DEPARTMENT OF THE INTERIOR

UNITED STATES GEOLOGICAL SURVEY

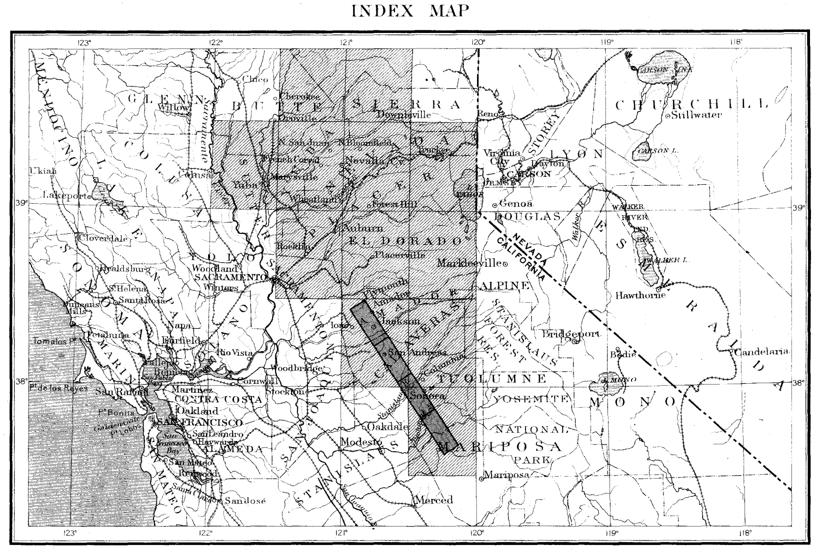
CHARLES D. WALCOTT, DIRECTOR

GEOLOGIC ATLAS OF THE UNITED STATES

MOTHER LODE DISTRICT FOLIO

CALIFORNIA

INDEX MAP



SCALE: 40 MILES = 1 INCH

AREA OF THE MOTHER LODE DISTRICT FOLIO

AREA OF OTHER PUBLISHED FOLIOS

LIST OF SHEETS

DESCRIPTION — TOPOGRAPHY — MINING CLAIMS — ECONOMIC GEOLOGY — STRUCTURE SECTIONS

FOLIO 63 — LIBRARY EDITION — MOTHER LODE DISTRICT

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.

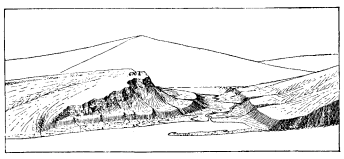
The Geological Survey is making a geologic map of the United States, which necessitates the preparation of a topographic base map. The two are being issued together in the form of an atlas, the parts of which are called folios. Each folio consists of a topographic base map and geologic maps of a small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



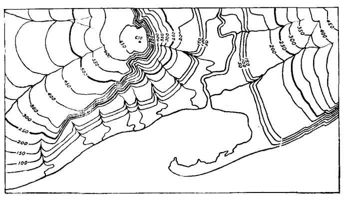


Fig. 1.—Ideal sketch and corresponding contour map.

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	Æ	Any colors.

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

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

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

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

THE VARIOUS GEOLOGIC SHEETS.

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

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

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

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

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

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

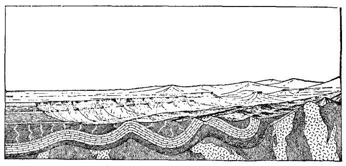


Fig. 2.—Sketch showing a vertical section in the front of the picture, with a landscape beyond.

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

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

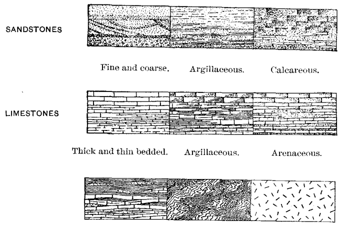


Fig. 3.—Symbols used to represent different kinds of rock.

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

CHARLES D. WALCOTT,
Director.

Revised June, 1897.

DESCRIPTION OF THE MOTHER LODE DISTRICT.

INTRODUCTION.

