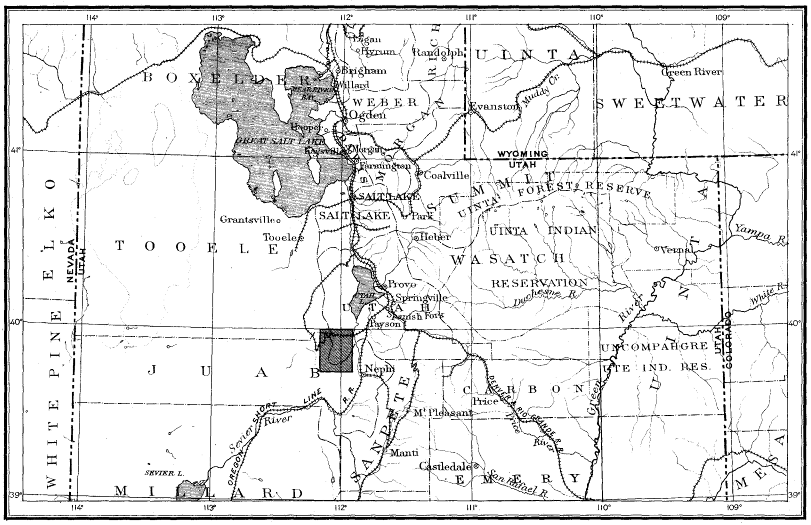
DEPARTMENT OF THE INTERIOR
UNITED STATES GEOLOGICAL SURVEY
CHARLES D. WALCOTT, DIRECTOR

GEOLOGIC ATLAS
OF THE
UNITED STATES

TINTIC SPECIAL FOLIO
UTAH

INDEX MAP



SCALE: 40 MILES-1 INCH

▨

AREA OF THE TINTIC SPECIAL FOLIO

LIST OF SHEETS

DESCRIPTION	TOPOGRAPHY	HISTORICAL GEOLOGY	ECONOMIC GEOLOGY	STRUCTURE SECTIONS

FOLIO 65 LIBRARY EDITION TINTIC SPECIAL

WASHINGTON, D. C.
ENGRAVED AND PRINTED BY THE U. S. GEOLOGICAL SURVEY
GEORGE W. STOSE, EDITOR OF GEOLOGIC MAPS S. J. KÜBEL, CHIEF ENGRAVER
1900

EXPLANATION.

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

THE TOPOGRAPHIC MAP.

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

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

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

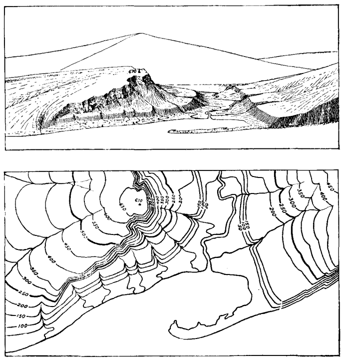


Fig. 1.—Ideal sketch and corresponding contour map.

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

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

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

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

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

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

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

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

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

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

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

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

THE GEOLOGIC MAP.

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

KINDS OF ROCKS.

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

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

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

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

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

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

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

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

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

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

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

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

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

AGES OF ROCKS.

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

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

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

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

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

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

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

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

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

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

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

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

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

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

THE VARIOUS GEOLOGIC SHEETS.

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

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

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

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

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

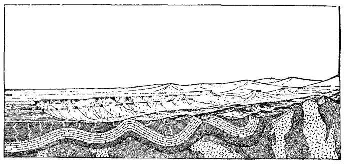


Fig. 2.—Sketch showing a vertical section in the front of the picture, with a landscape beyond.

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

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

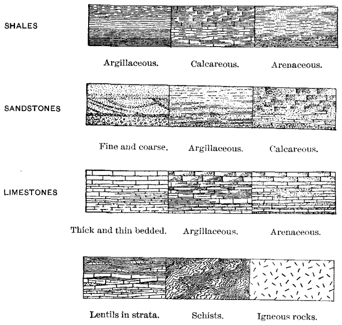


Fig. 3.—Symbols used to represent different kinds of rock.

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

CHARLES D. WALCOTT,
Director.

Revised June, 1897.

DESCRIPTION OF THE TINTIC SPECIAL DISTRICT.

GEOGRAPHY.

Situation and extent.—The Tintic special district is bounded by the parallels of north latitude 39° 45′ and 40° and the meridians 111° 55′ and 112° 10′. It is somewhat over 17 miles in length north and south by about 13 miles east and west, having an area of 229.22 square miles. It includes portions of Juab and Utah counties, Utah.

Basin ranges.

Topography.—The Tintic district includes the central portion of the Tintic Mountains, with parts of the adjacent valleys. These mountains form in this latitude the easternmost of the narrow mountain ranges which rise abruptly from the level valleys of the Great Basin, and they have the north-south trend characteristic of this type of mountains. In total length this range does not exceed 40 miles, but it may be considered as continuing to the north in the Oquirrh Mountains, and to the south in the Canyon Range, from which it is separated only by narrow passes. These three ranges have a common trend, and are from 5 to 10 miles wide.

Relief.

In the northern portion of the district the Tintic Mountains form a well-defined, narrow, and simple mountain ridge, bordered by wide valleys to the east and west. In the southern portion of the district important transverse spurs extend eastward beyond its boundaries and almost connect this range with the Wasatch. At the northern end of the range similar low spurs extend to the west. Within the limits of the district the crest of these mountains attains an altitude of over 8000 feet, Tintic Mountain being 8214 feet. In the northern portion the more important peaks are Packard and Eureka peaks, Godiva Mountain, Mammoth and Sioux peaks, and Treasure Hill. Tintic Valley, bordering the range on the west, has an elevation of 5600 feet, and Goshen Valley, on the east, is 4500 feet above sea level. The relief is marked, and the abruptness of the change from the steep mountain slopes to the almost level valley floors is a striking feature. The Tintic Mountains, in fact, represent only the upper parts of a mountain mass, the lower slopes and foothills of which are concealed beneath the valley deposits.

Lateral valleys.

Especially characteristic of this portion of the range are the canyons or "gulches" which extend westward into Tintic Valley. These have been cut well back toward the crest of the Tintic Mountains. The most important are Eureka Gulch, Mammoth Basin, Dragon Canyon, Ruby Hollow, and Diamond Gulch. The principal passes are at the head of Eureka Gulch and of Ruby Hollow. The former has been taken by the line of the Rio Grande Western, and is also an important wagon route from the ranches of Goshen Valley to the mining towns of this district. Silver Pass, at the head of Ruby Hollow, is used only for the latter purpose.

Streams.

Drainage and water supply.—The area of the Tintic district is tributary to three drainage basins: Tintic Valley, which is tributary in turn to Sevier Basin; Goshen Valley, which drains northward by the Jordan River into Salt Lake; and Cedar Valley, an independent inclosed basin. Only one perennial stream — Currant Creek — exists within this area, and it is not indigenous to the Tintic Mountains, but represents drainage from the slopes of Mount Nebo, in the Wasatch Range. Currant Creek cuts through the transverse spurs of the Tintic Mountains in a bold canyon at the head of Goshen Valley and flows northward into Utah Lake, furnishing water for the irrigation of Goshen Valley. The channels of the occasional or seasonal streams sculpture the slopes of these mountains with deep arroyos.

Springs.

Springs occur at a few points, being more important on the eastern slope of the range. In general any overflow from these springs is soon absorbed by the alluvium of the dry channels. At the head of Homansville Canyon extensive sinking and drifting in the alluvium and bed rock has developed a flow of water sufficient to supply several of the mines and mills. Throughout the summer and fall there is a steady decrease in the flow of these wells, showing the dependence of the supply upon the melting snow and the spring rains. The larger part of the water for the district is piped from Cherry Creek, a stream in the mountains west of Tintic Valley, 18 miles distant.

Vegetation.—The Tintic Mountains bear the scanty vegetation of an arid region. On exposed rocky points grow different species of the cactus. The more common trees of the higher slopes are the pinyon (*Pinus monophylla*) and the mountain mahogany (*Cercocarpus ledifolius*). Lower, maple thickets occur in the dry ravines, especially on the eastern slope, while aspens are found in sheltered spots, more commonly those of the northern exposure. All the trees show by their stunted, gnarled, and twisted trunks the severity of their struggle for existence. In the valleys the sagebrush (*Artemisia*) and the rabbit brush (*Bigelovia*) constitute almost the sole vegetation. Scattered tufts of grasses occur, but these are apparently dead during the summer months.

Towns.

Culture.—The population of the Tintic special district is confined almost wholly to the western slope of the mountains. The majority of the mines are situated in the area around Eureka Peak, Godiva Mountain, and Mammoth Peak. Eureka, Mammoth, Robinson, and Silver City are the towns within the limits of this mining district, which is one of the oldest in the State. All these towns are situated on the western slope. Homansville was important in the early days, and here the first mill and the first smelter were erected, while old Tintic, situated in the middle of Tintic Valley, was also important as the site of a smelter erected in 1884. The population of the mining district is estimated at 6500. Two railroad lines connect the Tintic mining district with Salt Lake City, which is about 75 miles distant. The Oregon Short Line, crossing the low divide between Rush and Tintic valleys, approaches Eureka and the other towns from the northwest, while the Rio Grande Western crosses Goshen Valley and follows up the valley of Pinyon Creek to the pass just east of Eureka.

Agriculture.

Outside of the mining district this area supports few inhabitants. At the head of Goshen Valley a few small ranches are carried on under irrigation, but the more important part of this valley, including the town of Goshen, is just east of the boundary of the special district. In the past these mountains afforded range for cattle, horses, and sheep, but now the herbage is so scanty that the grazing is limited to a few herds of horses.

GEOLOGY.

General features.

The Tintic Range is a composite mountain range, being built up of diverse kinds of rock. Like the Basin Ranges to the west, and Wasatch to the east, this mountain mass consists primarily of Paleozoic strata. The nucleus of sedimentary rocks has been in part buried by volcanic outflows and contains intrusions of igneous rocks, and all are in part concealed by surface accumulations of detrital material. Thus, the rocks occurring within the Tintic district are naturally grouped under three general classes — the surficial deposits, the sedimentary series, and the rocks of igneous origin. Both the sedimentary and the igneous rocks are of economic importance as the country rocks of valuable ore deposits. In the legend on the geologic maps, these are arranged in the above order, with the youngest above. Here, the sedimentary series will be discussed first, beginning with the oldest formation, followed by the next younger in turn. The igneous rocks will be described next, and finally the surficial deposits.

SEDIMENTARY ROCKS.

The series of sedimentary rocks exposed within the Tintic district consists mainly of quartzites and limestones of Paleozoic age, having a total thickness of nearly 14,000 feet. The series has been divided, mainly on lithologic grounds, into four formations: the Tintic quartzite, the Mammoth limestone, the Godiva limestone, and the Humbug formation. A complete section (see Section BB on the Structure Section sheet) is exposed in the region between the towns of Eureka and Mammoth. The lowest formation, the Tintic quartzite, forms Quartzite, Ridge at the western base of the range, and is followed by the Mammoth limestone, which extends eastward beyond Eureka Peak. Above this comes the Godiva limestone of Godiva Mountain, while on the eastern slope of this mountain occurs the Humbug formation. The same series is less completely exposed at various points in the southern portion of the district.

CAMBRIAN PERIOD.

Correlation.

Tintic quartzite.—This formation consists of clay slates and quartzites. Within the limits of the Tintic district no determinable fossils were found, either in the quartzite or in the slates. The correlation with the Cambrian of the Oquirrh Range, where a similar great thickness of quartzite with clay slates at the top has been found to contain Cambrian fossils, is supported by the general geologic relations as well as by lithologic similarity.

White quartzite and clay slates.

The exposed thickness of this formation is about 7000 feet, but the base is not found. The quartzite is white in color, weathering to brownish red on exposed surfaces. It is a very pure, compact, and fine-grained quartzite with occasional beds of fine quartz pebbles. The lowest beds contain some feldspar and muscovite, while zircon and rutile grains occur sparingly among the well-rounded quartz grains. Several beds of green, yellow, and red clay slates occur near the top of the quartzite. One or two beds of these slates are found below the highest bed of quartzite, while there are others in the limestone near its base. These strata appear to be conformable, but the beds vary greatly in thickness at different points within the area. In mapping, the base of the lowest bed of limestone has been taken as the contact, so that some of the slates are included within the Mammoth limestone.

CARBONIFEROUS PERIOD.

Absence of Silurian and Devonian.

Mammoth limestone.—The determination of the age of Mammoth limestone rests upon the identification of a single fossil — *Productus costatus* — occurring about 1500 feet above the base of the formation. Upon this determination the formation is assumed to be probably lower Carboniferous. Thus the Silurian and Devonian may be unrepresented. A similar hiatus in the geologic succession has been found in the Oquirrh Range to the north. In neither case has it been determined whether the possible absence of Devonian and Silurian strata is the consequence of non-deposition or of unconformity by erosion.

Dolomitic and shaly limestone.

The Mammoth limestone is named for one of the oldest and most productive mines of the district, the workings of which are in this limestone. The formation includes beds of dolomitic, cherty, and shaly limestone, which aggregate 4000 feet in thickness. At the base the dolomitic limestone is dense, and blue, black, or gray in color. Above, occasional beds of pure blue limestone and interbedded chert lenses occur, while at the top there is a great thickness of shaly, dolomitic limestone which weathers reddish.

A pure limestone.

Age of Godiva limestone.

Godiva limestone.—This formation, which overlies the Mammoth, is about 2200 feet thick. It takes its name from the mountain on the slopes of which it is best exposed. As distinguished from the Mammoth, which is dolomitic, it is essentially a pure limestone, gray or blue in color. In its lower portion a few sandy beds occur; in the upper, the beds are often carbonaceous, containing many fossils, chiefly corals and crinoids, with occasional beds rich in chert nodules and lenses. The fossils taken from these beds show that the Godiva limestone belongs to the Coal Measures. The fossils definitely recognized were two species of *Syringopora*, *Productus punctatus*, and zaphrentoid corals.

Alternating sandstones and limestones.

Humbug formation.—This formation overlies the Godiva conformably and corresponds paleontologically with it. It is separated, however, upon lithologic grounds. It takes its name from the mine where it is best exposed. The formation consists of a number of beds of fossiliferous limestones, alternating with arenaceous limestones and calcareous sandstones, with a total thickness of 250 feet. Different sections of this formation, however, show a marked difference in the order and thickness of these intercalated beds, few beds continuing for any distance along the strike. The formation is doubtless only partially represented within this district.

Résumé.—The Paleozoic section in the Tintic Mountains includes 7000 feet of Cambrian quartzite capped with clay slates and 6650 feet of limestones with a few sandy beds, of which the upper 5150 feet are determined from the fossil remains to belong to the Carboniferous. This sequence in the Paleozoic strata is similar to that which has been studied in the Oquirrh Mountains, which form the continuation of this range to the north. In the Oquirrh Mountains, however, the upper portion of the series is much more fully represented, indicating an erosion of many thousand feet of strata in the Tintic Mountains.

STRUCTURE.

The main structure of the sedimentary portion of the Tintic Mountains is synclinal. The section described above is that of the western limb of the major syncline, which pitches to the north. The axis has a general north-south trend and is situated on the eastern slope of Godiva Mountain and Sioux Peak. This western limb is characterized by steep dips, with beds often vertical or even overturned for a considerable distance. On the opposite side of the synclinal axis the dips are much less, rarely exceeding 35°.

Folds.

A similar unsymmetrical syncline with two great anticlines make up the Oquirrh Mountain to the north, while in the section of the Canyon Mountains exposed along Sevier River the Paleozoic strata are seen to be folded into an anticline and a syncline. Geologically, as well as topographically, the relation of these three ranges is close; they constitute one general line of uplift, and exhibit structures involving a considerable amount of horizontal compression of the Paleozoic strata.

The structure of the Tintic Mountains, then, is synclinal. Minor folds occur in different parts of the major folds, and some of these minor plications are readily distinguished, even when viewed from a distance. In the southeastern part of the Tintic district an anticlinal axis to the east of the major synclinal axis is indicated in the quartzite and limestone exposed there. Beyond the edge of the district another anticline is exposed in the canyon of Currant Creek; and thence almost to the base of Mount Nebo, of the Wasatch Range, eastward dips are seen in the limestone. On the western side of Tintic Valley the Tintic quartzite is found dipping to the west, thus showing the valley to coincide in position with an anticlinal axis. In this way the folded Paleozoic rocks are traced beyond the topographic limits of the Tintic Mountains, both longitudinally into the Oquirrh and Canyon ranges and transversely to the Wasatch on the east and to the West Tintic or Guyot Mountains on the west.

Faults.

