some of the large veins upon which there is no notable displacement where exposed may belong to the same period of fissuring with certain of the faults.

**Many fractures without recognizable system.**

In the description of the economic features (p. 15), by Mr. Purington, will be found statements as to the several systems of joints or fissures which are locally prominent in the Telluride quadrangle, and in his full report Mr. Purington dwells at some length upon the origin of these fractures. As the district studied is but a small portion of the San Juan region, no conclusive statement can as yet be made regarding the relation of these fissure systems to broad movements in the San Juan, nor can the fissures be classified in sets of contemporaneous origin. That some of these systems of fissures have been of much local importance in determining the course of erosion can not be questioned.

### DENUDATION OF THE SAN JUAN PLATEAU.

*Character of the plateau.*—From present knowledge it appears that at the period of maximum development the accumulations from the volcanic centers of the San Juan must have formed a great plateau, much greater in extent than the area now covered by the lavas and tuffs. The Telluride quadrangle, now situated on the extreme western border of the volcanic complex, must once have been far within its limits, and we have here the evidence of enormous erosion, by which the abrupt western front of the San Juan Mountains has been carved out of the old plateau. Degradation of the volcanic pile by ordinary agencies of subaerial erosion has doubtless been in progress since early Eocene time, the work of many of the earlier intervals in the volcanic history being undone by succeeding eruptions.

**Former extent of San Juan Plateau.**

The bedded series of tuffs, agglomerates, and lava flows, still preserved in the higher ridges and peaks of the Telluride quadrangle, proves beyond a doubt that a thickness of 3000 or 4000 feet of these rocks once covered the entire quadrangle above the level of the San Miguel conglomerate. The evidence of the large stocks indicates that a considerable further thickness of similar volcanic materials has been entirely removed, so that it seems to the writer quite within the bounds of reason to assume that there may once have been 6000 or 7000 feet of volcanic rocks present in this region. How far the volcanics extended to the westward is totally unknown, but it must have been many miles, judging from the thickness still preserved in this quadrangle.

*The cause of denudation.*—The work of erosion on this, the western, side of the San Juan has resulted in the almost complete removal of the entire bedded series back to the abrupt front which has been described. But erosion has not stopped with removal of the volcanics. The sedimentary rocks have been denuded over large areas down to a new plateau level — that of the Dakota sandstone — and deep canyons have been carved in the harder rocks below it. In view of the eastward tilting of the region, it is probable that the San Miguel River at Sawpit, only 16 miles from its present head, has cut at least 7000 feet, and possibly more than 10,000 feet, below the surface which existed at the close of volcanic activity. The penetration of the river to-day is only 8 miles beyond the mountain front. The Dolores River has also accomplished a great task of removal.

**Erosion on different sides compared.**

On the northern side the various branches of the Uncompahgre and on the southern side those of the San Juan have pushed back the mountain front and cut deeply into the sedimentary formations. These streams have all worked under similar conditions and have produced similar results, which contrast strongly with those achieved by the Rio Grande, penetrating the volcanic area from the east. From San Luis Park to the head of the Rio Grande, in the Silverton quadrangle, is 65 miles, and its fall in this distance is the same as that accomplished by the San Miguel in 16 miles.

While the configuration of the San Juan Plateau at the close of volcanic activity and the positions of the rivers, which at once began their attack upon it, are as yet matters of speculation, it is probable that two known factors have had great influence in determining the course of the denudation of the area. The first of these is the climatic condition by which the western portion of the San Juan has probably long received, as it now receives, a very heavy rainfall from the moisture-laden currents coming from the southwest over the arid lower country. The second factor of importance is the eastward tilting indicated in the Telluride quadrangle, which, if long continued at a rate not too rapid for the cutting power of the western streams, would stimulate their attack upon the retreating mountain front. If this relative movement consisted in a subsidence of the eastern area its effect in retarding the erosion of streams on that side is evident.

**Agencies active at the present time.**

The degradation of the western San Juan area is progressing to-day under the combined attack of several agencies. The most important of these is the diurnal change in temperature during a large part of the year. The continued action of freezing and thawing in finely jointed rocks saturated with moisture produces the enormous talus slopes represented in several illustrations of this folio. During the winter months snowslides are frequent, and they often carry rock masses with them, but the spring torrents from the melting of the snow are probably much more efficient agents of destruction. In the rainy season local "cloud-bursts" often carry enormous amounts of débris far down the slopes. During a period not far distant landslides of unusual magnitude occurred in this region, and this agency is still active, both in breaking up the old slide masses and in detaching fresh masses from the cliffs. Glacial erosion of a time not long past is indicated in many of the high amphitheaters, but the evidences of this action have been destroyed by more recent agencies on most of the lower slopes. The streams are still cutting their channels in the canyons and removing the fine detritus from their head waters.

### GLACIAL PHENOMENA.

In common with all other high mountain districts of Colorado, the San Juan Mountains present indisputable evidence of glacial action in the more elevated portions, and extending down the principal valleys for varying distances. Within the Telluride quadrangle there is considerable evidence of the former existence of glacial ice. Many of the amphitheaters above timber line are glacial cirques and contain small lake basins, which in some cases are excavated in the solid rock. Within some of these cirques, rock surfaces were seen to be polished and striated, and similar scorings were observed in certain of the stream canyons. Furthermore, deposits of glacial débris are found which indicate the former existence of an ice sheet extending out onto the mesa north of the Wilson group of mountains, and of an ice stream in the canyon of Lake Fork of the San Miguel River.

**Glacial striation.**

Distinct striation was noticed in the northern arm of Canyon Creek, not far above the Trust-Ruby mill; on Treasure Hill, northwest of Stony Mountain; on the ridge east of Bilk Creek; and on Howard Fork at Ophir Loop, where the rocks are finely polished. Similar markings were seen in other places, but in many of the basins the rock surfaces are covered by a great amount of talus and soil, and at best the comparatively soft volcanic rocks of the basin floors are not well adapted to the preservation of striæ.

Of interest in connection with these features of the high glacial amphitheaters is the remnant of crevassed névé ice, of a bluish color, which has been already mentioned as occurring on the north slope of the high ridge east of Dallas Peak. This and similar masses of névé ice, reported by R. C. Hills as present at the head of Henson Creek, in the Silverton quadrangle, suggest that only a slight change in climatic conditions has taken place since the high basins of the region were filled with ice from one year's end to another.

**Glacial débris.**

The glacial débris to the north of the Wilson group has not been represented upon the map. It consists of angular fragments of varying size, evidently derived from the formations of the adjacent mountains. This material seldom takes any of the familiar forms of glacial deposits, though some small retreatal moraines were noted, but is found in remnants scattered over the ridges and hill tops in the area which was covered by the ice.

The surficial rocks on the east side of the canyon of Lake Fork, which have been mapped as glacial bowlder deposits, have been somewhat of an enigma. Considerable areas of Mancos shale, and in places the Dakota sandstone, have been buried beneath an irregular thickness of the bowlder beds, and large amounts of similarly constituted débris are found upon the ridge west of the canyon and in the San Miguel Valley at the Keystone placer. The materials of the deposit are various; blocks of San Miguel conglomerate and of volcanic breccia are mixed with pieces of sandstone, apparently from the Dakota, and with different varieties of igneous rocks, including two types of granular rock. Many of the bowlders are rounded, but others are angular and subangular. The size of the fragments varies from coarse sand to bowlders several feet in diameter.

The glacial deposits have not imposed any distinctive topography upon the area in which they have been observed; they lie irregularly upon a shale slope, and south of Turkey Creek they are considerably obscured by landslide material, which seems to have come down over the bowlder beds. In the gorge of Main Fork there is a kind of coarse stratification of the materials, so that layers of cross-bedded sand are found alternating with bands carrying pebbles and bowlders.

**Alluvial deposits at Keystone placer.**

The origin of the alluvial deposits in the flat above the Keystone placer is thought to be intimately connected with that of the placer itself and the bowlder beds which have been described. The materials of the bowlder beds and of the alluvial beds were, however, derived from different sources. The former came from the drainage of Lake and Howard forks and from the basins adjacent to the Gold King Basin, while the latter were derived from the regions on either side of Main Fork. The truth of the first assertion is made certain by the occurrence of the diorite and granite-porphyry bowlders in the Keystone placer. There is no available source for them except in the area indicated. Concerning the second statement more will be said further on.

The conditions which gave rise to these formations seem to have been as follows: At the time the accumulation of ice upon the high ground was greatest there was a sufficient mass in the deep gorge of Howard Fork to furnish a stream of ice which filled the canyon of Lake Fork and reached to its junction with Main Fork. At its maximum the ice probably overtopped the walls of the canyon, which was, of course, closed as a line of water drainage. During the summer season, however, there must have been large volumes of water derived from the melting of the snows upon the southern and western slopes tributary to the drainage of Lake Fork, and these waters must have found an outlet by flowing between the wall of ice on the west and the shale slopes on the east. It is through the instrumentality of such a stream that the bowlder beds are conceived to have been formed. In no other way than by the action of running water can the rounded form of many of the bowlders be accounted for.

**Glacial lake in Lake Fork Valley.**

It seems that at the time Lake Fork was filled with ice there was no corresponding ice stream in Main Fork, so that its valley must then have contained a deep lake, caused by the ice dam, into which the lateral stream emptied a vast amount of débris, which received a rough stratification as it came to rest beneath the waters of the lake. After the retreat of the ice front the great delta-fan remained as an obstruction to the drainage and served as a dam, back of which the materials of the present flat continued to accumulate. At present the river is engaged in the removal of the obstruction, and will doubtless eventually attack the alluvial deposits which have resulted from the dam.

Should any attempt be made to win the gold which doubtless exists in the great alluvial deposit it will probably be found that the precious metal is distributed throughout its whole thickness, since the sorting power of the streams which brought the material into the supposed lake was rendered null as soon as their velocity was checked by the standing water of the lake.

WHITMAN CROSS,
*Geologist.*

June, 1899.

## ECONOMIC GEOLOGY.

### DISCOVERY AND DEVELOPMENT OF THE DISTRICT.

**The first mine locations.**

Whether or not the early Spanish explorers of southwestern Colorado actually passed through this district is uncertain. At any rate no traces remain to indicate that exploration for the precious metals was prosecuted before the middle of the present century, and the first active search for gold and silver in the Telluride district was in 1875. In that year locations were made on the vein now called the Smuggler. At that time, and in following years down to 1882, many locations were made and small amounts of the precious metals were produced. Although the available data concerning the early developments are of the most fragmentary character, it is probable that the total product of the quadrangle previous to the year 1882 did not exceed $50,000.

The region did not attain importance as a source of the precious metals until 1890, when the Rio Grande Southern Railroad was completed from Ridgway to the town of Telluride. It has since been extended south to Durango. Previous to the opening of railway communication, nearly all ore was transported on the backs of pack animals to distant smelters, and in the same manner the machinery for a few mines was brought into the district, at great expense. As a rule, however, only ore of very high grade could be selected for shipping, and the product was necessarily small.