In the preparation of the text of the Mother Lode Special folio an attempt has been made to keep in mind the needs of mining men. **Purpose of the folio.** The chief interest of the district centers in the gold veins of the Mother Lode rather than in any of the more general problems of geology or petrology. The miner wishes to know what the so-called "Mother Lode" really is, how it was formed, in what rocks the veins occur, how these rocks originated, and how they came to occupy their present position, whether a vein in one kind of rock is likely to prove richer than in another, why some veins are rich and others are poor, and to have many other queries of like import answered. Some of these questions are still unanswerable, but wherever actual knowledge has been gained the aim has been to impart it in the clearest way and in the simplest terms consistent with accuracy.

The present folio is intended, first of all, for use in the field by those interested in this district. Consequently the different rock formations are described with rather more local detail than would be warranted by their general geological interest alone. As far as is practicable a distinction has been made between facts of general importance and those of local interest, the latter being printed in smaller type. The principal aim has been to provide a working geological guide for use on the ground.

The map forming part of this folio was originally intended to accompany a report on the gold veins of the district, by Dr. George F. Becker. This report has been unavoidably delayed. The reader is referred to it for a fuller description and a more complete theoretical discussion of the gold veins than is possible in a folio.

The field work upon which this folio is based was finished in 1898, and consequently mining developments of later date than this are not available for description or deduction.

GEOGRAPHY.

The district treated in the present folio comprises a comparatively narrow belt of country extending in a nearly northwest-southeast direction along the western foothill region **Position of district.** of the Sierra Nevada. The length of this area is very nearly 70 miles, and its width is 6½ miles. It lies mainly within the Jackson and Sonora quadrangles, but includes also the extreme southwest corner of the Big Trees and the extreme northeast corner of the Oakdale quadrangles. It contains the principal mining portions of Amador, Calaveras, and Tuolumne counties, and a smaller part of Mariposa County. The boundaries of the map are merely arbitrary lines, so chosen as to permit the presentation, in convenient form, of the topography and geology of the region immediately adjacent to the auriferous quartz veins of the Mother Lode system. The general trend of this system is northwesterly and southeasterly, corresponding to the trend of the more important structural features of this portion of the range, and accordingly the district mapped constitutes a long, narrow rectangle which the meridians of longitude and parallels of latitude cross at angles of nearly 45°.

Looked at in a broad and general way, without regard for the moment to the topographical forms which have resulted from the very active post-Neocene erosion, the middle **General character of initial topography.** western slope of the Sierra Nevada is a peneplain, a word in common geological use to indicate a surface which erosion has reduced almost to a plain. Its surface is of prevailingly low and gentle relief and was carved in pre-Neocene time upon the Juratrias and older rocks which constitute the Bed-rock complex ("Bed-rock series" of the earlier Gold Belt folios). Upon this worn-down surface were spread the nearly horizontal rocks of the Superjacent series. Such remnants of these rocks as exist in the region of the Mother Lode consist chiefly of gravels and volcanic conglomerates, breccias, and tuffs.

The strip of country included within the area mapped lies along the lower portion of this unfinished and inclined peneplain about one-third of the distance from the edge of **Relation of district to Sierra Nevada.** the Great Valley of California to the crest of the range. It is a portion of what is commonly known as the "foothills" of the Sierra Nevada, this somewhat vague term being applied to the hilly country bordering the alluvial floor of the Great Valley and rarely attaining an elevation of more than 2000 feet. Owing to the general evenness of this slope no definite line can be drawn between the "foothills" and the "high sierra." The Mother Lode district is hilly throughout, and in places mountainous, the present **Relief.** topography being the result of the energetic Pleistocene (Sierran) and recent erosion of the uplifted, rolling, Neocene surface. In the northwestern part of the area the hills are of moderate height. A few conspicuous eminences only, such as Jackson Butte and Golden Gate Hill, rise above 2000 feet, and the slopes, except close to the larger streams, are comparatively gentle. Toward the south the relief is more pronounced. The great area of meta-andesitic breccias and tuffs ("diabase and porphyrite" of earlier folios, "greenstone" of the miners), extending from the Tuolumne River down to the Merced River near Horseshoe Bend, has a particularly bold and rugged topography. The principal summits in this vicinity range from 2500 to 3000 feet in altitude, the ravines are deep and narrow, and the slopes steep.