Faulting in this region is of minor importance as compared with the folding. A number of small faults can be observed at different localities, with displacements rarely exceeding a few feet. Other faults shown on the geologic maps have displacements of from 50 to 400 feet. An important fault cuts the limestone series between the head of Mammoth Gulch and the Northern Spy mine, with a displacement of about 1000 feet. The strike of this fault is nearly east-west, and it is also characteristic of the other faults that they are transverse to the axis of the range. In this feature, as well as in the amount of compression indicated by the folds, the Tintic Mountains differ from what has been called the typical Basin Range, or faulted monocline.

Fractures.

In the Tintic quartzite a considerable amount of sheeting is to be observed, which commonly forms a small angle with the strike and dip, where the latter can be determined. These shear planes are the result of dynamic action incident upon the folding of the strata, and are seen also in the overlying slates and limestones. In many places the cleavage of the clay slates is very well marked and its angle with the beds can be easily determined. Along the fractures which are developed in the limestone there may have been more or less displacement, as well as adjustment along the bedding planes, but faulting of this nature is extremely difficult to detect.

IGNEOUS ROCKS.

Extent of igneous rocks.

Igneous rocks of several distinct types occur within the limits of the area here described. They are both intrusive and effusive, and include rhyolites, andesites, monzonites, and basalt. Taken together, these igneous rocks cover by far the larger part of the area included within the Tintic district. In addition to their areal importance, some of the igneous rocks are of economic interest, since they are the country rocks of important ore bodies.

The Tintic Mountains have been the scene of volcanic activity, and the products of that activity have been important factors in the construction of the range. The rocks differ considerably in chemical and mineralogic composition as well as in appearance, yet they show a general relationship, and are all directly or indirectly connected with this volcanic activity.

Age of volcanism.

The age of the volcanism in the Tintic Mountains has not been exactly determined. On the basis of general relations it seems plausible to assign a Tertiary age to the igneous rocks. South of the Tintic Mountains, where the wash of the southern part of the range enters the valley of Sevier River, a red conglomerate is exposed, which is correlated with the Eocene conglomerate (Wasatch) to the northeast. Examination of the pebbles of this conglomerate failed to detect the presence of any rhyolitic or andesitic material, although the quartzite and limestone pebbles from the Tintic Range are numerous. In the alluvial material, contributed to this same locality from the Tintic Mountains, the detritus from the volcanic rocks is rather abundant. On this account the rhyolite and andesite are believed to have been erupted after the deposition of this conglomerate, thought to be of Eocene age. In this way a probable Neocene age is indicated for the igneous rocks of the Tintic Mountains. Of these rocks, the rhyolites are relatively the oldest, and the basalt the youngest, the andesite and monzonite belonging approximately to the same epoch of eruption.

Three types of rhyolites are distinguished— the Packard, the Fernow, and the Swansea.

Packard rhyolite.—Areally this rhyolite is an important rock within the limits of the mining district. It extends to the north and east of the town of Eureka, and there forms the crest of the range. Its vertical range is over 2700 feet, from the summit of Packard Peak eastward to the edge of Goshen Valley.

Composition and texture of Packard rhyolite.

The Packard rhyolite shows many variations in appearance, both in color and in texture. In color it ranges from light gray to a bright pink and light purple, although often on the surface the rock is yellowish or rusty. The texture of the rhyolite shows three distinct varieties. One type is granite-like, its granular appearance being due to the crowded phenocrysts. Another type is plainly porphyritic, with the crystals of quartz and feldspars less abundant than the groundmass. A third type shows glassy textures, all being banded, often porous and vesicular. In this type crystals are rarely seen, and in some occurrences it is an almost black obsidian.

The megascopic phenocrysts are quartz, feldspar, and biotite, the latter being often the most prominent. Quartz appears almost universally, its angular crystals often projecting from the weathered surface. In some occurrences of this rhyolite the fresh crystals of sanidine are large and so abundant as to make the rock much lighter colored than when it is less rich in these feldspar phenocrysts. Tridymite, hornblende, apatite, and zircon are occasional constituents, while magnetite is an almost universal accessory constituent. The microscopic constituents of this rhyolite show the range from holocrystalline groundmass to the typical glassy base with obsidian characters. Chemically this rhyolite approaches a trachyte. The abundance of free silica crystallizing as quartz, however, justifies the determination of the rock as rhyolite.

Contact of rhyolite and limestone.

The contact between the rhyolite and the limestone on the eastern slope of the Tintic Mountains is very irregular, the areas of the two rocks interlocking in a complex manner. This contact is often concealed by accumulations of surface detritus, but south of Packard Peak, on the northern end of Godiva Mountain, the Tetro tunnel cuts the contact, affording an opportunity for careful examination. Here there is a considerable thickness of angular blocks of limestone, constituting a heavy talus deposit. This has been covered and somewhat cemented by the rhyolite. Similar contact breccias can be observed in other mine workings, as well as at a few points on the surface. These make it evident that when the rhyolitic lavas were erupted the old talus-covered slopes of the limestone mountain were essentially the same as they are to-day.

Packard Peak the probable center of eruption.

In the central portion of the area of Packard rhyolite there is an absence of interbedded structure in the rock. Separate flows can not, therefore, be distinguished, and this, with the great thickness of rhyolite in this vicinity, suggests that Packard Peak was the center of an eruption which was of the nature of an outwelling of viscous lava rather than of an explosive ejection of volcanic material. Such a location of the eruptive center explains the manner in which the deep canyon underlying the present broad gulch in which the town of Eureka is situated was filled by the viscous rhyolite. But few small eruptive masses of rhyolitic rock occur in the vicinity of Packard Peak.

Fernow rhyolite.—The Fernow rhyolite occurs in several small areas in the southern part of the Tintic district. These appear to represent the northern extension of a mass of rhyolite which is rather important in the southern part of the Tintic Mountains. Here, as at the north, the contact with the limestone is often difficult to trace, but the relations appear to be similar. The Fernow rhyolite is like the Packard rhyolite in all essential characters, except that it is rather more glassy. A correlation of the two rhyolites is here avoided, since it is probable that they were erupted from two distinct vents, although doubtless about the same time and under similar conditions.

Swansea rhyolite.—This rock type is limited to a few occurrences. The principal area is a belt one-fourth mile in width extending from Robinson to Silver City. Separated from this only by the alluvium of the Robinson basin is a mass of rhyolite which forms the greater part of the hill just on the southeastern edge of the village of Robinson. These two areas doubtless belong to the same rock mass. Although areally more limited than the other rhyolites, the Swansea rhyolite has an economic interest as the country rock of the well-defined ore vein of the Swansea and South Swansea mines. Another occurrence of Swansea rhyolite is that of Horseshoe Hill, near the mouth of Diamond Gulch.

Distinction of Swansea from other rhyolites.

In mineralogic and chemical composition the Swansea rhyolite is essentially similar to the Packard rhyolite. It differs, however, in the texture of the groundmass, which makes the type commonly termed a "quartz-porphyry." Its geologic occurrence also distinguishes it from the other rhyolites of the Tintic Mountains, since its relations are those of an intrusive rock. These facts, as well as its economic importance, sustain local usage in distinguishing it from the effusive rhyolite of the Packard Peak area and of the area to the south.

The Swansea rhyolite is light gray in color, with phenocrysts of flesh-colored feldspar and clear quartz more or less abundant, but with a few traces of the presence of a darker constituent. The rock is commonly considerably altered, the feldspars being usually clouded and often completely altered. An interesting constituent in one occurrence is tourmaline. This occurs in aggregates of acicular crystals, which in part replace the feldspar and in part occur in the groundmass of the rock.

Areal importance of the andesite.

Andesite.—This rock occurs principally in the southern part of the Tintic district. Nearly one-half of the area comprised within the limits of this district, or more than 100 square miles, is covered by this andesite and its associated tuffs and breccias. The crest and both slopes of this portion of the range are of andesite, except a few small areas of quartzite, limestone, or rhyolite. Tintic Mountain, 8214 feet high, the highest peak of the range, is composed of flows of this andesite. It is thus preeminently the igneous rock that is most characteristic of the Tintic Mountains.

Composition and texture of the andesite.

This andesite exhibits considerable variation in its general appearance. In one locality it may be a loose-textured, gray rock; in another it is of a dark-purple color, compact and glassy; and again it may be bright green or deep red in color, with prominent phenocrysts. Commonly it is not bright colored, but dark gray, with a somewhat purple tinge. Usually rather compact, it often exhibits many of the vesicular and scoriaceous phases characteristic of lavas. Almost without exception the Tintic andesite is a porphyritic rock showing crystals of both feldspar and the darker constituents.

The Tintic andesite shows considerable mineralogic diversity, especially in its ferromagnesian constituents. Biotite, hornblende, augite, and hypersthene are present, together or separately; thus, several mineralogic types might be separated within this area. The most important porphyry constituent is the plagioclase, which is chiefly labradorite; biotite and hornblende are less important than the pyroxenes, while of the latter the monoclinic is the more important. In a few cases, however, the hypersthene is sufficiently predominant to constitute the rock a hypersthene-andesite. Magnetite and apatite are common accessories, while quartz and olivine are sporadic in their occurrence. The textures are those typical for andesitic lavas.

Latite rather than typical andesite.

The chemical analysis of a specimen from Tintic Mountain shows this andesite to be characterized by a higher percentage of the alkalies, and a lower of lime, than is usual in typical andesites. The two alkalies are nearly equal in their molecular proportions. Although this rock, as regards its silica percentage, resembles the andesites, it is not seen to have a relationship to the syenite-trachyte family. Such an effusive rock, which stands in chemical composition about midway between the typical trachyte and the typical andesite, has been given the name "latite." The chemical analysis shows the Tintic Mountain rock to be essentially similar to Ransome's type "latite," which occurs on the western slope of the Sierra Nevada.

Tuff and breccia.

On the geologic map the tuff and breccia are not separated from the andesite. Throughout the andesite area, however, beds of these pyroclastics are found capping or underlying the flows of massive andesite, and their association is so intimate that very detailed mapping would be necessary to represent the two types separately. These fragmental volcanic rocks are especially prominent on Volcano Ridge, southwest of Diamond and Long Ridge, in the southeastern part of the quadrangle. Here the tuffs and breccias are hundreds if not thousands of feet in thickness.

These pyroclastic rocks vary from the finest stratified tuffs to very coarse agglomeratic breccias. In the latter, huge blocks of lava, weighing tons, are mixed with smaller fragments of the same material, and are cemented with sand matrix of essentially the same composition. The fine-grained tuffs vary in color from brown or green to yellowish white. In general they are somewhat lighter in color than the accompanying lava flows. These tuffs are composed of glass and fragments of the crystals most abundant in the andesite lava.

An old volcano.

The occurrence of agglomerate on Volcano Ridge is of striking interest as indicating the vent through which much of the andesite and accompanying tuffs was erupted. Near the western end of Volcano Ridge this agglomerate contains blocks of limestone brought up from below, while immediately west the limestone blocks give place to large blocks of white, vitreous quartzite. Some of these are 20 and 30 feet in diameter and are plainly embedded in the volcanic material. With this agglomerate are associated irregular sheets and dikes of andesite, the whole presenting rather confused relations. Surrounding this point is an extensive area of bedded tuffs which are seen to constitute the remnant of a deeply eroded volcanic cone. These tuffs have dips of 10° to 20° and in their strikes express a roughly semicircular arrangement. The agglomerate locality is approximately at the center of this area of tuffs. The occurrence of included fragments of rhyolitic lava in this andesite agglomerate indicates the relative age of the two lavas.

Monzonite.—The area lying south of Robinson and Mammoth, and extending past Treasure Hill and Diamond to Sunrise Peak, is characterized by a rock locally termed "granite" or "porphyry." This belt is about 4 miles long from north to south and 2 miles or less in width. It lies wholly on the western slope of the range and is deeply cut by the alluvium-filled Ruby Hollow and Diamond Gulch. Its western boundary is hidden by the alluvium of Tintic Valley, except at the northern and southern ends, where its western limit is indicated by the areas of Swansea rhyolite.

Description of the monzonite.

This rock in general appearance closely resembles some diorites. Its color, which is light to dark gray, and its evenly granular texture, with the evident importance of its darker constituents, are points of such resemblance. Its chemical and mineralogic composition, however, show it to be intermediate between a syenite and a diorite—i. e., it is a monzonite. This rock varies greatly in appearance. In the northern portion of the area it is perfectly granular, with the lighter and darker constituents very evenly intermingled, and this granular phase of the monzonite can also be observed at different localities throughout the area. On the southern and the eastern edges of the monzonite mass, however, the rock is decidedly porphyritic. In this monzonite-porphyry the crystals of feldspar become more important. Both the granular and the porphyritic monzonite are compact and hard, being everywhere jointed, so that the sharp-edged joint blocks are very noticeable in the talus slides.

Constituents of the monzonite.

The more important constituents of the monzonite are plagioclase, orthoclase, biotite, hornblende, and quartz. Accessory constituents are magnetite, apatite, titanite, and zircon, with secondary chlorite, calcite, epidote, and pyrite. The orthoclase and plagioclase are in approximately equal amounts. The latter has a composition varying from that of basic andesine to that of basic labradorite; quartz is usually an important constituent. Of the ferromagnesian constituents biotite is the most abundant and augite the least. The green hornblende rarely equals the biotite in importance. The chemical analysis of a specimen of this monzonite showed it to be slightly richer in silica than in the alkalies, and poorer in lime than the most typical monzonite, so that it belongs rather to the syenite phase of this intermediate rock type A calculation of the mineralogic composition of the rock from the chemical analysis indicates that the orthoclase probably contains soda, and that this soda orthoclase would constitute over 32 per cent of the rock, with about 30 per cent of a basic andesine, 16 per cent of quartz, and 12 per cent of hornblende rather poor in alumina, with biotite and magnetite constituting the remainder of the rock. Quantitatively, therefore, as well as qualitatively, it is an orthoclase-plagioclase rock.

Relation of the monzonite to the andesite.

On the southern side of Sunrise Peak the monzonite is in contact with the andesitic tuffs, and sends out well-defined dikes into these bedded tuffs. One of these dikes can be traced southeast to a point where it evidently connects with an andesitic lava flow overlying the bedded tuffs. On the spur connecting Sunrise Peak with the main part of the range the monzonite-porphyry of the peak shows a perfect gradation into the andesite to the east. Any separation of the two rock types at this point must be wholly arbitrary. At a lower level, however, the distinction between the monzonite and the tuffs is again sharp. These relations point to the monzonite being the intrusive equivalent of the later flows of Tintic andesite. It intrudes the tuffs of the Volcano Ridge series, and these are likewise capped by the horizontal lava flows, which, it is believed, are the effusive equivalent of the monzonite. Petrographic and chemical study of the monzonite and andesite fully corroborates this field evidence.

Sheets and dikes.

Basalt.—Although basalt is of common occurrence south of the Tintic Mountains as well as in other parts of the Great Basin, it is found in only one locality within the Tintic district. House Butte is a prominent flat-topped hill about a mile west of Tintic Mountain. Here occur three small areas of basalt, the relations of which suggest intruded sheets. Immediately southeast basalt is found in the side of the ravine. In all of these occurrences talus accumulations somewhat conceal the geologic relations, but it is reasonably certain that the basalt is intrusive in the andesite. This rock is black and very compact, lacking the vitreous texture of the darker of the andesites. It is very fine-grained, and no megascopic crystals can be seen. Its microscopic constituents are olivine and augite in a holocrystalline groundmass of feldspar and augite.

RELATIONSHIPS OF THE IGNEOUS ROCKS.

Four types of igneous rocks have been described above as occurring in the Tintic district: rhyolite, andesite, monzonite, and basalt. No analysis was made of the basalt, which is of little importance in the Tintic district. The following table shows the analyses of the Swansea rhyolite, the Packard rhyolite, the Tintic andesite or latite, and the Sunbeam monzonite.

Analyses of igneous rocks occurring in the Tintic district.

[Analyst, H. N. Stokes.]

	SWANSEA RHYOLITE.	PACKARD RHYOLITE.	ANDESITE, OR LATITE.	MONZONITE.
	Per cent	*Per cent.*	*Per cent.*	*Per cent.*
SiO_2	71.56	69.18	60.17	59.76
TiO_2	.38	.69	.87	.87
Al_2O_3	14.28	14.37	15.78	15.79
Cr_2O_3	trace	trace	none	none
Fe_2O_3	.89	2.52	3.42	3.77
FeO	und.	.57	2.95	3.30
MnO	trace	.10	.11	.12
BaO	.28	.09	.14	.09
SrO	trace	trace	.09	trace
CaO	1.18	1.88	4.69	3.88
MgO	.42	.70	2.52	2.16
K_2O	4.37	5.00	4.16	4.40
Na_2O	3.00	3.58	2.96	3.01
Li_2O	none	trace	trace	trace
H_2O at 110°	.36	.35	.25	.31
H_2O above 110°	.79	.25	1.23	1.11
P_2O_5	.13	.26	.40	.42
V as V_2O_5	.02	.01	.01	.02
Mo	none	trace	none	trace
As	trace			
Cl	.06	trace	.04	.04
CO_2	none	none	none	.78
FeS_2	2.29			
Total	100.01	99.55	99.79	99.83

Monzonite and latite.