**Recent progress.**

During the last few years, development has been rapid. Many mills have been erected, and in most cases only the concentrated sulphurets, instead of the crude ore, are shipped for smelting. Besides the means of transportation afforded by the railroad, connection between the valleys and many of the mines situated at high altitudes has been effected by wire-rope bucket tramways, operated by gravity. Good trails, and in many cases excellent wagon roads, connect the mines with the railroad. The electric transmission of power generated by water has attained important development. Stamp mills are operated by electric power at distances of more than 10 miles, in a straight line, from the generating station, near Ophir Loop, and at elevations of 2000 or 3000 feet above the source of the power.

In the fall of 1896 about 400 stamps were in operation in the district, and nearly 2000 men were engaged in mining and milling the ore. Although for many years the principal product was silver, gold now constitutes two-thirds of the output. In 1896 the total amount produced was over $3,000,000, about two-thirds of which amount was gold. Since the first finding of ore in the district the product has been steadily increasing, the region never having been, in any sense, a "boom mining camp." A moderate estimate for the total product of the district is $25,000,000 up to 1897.

Development is almost entirely by tunnels run into the steep sides of the mountains, and by overhand stoping. The tunnels are, of course, when practicable, drifts on the veins, but in many cases adits of greater or less length have been run to cross-cut the veins. The longest of these adits is what is known as the Revenue tunnel, which has been run from the bed of Canyon Creek in a westerly direction a distance of 7500 feet to cut the Virginius vein. This it does at a distance vertically below the surface of over 2000 feet. Other veins in the district have been developed by similar methods. It is often found impracticable to work the veins in any other way, since the great altitude at which many of them outcrop precludes the sinking of shafts at the outcrop. Snowslides, especially in the steep gulches, are of common occurrence in winter, and the danger from these, as well as the expense of transporting machinery and supplies to the high basins, makes it, in most cases, advisable to have the surface openings of the mines at as low levels as possible.

The ore deposits of the quadrangle occur mainly in veins which are filled fissures. The discussion following will therefore relate, first, to the observed fissure systems, then to the veins, and last to the ore bodies found in the veins.

### THE FISSURES.

The word "fissure" should be distinguished from the word "vein." Fissure means "crack," with or without an appreciable amount of open space. "Vein," in a strict sense, means a fissure which has been filled with ore. The word "fissure" is often wrongly used in the sense of "vein."

*Fissure systems.*—Many well-defined systems of fissures occur within the area, single members of which are found at points widely distant from one another. These systems are subject to classification, and may be generally divided into five groups, having the direction indicated below.

N. 87° W.—This system is especially well developed in the Mount Wilson area and to the eastward, on Sunshine and Yellow mountains. Representatives of it occur more rarely on Silver Mountain and to the northward.

**Enumeration of fissure systems.**

N. 38° E.—This system has attained marked development in the Mount Wilson area and has an especially remarkable manifestation on the divide between Navajo Basin and Bear Creek, just above the Special Session mine. Crossing the long axis of the ridge at about right angles, the system shows a steep dip to the west up to a point a few hundred feet west of and above the Special Session mine. From here east the fissures have a steep easterly dip, so that a sort of broken anticlinal effect is given, the sides being very steep. As the fissures are not more than 2 feet from one another, the fissuring has the appearance of an immense schistosity, or of a series of great laminæ of slate.

N. 53°–63° E.—The fissures of this system, also especially prominent in the Mount Wilson area, dip steeply north, or stand vertical. Some of the subordinate ridges of the mountains, the development of whose topography seems in a measure dependent on the fissuring, also follow this direction. The northeast systems of fissures are not largely developed, although occasional representatives of both the above-mentioned systems may be seen as far north as the Virginius Basin.

N. 17° W.–N. 2° E.—Fissures whose directions fall within these limits are very common in the northern portion of the quadrangle, especially on Silver Mountain and its northern spurs. A prominent set of joints following the north-and-south direction is developed at Sawpit, in the very northwestern corner of the quadrangle.

N. 25°–51° W., dip almost without exception southwest.—There are within this group four sets of fissures, namely: N. 25° W., N. 36° W., N. 41° W., and N. 51° W. This group will not be considered in detail in this general account. The northwest fissures are of great interest from an economic standpoint, and their principal development occurs in the northeastern part of the quadrangle, in the region immediately about and to the northeast of the town of Telluride.

From the foregoing it is evident that there are four general directions of fissuring: east and west, and northeast, best developed in the central and southeast portions of the quadrangle; north and south, and northwest, best exemplified in the northeast portion.

*Spacing of the fissures.*—The distances across strike between the individual fissures of any one system are exceedingly variable, and the observations tend to show that the occurrences may be grouped into zones of widely and narrowly spaced fissures. An occurrence observed in the Silver Pick mine, which is regarded as, in a measure, typical of the development of fissuring throughout the region, is here recorded. In the drifts of this mine, as one goes southwest on the strike of the main vein, which runs to N. 40° E., dip SE., one sees, crossing the drifts, fissures, practically vertical, which strike N. 83° E. One notices that these fissures, from being 30 feet or more apart, become nearer and nearer together, the spaces between them gradually decreasing to 3 or 4 inches, causing a sheeting or slating of the rock, while still farther on, the spaces increase again in width. This alternation is many times repeated in the distance traversed by one of the longer drifts. Space does not here allow the citation of other illustrations. Many instances have, however, been seen, both over and underground, where narrow and wide zones of fissures alternate, the spaces between the fissures varying from several hundred feet down to an inch.

**Fissures in zones of variable spacing.**

It would seem most likely that where the spaces between fissures are narrow the zones themselves are narrow, and that where single fissures are separated by considerable blocks of unruptured country the zones are necessarily wide. The observations have shown this to be the case. The zones of narrowly spaced fissures rarely exceed 7 feet in width. Where the spaces are wider, having, say, 2 feet between each fissure, the zone is wider, being perhaps 70 or 80 feet. Where the broadest intervals occur the width of the zone must be reckoned in hundreds of feet, sometimes thousands. The peculiarities observed with regard to the spacing of the fissures of any one system appear to warrant the suggestion that there is exemplified here a sort of rhythmical recurrence of alternate wide and narrow belts, which may be due to a definite law.

*Origin of the fissures.*—The fissures penetrate all the rocks exposed in the area, and were formed later than the extrusion of the rhyolite and the intrusion of the diorite stocks. Although from the preliminary character of the present investigation it is considered unwarrantable to assign a definite cause to the fissuring, there is little doubt that it was produced by dynamic action having its source or sources in an area apart but probably not far removed from the field under consideration.

If the fissuring be due to pressure acting as above described the inference is that a considerable amount of open space would be formed along the zones of narrowly spaced fissures, caused by the crushing and grinding up of the country rock by the repeated motion of the walls. Examples of faulting along the fissures on a large or even perceptible scale have been rarely observed, but there is reason to suppose that minute faulting of the rock in connection with the fissuring was of widespread occurrence.

The presence of columnar joints in the lava flows, especially in the rhyolite which caps the divides, may to some extent cause confusion in the study of the fissuring. The effects of subsequent disintegration have, in addition, masked the original structure of all the rocks, especially those which outcrop at the higher altitudes.

### THE VEINS.

**Veins in narrow-spaced fissure zones.**

*Relation of veins to fissures.*—From the observations made throughout the district it seems hardly to be doubted that the lodes are the narrow zones of closely spaced fissures, which have been filled with ore. According to von Cotta's definition, which is generally accepted, a vein is a filled fissure. Thus, in its strict sense, the term vein is limited in its application to the material of extraneous origin filling the space between the two walls of a fissure. In the case where fissured zones have been thus filled, it is somewhat difficult to decide whether the term *vein* or the term *zone of veins* should be applied to the occurrence. For, as is the case in the Telluride district, such filled fissure zones generally consist of alternating bands and lenses of ore and country rock. In the present paper it seems better to use the word vein in its broader sense, as referring to the whole lode, but the above remarks on the subject of definition should be kept in mind.

The narrow zones of closely spaced fissures are well defined by limiting planes, outside of which no great amount of open space was developed. Where ore-bearing solutions have deposited ore along such zones, within the open space, these limiting planes now form the walls of veins. It is rarely the case that the ore — under which term is included, for the present, everything between walls which is not country rock — fills the entire width of the zone. The filled space within the zone varies from the whole width between walls to small seams less than one inch in width. Usually the ore, especially its metallic contents, follows one side of the vein rather than the other, generally the foot wall, while the accompanying decomposing influences have so affected the rest of the rock included between the walls that the resulting material, often called "gouge" matter, is comparatively easy to work, and is found convenient for blasting and "stripping" the vein. The width of the veins varies from 12 feet down, but an average of nearly 100 ore-producing veins examined is 3½ feet. It is, however, impossible to give a correct idea of the width of fissure zones which vary between such wide limits as do these. Many zones are 8 feet in width, while many are not more than 1 foot.

**No constant structure.**

*Structure of the veins.*—All gradations of ore filling are seen in the fissured zones, from those in which the entire width is occupied by ore to cases where the ore seam may be traced only with difficulty in the interstices between the fragments of country rock. Local ore chambers of limited dimensions, where the country rock has suffered more than usual crushing, and where the result is a breccia, with ore for the cementing material, are of not uncommon occurrence. Very large "horses" are occasionally included in the veins. One such in the Mendota workings on the Smuggler vein is several hundred feet in length. From this size the included fragments descend to microscopic proportions. Evidence is afforded by microscopic study, however, that the parallel fissuring of the rock has not reached minute dimensions, as is the case in ore-bearing rocks which have been reduced to slaty or schistose form. The width of the sheeted slabs of rocks and the space between the accompanying parallel fissures is probably never less than one inch. Very minute fissures are frequent, but they are irregularly disposed. Open vugs, that is, cavities lined with crystals, usually of quartz, are very common in the veins. One may observe gradations from this structure to that in which the quartz crystals lining the two sides of the lenticular cavities interlock, and still further to solid filling by gangue minerals.

**Veins best developed in the andesitic rocks.**

*Effect of the country rock on the veins.*—As has been already indicated, the fissure systems enumerated, and consequently the veins, penetrate all the rocks occurring within the area. There seems to be little doubt, however, that a mechanical influence on both the nature and degree of development of the fissured zones has been exercised by the rocks of the various horizons which they traverse. Thus in the case of the Smuggler and Tomboy veins it is evident from observation that the lodes are continuous from the breccias of the San Juan formation through the andesite and rhyolite flows above. In the upper workings on the Smuggler vein, however, where excellent exposures on the vein may be seen in both the rhyolite and underlying rocks, considerable differences are apparent. No change was observed in the amount of fissuring between the breccias and the overlying andesite, but in the upper rhyolite, although the fissures are constant in direction, and although the zone is equally wide, the amount of space now filled with ore is much less, and the fissures themselves did not apparently afford as much open space as did those below. It seems probable that the upper rock offered a greater amount of resistance to the rupturing force than those below.