As a whole, the Mother Lode district exhibits greater geological complexity than any other equal portion of the western slope of **Geological complexity.** the Sierra Nevada. Rocks of various kinds occur, often in small masses and in narrow belts or lenses. This disposition of material has in a measure controlled the erosive processes which have deeply etched and obscured the original Neocene surface upon which they began the work of the present cycle. A somewhat intricate geological structure, involving rocks which vary in resistance to decay and erosion, exposes many points of attack to disintegrating and eroding agents and is readily carved into a topography characterized by considerable detail and variety of form. The soft and thinly fissile rocks, such as the clay slates of the Mariposa formation or some varieties of the amphibolite-schists, are worn into ravines or small valleys, while the more massive and resistant rock masses, such as the meta-andesite breccias or the siliceous schists and quartzites of the Calaveras formation, are but slowly reduced in altitude, and persist above the general level as ridges, peaks, and knobs.

In spite of the linear arrangement of the closely compressed belts of schistose and slaty rocks in the Mother Lode district the drainage **Drainage.** is rather wanting in regularity, and shows noticeable lack of the parallelism which might be expected from the structure of the underlying rocks. The occurrence of a belt of clay slate, compressed between harder rocks, usually determines a small stream or ravine, such as Murphy Gulch south of Jackson, Black Gulch and Rich Gulch opening on the Mokelumne River, and several others. But the only cases in which streams of any length or importance **Subsequent streams.** have excavated courses along such belts of weak rocks are afforded by the South Fork of the Calaveras River and by Woods and Moccasin creeks, which empty into the Tuolumne River near Jacksonville. Such streams, classed by physiographers as *subsequent streams*, originated at a later date than the larger streams next to be described.

The prevailing course of the regional drainage, and that pursued by all of the larger streams, or rivers, as they are generally called, is southwesterly. These main streams, such as the Mokelumne, Stanislaus, Tuolumne, and Merced rivers, have their sources far to the eastward in the high sierra and on their way to the Great Valley flow across the strike of the steep-dipping schistose rocks of the Bed-rock complex As a rule, their courses are but slightly influenced by differences of hardness in the rocks across which they flow, although the Stanislaus west of Tuttletown is deflected southward for some distance in the soft Mariposa slates before entering the deep gorge through which it traverses the resistant volcanic masses of the Bear Mountains. These rivers **Consequent streams.** are *consequent streams*, i. e., their main direction is a consequence of the general south-westerly inclination given the western slope of the sierra at the close of the Neocene. Many smaller streams, although not heading so far back in the range, exhibit a similar consequent direction of flow. Such for example are Dry, Amador, Sutter, Jackson, Willow, and San Domingo creeks. Between these streams and those of subsequent character, such as Moccasin Creek, are countless small tributaries, too short or too irregular to be safely classified with either of the types mentioned. The Mokelumne, Stanislaus, Tuolumne, and Merced rivers are fed during the summer by melting snow and by springs far up in the crest region of the range, and carry considerable volumes of water even in dry seasons. The larger creeks also flow, as a rule, all the year round, although the flow is very small in summers of exceptional drought. Many of the smaller streams, particularly such as derive no part of their water from the forest zone of the higher slope, become entirely dry in summer.

The region is one of moderate rainfall and is, as a whole, below the altitude at which any important part of the precipitation falls **Climate.** as snow. The normal annual precipitation is 43 inches at the Kennedy mine, near Jackson, 33.42 inches at Jackson, 32.11 inches at Mokelumne Hill, and 32.04 inches at Drytown. The rains usually begin in October as showers, separated by days of delightfully clear weather free from the dust and heat of summer. The grass which springs up shortly after these first showers flourishes through winter and spring, but is generally brown and dry before the end of May. The summers are dry and hot. The temperature frequently rises above 110° during the daytime in July and August, but the nights are usually comfortably cool. The normal mean annual temperature at the town of Jackson is 55°. The normal annual range of the mean daily temperature is from 41.6° in January to 72° in July. Rain seldom falls between May and October, although rarely one of the thunder showers which are not infrequent higher up the sierra slope becomes sufficiently general to embrace the Mother Lode district.