From these analyses it is seen that the rhyolites have similar compositions, and that the two other rocks likewise show chemical affinities. The andesite is plainly the effusive equivalent of the monzonite. The slight differences in chemical composition of these two rocks are much less important than their similarity, which is especially striking in those features which may be termed characteristic of the two rocks. Such are the relative importance of the alkalies as contrasted with the lime and the potash-rich character of the two rocks. In mineralogic composition and texture the relationship of the two is not so apparent; both rocks contain labradorite as an essential constituent, but they differ somewhat in their ferromagnesian constituent. In the andesite or latite the pyroxenes are characteristic, with biotite less important and hornblende only accessory. In the monzonite, biotite and hornblende are more common than augite. In the latter rock orthoclase and quartz are rather important constituents, while in the latite quartz is very rare and orthoclase was not detected. This is to be explained by the fact that in a monzonite these two minerals are the last to crystallize, and would therefore be wanting in the effusive equivalent where the consolidation of the glassy base prevented their crystallization.

The two rhyolites contain 1 to 12 per cent more silica than the monzonite-latite type, and are much poorer in the alkaline earths. The latter type, on the other hand, is slightly richer in alumina, and contains more of the oxides of iron as well as of the titanic and phosphoric acids. The chemical characteristic of this group of rhyolites, monzonite, and latite, is the constant molecular ratio between the potash and the soda, which is nearly 1:1, the soda being always slightly in excess. This relation of the alkalies may be regarded as the best evidence of consanguinity in the igneous rocks of the Tintic Mountains. It is to be noted, also, that both the rhyolitic type and the monzonite-latite type approach trachyte in mineralogic and chemical composition.

ALTERATION.

Weathering and metamorphism.

The Tintic Mountains are in great part composed of comparatively young rocks, and their history has been relatively simple, yet these rocks show in their general as well as their microscopic appearance changes due to processes which have been active subsequent to the formation of these rocks. Such changes express the effect of varying conditions and may all be included under the term "alteration." These changes have been both mineralogic and structural, and have been effected by both chemical and physical agencies. The processes of alteration may act under superficial conditions within the range of our observation, or the processes may be such as to operate only at great depths under conditions known to us only through inference. The separation of the two classes is not always easy, since the same rock may have been subjected to both kinds of alteration. The superficial processes and reactions may be included under the term "weathering," while those that are deeper seated, or abyssal, may be comprised under the term "metamorphism."

Dynamic metamorphism.

The rocks of the Tintic Mountains have been subjected to metamorphic processes, and although these are less important here than in many regions, the closely related processes of ore deposition are of greatest moment. The closely folded Paleozoic rocks have been somewhat affected by dynamic metamorphism. The sheeting and crushing along certain zones have reduced massive limestone to a shale-like rock, which in turn is locally decomposed to a plastic clay. Since the processes of mountain folding antedate the eruption of the igneous rocks, the latter have been little affected by dynamic action.

Hydrometamorphism.

A more important type of metamorphism is one in which water is the principal agent. This has been termed hydrometamorphism. Changes due to this type of alteration are mineralogic. Thus it is a fact that in the igneous rocks secondary minerals are of common occurrence. Such minerals resulting from hydrometamorphism are chlorite, epidote, muscovite or sericite, serpentine, talc, magnetite, and pyrite. In the northern half of the monzonite area there are several large masses of bleached rock. In many cases the true nature of this rock is difficult to determine. In appearance the rock can be seen to have the same texture as the other monzonite. The rock is not at all disintegrated or less compact than the fresh rock. Analysis shows, however, considerable chemical change. The monzonite has lost the most of its iron oxide and all its lime, as well as all its soda. There is, however, a relative gain in potash and silica, as well as of water. Thus the rock has been silicified as well as leached.

Weathering.

The processes of superficial alteration have furnished the material for the extensive surficial deposits which are described below. These processes have modified the surface of the region and have also affected the rocks and ores lying nearest the surface. The zone of such alteration is that above ground-water level. Within this zone the action is that of oxidation, hydration, and carbonation, all resulting from the chemical activity of the surface waters and their occluded gases. Under this head also are to be included the physical changes due to temperature variations, or water and frost action. At the surface the action is, for the most part, physical rather than chemical. Disintegration of the rock mass takes place with comparatively little decomposition of the mineral constituents. Thus, in the areas of igneous rocks coarse mineral sands are of frequent occurrence, which are the result of the action of frost and sudden temperature changes. Wind erosion is also an important feature on the exposed rocky peaks.

Relative power of resistance.

Of the igneous rocks the monzonite is the most resistant to atmospheric agencies, being broken into angular blocks which form a protective mantle. The andesite breaks into smaller angular fragments, and in the more porous lavas there is a marked tendency to disintegration into sand, which is washed from the slopes and accumulates in hollows. The rhyolite weathers like the andesite, but is slightly less resistant. In their resistance to weathering action the sedimentary rocks stand in the following order: quartzite, limestone, sandstone, shale. The shale and sandstone yield to both frost action and solution, the latter removing the cementing material and thus disintegrating the rock. The limestone is broken into fragments by the frost on exposed points, and also suffers a certain amount of solution. This is most apparent where the Godiva limestone contains chert nodules, which stand out relatively unaffected. The caves occurring in the limestone at the surface are closely related to fissures, and may have an origin similar to that of the caves encountered in the mines of the region, and thus not be the result of purely surface erosion. Quartzite is affected both by temperature changes and by frost, but suffers little solution.

SURFICIAL ROCKS.

A thick mantle of disintegrated rock material covers a large part of the Tintic special district. This constitutes one of the most unfavorable conditions for geologic work, and has often seriously interfered with exploration for ore bodies. On the geologic map two of these surficial formations have been distinguished, the alluvium and the Bonneville lake beds.

Alluvial fans.

Alluvium.—Tintic Valley is bordered by alluvial cones which extend down from every ravine and valley along the western edge of the Tintic Mountains. These cones of stream-deposited material become flatter as they emerge from the mouths of the ravines and gulches, and here better deserve to be termed alluvial fans. Near the center of the valley the slopes are very gentle, yet the grade is sufficient for the wide transportation of coarse material. The exceptionally large proportion of run-off due to the cloud-burst character of the rainfall of this region gives to the occasional streams a greater capacity to transport than might be expected. Evidence as to the manner of transportation is seen in the angularity of most of the rock fragments found near the middle of the valley. Their journey from the rock slope to the outer edge of the alluvial fan has been a comparatively rapid one, and they have suffered less corrasion than would be incident to transportation in a well-defined stream channel.

Interbedded gravel and sand.

The structure of these alluvial fans can be seen where the deep arroyos are at present trenching them. They show stratification, sometimes imperfect, but usually readily distinguished. The materials are interbedded gravel and coarse sand. The freshness of all this detrital material is noticeable, since rock disintegration has been so far in excess of rock decomposition.

Distribution of alluvium.

In many cases the alluvial deposits extend far up into the mountains, following the different drainage lines, and their distribution is, therefore, greater than can be represented on the geologic map. In sinking the wells near Homansville, alluvium was found in one instance to a depth of 65 feet, consisting of interbedded clay and gravel, the former in beds a few inches thick. The alluvium of the hills and ravines above Goshen Valley is similar to that on the west side of the range, and does not require further description.

Bonneville lake beds.—Goshen Valley is about 1000 feet lower than Tintic Valley and is covered by deposits of a different character. The alluvium, which doubtless once covered the lower part of the valley as it yet covers the whole of Tintic Valley, has been hidden from view by lacustrine deposits, which are finer grained and more evenly distributed. The Pleistocene lake which covered the eastern part of the Great Basin extended into this valley, and this fine material now covering the surface was deposited from the waters of Lake Bonneville.

Old shore line.

The Bonneville shore line, which marks the highest water level, is well developed at the head of Goshen Valley, a few feet above the 5100-foot contour. The terrace here is mostly cut in alluvial material which extends down from the small ravines indenting the mountain slope. As shown in Mr. Gilbert's monograph* on the Pleistocene lake, this area formed a part of Utah Bay, an almost landlocked arm of the lake; therefore, the waves which beat on this shore having but little fetch and being relatively inefficient, the shore line is not so deeply carved as at more exposed points; yet the terrace marking the Bonneville level is readily observed, since it forms the line of division between two types of topography. Above, the rock has been sculptured into bold outlines which even the surface accumulations of rock detritus do not conceal. Below, the lines are softened and the gentle, even slopes of the lacrustine deposits afford a marked contrast. One interesting feature of the Bonneville shore line is a bar constructed across a reentrant angle in the shore, thus forming a natural reservoir. Sections of the wave-built terraces and bars show well-bedded sand, fine and well sorted. A few thin beds of coarse gravel occur interbedded with the sand. This gravel can be traced upward to the talus at the base of steep slopes of limestone. The deposits thus indicate an alternation of conditions — now the locally derived limestone fragments being deposited on the beach, and now the finer shore drift. Calcareous tufa has been deposited on the upper surfaces of the uppermost pebbles of these beds.

Currant Creek delta.

Faint traces of other shore lines can be detected, but what has been called the Provo shore line, although strongly marked at other localities, is not indicated here. There is, however, a conspicuous topographic feature directly connected with the Provo stage of the lake. Currant Creek emerges from its canyon immediately east of the Tintic district, and from the mouth of this canyon extends a large delta which forms a noticeable interruption in the broad concave sweep at the head of Goshen Valley. The surface of this delta has an elevation of slightly more than 4700 feet, thus approximating the level of the Provo shore line as seen elsewhere. Below, the delta face has a deep slope to the valley bottom, and Currant Creek has now cut a deep channel in the delta terrace. The origin of this delta is connected with the desiccation of the lake. When the water stood at its highest level, or the Bonneville stage, Currant Creek Canyon was a narrow strait connecting the water in Juab Valley with that in Goshen Valley. With the fall of the lake water to the Provo level there was a marked change of conditions; Currant Creek began to drain Juab Valley, having its point of discharge at the head of Goshen Valley. Here the delta was doubtless quickly built, and its upper surface may be taken as indicating the water level at that time. The uniform fineness of the material composing the Currant Creek delta is due probably to the fact that all coarser sediments were deposited in the lake-like expanse of the stream in Juab Valley above the canyon.

Talus deposits.—These deposits, although not indicated on the geologic maps, are very extensive in some portions of the district. They include the rock detritus which occurs in the form of talus slides and avalanche streams. The material is heterogeneous and unstratified and owes its removal from the original rock mass primarily to the action of gravity. Creep due to the action of frost and snow may occur in these talus slides, while on the steepest slopes avalanches of snow doubtless have been effective in the transportation of the rock fragments to lower levels. Well-defined avalanche streams occur in some ravines, and these have apparently not yet come to rest, judging from the comparative absence of vegetation on their surface.

Cemented talus.

In many places on the slopes of the Tintic Mountains the mantle of talus material has accumulated to a great thickness. Prospect tunnels, both in limestone and monzonite, show disintegrated rock to a depth of 50 or even 100 feet. So compact is this detrital material that roofs and walls have remained standing untimbered for many years in these deserted tunnels. In gulches also, where streams have cut trenches in the débris, the high angles at which the walls stand show a considerable degree of cohesion. This cementation of loose fragments into such coherent masses is a process connected with the aridity of the region. Chemical decomposition of the rock fragments has been slight, but sufficient water circulates through the deposits to leach out a small part of their soluble constituents. Such solutions are brought to the surface, so that on evaporation the material in solution is left near the surface, where it acts as a cement.

GEOLOGIC HISTORY.

Several epochs in the history of this region are recorded by the different rocks and deposits which cover the surface. Although the region has been one of constant change and unceasing geologic activity, four general epochs in the geologic history may be distinguished.

Sedimentation (*Paleozoic*).— The history, as recorded in the rocks, begins with Paleozoic sedi-

---

*Lake Bonneville: Mon. U. S. Geol. Survey, Vol. I, 1890.

mentation. Nothing is exposed below the Tintic quartzite, which is believed to be of Cambrian age. The position of the Cambrian shore line and the conditions which governed the deposition of the 14,000 feet of Paleozoic sediments can only be inferred.

Absence of coarse sediments.

In the first place it is to be noted that there is in the Paleozoic section of the Tintic Mountains no apparent stratigraphic break, such as a marked unconformity or an extensive conglomerate. These would be expected as the result of any considerable uplift or subsidence. The absence of coarse material in any of the sediments is noteworthy, a few pebbly bands in the Cambrian quartzite being the only exception. The sediments are all such as to show that their deposition at no time occurred near a shore line. As compared with the Paleozoic rocks of the Wasatch Mountains to the east, the Tintic sediments above the top of the Cambrian quartzite are characterized by their generally calcareous nature. In the Paleozoic of the Wasatch Mountains arenaceous and argillaceous rocks greatly predominate throughout the section, while in the Tintic series above the Tintic quartzite and associated shales only 110 feet of sandy limestone and quartzite occur with 6500 feet of limestones. This points to the existence of a deepening sea over the Tintic area after Cambrian time with conditions that were favorable for limestone deposition, while to the east arenaceous sediments were being deposited nearer the shore.

Limestone sedimentation.

The Mammoth and Godiva limestones record a long interval of sedimentation under conditions essentially uniform. They are not rich in fossils, and it is also noticeable that the fossils found were from a few well-defined beds in which, although the rock is markedly fossiliferous, the range in species seems to be decidedly limited. Thus it appears that the conditions were not especially favorable to organic life. A break in these uniform conditions seems to have been inaugurated with the deposition of the Humbug formation. Here arenaceous, argillaceous, and calcareous beds occur in succession, in consequence of more varied conditions of sedimentation; the depth of water was doubtless somewhat lessened, so that arenaceous as well as calcareous material was contributed to the area of deposition, and, changing currents being only partially able to perform the task of sorting this heterogeneous material, calcareous sandstones and sandy limestones were deposited. These beds of mixed sediments were also limited in extent, so that the rocks as now seen are not persistent in character along the strike.

Uplift and erosion (*Mesozoic*).—This area of Paleozoic sediments is believed to have been raised above sea level early in Mesozoic time. Although sediments of Mesozoic age occur both to the east and to the south, none are found within this area, and it probably was situated in the southeastern part of the Mesozoic continent.

Folding of Paleozoic rocks.

In the Tintic Mountains the Carboniferous strata have suffered compression to a considerable extent. At what time such folding took place can not be determined within the limits of the Tintic district, but immediately to the south, in the Canyon Range, it is seen that the Carboniferous limestones continue the folds of the Tintic Mountains, while early Tertiary conglomerates in the same locality show only a slight tilting. So marked an unconformity between the Tertiary and Paleozoic rocks makes it evident that the mountain-building movements which caused these folds were of Mesozoic age. They may have been connected with the birth of the Mesozoic continent.

Extensive erosion.

This uplift inaugurated a decided change in the history of the area. Erosion was substituted for sedimentation and the new land area immediately began to waste at its surface. Many thousand feet of Carboniferous strata have probably wholly disappeared from the Tintic region, and their erosion was pre-Tertiary. Such a thickness of overlying strata was doubtless necessary for the production of the close folds which characterize the structure of the Carboniferous rocks of the Tintic Mountains.

Volcanic activity (*Tertiary*).—The third epoch in the history of the Tintic Mountains is that of volcanism. The mountains had been deeply carved by erosion, portions of the range being reduced nearly to the valley level, when volcanism began its task of rejuvenating the mountain range. Deep canyons were filled with volcanic material, thus restoring in great measure the topographic continuity of the range.

Rhyolitic eruptions.

The earliest lavas to be erupted were the rhyolites. From the vicinity of Packard Peak an outwelling of viscous rhyolitic lava filled the deep canyon north of Godiva Mountain and Eureka Peak, and the lava also flowed off to the southeast, down the Goshen slope, making the range much wider than at the commencement of the eruption. Similar eruptions occurred in the southern part of the district, as well as contemporaneous intrusions of rhyolite in the central portion of the area.

Andesitic eruptions.

Following this volcanic activity were the eruptions of andesitic lavas, quite different in character. Volcanic cones were built up by the lava flows and the accompanying fragmental material, which was ejected in great quantities. A later eruption in the Diamond area was less explosive in character, and appears to have been of the nature of a quiet extravasation of lava from a fissure. The outlines of this fissure are approximately defined to-day by the area of monzonite and andesite-porphyry, rocks which consolidated below the surface. Higher up, andesites flowed from this fissure, covering the fragmental deposits and lavas of the older volcano. A Tertiary age is given to these volcanic rocks on the basis of general relations.