**Narrow veins in the Dolores formation.**

Although space does not permit a description of all the observed examples of comparative fissuring, the following general statements appear to be warranted by the observations made. In going from the San Juan formation into the San Miguel conglomerate below, the veins do not appear to become narrower, but they assume an irregularly broken and brecciated structure rather than the link-vein and banded character which they possess in the rocks above. In the Contention and Champion mines, and in the mines above Ophir, on Silver Mountain, exposures of veins in the San Miguel conglomerate were seen. In regard to the remaining sedimentary formations in which the veins have been seen — namely, the Mancos shales, the McElmo shales, and the Dolores red sandstone — it may be said that exposures are so few and opportunities for comparison so scant that deductions are not of great value. In general it may be said, however, that the veins in the Mancos and McElmo are wide, those in the Dolores narrow. In fact, with the marked exception of the Silver Chief vein, the fissured zones of the upper rocks appear to have been reduced to single fissures in the Dolores. This sandstone underlies the region of Marshall, Savage, and Virginius basins, where so large a part of the mining development has been done, but none of the veins from which ore has been largely produced are as yet worked down to the horizon of the sandstone, so it can not be said that fair opportunities for comparison are given. Since, however, it is highly probable that a large amount of wearing down, representing a considerable vertical thickness of rock, has taken place since the fissuring was formed, and since, even at the present stage, the sandstone lies at a depth of several thousand feet below the tops of the highest peaks, it can not be supposed that the rupturing forces would have affected it so violently as they did those rocks which lay nearer the original surface. Such observations as have been made on the veins in the sandstone tend to confirm the above suggestion. In the diorite the zones are perhaps as wide as those seen in the volcanics, but the amount of open space which has been filled by ore is subject to much more variation. Local bunches of ore often alternate with places where the veins have pinched to narrow seams. Reticulated or net-like structure is of common occurrence in the veins in diorite. The Mount Wilson veins are especially well defined, and make sharp cuts in the dividing ridges of the mountains.

**Veins of unusual continuity.**

*Continuity of the veins in length.*—The example afforded by the Smuggler vein, from which ore has been produced for a length of more than 2 miles, makes it evident that lodes of unusual continuity exist in the Telluride district. Other veins have been worked continuously for longitudinal distances of more than half a mile, while observations on the fissured zones in general show that a large number of them continue for long distances in unchanged direction and strength. The intersections of the narrow fissured zones of systems, whose directions vary from one another by only a few degrees, often has an important bearing on the continuity or noncontinuity of the lodes. This is especially the case in Marshall and Savage basins, where the four fissure systems extending N. 25° W., N. 36° W., N. 41° W., and N. 51° W. are so well marked. Certain of the veins follow more than one set of the fissures, where the intersections occur, the ore switching from one set to another as it found space for deposition. In the Tomboy vein, observations have led to the conclusion that an intersection of three of the narrow zones of fissures has occurred, accompanied by an unusual amount of grinding up of the country rock, and development of open space. In this case the intersections have been beneficial in effect, since a vein of exceptional development has resulted. Several instances have been observed, however, where the intersection of a zone of widely spaced fissures with a lode has resulted in local impoverishment and sometimes in complete shattering and fraying out of the vein. The last effect cited is due to the fact that the ore, instead of following the main fissured zone, has filled the single cross fissures to such an extent that it is impossible to extract it at a profit. Thus in the investigation of the veins of this district, as regards their continuity in length, it would seem advisable to study with considerable care the distribution of the fissured zones and their intersections.

**Faulting not common.**

*Faulting of veins*—Several instances have been noted, especially in the Virginius and the Smuggler mines, where the veins swell or widen on steep dips and pinch where the dip is flatter. As pointed out long ago by von Cotta, such occurrences are indications of normal faulting along the fissures — that is, a movement of the hanging wall down with reference to the foot wall, or vice versa. Had the faulting been reversed, the wide portions of the veins would have been on the flat dips; the narrow places, along the steeper dips. Lateral faulting of the veins occurs where the ore of one vein is distinctly cut by that of another, but the observed occurrences suggest no definite conclusions. The most marked displacement is along the vein known as the Pandora, running about east and west, lying to the south of Marshall Basin, and to the north of the San Miguel Valley. This is known to displace three, and it probably displaces four, of the northwestward-running veins, in each case throwing the northern portion from 40 to 75 feet to the east.

### THE ORE DEPOSITS.

**Primary minerals observed.**

*The minerals of the veins.*—The minerals occurring in the veins, besides gold and silver, are grouped as ores and gangue minerals. The minerals classed as ores, including here only those in which the precious metals are in all probability chemically combined, are galena, freibergite (argentiferous gray copper), polybasite, proustite, pyrargyrite, stephanite, and probably other of the rarer silver compounds, in minute quantity. The foregoing are given as ores of silver, since none of the tellurides or other of the possible rare compounds of gold occur within the area, so far as has been determined by the present investigation. As is well known, however, no silver ore occurs in which there is not, in the free state, more or less gold. But these minerals, as, for example, galena, while they are to be considered as ores of silver, are, like iron pyrite, merely the gangue or mechanical matrices of gold. The metallic gangue minerals are, in addition to the above, iron pyrite, chalcopyrite, zinc blende, mispickel, magnetite, stibnite, and native copper. The nonmetallic gangue minerals are quartz, calcite, siderite, rhodochrosite, dolomite, fluorite, barite, sericite (white mica), biotite, chlorite, amphibole, apatite, garnet, orthoclase, picotite, and kaolinite.

**Secondary minerals.**

The attempt has been made to exclude from the above lists all secondary products. An uncertainty exists in the case of kaolinite, the occurrence of which in the Tomboy vein is proved, but the genesis of which is regarded as doubtful. Of the secondary minerals the copper sulphate, chalcanthite, of the Silver Pick and Special Session mines is the most remarkable. Its presence is due to the constantly frozen condition of the ground, allowing the percolating water to carry but a small part of it away in solution. Small amounts of copper carbonate are not uncommon in the veins which bear copper pyrite. Lead carbonates and sulphates are usually present with galena, as decomposition products. Massive cerusite occurs in the flat ore beds at Sawpit, replacement deposits in limestone. Limonite is very common as a decomposition product of the iron minerals, and the staining due to its presence may be seen in all portions of the veins above the permanent water level. It should be stated that some of the vein minerals occur in very small amount, and have been detected only with the aid of the microscope.

**Mount Wilson district.**

*Distribution of the ore.*—In the Mount Wilson district the character of the ore is much the same in all the veins. The Silver Pick and Special Session mines show the most development. The product is almost entirely gold, which appears to be held mostly in the arsenical sulphuret, mispickel. The pay streak of the vein lies on the foot wall, is from 4 to 12 inches in width, and consists of straight, narrow bands of quartz, with iron and copper pyrite and mispickel, and smaller amounts of calcite, galena, and zinc blende. The quartz is usually white and crystalline. Open vugs and comb structure are common. The principal sulphuret, mispickel, is usually coarsely crystallized. The separate streaks of quartz sometimes have the character of ribbon ore, having merely a parting between, while they are in other places separated by narrow streaks of country rock. The veins are from 3 to 4 feet in width, but the pay streak is usually so narrow that, notwithstanding its high value, it is only where the ore can be handled on a large scale that the mines in this region have been found profitable.

**Yellow Mountain.**

On Yellow Mountain the veins, which generally run nearly east and west, are almost all silver bearing, so far as hitherto developed. Like the veins of Mount Wilson, they lie almost wholly in diorite-monzonite. The fissured zones are from 3 to 6 feet in width, the pay streak averaging about 2 feet. The ore consists of quartz, sometimes of dark color, usually carrying zinc blende, calcite, and a mixture of the carbonates, rhodochrosite and siderite, accompanying galena; and freibergite, sometimes associated with the carbonates, sometimes with barite. The silver values are in the galena and freibergite, while an increase in copper pyrite is often accompanied by an increase in the gold values. These veins are also characterized by banded structure, not, however, to such a marked degree as those in the Mount Wilson district. The quartz is often white, and comb structure is not uncommon. In places the veins swell, forming chambers of ore of limited extent, which have the character of angular breccias of country rock cemented by ore. Such veins occur in the Terrible, Silver Bell, Carribeau and other mines near these.

**Ophir.**

In immediate connection with the silver-bearing veins just described there occur veins of auriferous quartz, having different physical characteristics. They consist of white quartz, of saccharoidal nature, with disseminated fine-grained auriferous pyrite and free gold. They have more the character of solid ore-filling between two walls than the silver veins. The Badger vein, on the lower southern slope of Silver Mountain, is of this character, and in the Terrible mine, on the west end of Yellow Mountain, such a vein lies parallel to and within a few feet of a vein carrying almost entirely silver ores.

**Northeastern section.**

In the northwestern part of the quadrangle, in the region of Marshall, Savage, and Virginius basins, there is also a close association of the gold and silver veins. Even more remarkable is the increase in gold values and the decrease in those of silver from north to south in several of the principal veins. It seems evident, from many observations, that an increase in gold values in these veins is accompanied by an increase in the amount of iron pyrite, both in the vein itself and as impregnation of the wall-rock. Thus in the northern end of the Smuggler vein the ore consists of quartz, generally of a dark-gray or blue color, a rather small amount of iron and copper pyrite, calcite, and rhodochrosite, with galena, stephanite, polybasite, pyrargyrite, galena, and zinc blende. There is usually a subordinate amount of white quartz. Toward the south end the vein is occupied much more by white, coarsely crystalline quartz, the ores of silver are less frequent, and a considerable amount of iron pyrite is present in the vein. Moreover, a much greater amount of decomposition appears to have taken place in the country rock, due to the oxidation of a large proportion of the iron pyrite with which it was impregnated. These features are characteristic of all the veins which exhibit the change from silver to gold values toward the south.

**Occurrence of the metals.**

In the Virginius vein silver values are in freibergite and galena. In the Trust Ruby mine, in the bed of Canyon Creek, two veins, one bearing gold the other silver values, are intimately associated. In the Big Elephant or N. W. H. jr. mine, in the bed of Savage Basin, an unusually wide vein consists of white quartz with disseminated bunches of sulphurets, chiefly resinous zinc blende, which were said to contain almost entirely gold values. The Tomboy vein (just over the line in the Silverton quadrangle), consists largely of white, coarsely saccharoidal quartz, with subordinate amounts of calcite, fluorite, kaolinite, sericite, and small amounts of iron pyrite, copper pyrite, galena, and zinc blende. The metallic sulphides seem mostly confined to narrow streaks. The gold, so far as is known, is almost entirely free, and its distribution bears no relation to that of the metallic sulphides. From the foregoing it will be seen that the veins of this most important part of the quadrangle vary greatly from one another in their characteristics. In general it may be said that the silver is contained in galena, freibergite, and the rarer sulphides and sulpharsenides, while the gold is either free in the quartz or mechanically combined with sulphurets, usually iron pyrite. It has been noted that the dark-colored quartz is most prevalent in the silver veins, while the coarser white quartz is more characteristic of the veins carrying gold. The iron pyrite which accompanies the argentiferous minerals appears to be generally more finely crystallized than that with which gold is associated. The statement sometimes made that the finely crystalline pyrite is richer in the precious metals than the coarse is not regarded as generally applicable. The veins average 4 to 6 feet in width, with a pay streak of from 2 to 3 feet. As stated below, the tenor of values in the precious metals is moderate. The strike of all these veins is northwest, the dips southwest.