In the character of its vegetation the Mother Lode district stands midway between the rolling, nearly treeless, grassy hills, which char- **Vegetation.** acterize the transition ground between the floor of the Great Valley and the sierra slope, and the real "timber belt" or forest zone of the sierra. The most characteristic trees are the scrawny digger pine (*Pinus sabiniana*) and a rather stunted variety of white oak (*Quercus douglasii*). These trees grow in thin groves or scattered over the grassy slopes, the oaks being particularly abundant on areas underlain by the older volcanic breccias and tuffs (meta-andesites). Some yellow pines (*Pinus ponderosa*) occur on the higher ridges along the eastern edge of the area, being an outlying fringe of the great forests of the timber belt, which consists largely of this pine. Many of the hills are thickly clothed with the so-called grease wood (*Adenostoma fasciculatum*), an evergreen shrub whose dark-green color is a pleasant contrast in summer with the brown of the parched grass, and with the pale gray-green foliage of the digger pine and stunted oaks. This shrub requires but little moisture and flourishes well on the poor soil derived from the clay slates. Various other shrubs, such as several species of wild lilac (*Ceanothus*), the Christmas berry or toyon (*Heteromeles arbutifolia*), and manzanita (*Arctostaphylos*) grow thickly over many of the slopes.

Mining is naturally the principal industry of the Mother Lode district, such agriculture as is practised being chiefly directed toward supplying the local demands of a mining population. Alluvial or bottom land is found only in a few relatively small patches. Grain and hay are grown, however, on the gentler slopes. **Industries.** The red soils resulting from the decay of the old volcanic rocks of the Bed-rock complex are well adapted for growing grapes and most of the common fruits, wherever irrigation can be resorted to during the summer. The lack of convenient railway transportation is, for the greater part of the district, an obstacle to supplying other than a local demand for agricultural products.

GENERAL GEOLOGY.

For a general account of the geological history of the whole Gold Belt, of which the present area is but a part, the reader is referred to the Description of the Gold Belt prefixed to the regular Gold Belt folios. Such portions of that history as apply to the limited area forming the subject of this folio will be, however, briefly summarized after the rocks themselves have been described. It is sufficient for the present to keep in mind the fact that the rocks of the Sierra Nevada fall naturally into two great **Two distinct groups of rocks.** groups: (1) An ancient complex of steep-dipping schistose rocks invaded by intrusive igneous masses—the Bed-rock complex (Bed-rock series of earlier folios), and (2) a very much younger group of flat-lying rocks, the Superjacent series, resting upon the upturned and eroded edges of the older complex. To the older group belong the slates, schists, and "granites"; to the younger, the auriferous gravels and Neocene lavas. The two groups are separated by a very conspicuous unconformity.

THE BED-ROCK COMPLEX.

The Bed-rock complex consists of both sedimentary and igneous rocks. The sedimentary rocks were originally beds of mud, sand, and gravel. They represent the mechanical waste of ancient land surfaces which were long ago deformed and have been carved by erosion into new forms or buried under later sediments and perhaps partly fused by invading, deep-seated igneous intrusions. The sediments derived from this old land mass remain, but the land **Sediments, volcanics, and intrusives.** mass itself has disappeared during the slow progress of geological change. Carried down by the streams, this material was spread by waves and currents over the sea bottom in nearly horizontal layers. There were periods of volcanic activity during the deposition of these early sediments. Igneous material, thrown out either as loose fragments or as volcanic mud, was also spread over the sea bottom, accompanied probably by flows of molten lava. These beds and the associated volcanic rocks have been folded and compressed chiefly in a northeast-southwest direction, and have been irregularly intruded by masses of igneous rocks, such as granite, diorite, and gabbro. The sediments have been hardened and changed by the long-continued action of underground solutions, the pressure and movement of folding, and the heat of igneous intrusions until they often bear no resemblance to their original condition. The Bed-rock complex is therefore made up of both sedimentary and igneous rocks. It is an intricate assemblage of many different kinds of rocks, differing considerably in age. It contains probably more than one sedimentary series, as that term is commonly used in geology. For these reasons it seems best to speak of it as a *complex*.