Deposition of surficial formations (*Neocene and Pleistocene*).—Erosion continued its work even before the cessation of volcanic activity. The rhyolitic flows were somewhat eroded previous to the first eruption of andesite, while the volcanic cone of Volcano Ridge had begun to be carved by atmospheric agencies before the intrusion of monzonite cut across one side, and the flows of andesite covered the earlier volcanic deposits. Since then erosion has continued without interruption, and to-day the region is one of marked relief, although the products of Tertiary volcanism had concealed to a large extent the earlier work of erosion.

Amount of post-volcanic erosion.

An exact measure of this post-volcanic erosion can not be easily given. The upper slopes of Godiva Mountain do not appear to have been greatly reduced, although the volcanic material covering the lower slopes has been in part removed, yet the bottom of the pre-volcanic canyon at the head of Eureka Gulch has not yet been reached. In the southern part of the Tintic Mountains evidently a large amount of the volcanic rock has been removed by erosion. Buckskin Mountain and Tintic Mountain have been carved from horizontal flows of andesitic lava. Andesite once covering the monzonite of Sunrise Peak and the area to the north has almost wholly disappeared.

Surficial deposits.

Some measure of the amount of erosion in the Tintic Mountains is afforded by the extensive surficial deposits. In Tintic and Goshen valleys the alluvial and lacustrine deposits are doubtless very deep; even well up into the mountains the mantle of alluvium is considerable. Alluvial deposits of this character and extent testify to climatic conditions favorable to both erosion and transportation. At present the agencies of transportation are inadequate, so that the rock detritus accumulates in talus deposits. It is evident, therefore, that a period characterized by greater precipitation preceded the present one of aridity. The lacustrine deposits of the now extinct Lake Bonneville afford further evidence of this in Goshen Valley, where the lake beds were deposited, covering the alluvium of that valley. Later, when the rainfall became insufficient to maintain this body of water, it disappeared. Since that time these deposits have remained practically undisturbed. Currant Creek trenched its delta as the lake level was lowered, cutting down over 100 feet into the delta deposits. The lowering of Lake Bonneville, with the sudden change of water level, also caused an increase of efficiency in other streams tributary to the lake. In Tintic Valley there are stream terraces which are referable to this period of marked activity, but in the rich bottom lands of this valley there is little other evidence of the stream that once flowed. Along the edge of the valley alluvial fans are still being trenched by the occasional streams.

Résumé.—In Paleozoic time the area was one of sedimentation. Beginning with the deposition of well washed sand, the succeeding sediments were calcareous muds followed by more argillaceous and arenaceous sediments. This series, which comprises thousands of feet of sediments, was deposited in the deeper waters of the sea, and, for the most part, at a considerable distance from the shore.

In Mesozoic times these sediments were lifted above the sea level and the horizontal beds were compressed into close folds. Atmospheric agencies immediately began to wear away these rocks, giving a marked relief to the Tintic Mountains.

In Tertiary time volcanic eruptions of tuff and lava added greatly to the mass of these mountains, and the results of the Mesozoic erosion were largely concealed.

Since the volcanic eruptions, erosion has cut deeply into the accumulations of volcanic material and the products of this erosion have been deposited as alluvium and lake beds in the valleys and as talus on the upper slopes.

GEORGE OTIS SMITH,
Geologist.

June, 1899.

MINING INDUSTRY.

HISTORY.

Early locations.

Tintic is one of the oldest mining camps in the State. Ore was discovered by a party of prospectors returning from western Utah in December, 1869, and the districts were organized in the following spring. The only districts in the State discovered previous to Tintic were those of Bingham in 1863 by the soldiers of Gen. P. E. Connor; Rush Valley, or Stockton, also in 1863; and Little Cottonwood, in 1868. The first claim recorded in the Tintic district was called the "Sunbeam," and was located on December 13, 1869. The second location, the Black Dragon, a short distance north of the Sunbeam, was made on January 3, 1870. The third location was made on February 26 of the same year, on the site of the present Mammoth mine, and two days later stakes were set on the Eureka Hill ledges.

Mining centers.

These early locations were in parts of the district which have continued to be the important centers of the mining industry. The first is in the area of igneous rock in the southern part of the district, in the vicinity of Silver City. The next area north is that of Mammoth Basin, the most important mine of which was the third location of the district. North of this basin, and separated from it by a high ridge of limestone, is the Eureka area, with the Bullion–Beck, Eureka Hill, Centennial–Eureka, and Gemini mines. East of the Eureka and Mammoth groups of mines is another locality rich in ore deposits. This includes the Godiva, Uncle Sam, Humbug, Utah, and Sioux mines, which are situated on the eastern slope of Godiva Mountain and Sioux Peak.

Early ore shipments.

Amalgamation mills.

For a number of years rapid development of the mines in this district was not possible, owing to poor facilities for transportation. There was, however, a very considerable amount of ore near the surface which was rich enough to be mined in the face of almost any difficulty. These rich ores were shipped to San Francisco, California; to Reno, Nevada; to Baltimore, Maryland; and even to Swansea, Wales. The average value of the ores was not sufficiently great to warrant shipment to such distances, and attention was turned at an early date to the erection of mills and smelters in the vicinity of the mines. The first mill erected was at Homansville, in May, 1871. The second mill in the same locality was completed in the fall of the same year. The Wyoming mill, the Miller mill, the Shoebridge mill, southwest of Diamond, and the Copperopolis mill were constructed in 1873; the Mammoth mill, at Tintic, in 1879; the Roseville mill, southeast of Mammoth, at about this time, and more recently the present Mammoth mill, at Robinson, in December, 1893; the Eureka Hill and Bullion–Beck mills, at Eureka, in 1894; and the Farrell mill, at Robinson, in 1895.

Local smelters.

Owing to the poor success of the early amalgamation mills and the refractory nature of much of the ore, smelting has been tried frequently. The first smelter erected in the district was built at Homansville in 1871. The second, the Tintic Milling and Smelting Company's works at Diamond, was also built in 1871. The third smelter was the Copperopolis, built in 1873. Others were the Crismon–Mammoth, built at Tintic in 1884; the Latham furnace, built at Goshen in 1874; and the Clarkson, at Homansville. Like the earlier milling processes, smelting was unsuccessful.

Leaching plants.

The process of leaching the ores has been tried on two occasions — once at Goshen, in 1876, and again on the site of the old Miller mill, in 1879. This method of winning values was even less successful than milling and smelting.

The scant supply of water contributed largely to the want of success in the early mills. The Mammoth and Farrell mills are to-day supplied through a pipe line from Cherry Creek, 18 miles to the west; while at Eureka this supply is augmented by water from wells sunk at Homansville.

The development of the mines was greatly accelerated upon the advent of the railroads—the Oregon Short Line from the west in 1883, and the Rio Grande Western from the east in 1891.

Present conditions.

There are now four pan-amalgamation mills of the most modern type in the district: the Mammoth and the Sioux or Farrell mills at Robinson, and the Eureka Hill and Bullion–Beck mills at Eureka. These treat successfully the lower-grade ores of the district and ship both bullion and concentrates.

Producing mines.

The richer ores from the mines are shipped to the large smelters in the vicinity of Salt Lake City and elsewhere. The shipping mines in 1899 were: the Mammoth, Bullion–Beck, Centennial–Eureka, Grand Central, Gemini, Eureka Hill, Swansea, South Swansea, Godiva, Humbug, Uncle Sam, Sioux, Sunbeam, Ajax, Star Consolidated, Four Aces, Carissa, Joe Bowers, May Day, Northern Spy, Eagle, Treasure Hill, Lower Mammoth, Tesora, Alaska, Shower's Consolidated, Boss Tweed, Utah, Rabbit's Foot, and Silver Park. The Tintic iron mine shipped nearly 600 cars of iron ore to be used as flux. It will be noted that the above list of producing mines includes three of the four mines first located in the district, a fact which speaks well for the permanence of the ore bodies.

PRODUCTION.

In the first few years after the discovery of precious-metal deposits in these mountains the production was about equally divided between the deposits in the sedimentary and those in the igneous rocks, or between the northern and the southern districts. Upon the exhaustion of the oxidized ores in the igneous rocks the output of the southern portion of the district became practically nothing, and most of the mines were abandoned. A few, however, pushed their shafts to greater depths, until, finally, after a lapse of nearly twenty years, rich sulphide ores were found in several of the mines, notably in the Swansea and South Swansea. Since then these mines have produced constantly, and the renewed interest in the veins of the igneous rocks that their developments have created has already accelerated development in other mines and added greatly to the production of the district.

From the earliest times the mines in the sedimentary rocks have been productive, and the development has kept so far ahead of the actual breaking down of the ore in the stopes that the production has been one of constantly increasing proportions.

The following table, compiled from the reports of the Director of the United States Mint, affords the best data on production obtainable. The individual reports of production from the various mines have been used, so far as possible, as a check on this table, but, as it has been impossible to get reports on all the mines, and as many of the reports are incomplete, the production of the earlier years has not been verified.

Production of the Tintic mining district.

YEAR.	GOLD.	SILVER.
	Ounces.	*Ounces.*
1880	3,012	8,682
1881	2,332	105,354
1882	3,000	232,558
1883	2,000	224,800
1884	1,500	612,016
1885	868	868,925
1886	2,300	825,000
1887	3,200	1,412,463
1888	7,110	1,201,620
1889	14,940	2,055,700
1890	24,633	3,801,700
1891	19,444	2,901,730
1892	16,470	2,011,642
1893	15,097	1,990,860
1894	18,066	2,582,033
1895	27,525	3,517,166
1896	40,470	3,955,843
1897	37,039	2,877,600
1898	38,136	3,389,507
	277,142	34,575,199

It is thought that the production of silver and gold previous to 1880 did not exceed $2,000,000 in value.

In addition to the silver and gold, Tintic has produced a large amount of lead and copper, the production for 1898 being over 2,000,000 pounds of copper and 29,000,000 pounds of lead.

FRACTURE SYSTEMS.

The fracture systems of the district may be divided into two distinct classes: the first and more important are those which occur in sedimentary rocks; the second are confined to the igneous rocks.

Fracturing and mineralization in the sedimentary rocks occurred before the volcanic activity and therefore previous to fracturing and mineralization in the igneous rocks.

FRACTURES IN SEDIMENTARY ROCKS.

Fractures in the sedimentary rocks are very abundant and may be seen in almost every outcrop. They are most readily traceable in the quartzites and harder limestones. The Robinson quartzite is so profoundly sheeted by the N.–S. fractures as to conceal the bedding in most places. The fractures are most abundant in the vicinity of the three great mineral-bearing zones: the Eureka zone, the Mammoth zone, and the Godiva–Sioux Mountain zone.

The great majority of the fractures occur in the NE. and SW. quadrants, but the most persistent are within a few degrees of N.–S. The fractures in the NW. and SE. quadrants are less abundant. The fracture planes are nearly vertical, but in a few cases dip east or west at an angle that is rather less than 70°.

Principal fractures.

There are four principal directions of fracture: N.–S., including variations of less than 10° east or west of the meridian; N. 15° E., N. 25° E., and E.–W. Of these the N.–S. are the most important and the N. 15° E. fractures are the commonest planes at an angle with them. The N. 25° E. and the E.–W. fractures cross the stratification and hence are readily recognized. They are apparently later than the other fractures. The Spy–Ajax fault, which crosses from Mammoth Gulch to the Northern Spy mine, is the most prominent E.–W. fracture, having a displacement of a thousand feet. E.–W. fractures are most common along the contact of the Robinson quartzite and the Eureka limestone, where they have a maximum displacement of 200 feet. These fractures are almost always vertical.

Subordinate fractures.

The subordinate fractures, which, while constantly present, are much less persistent than the other fractures, have the following directions: NW., N. 35° W.; N. 20° W., and NE. They are usually vertical, but those which are parallel to the strike of the rocks are also parallel to the dip. The N. 20° W. and N. 35° W. fractures are the most abundant. The latter are confined to sharp flexures in the stratified rocks along Eureka Gulch, and are accompanied by much brecciation of the strata. In the former the individual strata have slipped past each other, forming open spaces of small dimensions.

Intersections of fractures.

The interrelations of the various fractures are very complex. The majority of the fractures cross, but appear not to have faulted one another. The exceptions to this that have been noted are along Quartzite Ridge and the Spy–Ajax fault, where N.–S. fractures are faulted by E.–W. fractures; also in the mines of Eureka and Godiva mountains, where N. 25° E., N.–E., and E.–W. fractures are seen occasionally to break the continuity of the other fractures.

The N.–S. fractures, which are by far the most common, are also most abundant on the west limb of the syncline, where the strata are nearly vertical. On the east limb, where the strata dip at low angles, they are not common. The NNE. and NE. fractures are most common at the southern end of the syncline, where they cross the beds nearly at right angles. The E.–W. fractures are found in the central and northern parts of the area of stratified rocks. The NNE., NE. and E.–W. fractures cross the stratification and appear to have been formed, for the most part, subsequently to the N.–S. fractures.

Ore bodies follow fractures.

Since the ore bodies follow the fractures, their general direction is north-south. There are, however, many small ore bodies and portions of large ore bodies which follow the other fracture directions; but these are subordinate in amount. The fractures which fault ore bodies are very few; and since their courses are generally parallel to them, it is only possible to distinguish them as later fractures when they actually cross them. The faulting fractures trend N. 25° E., NE., and E.–W. They are necessarily of later origin than the mineralization, and hence than the great majority of the fractures, but they appear to be older than the volcanic activity, for in no case have they been traced into the igneous rocks. The E.–W. fractures, which occur at the contact of the Robinson quartzite and Eureka limestone, have not intersected any known ore bodies, hence their relation to ore deposition is not determined. They are undoubtedly older than the volcanic rocks, because in the northern part of the district they have been found to stop at the contact. There thus appears to have been an earlier series of fractures, trending NNW. and NW., which was later intersected by the series of cross fractures trending N.–S., NNE., NE., and E.–W. With few exceptions the displacements on these planes do not seem to have been very considerable. They preceded the mineralization; but a few fractures are found which have been subsequent to the mineralization.

Earlier and later fractures.

Eureka fracture zone.—This zone extends from the Gemini mine, northwest of the town of Eureka, through the Bullion–Beck, Eureka Hill, and Centennial–Eureka mines, to the Southern Eureka, Tennessee Rebel, and Opex mines in Mammoth Basin. In this zone the greatest fracturing has been between the Bullion–Beck and Eureka Hill shafts. To the south, though nearly as many fractures exist, there are fewer fracture directions, N.–S. being the most common, and to the north there are neither so great a number of fractures nor so many fracture directions, the principal open spaces being parallel to the bedding planes. The ore bodies follow the fracture planes in their varying directions.

In the Centennial–Eureka mine their general course is N.–S., with minor irregularities. In the south end of the Eureka Hill mine they also trend N.–S., but turn gradually to the west, and between the Eureka Hill and Bullion–Beck shafts are mainly N. 35° W. North of the Bullion–Beck shaft they trend within a few degrees of N.–S.

In the two southern mines the ore bodies are fairly continuous and extend to great depth, but in the north they are less continuous; they have a small vertical range and consist of a number of lens-shaped bodies scattered widely throughout the ore zone. But very few later or secondary fractures were observed in this zone.

Mammoth zone.—This zone commences on the north at the Eagle mine, and extends thence southward through the Grand Central, Mammoth, Ajax, and Lower Mammoth mines. The most prominent and most numerous fractures have a general N.–S. direction. N. 25° E. and NE. fractures are common to all the mines of the zone, and are especially well seen in the Ajax, where they have been extensively mineralized. The N. 15° E. fractures are peculiar to the Mammoth mine, where, together with the N.–S. fractures, they have been found on planes of heaviest mineralization. N. 20° W. and NW. fractures have their greatest development in the Grand Central mine, and are apparently the result of slipping on the planes of stratification.

The Spy–Ajax fault, which crosses this zone, has displaced the strata on the south side a thousand feet to the eastward. Adjacent to this fault on either side are many parallel fissures, some of which are ore bearing. The exact relations of the ore bodies on the north to those on the south of this fault are not clearly understood.

At the southern end of the Mammoth mine, at the intersection of several fissures, the ore forms a large, elliptical shaped chimney, which has been traced continuously for more than 1600 feet in depth. This sends off several fingers to the east, but the main channels are N.–S. or N. 15° E. In the Grand Central mine the ore body follows N.–S. fractures in part, but its main axis is N. 30° W., or nearly parallel to the strike and dip of the strata. In the Eagle mine the ore body trends a few degrees west of north, parallel in strike with the stratification, but with a vertical dip. The ore bodies which follow simple N.–S. fractures are of much smaller vertical extent than the Great Mammoth chimney, and are largest near the surface. On the other hand, the top of the great ore body in the Grand Central mine seems to have been nearly 1000 feet below the surface.

The only observed post-mineral fractures in the Mammoth mine trend N.–S. and include an irregular band, varying in width from 20 to 100 feet, of broken, angular fragments of limestone, which is popularly known as the "dike."