In the region about Bear Creek and on the northern spurs of Silver Mountain a number of veins have been worked, running approximately north and south and east and west. They carry almost exclusively gold values, and are much decomposed in all the exposures seen. The presence of sulphurets was not apparent in them. It is evident, however, that considerable iron pyrite is present in the oxidized state, and it is probable that the gold, now found in large measure free, was originally contained in the pyrite, and that, consequently, in depth the gold will be found largely in the form of sulphuret ore. The Contention and Hamburg veins, in Bear Creek, are examples of these lodes, on which a considerable amount of development has been done.

**Impregnation especially developed near Ophir.**

*Impregnations.*—In consideration of the gold deposits of Silver Mountain, of which the Suffolk and Gold King mines offer the best examples, a brief prefatory note concerning the impregnations in the district in general seems in place. As the word impregnations is now used, its application is restricted to those occurrences where separate crystals, usually of metallic sulphides, fill spaces, however small, which have previously existed in the zones of rock forming and laterally bounding the walls of metalliferous veins. As a necessary accompaniment of impregnations, channels through which mineral-bearing waters can circulate must exist. But it is not necessary that such channels should be visible, even microscopically. In many cases the paths traversed by the solutions are visible, and seem to be filled with quartz, calcite, or whatever material has served as the gangue. Impregnations of the wall rock by iron pyrite occur almost without exception in connection with the veins of the Telluride quadrangle. Their development varies greatly in degree, and almost inseparably connected with them is partial replacement of the original minerals of the country rock by iron pyrite, white mica (sericite), and, more rarely, silica and chlorite. As an accompaniment of these processes there has often been developed hydrothermal decomposition of the rock, to which are due the brilliant red, white, and yellow colors by which the mineralized zones are now marked at the surface. There can be little doubt that the hot-water solutions from which ore was deposited in the veins also caused the impregnations and accompanying phenomena which now exist in the walls. Nevertheless, the vein walls have, as it were, acted as a septum for the solutions, causing them to deposit by far the greater part of their metallic contents, including the precious metals, in the veins themselves, while only a relatively small per cent of the iron pyrite and the accompanying gold has gone into the walls. Thus it is in most cases found that the pyrite of the impregnated wall rock is only slightly auriferous, and always less so than the pyrite of the accompanying veins. On Silver Mountain, however, the deposit worked in the Gold King and Suffolk mines appears to be an impregnation which is auriferous to a workable extent. Veins running for the most part north and south penetrate this portion of the mountain, but they are narrow, often having the character of single quartz streaks not over 3 inches in width. These frequently contain much free gold. It appears to be along the course of these veins that impregnation occurs, and belts of the country rock 5 to 10 feet in width are taken out and milled as ore. Other mines in the vicinity are worked on the same character of ore. Impregnation as above described occurs especially in the rocks of volcanic origin, the breccias and andesite. The San Miguel conglomerate, where it outcrops along the slope of Yellow Mountain, has also been impregnated by iron pyrite. A portion of the ore mined in the Gold Crown appears to be merely this impregnated conglomerate. The impregnation occurs in the material cementing the pebbles, and is occasionally so heavily developed that it is a question whether the ore body should not be classed as vein filling rather than impregnation. This mineralization of the San Miguel conglomerate was not observed except along the southern slope of Silver Mountain.

The veins of the Valley View and Gold and Silver Chief mines to the north of the Telluride Valley appear to correspond in general character to those of Marshall and Savage basins. In Bridal Veil Basin little development has been done, but the exposures of the veins as so far developed bear a resemblance in part to those of the Bear Creek region, in part to those of Yellow Mountain. The ore-beds of Sawpit will be separately described.

**Deposition principally a filling of open spaces.**

*Manner of ore deposition.*—Probably no region will afford better illustrations of the filling by ore of interstitial space in crushed and sheared zones of rock than the Telluride quadrangle. The parallel fissuring does not seem to be spaced more closely than one inch in any observed case. At the same time there are, as shown by microscopic examination, veinlets of the most minute size existing in these zones. These small veins occupy the irregular interstices between the fragments into which the rock between the fissures has been crushed. The presence of comb structure, of open vugs, and in general the evidence that crystals have formed unresisted in open spaces in the veins shows that substitution of country rock by ore has had but little if any part in the formation of the veins. More convincing still that there has not been complete replacement of any portion of the country rock is the fact that all fragments and horses now included in the ore have sharply angular corners, whereas if any complete replacement had taken place, such corners would have been rounded off. The phenomenon here referred to must not be confused with the partial replacement of the constituent minerals of the wall rocks, which action, as has been stated, was a probable accompaniment of the impregnations.

*Values in the ore.*—Owing to the wide variation in the tenor of the ore in the Telluride district, estimates of only the most general nature can be given. In the Mount Wilson gold veins the narrow pay streak of the veins runs from $50 to $150 in gold per ton of ore. In the silver veins of Yellow Mountain the pay streak averages 75 ounces silver and $3 to $12 in gold. The accompanying gold veins are said to run $17 to $20 in gold. The gold veins of Bear Creek run $14.50 to the ton, milling ore, as an average of 22 productive veins. It is especially difficult to represent by single figures the yield of the veins of Marshall, Savage, and Virginius basins. On a milling basis, 20 ounces in silver and $9 in gold to the ton appears most representative. The yield of the Tomboy vein is $20 to the ton in gold. In the impregnated zones of country rock worked as gold-ores on Silver Mountain the yield is from $5 to $10 in gold. In the Sawpit deposits the ore shipped for smelting averages 11 ounces in silver and $22 in gold, besides 15 per cent to 20 per cent in lead.

The fineness of gold in the district varies from .850 to .650. Data concerning the fineness were not often available, consequently this estimate must be regarded as only partially representative.

**Rocks in which the veins are found.**

*Influence of the country rock on the ore.*—The rocks in which the greater number of the veins of the Telluride quadrangle have been found are the granular rocks of the stocks along the central east-and-west portion of the area, and the heavy andesitic breccia, tuff, or agglomerate, now included in the San Juan formation, having its greatest development in the northern half of the area. A few veins are exploited in the overlying flows of andesite, and the upper workings on the Smuggler vein are in the rhyolite which caps the divides. No one vein has been worked throughout the whole section of igneous and sedimentary rocks exposed, although, as has been stated, there can be little doubt that the fissuring has affected all the rocks represented. The evidence available in the field was not sufficient to justify conclusions as to the comparative value of veins in the rocks above and those below. By far the greatest product has come from the horizon of the San Juan formation. Productive veins are, however, worked in the San Miguel conglomerate and the underlying sedimentaries. It has been proved by exploitation that in the stock rocks, the breccias, the volcanic flows, and in some cases in the sedimentary rocks, the values are generally good. In view of the immense thickness of the volcanics it seems likely that many years' work will be required to exhaust the product of the veins within these rocks. The limited study of the region permitted in the present reconnaissance does not justify the assertion that veins which have been found good in the San Juan formation suffer impoverishment of values in the underlying sedimentaries.

**Possibilities in deep-seated limestone horizons.**

At a distance of less than 1000 feet vertically beneath the level of the Telluride Valley there is probably developed the series of upper Carboniferous limestones which have such marked prominence on Dolores Mountain, near Rico. These beds at Rico, where traversed by veins, have been heavily replaced by sulphurets, argentiferous to greater or less extent, and bedded deposits not unlike those at Leadville have been formed. It seems possible that if these limestones are developed beneath the Telluride volcanics, similar ore deposits may exist in them in proximity to veins. It is not probable that the values in these deposits would pay for the sinking necessary to reach them, yet it cannot be denied that a possibility exists of the occurrence of workable ore in depth.

**Great undeveloped resources.**

*Value of the Telluride mining district.*—The region is one of precipitous topography. Most of the veins now worked have been exposed by erosion, and their outcrops are in many cases visible for long distances across country. As the veins are usually worked at considerable elevations above the valleys, transportation of supplies to and of ore from the mines is often difficult and expensive. Water is not plenty in the high basins, and it is usually found inexpedient to mill the ores at the elevation of the mines. Wire-rope bucket tramways working by gravity have been found most expedient for ore transportation, and many are in operation. No sinking of shafts or pumping has as yet been resorted to, all development being done by means of drifts which are themselves open to the air, or are connected with adits. The Revenue tunnel, 7500 feet long, which has cut the Virginius vein at an elevation of 10,800 feet, has proved a successful venture, notwithstanding its great length and the moderate tenor of the ore in the vein. It seems likely that a portion of the veins of the district continue in length for considerable distances while others become broken up and thin out into mere stringers, although further prospecting on the strike line beyond the cross zone of fissures along which the breaking up occurs would sometimes result in a continuation of the vein being found. Other permanent veins will doubtless be discovered. It is one of the best known laws of ore occurrence that veins are formed in groups, and that where one or two veins have been found productive, others similar in character usually exist.

**Ore derived from ascending solutions.**

*Origin of the ore.*—The ore now filling the veins in the Telluride district appears, from all the evidence collected, to have been deposited from ascending hot-water solutions which penetrated all portions of the fissured zones, wherever open space was found. Surface waters, descending by capillarity, or possibly in part by means of the fissures themselves, have taken into solution, in the form of sulphides, alkalies from the constituents of the igneous rocks encountered in their paths. Getting hotter as they descended toward the source of the magma from which the igneous rocks have been derived, the alkaline solutions probably became further charged with sulphydric and carbonic acids derived from volcanic sources, thus becoming solvents for the metals, and for the silica, lime, etc., they gathered from the more basic portions of the magma. By these ore-bearing solutions the metals — gold, silver, lead, copper, iron, and zinc— as well as sulphur, lime, silica, and the alkalies, were probably all brought up from the subterranean region to be deposited in various combinations as the waters approached the surface. The gold quartz and the sulphides of the metals were deposited in the veins themselves, while the penetration of the wall rocks by the alkaline solutions containing sulphydric acid resulted in changes in the form of the iron of the ferromagnesian silicates of the rock and the deposition of potash combined in the silicate sericite. Carbonates, especially of lime, were deposited in the walls, probably for the most part from action of the percolating waters on the lime feldspars. Silica was set free from the bisilicates and feldspars, and has passed mostly away from the wall rocks, being present only in exceptional cases. As has been stated, the gold appears to have been carried into the walls to some extent. Fluorite, which occurs largely in the Tomboy and some other veins, may be accounted for if it be presumed, as Mr. Penrose suggests in regard to the Cripple Creek occurrence, that hydrofluoric acid, or other fluorine compounds in which silica forms a part, accompanied the other elements in solution and, uniting with lime, deposited fluorite in the veins. The fluorite is not purple here, but of a light-green color. Sericite, often spoken of as "talc," occurs in the veins, sometimes in considerable amount, and perhaps represents the form in which a portion of the potash and silica of the ore-bearing solutions has combined. Small amounts of kaolinite are occasionally mixed with this. Chlorite is notably scarce. It is not likely that more than one general deposition of ore has taken place. In local instances successive crystallizations, at intervals not far apart, of the ore and gangue minerals are evident, but these cases are not frequent and no correlation can be established.