SEDIMENTARY ROCKS.

Calaveras formation.—The rocks making up this formation are the oldest in the area. They comprise conglomerates, sandstones, **Age.** slates, limestones, cherts, quartzites, and mica-schists, with smaller amounts of other schistose rocks. These various rocks are not distributed uniformly in the different Calaveras areas, but, as will be more fully shown later, certain areas or belts are to some extent characterized by rocks of certain kinds. The occurrence of limestone, usually in small lenticular masses, is a characteristic feature of the Calaveras formation, and as the only fossils thus far found in the series occur in these limestone lenses, the latter acquire special significance. The fossils are neither abundant nor varied, but indicate that the limestones are of Carboniferous age. Accordingly, that portion of the Calaveras formation in which the limestone lenses occur must also be Carboniferous. It is possible that the Calaveras formation, as mapped in the Gold Belt folios, may also include some still older rocks, but such doubtful portions lie almost wholly to the eastward of the area now under discussion and need not be considered here.

Source of sediments.

At many points in the Calaveras formation there are conglomerates containing pebbles of vein quartz, chert, slate, mica-schists, sandstone, and grit, indicating that the oldest sedimentary series in the district was derived from still more ancient and in part metamorphosed sediments. Practically nothing is known of the extent and form of the rock masses whose disintegration furnished these materials. To the eastward, the granitic rocks of the high sierra have invaded the Calaveras rocks and obliterated the basement upon which the latter were laid down, and from which their materials may have been in part derived. The eastern limit of the Calaveras formation is everywhere, as far as known, an eruptive contact of intrusive rocks. It is possible that the conglomerates may indicate one or more undiscovered unconformities within the assemblage of rocks which has been called the Calaveras formation.

Cherts.

Light-colored cherts are of frequent occurrence in some portions of the Calaveras formation and not infrequently form lenticular beds several feet in thickness. In some cases these cherts are closely associated with the limestones and may be due to siliceous replacement of calcareous material. But many of the larger and more persistent beds have a different origin. They were originally highly siliceous conglomerates in which the pebbles have been so flattened and welded by pressure as to make an almost homogeneous rock. The selective action of the weather on exposed surfaces reveals, however, the true structure. Such squeezed conglomerates can be well studied 2½ miles northwest of San Andreas, north of the North Fork of Calaveras River.

Tuffs.

Although made up chiefly of rocks that were originally siliceous and argillaceous sediments, the Calaveras formation, as outlined upon the map, contains some material of igneous origin which it was not practicable to map separately. Thus, lenticular bodies of old andesitic or basaltic tuffs are not infrequently intercalated in the clay slates or siliceous schists. Such tuffs are invariably altered. In some cases they have been indurated so as to form hard, ringing rocks of fine grain and massive aspect. But they are more often schistose, and have frequently been transformed into amphibolite-schist by recrystallization of the original minerals. Such altered igneous material has always a greenish tint, due to green hornblende, chlorite, and other greenish minerals, and weathers to a rusty soil.

Gradation between tuffs and sediments.

In certain portions of the area the argillaceous slaty and schistose rocks of the Calaveras formation pass so insensibly into amphibolite-schists derived from ancient tuffs that no sharp boundary can be established between the two rocks, even with the best of exposures. The intimacy of the relation between the two classes of rocks may be revealed in somewhat different ways. A belt of siliceous or argillaceous schists and slates, when followed along the strike, may be found passing irregularly into a belt of amphibolite-schist. Good exposures across such a transition zone will sometimes show an intimate interlamination of clay slates or phyllites with slaty amphibolite-schist, together with considerable slaty material that is neither typical green amphibolite-schist nor an ordinary slate derived from residual non-volcanic sediments. In other instances bands of amphibolite-schist, too narrow to map individually, alternate with bands of slate or siliceous schist and it becomes necessary to generalize and map the area either as Calaveras or as amphibolite-schist, according as one or the other rock appears to predominate. In still other cases, facies (varieties) may occur which, while not typical amphibolite-schists, yet show by the development of green hornblende and other minerals that they originally contained a certain proportion of igneous detritus in addition to the ordinary sands and clays of nontuffaceous sediments. As a general rule such rocks have been mapped with the amphibolite-schist series.