Godiva–Sioux Mountain zone.—This begins on the south at the North Star, extends NE. to the east side of Sioux Mountain, thence northward to Godiva Mountain, and finally NNW. to the north side of this mountain. The principal fracture directions at the south end are N.–S. and N. 25° to 35° E.; in the central portion N.–S. and N. 15° E. fractures are more abundant; at the north end N.–S. and N. 15° to 30° W. fractures prevail. They are all vertical. The ore bodies follow the fractures; that is to say, they are NNE. at the south end, N.–S. along the east flank of Godiva and Sioux mountains, and NNW. at the north end of Godiva Mountain. At the south end the ore zone is composed of several short ore bodies, while in the central portion there is a single ore body which has been followed continuously from the Clarissa to the Utah mine, a distance of 5000 feet. Beyond this to the north the bodies are less regular, being short and lens-shaped, with a pitch south of east. In the Northern Spy, Sioux, and Utah mines, in the central portion, the ore bodies, which are vertical, or have a steep western dip in the lower levels, are inclined to depart from the fractures at the contact of the Godiva and Humbug formations and follow the bedding planes of the strata, which dip eastward at angles of from 25° to 65°. Secondary fracturing is slight in this zone and is principally seen in the Utah mine, where an E.–W. fault has displaced the ore body.

Age of fractures.

The fact that some of the ore-bearing fractures are faulted shows that there must have been two periods of fracturing. The fractures on either side of the Spy–Ajax fault do not correspond, which indicates that this fault was produced subsequently to the N.–S. fracturing; this fault is traced up to but does not enter the rhyolite, the earliest of the igneous eruptives, hence must have been formed previous to volcanic activity. As the most recent sedimentary strata belong to the Carboniferous age it is probable that their deformation, and the subsequent mineralization, occurred during Jurassic time, or at least prior to the Tertiary, which was the age of volcanic activity.

FRACTURES IN IGNEOUS ROCKS.

The fracturing in the igneous rocks occurs mostly in the more solid types, the monzonite and quartz-porphyry, and is most abundant in the more coarsely granular of these rocks.

The mineral-bearing fractures have a maximum development between Silver City and the Sunbeam mine, becoming few and insignificant east of the latter. Some mineralized fractures have also been developed in the porphyritic monzonite on Treasure Hill and Sunrise Mountain.

Trend of fractures in igneous rocks.

There is not so wide a range in the trend of these fissures as in the sedimentary rocks. Fissures trending N. 15° E. and N. 35° E. are the most abundant. N.–S. and N. 10° W. fractures also occur, the latter being limited to mines north of Silver City. A few have a trend N. 70° E. They are always nearly vertical, the dip rarely being less than 80°; but it is not uncommon for the dip to change from east to west within a hundred feet. The fractures all die out near the sedimentary rocks.

In the mines north of Silver City—the Swansea, Park, Four Aces, and Silver Bow—N. 10° W. and N. 15° E. fractures predominate. On the north side of Dragon Gulch, N. 20° to 35° E. fractures are the more common, and in the mines to the east of Silver City—the Martha Washington, Sunbeam, Undine, Joe Daly, and others—N. 25° to 45° E. directions prevail.

Secondary fractures are very rare, the only ones noted being two in the Swansea mines, with directions of N. 55° W. and N. 70° E., which displace the mineral-bearing veins about 10 feet each.

As the igneous rocks are of Tertiary age, the fractures must be late Tertiary or early Pleistocene.

ORE DEPOSITION.

Ores deposited along fracture zones.

The ore deposits of the region occur along fracture zones within the sedimentary and igneous rocks and at the contact between the two. Those in the sedimentary rocks are practically confined to the three fracture zones above mentioned, the Eureka, the Mammoth, and the Godiva–Sioux Mountain zones. In the igneous rocks the deposits consist of a number of short, widely interspaced veins, with a general strike N.–S. and NE.–SW. The principal mines are the Swansea, South Swansea, Sunbeam, Martha Washington, Treasure Hill, Homestake, and Joe Bowers. The Tintic iron mine, on the northern side of Dragon Gulch, has the most considerable contact deposit. The more common minerals of these deposits are pyrite, galena, sphalerite, and enargite and their oxidation products, carrying silver and gold, with quartz and barite as gangue minerals. In the sedimentary rocks quartz is the predominant mineral; in the igneous rocks the metallic sulphides predominate. The ores in the sedimentary rocks are mostly oxidized down to the greatest depth yet mined—about 1600 feet below the surface. In the igneous rocks the ground-water level varies from 200 to 700 feet below the surface, being deepest in the Swansea mine. In these the ore deposits are completely oxidized above and unaltered below the water level, the line of separation being very distinct. In the stratified rocks the ores in some cases fill irregular spaces and chambers along the fissure zones; in others they replace the country rock. The minerals in the igneous rocks, on the other hand, occur only within the walls of the fissure planes.

Depth of oxidation.

Distribution of metallic minerals.

The lead and silver ores predominate almost to the exclusion of copper and gold ores at the northern end of the various ore zones, as in the Gemini and Godiva mines, while the Centennial–Eureka and North Star, at the southern end of these zones, produce more copper and gold than lead and silver. Gold, which is found almost exclusively in the deposits in the sedimentary rocks, is rarely detectable by panning, and hence probably occurs in some chemical combination. Silver yields the principal values in all the deposits; it is largely in the form of cerargyrite in the deposits of the sedimentary rocks, where it coats the breccias of vein material and country rock. In the igneous rocks it is found both as cerargyrite and as argentite. The other minerals of commercial value are lead and copper, the former occurring in both the sedimentary and the igneous rocks, the latter principally in the sedimentary rocks. The iron of the contact deposits is valuable, being used for fluxing purposes. The bodies of unoxidized ore found in the sedimentary rocks, and the ores exposed in the lower workings of the igneous rock deposits, show that, in their original forms, these ores were sulphides and sulpharsenides, which form 5 to 90 per cent of the ore in the sedimentary rocks and 50 to 80 per cent in the igneous rocks.

Original form of deposits.

Galena and pyrite are the most abundant metallic sulphides, and enargite is the principal form of copper as originally deposited. By the oxidation of the deposits in the sedimentary rocks the metals have been separated into ore bodies in which one or the other predominates. Thus, in the Eureka Hill, Mammoth, Ajax, Carissa, and Northern Spy mines large bodies of oxidized copper ore have been found which carried practically no lead values. Equally large bodies, almost exclusively of lead ore, occur in the Eureka Hill, Bullion–Beck, Utah, Sioux, and Mammoth mines, while large amounts of cerargyrite were taken from the Gemini mine. Such ore bodies occur filling caves, or in zones of brecciated vein-material or country rock adjacent to the original ore bodies.

In structure the original ores are either massive or banded, or imitate the texture and color of the inclosing rocks. Banded structure, found in both the igneous and the sedimentary rocks, is due to variations in the amount of silica deposited. In the deposits in the sedimentary rocks massive and pseudomorphic structures are the more common.

Structure of original ores.

Contact deposits occur on or directly connected with the contact of the igneous rocks with limestone, and are, for the most part, replacements of limestone along this contact. Mineralization has formed great masses of siliceous material impregnated with hematite and limonite and containing locally small amounts of the precious metals. They consist principally of jasperoid, or silicified limestone. A typical exposure may be seen on the southwest slope of Mammoth Peak, near the new East Tintic Railway, where great masses of silicified rock project from 15 to 20 feet above the surface. The jasperoid is similar in every respect to the cryptocrystalline quartz which occurs in the other deposits of the district. It contains also spots and small masses of unreplaced limestone and dolomite. It so closely imitates the structure of the rock it replaces that frequently it can be distinguished from the latter only by its hardness and its failure to effervesce. The contact deposits always carry a considerable amount of hematite and limonite, and in the Tintic and Black Stallion iron mines these have been found profitable to extract. The iron ore of the Tintic iron mine contains about 80 per cent of iron oxide, 14 per cent of water, and 3 per cent of silica, with very small amounts of alumina, lime, magnesia, and sulphuric and phosphoric acids.

Contact deposits.

Jasperoid replacement.

MINERALS OF THE ORE DEPOSITS.

Quartz	SiO_2
Chalcedonite	SiO_2
Barite	$BaSO_4$
Calcite	$CaCO_3$
Dolomite	$MgCO_3$
Selenite	$CaSO_4$

Gold Minerals.

Native gold	Au

Silver Minerals.

Stephanite	Ag_5SbS_4
Argentite	Ag_2S
Cerargyrite	AgCl
Native silver	Ag

Lead Minerals.

Galena	PbS
Anglesite	$PbSO_4$
Cerussite	$PbCO_3$
Minium	Pb_3O_4

Copper Minerals.

Enargite	Cu_3AsS_4
Tetrahedrite	$Cu_8Sb_2S_7$
Tennantite	Cu_8AsS_7
Chalcopyrite	$CuFeS_2$
Bornite	Cu_3FeS_3
Chalcocite	Cu_2S
Olivenite	$Cu_3As_2O_8Cu(OH)_2$
Clinoclasite	$Cu_3As_2O_83Cu(OH)_2$
Erinite	$Cu_3As_2O_82Cu(OH)_2$
Tyrolite	$Cu_3As_2O_82Cu(OH)_3+7H_2O$
Chalcophyllite	$7CuOAs_2O_5.\ 14H_2O$
Conichalcite	$(Cu, Ca)3As_2O_8.\ (Cu, Ca)(OH)_2+\frac{1}{2}H_2O$
Chenevixite	$Cu_2(FeO)_2.\ As_2O_8+3H_2O$
Lettsomite	$4CuOAl_2O_3SO_3.\ 8H_2O$
Brochantite	$CuSO_4.\ 3Cu(OH)_2$
Mixite	$20CuO.Bi_2O_35As_2O_5.\ 22H_2O$
Chrysocolla	$CuSiO_3+2H_2O$
Malachite	$CuCO_3.\ Cu(OH)_2$
Azurite	$2CuCO_3.\ Cu(OH)_2$
Melaconite	CuO
Cuprite	Cu_2O
Native copper	Cu

Iron Minerals.

Pyrite	FeS_2
Scorodite	$FeAsO_4+2H_2O$
Pharmacosiderite	$6FeAsO_4.\ 2Fe(OH)_3+12H_2O$
Jarosite	$K_2O3Fe_2O_3.\ 4SO_4.\ 6H_2O$
Utahite	$3Fe_2O_3.\ 3SO_3.\ 4H_2O$
Borickite	$Ca_3Fe_2(PO_4)_4.\ 12Fe(OH)_3+6H_2O$
Hematite	Fe_2O_3
Limonite	$2Fe_2O_3.\ 3H_2O$

Zinc Minerals.

Sphalerite	ZnS

Bismuth Minerals

Native bismuth	Bi
Bismutite	$Bi_2O_3CO_2H_2O$

Sulphur.

Native sulphur	S

Quartz is always present in these deposits, frequently occurring in great masses in the limestone, but with so little of the metallic minerals as to be of no commercial value. It occurs either in crystals or crystalline masses deposited in open spaces or in cryptocrystalline masses replacing the country rock; it has been deposited at various intervals during the mineralization, and has also been found as a secondary deposit formed subsequently to the oxidation. Microscopically the individual crystals frequently show enlargement. Cases have been observed where the quartz lines cavities in galena, and on the walls; it has been found coated with barite, to which, in turn, younger quartz crystals cling. Quartz which was plainly more recent than the oxidation has been seen coating crystals of calcite and the rough surfaces of copper carbonates. The cryptocrystalline masses of silica which replace the limestone preserve its texture and color and often contain irregular patches of carbonate of lime or magnesia. Chalcedonite is, on the whole, rare. It occurs in intimate association with the quartz, but can not be distinguished from it without the aid of a microscope.

Barite, next in importance to quartz, was one of the earliest minerals to form in the deposits in the sedimentary rocks; it is quite generally distributed through them. In the Carissa mine it forms a nearly solid body almost 25 feet wide, 40 or more feet long, and 50 feet in vertical extent.

Calcite and *dolomite* form residual spots and irregular patches throughout the cryptocrystalline quartz representing, presumably, unreplaced portions of the country rock. There has also been much secondary calcite deposited in open spaces, whatever be the nature of the inclosing rock. In frequent instances oxidized ores are found coated with calcite.

Selenite forms as the result of the oxidation of the sulphide ores in the presence of the limestone country rock.

Gold, on account either of its finely divided state or of its chemical combination, is rarely revealed by panning. The richest gold ores invariably contain a large amount of barite in minute crystals. *Tellurium* has been found in the ores, but it is not certain that the gold was originally all in the form of telluride of gold; some may have been associated or combined with the large amount of pyrite which originally existed in the ore.

Argentite and *stephanite* occur occasionally as minute grains or crystalline inclusions in the galena ore. *Cerargyrite*, or *horn silver*, forms films and crystals coating the fragments of vein or country rock. In the oxidized zones of all the mines horn silver is constantly found. In the Centennial–Eureka and Gemini mines large masses of ore have been mined for their silver content only. *Native silver*, which has never been a common mineral, is seen only in greatly decomposed portions of the ore bodies near the surface.

Galena and its oxidation products, *cerussite* and *anglesite*, are the most abundant metallic minerals of the Tintic deposits. In the Uncle Sam mine hundreds of tons of ore have been mined which carry 75 per cent of lead and little or no other metallic minerals. It occurs in irregular masses associated with pyrite, zinc blende, and quartz. In the Centennial–Eureka mine it is seen to form the shell of an ore shoot the center of which is composed of enargite and galena. Its association with quartz and pyrite proves it to be one of the earliest-formed minerals.

Anglesite, a rather uncommon, colorless mineral, has formed in the cavities in the galena as the result of the decomposition of the latter.

Cerussite is the most common form of lead ore. It occurs in aggregations of crystals as well as in irregular masses without crystalline form. It is mixed with quartz and jasperoid, and fills cracks and crevices in the vein material and country rock.

Minium, resulting from the decomposition of other minerals, is occasionally seen.

Enargite is found most frequently in the lower levels of the deep mines and in a few of the mines in igneous rocks near Diamond City. Specimens from the Homestake mine show crystals of enargite fully one-half inch in length. The minerals observed in the sedimentary rocks are in cryptocrystalline masses which are always coated with oxidation products and sometimes contain chalcopyrite.

Chalcocite, like bornite, is an uncommon mineral and results from the decomposition of tetrahedrite, chalcopyrite, or possibly bornite.

Olivenite, one of the first products of the oxidation of enargite, occurs in hair-like crystals, which shade from pale to dark olive-green, and also in compact, fibrous, wood-brown masses. It forms around masses of enargite, or lines cavities in altered limestone. It is often coated with other copper minerals, with calcite, or even with quartz.

Clinoclasite differs from olivenite by its crystal form and its very uniform dark bluish-green color. The crystals sometimes produce a rough, shining, plated surface, as they frequently group themselves in radial clusters. Its association and mode of occurrence are the same as those of olivenite.

Erinite, which is dark emerald-green in color, occurs in hair-like groups of crystals lining cavities and closely associated with enargite, azurite, and clinoclasite.

Tyrolite is of a very brilliant green color, intensified by its mica-like cleavage and radial structure.

Chalcophyllite is found in the form of small hexagonal plates arranged in rosettes differing from the radial structure described for tyrolite. Its color is bright apple-green with pearly luster and it has marked cleavage.

Chenevixite is a compact, greenish, opaque mineral scattered in irregular patches throughout portions of ore that occurs in hard lumps, and gives a mottled appearance to a broken surface. Its color is olive-green, shading into greenish yellow after exposure, with little or no luster.

Conichalcite, in color varying from pistachio- to emerald-green, strongly resembles malachite. It is reniform and massive, coating surfaces with decomposed copper arseniates.

Lettsomite (*cyanotrichite*), from the Ajax mine, occurs in druses, forming a velvety lining of short capillary crystals, sometimes like spherical globules. Its color is a clear smalt-blue, sometimes passing into sky-blue.

Brochantite occurs in two distinct forms: (1) in the ordinary form, with prismatic habit, the transparent crystals having a dark-green color; (2) with curved double wedge-shaped crystals, light green in color; the crystals do not exceed 2 or 3 millimeters in length.

Mixite occurs in pale bluish-green hair-like crystals, arranged in radial clusters, and often forming a very soft, velvety coating on tabular crystals of barite. It is associated with olivenite and bismutite.

Chrysocolla, varying in color from blue to green, occurs abundantly in irregular masses in decomposed vein material and country rock. It results from a decomposition of all the copper minerals mentioned above.

Malachite, occurring in crystals and amorphous masses, is abundant as the result of the decomposition of the hydrous arsenates and arseniates, especially of olivenite and clinoclasite.