**Relation of ore to igneous rocks.**

No evidence in favor of the lateral secretion theory, in the narrow application advanced by Sandberger, has been found. The hypothesis outlined above seems the most plausible in view of the evidence at hand. In cases where tests for the precious metals have been made in the constituent minerals of igneous rocks, in previous investigations of ore-bearing districts, the basic minerals, hornblende, augite, biotite, etc., have been found to contain the larger quantities. Much more basic phases of the Telluride igneous rocks than those generally exposed are occasionally seen in the quadrangle as dikes, inclusions, etc., of small extent. It appears probable that, in the magma wherein the rocks had their source, a basic portion, of which these fragments are representative, exists. This more basic portion is a possible source of the ore, since it does not seem necessary to go beyond the limits of the rock magma for the required constituents. The ore deposition was probably not greatly subsequent in age to the close of the volcanic eruptions, although it must necessarily have taken place later than the fissuring of the country.

*Surface alteration.*—The veins throughout the district show remarkably little decomposition due to surface agencies. Where the impregnations of the walls by iron pyrite are strongest, surface alteration of both the walls and the veins appears most manifest. It is often difficult to distinguish this from the hydrothermal decomposition which was an accompaniment of the ore deposition. In the high basins and on the peaks the constantly frozen condition of the ground goes far toward retarding surface alteration, but at the same time the continual melting and re-freezing of much of the water that percolates through the mass causes rapid breaking down of the rock, and the accumulation of fragments results in the formation of immense heaps of talus.

### THE SAWPIT DEPOSITS.

**Ore associated with La Plata limestone.**

In the northwest corner of the Telluride quadrangle, along the northeast wall of the canyon of the San Miguel River, the impure calcareous layer included in the horizon of the La Plata sandstone has been partially replaced by ore, four-fifths of the value being in gold. The ore bodies as they have been found up to the time of this examination occupy the upper portion of the 8-foot layer of limestone. Their dimensions are usually 100 to 200 feet in length (east and west), 25 feet in width, and 3 to 5 feet in height. They lie parallel to one another, the longest dimensions corresponding in orientation to east-and-west fissures which form one of the systems here prominently developed. Where ore has been taken out, cavities with well-marked walls, characterized by smooth, undulating surfaces, are left. The ore has been for the most part formed by replacement of limestone by metallic sulphides, principally iron pyrite and galena. It now occurs, however, mostly in the form of oxides and carbonates of the metals, the lamellar structure showing rearrangement by water. Masses of the original iron pyrite and galena may be seen inclosed entirely by massive cerusite and limonite. In general, a mixture of secondary ferric material having the appearance of a light-brown mud is the richest in gold, while the subordinate amount of gray, massive cerusite carries the silver values. Free gold is never seen in the ore. Vertical veins filled with calcite and barren of any value cut some of the beds, and penetrate the red sandstones beneath. Barren "verticals" are now recognized in several mining districts as the mineralizers of adjacent ore-beds, and it is possible that these veins may have served in part as channels for the mineral solutions which have brought up the ore. It is of importance also in considering the origin of these deposits to take notice of a dike of rather basic rock, 3 feet in width, which strikes about east and west and which occurs in close proximity to the ore-deposits. This dike, which is probably an offshoot of a much larger igneous mass, may have been in part the cause of the mineralization. It may be said, as of the part of the district farther east, that there is a possibility of further replacement by metallic sulphides of the beds of upper Carboniferous limestone which it is reasonable to suppose underlie the Trias in this portion of the field.

### PLACERS.

**Source of the gold.**

**Difficulties in working deposits.**

Much of the gold of the San Juan region is in a very finely divided state, and from all evidence it can not be doubted that large quantities of it have been deposited along the courses of the streams draining the region. The area over which it has been distributed is probably large, and, indeed, alluvial gold is known to occur along the San Juan River and Grand River hundreds of miles below the sources of their tributaries. It is probable that a large part of this gold was derived from veins in the San Juan Mountains. The alluvial plain which fills the valley of the San Miguel from Pandora nearly to Vance Junction is a repository for much of the gold which comes from the sides of the mountains, yet this ground has been explored with considerable thoroughness without profitable results. In fact, ever since the district was first explored placer mining has been carried on along the course of the San Miguel River for many miles beyond the limits of the Telluride quadrangle. Although more than $100,000 has been taken out in alluvial gold, many times this sum has been spent in the operations. The principal difficulties experienced in working the gravels of the Telluride valley were the large size of the bowlders and the unusual weight of the gravel itself. The gravels appear to have been deposited in a lake, whose origin was due to glacial conditions. Where alluvial gold has been deposited in a lake bed it is not usually sufficiently concentrated to pay for working. So far as present developments show, this lack of concentration has been one of the difficulties experienced in the Telluride deposits. In those placers which have been worked farther down the stream, the additional difficulty has been experienced of getting water to a sufficient height to wash the gravel, for the deposits are not found at the present river bed, but are remnants of terraced gravel beds lying at heights of from 30 to 150 feet above the stream. The gravels are said to run from 10 cents to 20 cents per cubic yard. The character of the gold is generally fine, but not scaly. It does not seem probable that placer mining, according to the methods now generally employed, will ever attain to much importance in the district.

### COAL.

In the southwest corner of the quadrangle the Dakota sandstone contains lignitic coal. The bed is from 20 to 30 inches in thickness, and its occurrence is widespread. About 20,000 tons of the coal have been mined. It is said to be fairly good coking coal, containing little clinker but a large per cent of ash.

CHESTER WELLS PURINGTON,
*Assistant Geologist.*

June, 1897.

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

# TOPOGRAPHIC SHEET

COLORADO
TELLURIDE QUADRANGLE

Henry Gannett, Chief Topographer.
E. M. Douglas, Topographer in charge.
Triangulation by Hayden Survey.
Topography by Frank Tweedy.
Surveyed in 1894.

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.*

Edition of June 1898.

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

# HISTORICAL GEOLOGY SHEET

COLORADO
TELLURIDE QUADRANGLE

## LEGEND

### IGNEOUS ROCKS
*(continued)*

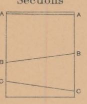
ALGONKIAN

Arh
**Older rhyolite**
*(associated with Algonkian quartzite)*

Faults

Landslide boundaries

Sections



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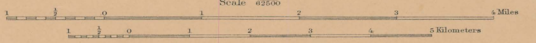


Contour interval 100 feet.
*Datum is mean sea level.*

Edition of Mar 1899.

Areal Geology by Whitman Cross.
Assisted by H. S. Gane, E. C. E. Lord, and A. C. Spencer.
Economic Geology by Chester W. Purington.
Surveyed in 1895–96.

## LEGEND

### SURFICIAL ROCKS

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

PLEISTOCENE

Pal
**Alluvium**
*(lake and river deposits)*

Pg
**Glacial bowlder deposit**

### SEDIMENTARY ROCKS

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

EOCENE ?

Esm
**San Miguel formation**
*(conglomerate containing pebbles of granite, schist, quartzite, limestone, and sandstone.)*

CRETACEOUS

Kmc
**Mancos shale**
*(includes the Benton and Niobrara formations and part of the Pierre.)*

Kd
**Dakota formation**
*(mainly sandstone, with shale and impure coal)*

JURATRIAS

*Gunnison formation*

Jme
**Mc. Elmo formation**
*(alternating sandstones and shales)*

Jlp
**La Plata sandstone**
*(two white sandstone beds with dark limestone between)*

Jd
**Dolores formation**
*(sandstone, grit, conglomerate, and some shale, prevailing color red.)*

ALGONKIAN

Aq
**Quartzite**

### IGNEOUS ROCKS

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

EOCENE AND NEOCENE

**Basic dikes**
*(basalt and several other dark dense rocks)*

an
**Andesite**
*(decomposed, relation to other andesites not known.)*

gp
**Granite-porphyry**
*(irregular intrusive bodies)*

gd
**Gabbro-diorite**
*(stocks and associated dikes or sheets)*

dm
**Diorite-monzonite**
*(stocks and associated dikes or sheets)*

mz
**Monzonite**
*(large stock)*

dp
**Diorite-porphyry**
*(laccoliths, sheets, and dikes)*

rh
**Rhyolite**
*(volcanic plugs piercing Cretaceous shale)*

prh
**Potosi rhyolitic series**
*(several flows and variable tuff beds)*

is
**Intermediate series**
*(commingled andesitic and rhyolitic flows, tuff, breccia, and agglomerate)*

sj
**San Juan series**
*(bedded tuff, breccia, and agglomerate of andesitic material)*

lds
**Landslides**
*(San Miguel formation and San Juan and higher volcanic series in confused relation)*

*Legend is continued on the left margin.*

## LEGEND

IGNEOUS ROCKS
*(continued)*

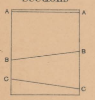
ALGONKIAN

- Arh — **Older rhyolite** *(associated with Algonkian quartzite)*

Faults

Landslide boundaries

Sections



- *Gold quartz veins showing dip and strike*
- *Gold and silver mines*
- ⚒ *Coal mines*

Known productive formations

- ▨ *Gravel somewhat auriferous*

NAMES OF MINES.