Folding and compression.

In common with all the sedimentary rocks of the Bed-rock complex, the Calaveras rocks have been closely folded and strongly compressed, and the resulting isoclinal folds have been deeply truncated by erosion. As a result of this folding and compression, a more or less perfect schistose or slaty structure is everywhere characteristic of the rocks of this formation. In many cases the planes of schistosity do not depart sensibly from the bedding planes of the original sediments. Frequently, however, the bedding planes have been obliterated and schistosity is the only structure recognizable. Cases in which schistosity cuts across the bedding are exceedingly uncommon. Such structure would occur in the crests of anticlines, but erosion has long since carried away these portions of the folds. Folds are never of infinite length, but every anticline must ultimately die out at the ends, and in a system of folds will be succeeded by a syncline in the line of its prolongation. Wherever an anticline pitches downward and passes into a syncline, the bedding planes will cross at varying angles the planes of schistosity developed by the forces producing the general folding. Consequently cleavage and schistosity across the bedding planes will be developed. Such cases of transverse cleavage or schistosity have been but rarely observed in the Calaveras rocks. Their absence, however, is taken rather as an indication of the intense pressure concerned in the compression of the folds and in the production of schistosity, than as pointing to the original absence of pitching and complex folds.

Relation of cleavage to bedding.

Exposures of Calaveras rocks show planes of cleavage or schistosity having a prevailing northwest-southeast strike and a dip of 70°–80° NE. Locally, however, both direction of strike and amount and direction of dip may vary widely, even when such irregularities are not traceable to the disturbing influence of igneous intrusions. Such variations in the dip and strike of the cleavage planes indicate that the rocks undergoing deformation did not behave as a homogeneous material. Lack of homogeneity caused local resolution of the main stresses into minor stresses acting along lines making considerable angles with those of the major forces.

The eastern area of Calaveras rocks.

In describing the rocks of the Calaveras formation in greater detail it will be convenient to consider first the large and very irregular area of these rocks which lies chiefly to the eastward of the Mother Lode veins and occupies many hundred square miles of the higher mountain slopes, beyond the northeast boundary of the area mapped. Attention will afterwards be directed to the smaller, not necessarily entirely detached areas, which are more closely associated with the Mother Lode vein system or lie to the west of that zone.

Slaty biotite-schists.

The rocks composing this large eastern mass of the Calaveras formation are fairly uniform in character, and consist for the most part of dark, fine-grained, slaty mica-schists such as, in common with the clay slates of the Mariposa formation, are usually termed "black slates" by the miners. These rocks, however, seldom exhibit the very even and characteristic cleavage of the unaltered clay slates, and close inspection of a fresh specimen generally reveals minute mica scales lying in a finely crystalline groundmass. They are, indeed, very fine-grained crystalline schists, consisting of abundant quartz, biotite, and black dust-like particles (carbon ?), which latter give to these schists their dark color. Typical schists of the character described may be seen along the main road between Priest and Big Oak Flat and at many other points. Some thinly fissile slates do occur, particularly in the western portion of the mass, but even these slates are frequently micaceous and plainly represent much more altered sediments than do the ordinary Mariposa slates. Not infrequently the siliceous biotitic schists are intimately associated with streaks and lenses of amphibolitic schist, which weather to a rusty red soil. Such bodies of schist may in some cases represent altered dikes, but have probably in most instances been derived from basic tuffs, deposited contemporaneously with the argillaceous and siliceous sediments. These lenses, when of sufficient size, are shown upon the map, but many of them are too small, or too poorly defined, to make it practicable to indicate them on a map of this scale. Such amphibolites occur just north of Jackson Butte, east of Dogtown, about the reservoir 3 miles northeast of Angels Camp, north of Carson Flat, and at many other localities.

Limestone.