Azurite, which is not so abundant as malachite, is commonly found in crystals attached to solid masses of copper sulphides. It is highly probable that malachite is the result of the oxidation of sulpharsenides, and azurite of sulphides of copper. Their occurrence indicates the former presence of enargite and tennantite in the one case, and of chalcopyrite and tetrahedrite in the other.

Melaconite, coal-black, without crystalline outline, is abundantly present in irregular masses, and results from a decomposition of all copper minerals except cuprite and native copper.

Cuprite, resulting from the reduction of melaconite, is always intimately associated with it, merging into it by almost insensible degrees.

Native copper in small quantities is found as the result of deoxidation in nearly all the mines. A specimen from the Boss Tweed showed a mass of native copper inclosed by cuprite, and in the thin sections the transitions from enargite, olivenite, malachite, melaconite, and cuprite to metallic copper were seen.

Pyrite is rare in the sedimentary rocks because of the thorough oxidation of the deposits. It is occasionally seen in the small patches which are coated with iron oxide, except where it has resulted from the decomposition of copper sulphides. It is certain from the great amount of iron oxide now present that pyrite was at one time a very abundant mineral. In the igneous rocks, where the water level is near the surface, the pyrite is well preserved and can be seen disseminated throughout the veins and impregnating the country rock near them. It also occurs frequently in large lens-shaped bodies of almost solid pyrite, especially near the ground-water level.

Scorodite occurs in crystals varying from lake-green to olive-brown; it is amorphous and earthy.

Pharmacosiderite is found in brown cubic crystals attached to rusty quartz. In color it is straw-yellow and pale green. The crystals are so small that it is often overlooked or confounded with jarosite and scorodite.

Jarosite occurs in druses of minute crystals in clusters or as an incrustation. In color it is yellow or clove-brown.

Utahite forms in fine orange-yellow scales which have a soft, silky lustre. It is found in the Eureka Hill, Bullion–Beck, Mammoth, and Ajax mines.

Borickite is a compact, massive mineral without cleavage. Its lustre is waxy and its color reddish brown.

Hematite and *limonite* are common to the oxidation zones of all the deposits. They result from the alteration of pyrite, and, to a small extent, from the decomposition of other copper minerals which contain iron. Neither limonite nor hematite were originally deposited as such, it is thought, except possibly in the contact deposits in the Tintic iron mine. They occur in irregular masses and in minute particles in all portions of the oxidized zone. In the Ajax mine a large cave was found across which extended at various angles hollow diamond-shaped rods of limonite from which hung stalactites. The form of the open space in the rod and an occasional corroded mass of gypsum showed that the cave must have been crossed by numerous long, slender crystals of the latter mineral.

Sphalerite, or zinc blende, was found in the Swansea mines in association with pyrite and and galena. It is an original mineral which has been but little altered. It is usually without crystalline outline, is resinous yellow in color, and shows characteristic cleavage.

Native bismuth, in very delicate crystals, was found in the Emerald and Boss Tweed mines in perfectly fresh limestone apart from any known ore deposit or vein. On account of the smallness of the crystals its determination rests upon analysis.

Bismutite is associated almost exclusively with quartz and barite. It is a grayish straw-colored mineral without crystalline form.

Native sulphur was found in crystals coating cavities in massive galena ore. In the Eureka Hill mine some of these crystals, one-eighth of an inch in diameter, were nearly perfect. Its mode of occurrence, coating cavities and attached to known products of oxidation, indicates its origin as a part of that general process.

Order of deposition.—Microscopic study shows that quartz is formed almost continuously from the beginning to the end of the process of mineralization, that it frequently replaces limestone, and that some of it has been formed subsequent to the oxidation. Barite is earlier than the metallic minerals. The metallic minerals were all deposited about the same time, but later than the earliest quartz and the barite. In the Boss Tweed mine quartz was found in distinct crystals containing hexagonal skeletons of a finely divided dark mineral. It was also seen in irregular masses inclosing malachite and chrysocolla and lining druses in soft, decomposed vein material and country rock. In the Eureka Hill mine in one case quartz was found coated with and coating both sulphides and oxidation products. In another case fine-grained quartz was seen lined with coarsely crystalline quartz containing crystals of barite. Upon the latter quartz formed subsequently; some of it was highly altered and coated with still more recent quartz. Quartz pseudomorphic after calcite occurs in the Mammoth, Centennial–Eureka, and Bullion–Beck mines.

GEOLOGICAL RELATIONS OF DEPOSITS.

Rock alteration.—The changes in rocks due to fissuring and vein formation are either mechanical or chemical in their nature.

Mechanical alteration in the sedimentary rocks has caused the sheeting of the more resistant strata, such as quartzites, and the brecciation of the limestone and dolomite. An unusual example of brecciation found in the Mammoth mine is locally known as "the dike." It is a large mass of greatly brecciated limestone which can be traced on the surface and below it for many hundreds of feet. It is of so recent origin that the fragments are without calcite or secondary mineral cement.

Alteration in sedimentary rocks.

It is along the channels produced by mechanical alteration that the chemical changes have taken place. Chemical alteration in the sedimentary rocks has affected the walls of the fissures by replacing them with silica, galena, and some, possibly all, of the other minerals of the vein deposits. The commonest change is the substitution of silica for lime. This process does not affect the original structure, texture, or color of the rock, but chemical analysis shows that it changes a rock containing 75 per cent carbonate of lime to one carrying nearly 85 per cent of silica.

Mechanical alteration in the igneous rocks has been confined almost entirely to the more compact, granular rocks, and in no case has a large fissure been found. No shearing or granulation of the individual minerals of these rocks was observed. Chemical alteration is confined in these rocks to the few inches next to the veins and to the contact of the sedimentary rocks. It has produced quartz, pyrite, and sericite in the wall rocks next to the veins. Pyrite occurs both as an impregnation of the country rock and as a filling of microscopic cracks. Quartz and sericite appear to be the result of the alteration of the original rock, the former having been seen to replace certain of the feldspars.

Alteration in igneous rocks.

Ore bodies in sedimentary rocks.—The ore bodies of the sedimentary rocks are found along nearly vertical fractures, and extend into the country rock on both sides for from a few inches to more than 50 feet. These bodies are extremely irregular and are seldom bounded by definite walls, so that the change from ore to country rock is vague and must be determined either by assay or by the hardness of the rock, the silicified limestone being invariably harder than the unaltered.

The ore bodies follow, for the most part, N.–S. fissures, but fissures of all directions have been found between N.–S. ore bodies. The ore bodies rarely branch or split. When two fissures meet, the ore body is usually larger at the intersection if the vein continues its course beyond the point of intersection than if it departs on the intersecting fissure.

The vertical extent of individual ore bodies is rarely more than 200 feet, though a large shoot in the Eureka Hill mine has a length of 600 feet, and another in the Mammoth mine of 1600 feet. Small horizontal pipes are common in all the mines. The longitudinal extent of the ore bodies is as variable as the vertical. Those bodies which occupy strong fractures having a definite angle with the planes of stratification are more continuous than those which occur in openings that result from the slipping of individual beds on one another. The longest observed ore body extends from the Utah to the Carissa mine, a distance of 5000 feet, while in the Bullion–Beck and Gemini there are many ore bodies not more than 25 feet long.

Extent of ore bodies.

There appears to be no definite order in the distribution of the richer portions of the ores. The smaller ore bodies average higher generally than the large ones, and it has also been found that the ore is richer where the ore body widens at the intersection of two fissures. The greatest depth of ore mined at the present time is in the Bullion–Beck, where the workings have reached a depth of 1600 feet (about 4750 feet above sea level).

The outcrops of the ore bodies give no idea of their size. In the Bullion–Beck mine it was said that no ore was encountered until the workings reached a depth of 80 feet. In the Gemini, ore was struck only below the 400-foot level.

Ore bodies do not always outcrop.

The average value of the ore appears to be decreasing, a fact which is due rather to the passing from the totally oxidized ores, which have become richer in the process of oxidation, to the less oxidized, than to an actual decrease in the value of the original ore.

Ore bodies in igneous rocks.—In the igneous rocks the ore bodies vary from a mere seam to veins 10 feet in width. Their limits are always well defined, though clay seams or friction breccias separating ore from country rock are rare. The most continuous ore body is the Sunbeam vein, which is 2000 feet long; the majority of the veins are not more than a few hundred feet in length. As in the sedimentary rocks, the ore follows mainly N.–S. or NNE. fissures. The veins of parallel and adjacent fractures do not overlap and are generally connected by ore-bearing cross fractures, the cross fissures being barren beyond the intersections.

There is a marked banding in the ores, produced by the varying proportions of the minerals. The bands containing the greatest amount of galena constitute pay shoots. Individual bands are sometimes separated by clay seams. The pay shoots are lens-shaped and without definite pitch, though their longest axis is usually horizontal.

While there is a marked decrease in value from the oxide to the sulphide ores, and the veins are never large, still there is no good reason for believing that they will not persist to a much greater depth than that at which they are now worked.

Contact deposits.—In the limestone, along its contact with igneous rocks, either monzonite or rhyolite, occur bodies of jasperoid which contain in places sufficient iron to render the ore valuable for fluxing purposes. The most important deposits are, first, the Tintic iron mine, which is situated south of Mammoth Mountain, on the contact of Eureka limestone with monzonite; and, second, those on the first ridge east of Mammoth Mountain, just beyond the border of the area mapped, along the contact of rhyolite and Eureka limestone on which is situated the Black Stallion group of mines. The rocks on either side of the contact have been extensively altered, the alteration taking the form of replacement of the limestone, while in the monzonite the feldspar has been changed to sericite.

Origin of deposits.—Deposits in the sedimentary and in the igneous rocks were probably made by ascending heated waters carrying hydrogen-sulphide, alkaline sulphides, and arsenical sulphides, with some forms of silica, barium, lead, copper, silver, and gold. Where ore bodies occur replacing the limestone it is probable that there has been a chemical reaction between the components of the vein solutions and the carbonates of lime and magnesia of the wall rocks. Deposits forming in preexisting spaces, whether in sedimentary or in igneous rocks, may be the result of chemical precipitation due to loss of temperature or of pressure, or to changes brought about in the solutions upon mixing with surface waters containing oxygen, carbonic acid, or organic matter.

The structure and composition of the contact deposits indicate a different method of formation. It is probable that they were formed comparatively near the surface by thermal springs. Of these three forms of deposits, those in the sedimentary rocks are the oldest, as shown by the facts that they are cut off by the igneous rocks, that fragments of their vein material are found in the talus, which in some cases separates the sedimentary from the igneous rocks, and that portions of these veins are found in the contact deposits. The evidences of the relative age of the deposits in the igneous rocks and those along the contact are not conclusive. Deposits in the igneous rocks are composed of sulphides, while the latter are oxides. The fact that these oxides may have been derived from secondary sulphides in the neighboring eruptive rocks is suggestive of a more recent age for the contact deposits.

Relative age of original deposits.

Secondary deposits.—In both sedimentary and igneous rocks the surface waters have oxidized the ore bodies, leached the deposits, and rearranged the various minerals, forming new chemical combinations among the metals. By this process the metals have been separated into distinct ore bodies, which occur in open spaces in the vein and country rock, made since the original mineralization. In the sedimentary rocks these deposits extend to a depth of 1500 feet; in the igneous rocks to 200 or 300 feet.

In this process the pyrite, galena, and enargite have been changed to limonite, cerussite, and cerargyrite, respectively. The enargite has passed through various forms of hydrous arsenates and arseniates into the oxides of copper and native copper. The alteration has been effected by surface waters carrying atmospheric oxygen, organic matter, chloride of sodium, and phosphoric and carbonic acid. The separation of the minerals of the originally complex ore bodies into deposits containing only one of the various metals is probably due to difference in stability and solubility of the original minerals, though the changes through which these original minerals have gone have probably been an important factor in the final separation.

GEORGE WARREN TOWER, Jr.,
Geologist.

November, 1899.

GENERAL CONCLUSIONS.

A review of the facts gathered by Messrs. Smith and Tower in their geological study of the Tintic special district leads to the following general conclusions with regard to the economic geology of the district.

Age.—It seems well established by the evidence obtained that the original deposition in the sedimentary rocks occurred previous to the eruption of the igneous rocks, but in the usually oxidized condition of these deposits one can not be sure that additional mineralization has not subsequently taken place in the sedimentary rocks, and possibly at the time of the ore deposition in the igneous rocks. There has undoubtedly been a later shattering or fissuring of the sedimentary rocks since the formation of the original fissures, and it may reasonably be assumed that this took place at the time of the formation of the fissures in the igneous rocks that have since become mineral-bearing veins. It is noteworthy that the latter have a similarity in general direction and relative position to the older fissure zones.

Secondary fissuring.

The original fissuring in the sedimentary rocks is assumed to be mainly of later date than the folding, for the reason that a great number of the fractures cross the bedding at a low angle either in strike or in dip. A certain amount of slipping on bedding planes may have accompanied the folding, but it seems probable that such as caused a buckling or bending apart of adjoining strata, sufficient to leave a space for the accumulation of ore, must have been caused by later dynamic movement. If the assumption is correct that the fissuring in the igneous rocks was accompanied by a renewal of movement in the fracture zones of the sedimentary rocks, it is probable that the fissures in the latter now extend to a considerable depth and are not likely to decrease in value with depth, except as a change from enriched oxides to sulphides and arsenides, until the fractures have passed into the underlying quartzite at the bottom of the supposed synclinal basin.

Fissuring later than folding.

Ground-water level.—The remarkable difference in the level of the ground water in sedimentary and igneous rocks is significant, but its interpretation is not in every respect clear. It is in so far a confirmation of the induction that the fissures in the sedimentary rocks are the older, since it shows that there is no present connection between them and those of the igneous rocks. It might be assumed to indicate that the latter do not extend through these rocks into the underlying sedimentary rocks; hence that they are likely to be found of less extent in depth.

Significance of variation in ground-water level.

Contact deposits.—The contact deposits probably do not owe their existence solely to the fact of their occurrence at the contact of limestone and igneous rocks, but their concentration at the observed points was probably due to some fissuring which admitted the mineralizing solutions and from which they spread out into and replaced the adjoining limestone. Further, there does not seem to be any final proof that they were originally deposited as oxides. It is not improbable that they may have been deposited as sulphides at or near the present location of the limonite ores, and, by the action of thermal springs, have since been altered to hydrous oxides and more or less transposed.

Contact deposits influenced by fissuring.

Cave deposits.—Cave deposits constitute an unusually interesting and important feature of the Tintic ore bodies in limestone. The great elevation of the limestone mass above the bottom of the surrounding valleys, which must have been even more marked previous to the igneous eruptions, afforded a great depth of run-off to surface waters, and hence favored the formation of caves in the mass of the limestone strata. Nevertheless, there does not appear to be any definite evidence that the original deposits in limestone at Tintic were cave deposits. They are mostly replacement deposits, and, in some cases, the filling of open spaces formed by dynamic movement or fissuring. A large proportion of the actually existing open caves occur over oxidized ore bodies and evidently owe their existence to the settling to the bottom of the material of a large ore body. It is well known that in the oxidation of a body of sulphides which has replaced limestone there is a removal of a certain part of the constituents, and it is possible that the original sulphide replacement was accompanied by a slight contraction of the mass. The former is, however, the more important operation from the present point of view. It leaves the mass in a porous condition, somewhat in the nature of a loose aggregation of sand grains, which would be the less coherent the greater the amount of leaching to which it had been subjected. A shaking up of the mountain mass, such as must have accompanied the formation of what is called the

Caves the result, not the cause, of ore deposition.

"dike" in the Mammoth mine, would have loosened and caused to settle to the bottom the less coherent material, leaving an open space or cave above, just as would be occasioned by the shaking down of sand in a loosely filled glass tube. In the cave in the 1300-foot level of the Mammoth mine, for instance, portions of the ore are seen to be still clinging to the roof of the cave. Other caves which are now filled by stratified material are probably of similar though perhaps earlier origin, but have been filled by material washed in from above by downward-seeping waters. Hence, where a rich body of oxidized ore is found, its continuation should be looked for above as well as below, for it is evident that where during oxidation there has been a transposition of valuable metals, it would be downward rather than upward, and the distance to which they would be carried would bear some relation to the relative solubility of the sulphates of the respective metals.

Future explorations.—It may be assumed that in the future, as has been the case in the past, the ore bodies in the sedimentary rocks will be found to be richer and more extensive than those in the igneous rocks. Their secondary alteration, and consequent local enrichment, has been unusually extensive, and it may naturally be expected that when the entirely unaltered deposits are reached they will be found to be on the average less rich than those that have already been worked. Still, there is no definite evidence that the lower limit of secondary enrichment has been reached, and as the valuable ore bodies do not always outcrop at the surface, it may well be that present workings have not detected all that exist within the oxidized zone, and further explorations may, therefore, prove remunerative.

In depth there seems to be no valid reason to expect that the ore bodies will be found to be less extensive or less continuous than they have been in the ground already explored, at least within the probable limits of profitable exploitation.