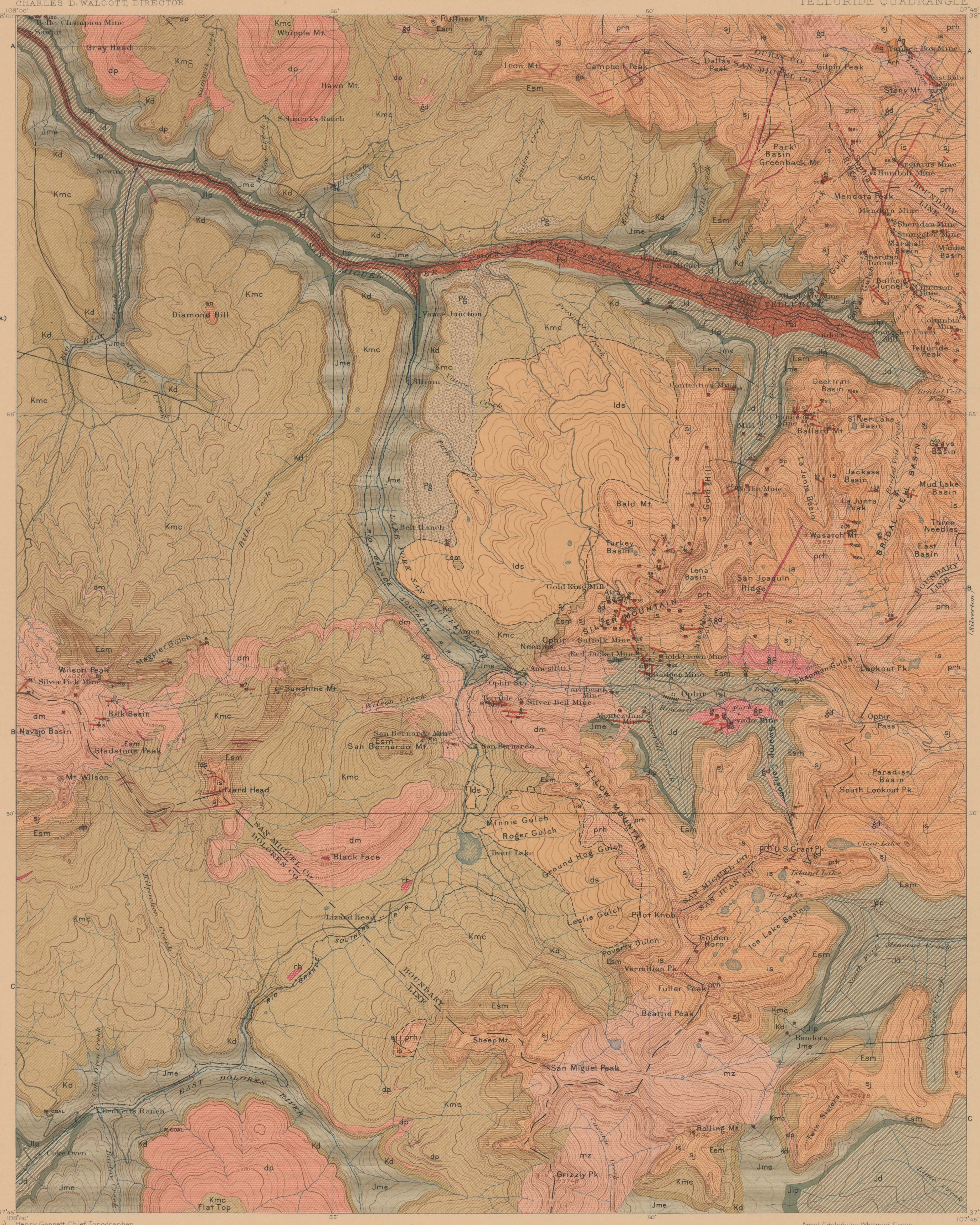
(Indicated on the map by numbers.)

1 Silver Pick.
2 Tam O'Shanter.
3 Colorado.
4 J. W. C.
5 Lakeside.
6 Independence.
7 Magpie.
8 Morning Star.
9 Belcher.
10 San Bernardo.
11 Garibaldi.
12 Butterfly.
13 Terrible.
14 Silver Bell.
15 Butler.
16 Carribeau.
17 Montezuma.
18 American Frenchman.
19 Nevada.
20 Wat Cheer.
21 Santa Cruz.
22 Lookout Tunnel.
23 Attica.
24 Gold Crown.
25 Red Jacket.
26 Suffolk.
27 Single Standard.
28 Badger.
29 Winnemucca.
30 Currency.
31 Grand View.
32 Summit.
33 Gold King.
34 Silver King.
35 Alta.
36 Crown Jewel.
37 Bohemia.
38 Palmyra.
39 Atlanta.
40 Lone Star.
41 Turkey Creek.
42 Confidence.
43 Little Olla.
44 Stella.
45 Star Gazer.
46 Nellie.
47 Silver Chief.
48 Northern Ohio.
49 Contention.
50 Champion.
51 Elizabeth.
52 Aurora.
53 Golden Butterfly.
54 Ballard.
55 Franklin.
56 La Junta.
57 Junebug.
58 Fairview.
59 Pulaski.
60 Broad Gauge.
61 Gold Cable.
62 Horatio.
63 Hallowell.
64 Gold Reserve.
65 Lewis.
66 Telluride.
67 Waterfall.
68 Royal.
69 Waterloo.
70 Mayflower.
71 Columbia.
72 Cincinnati.
73 N. W. H., Jr.
74 Alamo.
75 Bradley-Pioneer.
76 Cimarron.
77 Bullion Tunnel.
78 Sheridan Tunnel.
79 Smuggler.
80 Sheridan.
81 Mendota and K. C.
82 Humboldt.
83 Bank of San Juan.
84 Sweepstakes.
85 Terrible.
86 Yankee Boy.
87 Trust Ruby.
88 Virginius.
89 Montana.
90 Gold and Silver Chief.
91 Liberty Bell.
92 Dynamo.
93 Valley View.
94 Alleghany.
95 Wonder.
96 Silver Glade.
97 Boomerang.
98 Crescent City.
99 Belle Champion.
100 Lizzie G.

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

# ECONOMIC GEOLOGY SHEET

COLORADO
TELLURIDE QUADRANGLE



Henry Gannett, Chief Topographer.
E. M. Douglas, Topographer in charge.
Triangulation by Hayden Survey.
Topography by Frank Tweedy.
Surveyed in 1894.

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.*

Areal Geology by Whitman Cross.
Assisted by H. S. Gane, E. C. E. Lord, and A. C. Spencer.
Economic Geology by Chester W. Purington.
Surveyed in 1895–96.

Edition of Mar. 1899.

## LEGEND

SURFICIAL ROCKS

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

PLEISTOCENE

- Pal — **Alluvium** *(lake and river deposits)*
- Pg — **Glacial bowlder deposit**

SEDIMENTARY ROCKS

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

EOCENE ?

- Esm — **San Miguel formation** *(conglomerate containing pebbles of granite, schist, quartzite, limestone, and sandstone)*

CRETACEOUS

- Kmc — **Mancos shale** *(includes the Benton and Niobrara formations and part of the Pierre)*
- Kd — **Dakota formation** *(mainly sandstone, with shale and impure coal)*

JURATRIAS

*Gunnison formation*

- Jme — **Mc. Elmo formation** *(alternating sandstones and shales)*
- Jlp — **La Plata sandstone** *(two white sandstone beds with dark limestone between)*
- Jd — **Dolores formation** *(sandstone, grit, conglomerate, and some shale; prevailing color red)*

ALGONKIAN

- Aq — **Quartzite**

IGNEOUS ROCKS

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

EOCENE AND NEOCENE

- **Basic dikes** *(basalt and several other dark dense rocks)*
- an — **Andesite** *(decomposed; relation to other andesites not known)*
- gp — **Granite-porphyry** *(irregular intrusive bodies)*
- gd — **Gabbro-diorite** *(stocks and associated dikes or sheets)*
- dm — **Diorite-monzonite** *(stocks and associated dikes or sheets)*
- mz — **Monzonite** *(large stock)*
- dp — **Diorite-porphyry** *(laccoliths, sheets, and dikes)*
- rh — **Rhyolite** *(volcanic plugs piercing Cretaceous shale)*
- prh — **Potosi rhyolitic series** *(several flows and variable tuff beds)*
- is — **Intermediate series** *(commingled andesitic and rhyolitic flows, tuff, breccia, and agglomerate)*
- sj — **San Juan series** *(bedded tuff, breccia, and agglomerate of andesitic material)*

- lds — **Landslides** *(San Miguel formation and San Juan and higher volcanic series in confused relation)*

*Legend is continued on the left margin.*

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

# STRUCTURE-SECTION SHEET

COLORADO
TELLURIDE QUADRANGLE

(Rico) Henry Gannett, Chief Topographer.
E. M. Douglas, Topographer in charge.
Triangulation by Hayden Survey.
Topography by Frank Tweedy.
Surveyed in 1894.

Scale $\frac{1}{62500}$
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Economic Geology by Chester W. Purington.
Surveyed in 1895–96.

## LEGEND

### SURFICIAL ROCKS

SHEET SYMBOL

PLEISTOCENE
- Pal — Alluvium (*lake and river deposits*)
- Pg — Glacial bowlder deposit

### SEDIMENTARY ROCKS

SHEET SYMBOL / SECTION SYMBOL

EOCENE ?
- Esm / Esm — San Miguel formation (*conglomerate containing pebbles of granite, schist, quartzite, limestone, and sandstone*)

CRETACEOUS
- Kmc / Kmc — Mancos shale (*includes the Benton and Niobrara formations and part of the Pierre*)
- Kd / Kd — Dakota formation (*mainly sandstone, with shale and impure coal*)

JURATRIAS
- *Gunnison formation*
  - Jme / Jme — Mc.Elmo formation (*alternating sandstones and shales*)
  - Jlp / Jlp — La Plata sandstone (*two white sandstone beds with dark limestone between*)
- Jd / Jd — Dolores formation (*sandstone, grit, conglomerate, and some shale; prevailing color red*)

ALGONKIAN
- Aq / Aq — Quartzite

### IGNEOUS ROCKS

SHEET SYMBOL / SECTION SYMBOL

EOCENE AND NEOCENE
- Basic dikes (*basalt and several other dark dense rocks*)
- an — Andesite (*decomposed; relation to other andesites not known*)
- gp — Granite-porphyry (*irregular intrusive bodies*)
- gd / gd — Gabbro-diorite (*stocks and associated dikes or sheets*)
- dm / dm — Diorite-monzonite (*stocks and associated dikes or sheets*)
- mz / mz — Monzonite (*large stock*)
- dp / dp — Diorite-porphyry (*laccoliths, sheets, and dikes*)
- rh — Rhyolite (*volcanic plugs piercing Cretaceous shale*)
- prh / prh — Potosi rhyolitic series (*several flows and variable tuff beds*)
- is / is — Intermediate series (*commingled andesitic and rhyolitic flows, tuff, breccia, and agglomerate*)
- sj / sj — San Juan series (*bedded tuff, breccia, and agglomerate of andesitic material*)
- lds — Landslides (*San Miguel formation and San Juan and higher volcanic series in confused relation*)

ALGONKIAN
- Arh / Arh — Older rhyolite (*associated with Algonkian quartzite*)

Faults
— — —

Landslide boundaries
- - - - - - - -

*Gold quartz veins showing dip and strike*

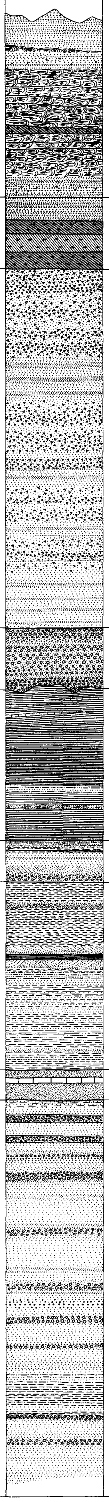
Known productive formations

▨ *Gravel somewhat auriferous*

# COLUMNAR-SECTION SHEET

## GENERALIZED SECTION OF THE SEDIMENTARY AND BEDDED VOLCANIC SERIES OF THE TELLURIDE QUADRANGLE.

SCALE: 400 FEET = 1 INCH.



| Period. | Formation Name. | Symbol. | Columnar Section. | Thickness in Feet. | Character of Rocks. |
|---|---|---|---|---|---|
| EOCENE AND NEOCENE | Potosi rhyolitic series. | prh | | 1300+ | An alternation of rhyolite flows and tuffs, the former predominating near the base. Some of the thin upper flows are glassy. A thin augite-andesite sheet occurs between rhyolite flows in the lower portion. Thirteen hundred feet is the maximum thickness preserved in the quadrangle. |
| | Intermediate series. | is | | 1300 | An alternation of andesite and rhyolite flows and of tuffs containing both rocks. Andesite flows are usually prominent near the base. Some of the rhyolite flows are glassy. The series is of very irregular development in different places. The maximum thickness of 1300 feet is found near Ophir Pass. |
| | San Juan series. | sj | | 2000 | Almost exclusively 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 series varies greatly in thickness from both primary causes and erosion preceding the eruption of the Intermediate series. The observed maximum thickness of 2000 feet is present on Marshall Creek. |
| EOCENE? | San Miguel formation. | Esm | | 200-1000 | Chiefly a coarse conglomerate containing bowlders of granite, gneiss, Algonkian quartzite and schist, Paleozoic limestones, and rarely red sandstone. In Mount Wilson sandstone and shale become prominent. No fossils are known. |
| | | | | | UNCONFORMITY |
| CRETACEOUS | Mancos shale. | Kmc | | 2000+ | Gray sandy shales, with local calcareous bands and sandstones. Embraces the Colorado group and a portion of the Pierre division of the Montana. Fossils occur sparingly. *Gryphæa newberryi* and *Ostrea congesta* characterize different layers near the base. The full original thickness of the Mancos shale is nowhere preserved in this vicinity, having been removed, with still higher Cretaceous beds, by the pre-San Miguel erosion. |
| | Dakota formation. | Kd | | 125-175 | Gray or rusty-brown quartzose sandstones, with a variable conglomerate containing small chert pebbles at or near the base. Carbonaceous shale partings occur at several horizons. Coal is locally developed in these shales. Poorly preserved plant remains are the only fossils. |
| JURATRIAS | McElmo formation. | Jme | | 600-900 | Many alternating beds of friable, fine-grained, gray sandstone and variegated shales, often sandy. Fossils have not been found. |
| | La Plata sandstone. | Jlp | | 100-175 | Two white, even- and fine-grained sandstones, separated by a thin black limestone or calcareous shale. No determinable fossils have been found. |
| | Dolores formation. | Jd | | 1550+ | A series of reddish quartzose sandstones, grits, and conglomerates, the latter usually containing granitic débris and fragments of Algonkian schists and quartzites. Several thin limestone conglomerates with small pebbles characterize the upper part. These contain fossils, among which are teeth of a crocodile (Belodon) and of a megalosauroid Dinosaur, remains of a ganoid fish, a gastropod like Viviparus, a Unio, and some undetermined species of plants. |

C. WHITMAN CROSS,
*Geologist.*

# SPECIAL ILLUSTRATIONS

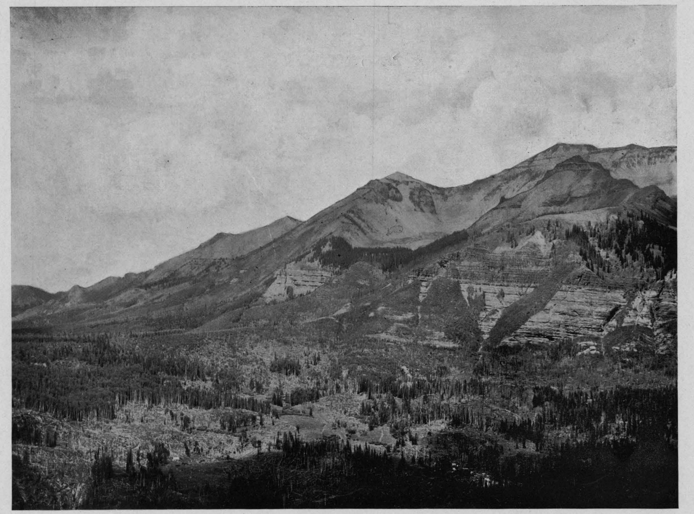


FIG. 1.—MOUNTAINS NORTH OF THE SAN MIGUEL RIVER, FROM EAST OF MILL CREEK.

The view is from the ridge between Mill and Butcher creeks, looking northwest. Campbell Peak is near the center, Iron Mountain on the left, and the high ridge on the right leads to Dallas Peak. The light-colored cliffs are caused by the San Miguel conglomerate; above them appear the clearly bedded San Juan tuffs. The highest levels are occupied by the Potosi rhyolite series. The talus slopes are typical of the region. (See page 8 of text.)

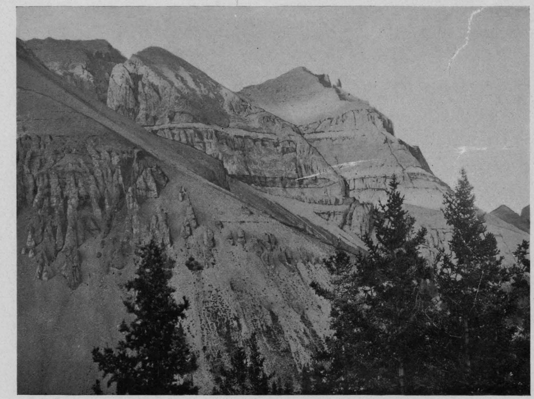


FIG. 3.—CLIFFS OF THE SAN JUAN TUFF-AGGLOMERATE AND THE POTOSI RHYOLITE SERIES, EAST OF EDER CREEK.

View from the ridge leading up to Campbell Peak, looking east across Eder Creek to the cliffs of Dallas Peak. It shows the turret-like erosional forms often cut out of the San Juan tuffs, and the more massive cliffs of the rhyolite series. (See page 8 of text.)

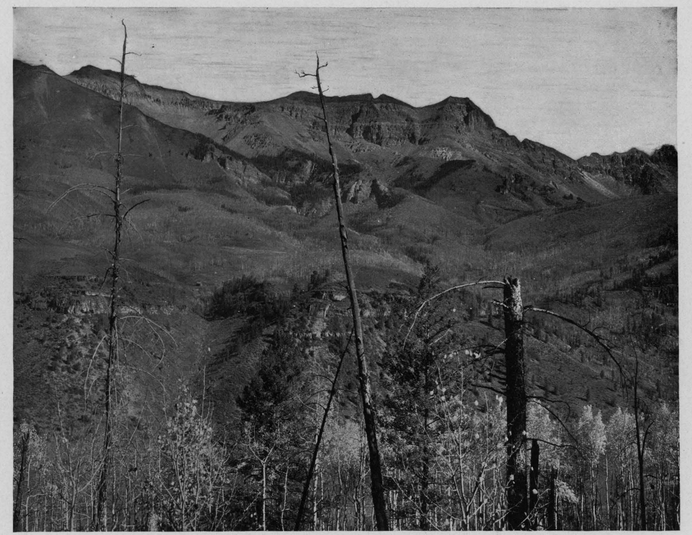


FIG. 2.—VIEW FROM THE SOUTH SIDE OF THE SAN MIGUEL RIVER, LOOKING TOWARD DALLAS PEAK, WHICH LIES TO THE RIGHT OF THE CENTER.

This shows the characteristic sculpturing of the volcanic series above the San Miguel conglomerate, which is hidden by talus, except on Eder Creek. The smooth, aspen-covered shale slopes lead down to the ledge of Dakota sandstone, across the San Miguel Valley from the point of view. (See page 8 of text.)

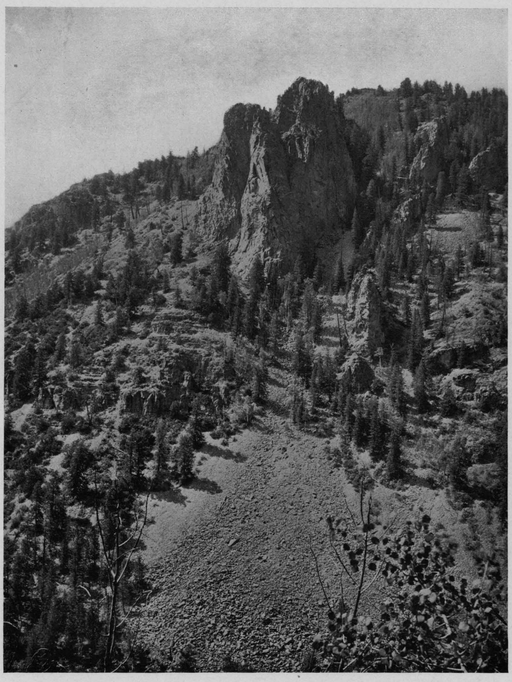


FIG. 4.—GABBRO-DIORITE STOCK AT THE SOUTH BASE OF RUFFNER MOUNTAIN, FROM ACROSS EAST DEEP CREEK.

The common form of outcrop of the smaller stocks. The indurated and metamorphosed Cretaceous shales appear on either side. (See page 8 of text.)

FIG. 5.—THE MOUNTAINS ABOUT MARSHALL BASIN, AS SEEN FROM BRIDAL VEIL BASIN.

The buttressed cliffs of the centerground lie between Marshall and Ingram creeks, and are carved from the San Juan formation. On the left is Marshall Creek, with its zigzag trail leading up to the basin, which is partly concealed by the ridge from Mendota Peak. The columnar cliffs of the background are in the Potosi rhyolite series. (See page 8 of text.)

FIG. 6.—MOUNTAIN CREST SOUTH OF VIRGINIUS BASIN, FROM STONY MOUNTAIN.

The Virginius and Terrible mines appear on the right hand. The trail to Marshall Basin passes through the notch above the mines. This view exhibits the topographic forms common in the zone of the Potosi rhyolite series. Below are the bare, avalanche-swept slopes of the Intermediate and San Juan series. (See page 8 of text.)

# SPECIAL ILLUSTRATIONS

FIG. 7.—POTOSI PEAK, FROM THE SOUTH SIDE OF STONY MOUNTAIN.

On the right are the forks of Canyon Creek. This presents nearly the whole bedded volcanic series projected against the massive crags of the Stony Mountain gabbro stock. (See page 8 of text.)

FIG. 8.—MOUNT SNEFFELS, SEEN FROM STONY MOUNTAIN.