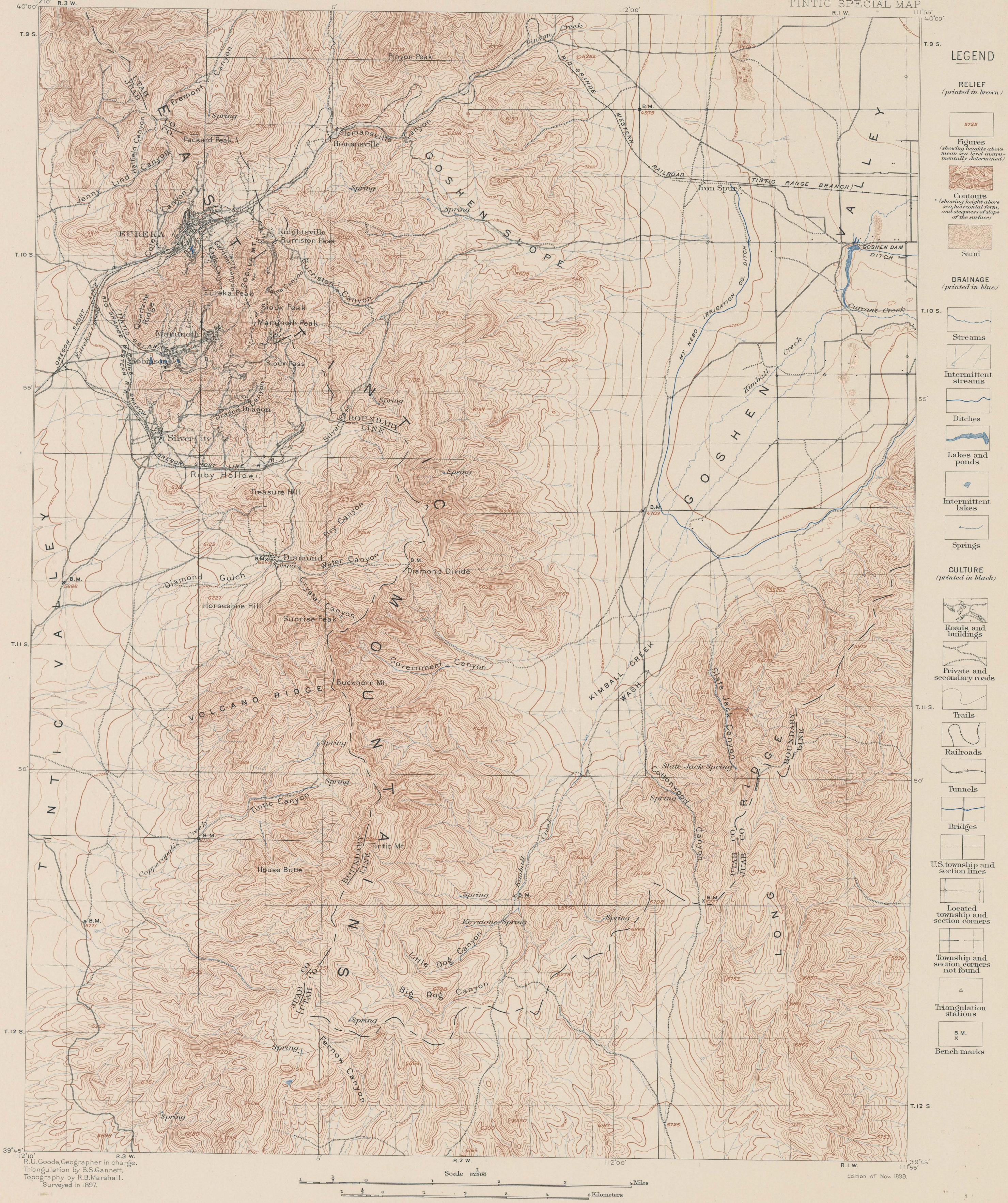
SAMUEL FRANKLIN EMMONS,
Geologist.

January, 1900.

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

TOPOGRAPHIC SHEET

UTAH
TINTIC SPECIAL MAP



R.U. Goode, Geographer in charge.
Triangulation by S.S. Gannett.
Topography by R.B. Marshall.
Surveyed in 1897.

Scale $\frac{1}{62500}$

1 ½ 0 1 2 3 4 Miles

1 ½ 0 1 2 3 4 5 Kilometers

Contour interval 50 feet.

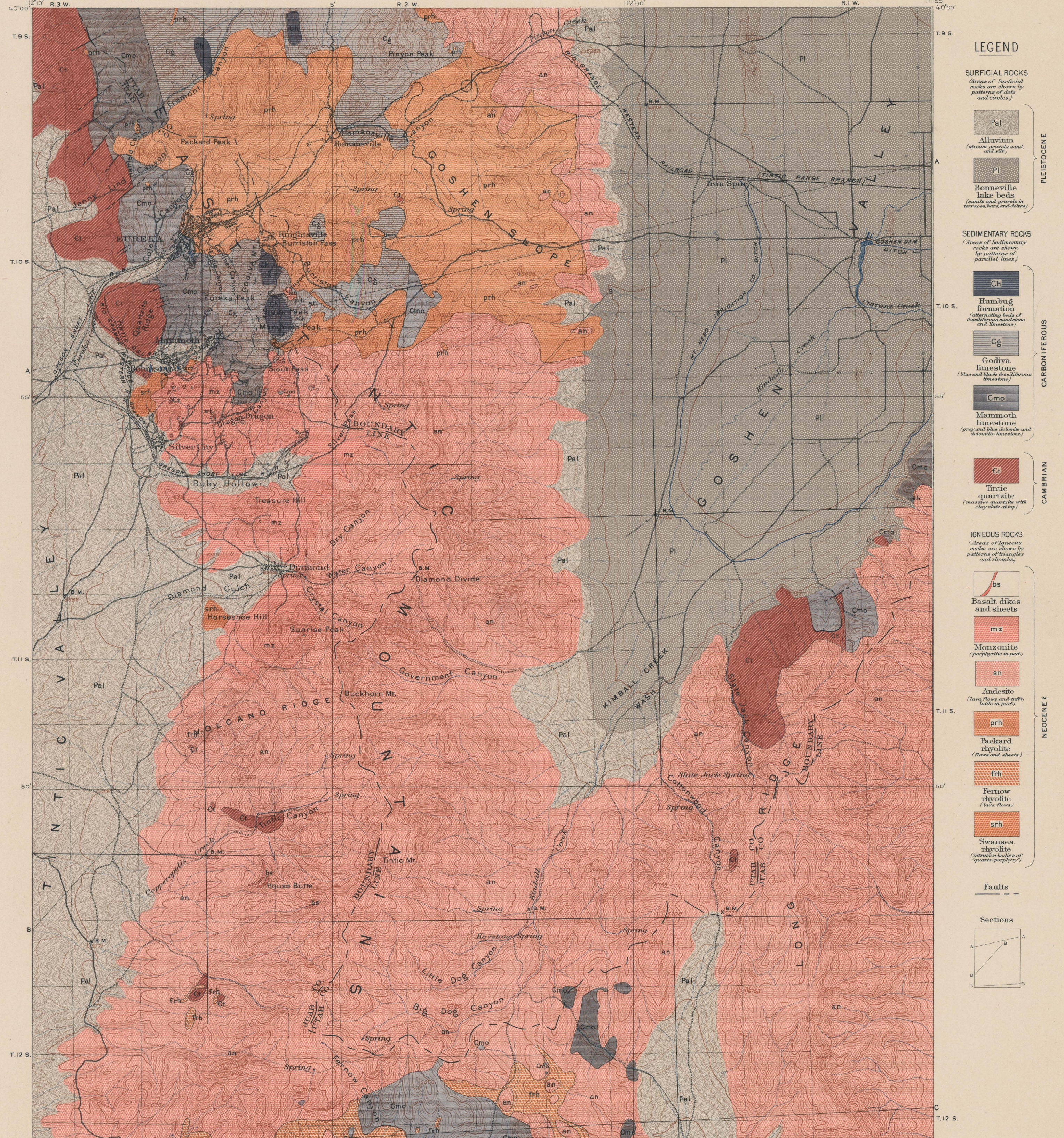
Datum is mean sea level.

Edition of Nov. 1899.

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

HISTORICAL GEOLOGY SHEET

UTAH
TINTIC SPECIAL MAP



R.U. Goode, Geographer in charge.
Triangulation by S.S. Gannett.
Topography by R.B. Marshall.
Surveyed in 1897.

Scale $\frac{1}{62500}$

1 ½ 0 1 2 3 4 Miles

1 ½ 0 1 2 3 4 5 Kilometers

Contour interval 50 feet.

Datum is mean sea level.

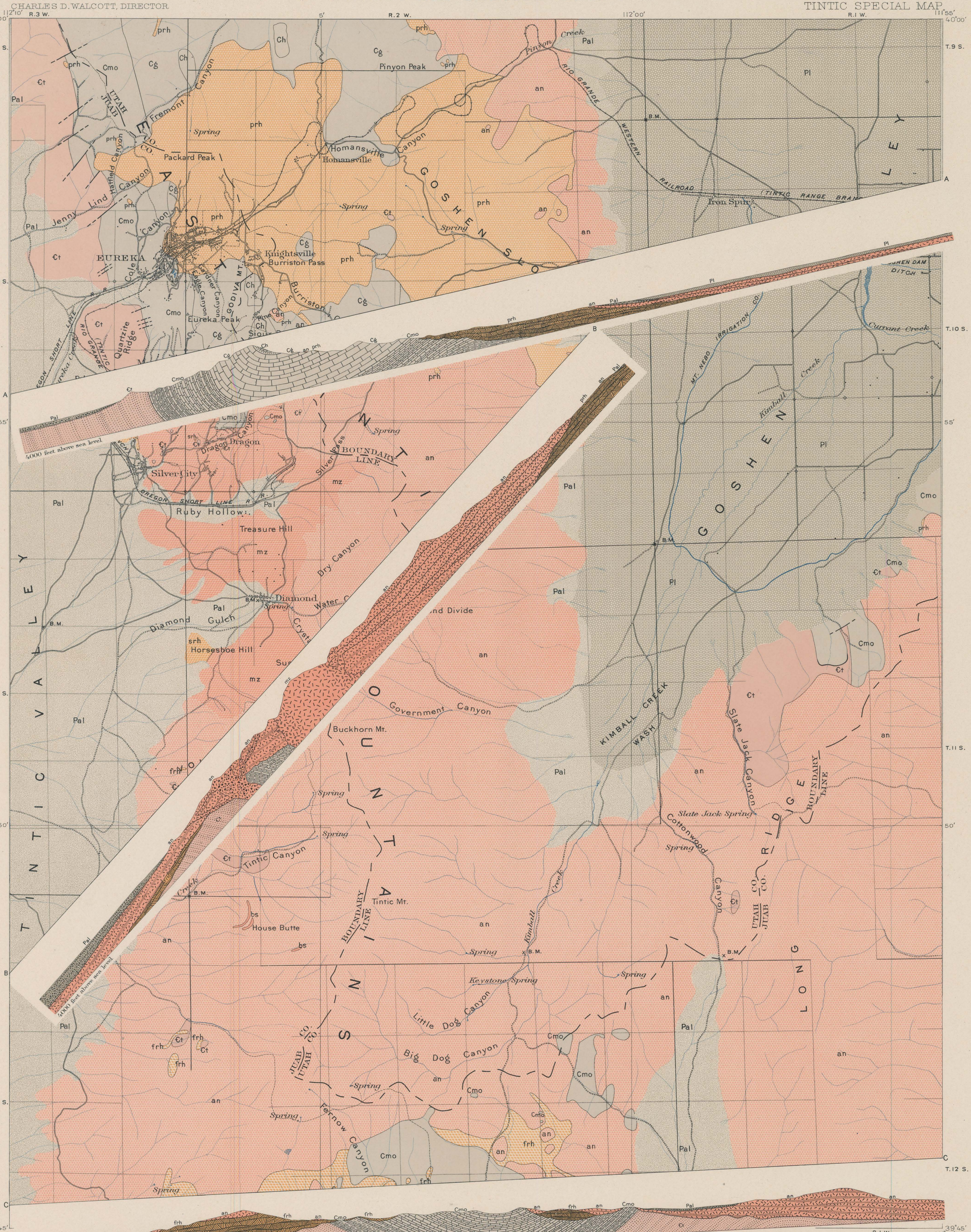
Edition of Jan. 1900.

S.F. Emmons, Geologist in charge.
Geology by George Warren Tower, Jr.
and George Otis Smith.
Surveyed in 1897.

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

STRUCTURE-SECTION SHEET

UTAH
TINTIC SPECIAL MAP



Scale $\frac{1}{62500}$

1 ½ 0 1 2 3 4 Miles

1 ½ 0 1 2 3 4 5 Kilometers

LEGEND

SURFICIAL ROCKS

SHEET SYMBOL / SECTION SYMBOL

PLEISTOCENE

Pal — Pal
Alluvium
(stream gravels, sand, and silt)

Pl — Pl
Bonneville lake beds
(sands and gravels in terraces, bars, and deltas)

SEDIMENTARY ROCKS

SHEET SYMBOL / SECTION SYMBOL

CARBONIFEROUS

Ch — Ch
Humbug formation
(alternating beds of fossiliferous sandstone and limestone)

Cg — Cg
Godiva limestone
(blue and black fossiliferous limestone)

Cmo — Cmo
Mammoth limestone
(gray and blue dolomite and dolomitic limestone)

CAMBRIAN

Ct — Ct
Tintic quartzite
(massive quartzite with clay slate at top)

IGNEOUS ROCKS

SHEET SYMBOL / SECTION SYMBOL

NEOCENE ?

bs
Basalt dikes and sheets

mz — mz
Monzonite
(porphyritic in part)

an — an
Andesite
(lava flows and tuffs; latite in part)

prh — prh
Packard rhyolite
(flows and sheets)

frh — frh
Fernow rhyolite
(lava flows)

srh
Swansea rhyolite
(intrusive bodies of "quartz-porphyry")

Faults

R.U.Goode, Geographer in charge.
Triangulation by S.S.Gannett.
Topography by R.B.Marshall.
Surveyed in 1897.

Edition of Jan. 1900.

S.F.Emmons, Geologist in charge.
Geology by George Warren Tower, Jr.
and George Otis Smith.
Surveyed in 1897.

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

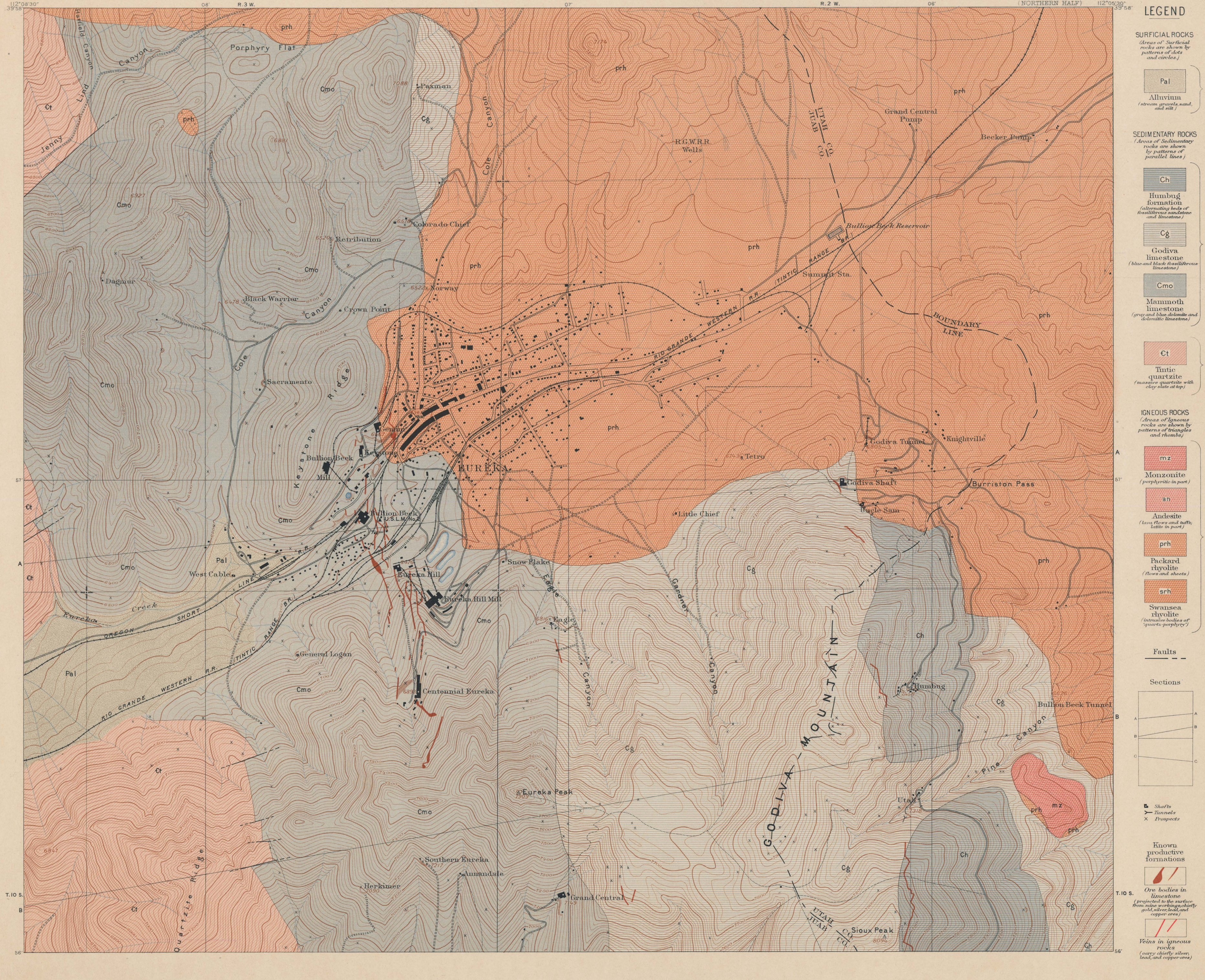
TOPOGRAPHIC SHEET

UTAH
TINTIC MINING MAP
(NORTHERN HALF)

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

ECONOMIC GEOLOGY SHEET

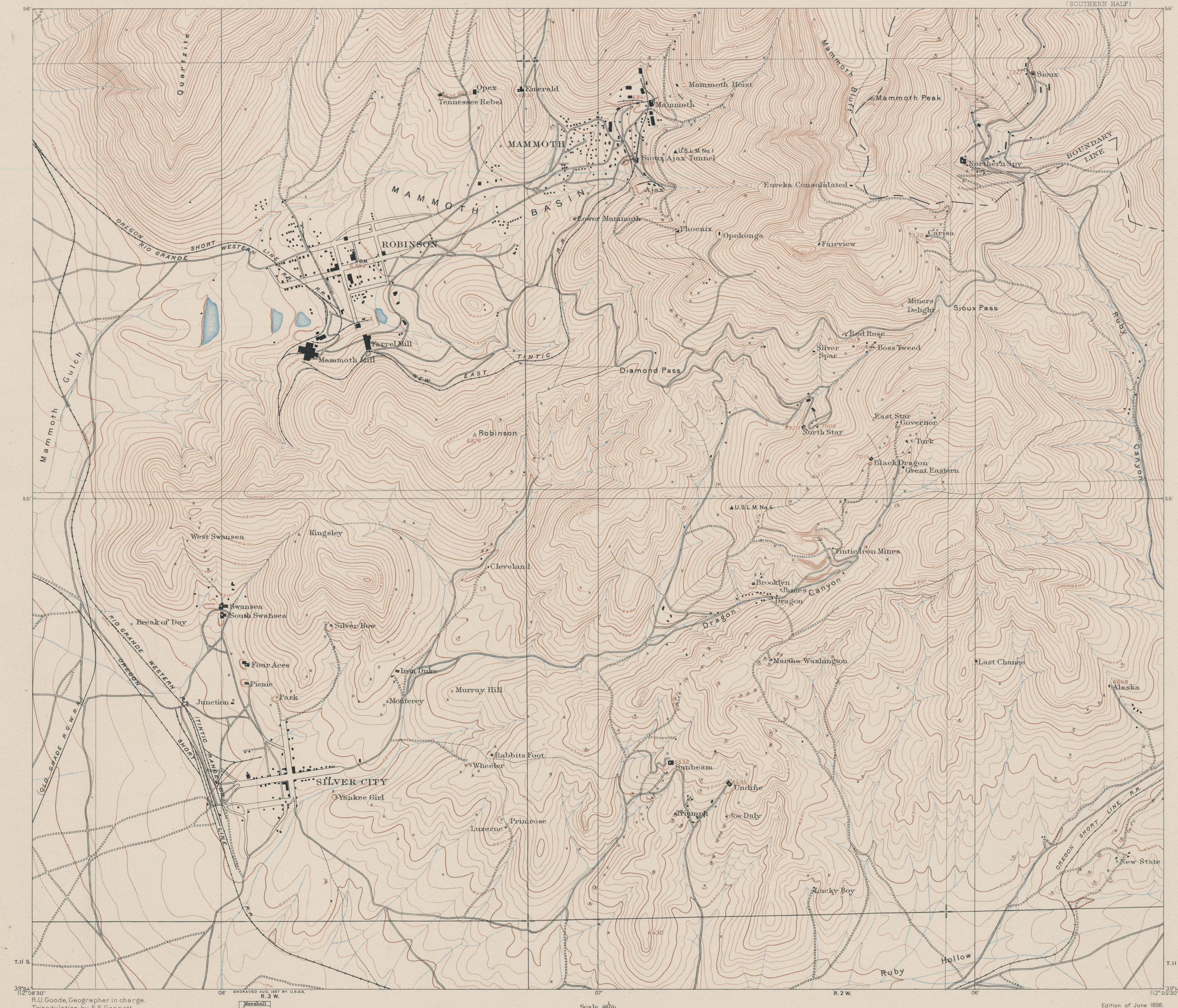
UTAH
TINTIC MINING MAP
(NORTHERN HALF)



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

TOPOGRAPHIC SHEET

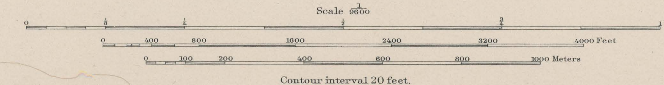
UTAH
TINTIC MINING MAP
(SOUTHERN HALF)



ENGRAVED AUG. 1897 BY U.S.G.S.

R.U. Goode, Geographer in charge.
Triangulation by S.S. Gannett.
Topography by W.T. Griswold and R.B. Marshall.
Revision by R.B. Marshall.
Surveyed in 1896-97.

Scale $\frac{1}{9600}$

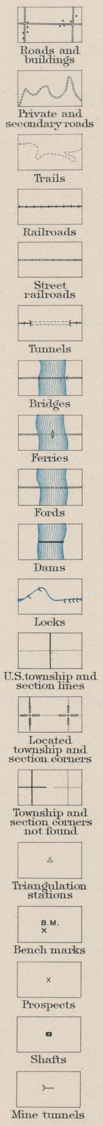


Contour interval 20 feet.
Datum is mean sea level,
based upon elevation of Oregon Short Line R.R. Station at Eureka taken as 6387 feet.

Edition of June 1898.

CONVENTIONAL SIGNS

CULTURE
(printed in black)

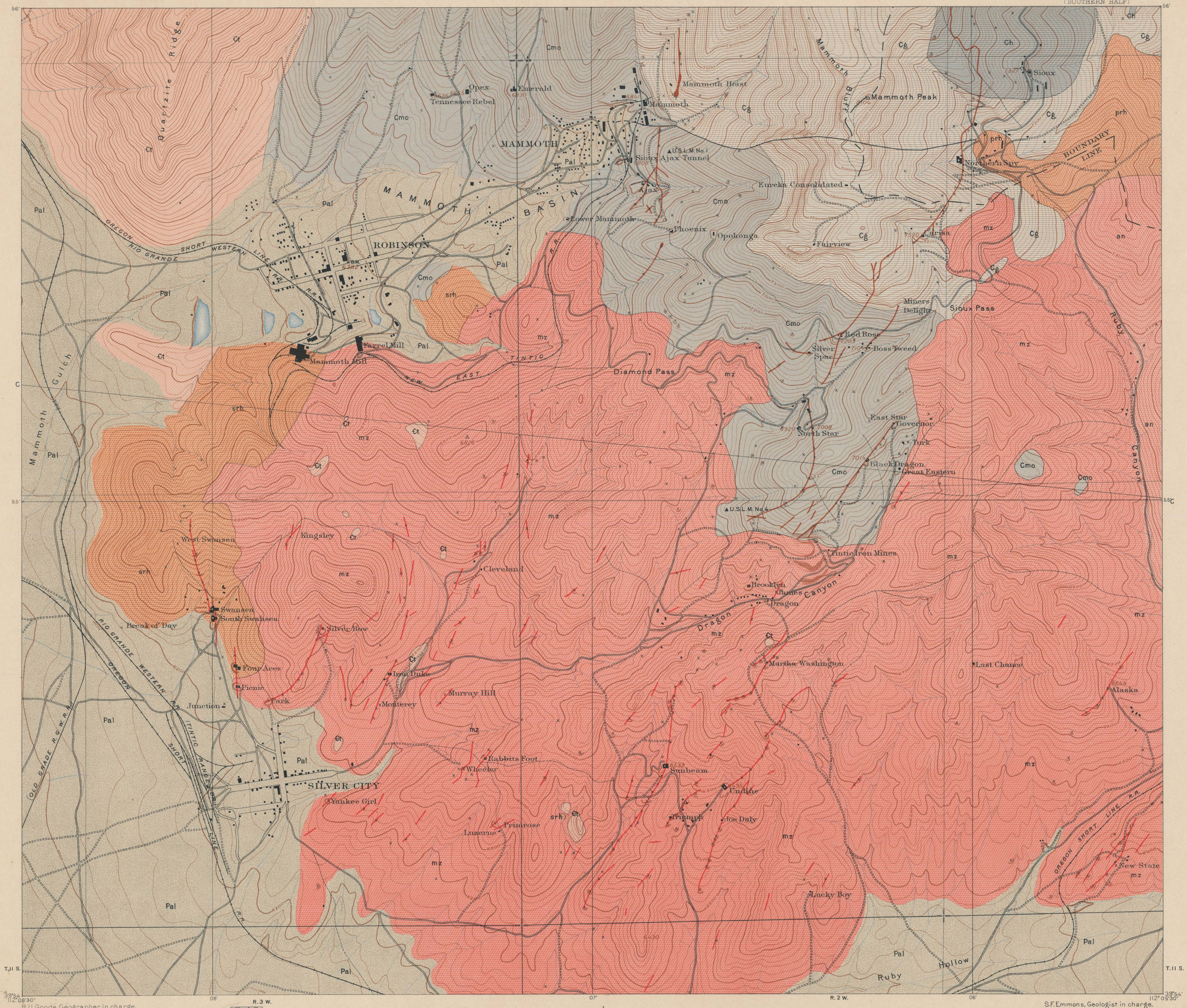


The above signs are in current use on the topographic maps. Variations from this usage appear in some maps of earlier dates.

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

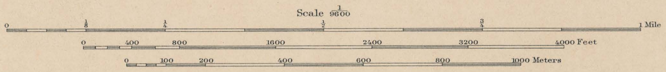
ECONOMIC GEOLOGY SHEET

UTAH
TINTIC MINING MAP
(SOUTHERN HALF)



R.U. Goode, Geographer in charge.
Triangulation by S.S. Gannett.
Topography by W.T. Griswold and R.B. Marshall.
Revision by R.B. Marshall.
Surveyed in 1896-97.

Scale $\frac{1}{9600}$



Contour interval 20 feet.
Datum is mean sea level,
based upon elevation of Oregon Short Line R.R. Station at Eureka taken as 6387 feet.
Edition of Jan. 1900.

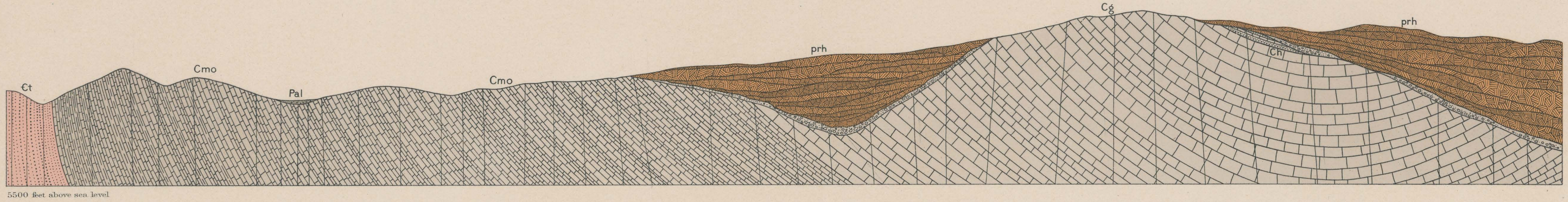
S.F. Emmons, Geologist in charge.
Geology by George Warren Tower, Jr.
and George Otis Smith.
Surveyed in 1897.

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

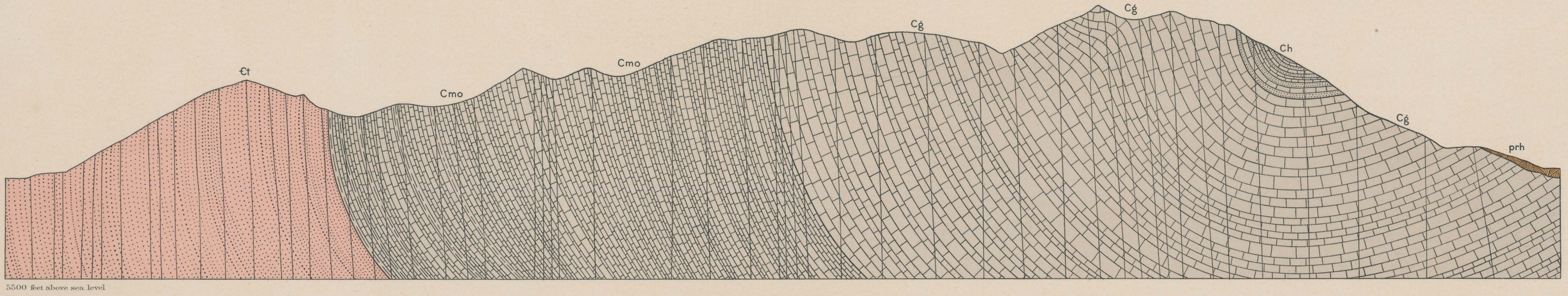
STRUCTURE-SECTION SHEET

UTAH
TINTIC MINING MAP

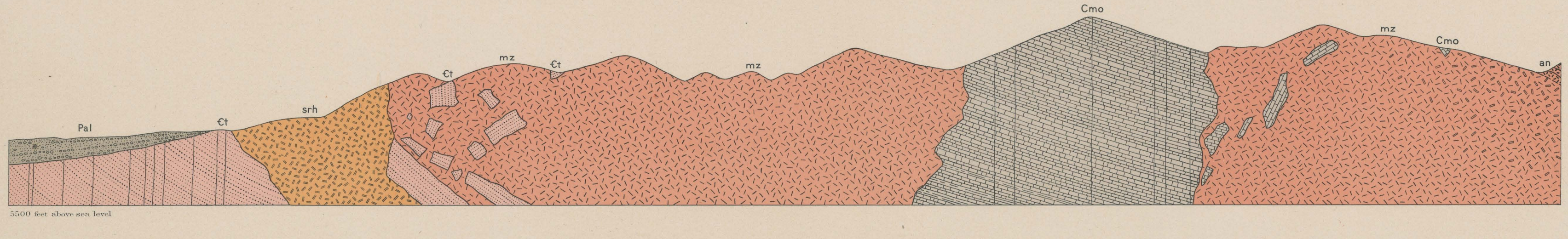
Section along A-A.



Section along B-B.



Section along C-C.



LEGEND

SURFICIAL ROCKS

PLEISTOCENE
- Pal Alluvium *(stream gravels, sand, and silt)*

SEDIMENTARY ROCKS

CARBONIFEROUS
- Ch Humbug formation *(alternating beds of fossiliferous sandstone and limestone)*
- Cg Godiva limestone *(blue and black fossiliferous limestone)*
- Cmo Mammoth limestone *(gray and blue dolomite and dolomitic limestone)*

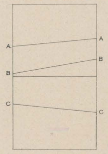
CAMBRIAN
- Ɛt Tintic quartzite *(massive quartzite with clay slate at top)*

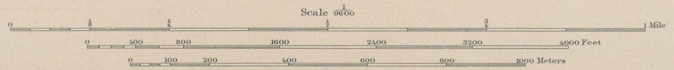
IGNEOUS ROCKS

NEOCENE ?
- mz Monzonite *(porphyritic in part)*
- an Andesite *(lava flows and tuffs; latite in part)*
- prh Packard rhyolite *(flows and sheets)*
- srh Swansea rhyolite *(intrusive bodies of "quartz-porphyry")*

‖ Fracture lines

Position of sections





Edition of Jan. 1900.

S.F. Emmons, Geologist in charge.
Geology by George Warren Tower, Jr.
and George Otis Smith.
Surveyed in 1897.

Information Concerning

Topographic and Geologic Maps and Folios

and Other Publications of the Geological Survey

can be had on application to

The Director, U. S. Geological Survey,

Washington, D. C.