On the left is the pass between Gilpin Peak and Mount Sneffels, and below it a typical glacial cirque whose rocky floor is now almost hidden by talus. The summit of Mount Sneffels (14,158 feet) rises above the bedded volcanics of the region. The jagged and pinnacled cliffs are characteristic of the large stocks of the San Juan. (See page 8 of text.)

FIG. 9.—VIEW DOWN HOWARD FORK, FROM SOUTH OF OPHIR PASS.

In the valley is the town of Ophir, and beyond it are the crags of Ophir Needles. In the background are the summits of the Mount Wilson group, scarcely distinguished in the photograph from the line of Yellow Mountain, owing to the clearness of the mountain air. (See page 9 of text.)

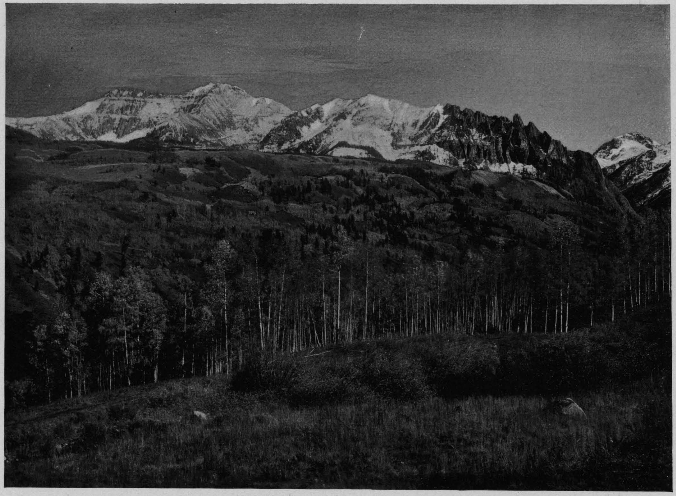


FIG. 10.—SILVER MOUNTAIN AND OPHIR NEEDLES, FROM THE WESTERN SIDE OF LAKE FORK, OPPOSITE THE BELT RANCH.

In the middleground is the characteristically uneven landslide surface about the Currency mine, the shaft house appearing to the left of the center. Above the landslide surface are seen the snow-covered peaks and ridges of the volcanic series, and on the right the dark points of the Ophir Needles stock. (See page 9 of text.)

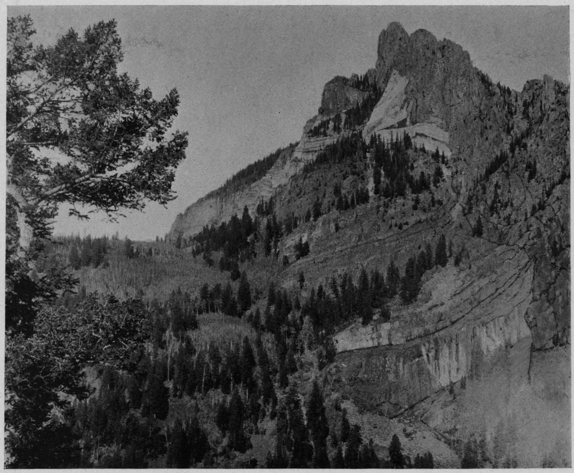


FIG. 11.—CONTACT OF THE OPHIR NEEDLES STOCK WITH SEDIMENTARY ROCKS.

View from above the railroad station at Ophir Loop, looking northeast across Howard Fork. Above is the light-colored San Miguel conglomerate, split by a short wedge of diorite-monzonite. Below are the darker, greatly indurated beds of the McElmo, whose stratification is almost obliterated near the stock. (See page 9 of text.)

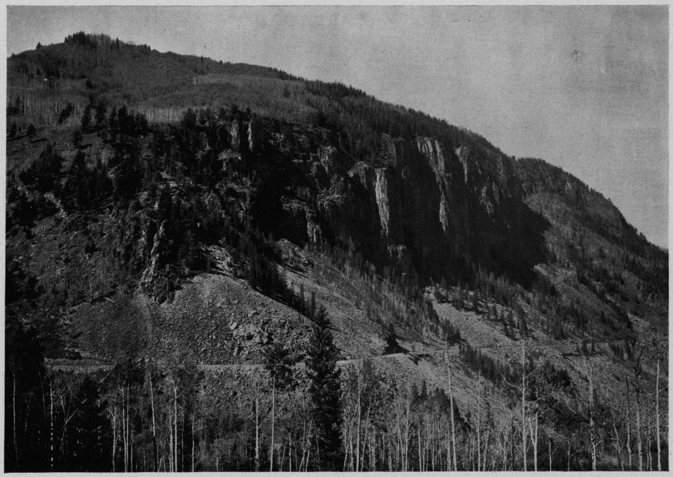


FIG. 12.—CLIFF OF DIORITE-MONZONITE WEST OF, LAKE FORK, FROM ABOVE OPHIR LOOP.

The cliff is entirely in igneous rock. At its top runs the Dakota sandstone, belonging normally at the base of the cliff. This is a part of the connecting arm between the stocks of Mount Wilson and Ophir Needles. (See page 9 of text.)

# SPECIAL ILLUSTRATIONS

FIG. 13.—DIORITE-MONZONITE AT OPHIR LOOP, WITH INCLUDED FRAGMENTS OF VARIOUS ROCKS.

This cut is on the lower railroad grade, and the rock is equally rich in inclusions for several hundred yards. (See page 7 of text.)

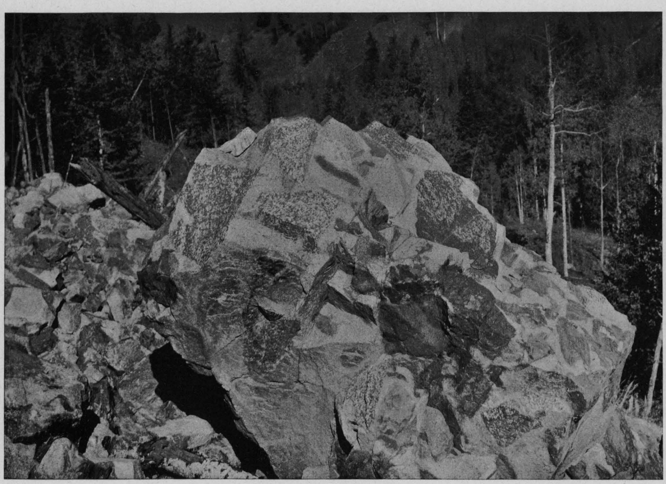


FIG. 14.—A BLOCK BLASTED FROM THE RAILROAD CUT SEEN IN FIG. 13.

This view shows the fine texture of the inclosing rock, the varying textures and shades of the inclusions, and, in one fragment, a change in composition from amphibolite to coarse diorite. It also represents the abundance of the inclusions. (See page 7 of text.)

FIG. 15.—PILOT KNOB AND THE CLIFF TOWARD YELLOW MOUNTAIN.

The view is southeast from a knob on the landslide block, between Leslie and Ground Hog gulches, the building on the Sulphuret No. 2 claim showing on the left. It illustrates the common details of the precipitous San Juan front within the andesitic tuff and agglomerate zone. Potosi rhyolite forms the summit of the mountain. (See page 9 of text.)

FIG. 16.—LANDSLIDE BLOCK SOUTH OF YELLOW MOUNTAIN.

The view is from the divide between Leslie and Ground Hog gulches, looking toward Yellow Mountain, and shows the upper extremity of the large slide east of Trout Lake, consisting of Potosi rhyolite, interrupting the dark cliff of San Juan tuff, which is a continuation of that seen in fig. 15. (See page 10 of text.)

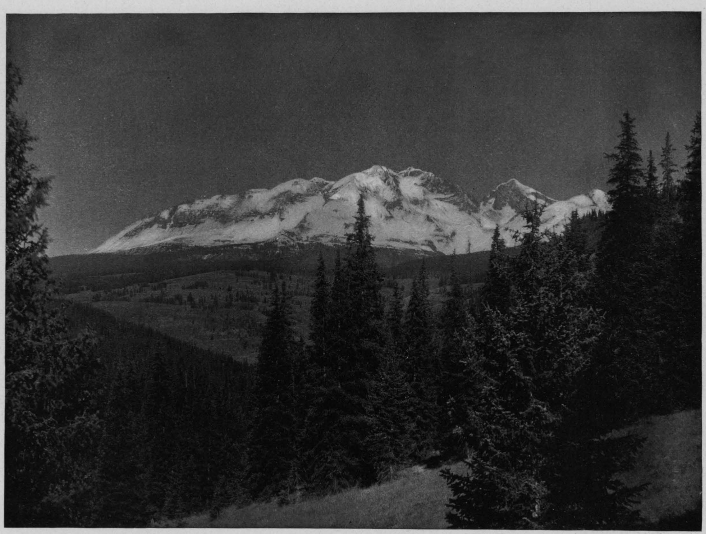


FIG. 17.—THE MOUNT WILSON GROUP, AFTER AN EARLY SNOWFALL, SEEN FROM THE DOLORES VALLEY AT THE NORTHEASTERN BASE OF FLAT TOP.

The illustration brings out the alpine character of this isolated outlier of the San Juan. The rugged summits, within the diorite-monzonite stock, reach the altitude of 14,210 feet. The left-hand shoulder is indurated San Miguel strata. Below are the gentle shale slopes descending to the Dolores Canyon. (See page 12 of text.)

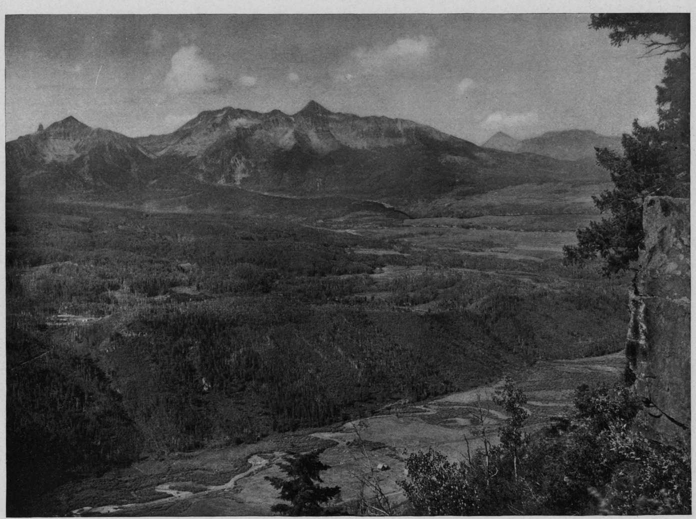


FIG. 18.—THE MOUNT WILSON GROUP, FROM THE DAKOTA LEDGE WEST OF MILL CREEK, LOOKING SOUTHWEST.

In the foreground is the Pleistocene lake bed, below Telluride; beyond it the Dolores Plateau, cut by Bilk Creek and Lake Fork; in the distance rise the peaks of the Mount Wilson group, and on the right is Dolores Peak. (See page 12 of text.)