The limestone bodies in this main area of Calaveras rocks are noteworthy both on account of their extent and because of their frequently exceedingly irregular outlines. Both these facts are, however, only partially illustrated within the limits of the present map. The three patches of limestone shown near the edge of the map (section 3), one at Natural Bridge, one northeast of Tuttletown, and one a little north of east from Jamestown, are merely portions of a single very irregular area, as may be seen by placing together the geological maps of the Sonora and Big Trees quadrangles. The other large mass of limestone, northeast of Algerine, curves around a large intrusive granitic mass, and, as shown in the Sonora folio, divides into several branches toward the southeast. The limestone of these easterly areas is generally recrystallized and may properly be termed marble. No fossils have been found in these masses within the limits of the area mapped, but they are in the line of strike of a similar group of limestone areas in the Yosemite quadrangle in which foraminifera (*Fusulina*) are known to occur.

The western belt of Calaveras rocks.

The Calaveras rocks comprising the broad belt west of Drytown differ considerably from those so characteristic of the area just considered. They are more heterogeneous and less altered. Clay slates and conglomerates predominate, while small lenses of limestone are often very numerous. The limestone is apparently not limited to any single geological horizon, but its small masses occur irregularly distributed through the belt. No fossils were detected in these limestone lenses within the area mapped, but Mr. H. W. Turner has reported fossils from several points in this same Calaveras belt, within the Jackson quadrangle. These fossils were referred by Mr. C. D. Walcott to the Carboniferous, and are as follows: *Fusulina cylindrica*, *Zaphrentis* (?), *Lithostrotion* (?), and crinoid stems.

Fossils in Calaveras formation.

There are also some beds of light-colored chert in this area, particularly in Grapevine Gulch, but they constitute only a small fraction of the whole. The slates of this western belt of the Calaveras formation frequently resemble very closely the clay slates of the Mariposa beds, but they lack as a rule the very homogeneous character and even cleavage of the latter rocks. Compared with the slaty schists of the eastern area of Calaveras, they are much less altered. They have not undergone recrystallization, and such metamorphism as they have been subjected to has been chiefly of a mechanical nature and is recorded in the evidences of compression and the development of cleavage.

Peculiar conglomerate.

A conglomerate of somewhat peculiar character alternates with the beds of slate and almost or quite equals the latter in amount. Typical exposures of this conglomerate occur on Sutter Creek, about 2½ miles below the town of the same name. The beds vary in coarseness from fine grits to moderately coarse conglomerates. Pebbles of quartz and chert predominate, but slate, fine mica-schist, grits, and a fine-grained rusty sandstone were also noted. The pressure involved in folding these beds into their present nearly vertical position has squeezed the pebbles, many of which were originally flat or schistose, and has rendered the conglomerate roughly schistose, or flaky. At this point the conglomerate contains little or no volcanic material. But at very many places, particularly in the western portion of the area, conglomerates occur in which pebbles and fragments of meta-andesite and related volcanic rocks occur so abundantly as to render it extremely difficult to discriminate consistently between the non-volcanic conglomerate of the Calaveras formation and the meta-andesitic tuffs and breccias All gradations may indeed be found, ranging from a conglomerate, such as that described on Sutter Creek, through various tuffaceous facies to a more or less angular volcanic breccia. Such a transition can be well studied 4 miles southwest of the town of Sutter Creek, near the edge of the area mapped, and also south and west of the hill called Sugarloaf This intimate relation between the sedimentary Calaveras formation and the ancient clastic andesites (or meta-andesites) will be reverted to when the latter rocks are described in their turn.

Dikes in Calaveras formation.

Dikes of light-colored porphyry are numerous, especially along the eastern border of the belt. The larger of these have been mapped and will be described with the igneous rocks.

A much smaller but interesting strip of Calaveras rocks begins at a point about 1¼ miles east of Amador and, passing just east of Jackson, extends down to within less than a mile of the Mokelumne River. This belt consists of the slaty schists (or micaceous slates) characteristic of so large a portion of the Calaveras formation, together with cherty beds and at least one rather thin lens of limestone No fossils were found in this strip, and its assignment to the Calaveras formation is made purely on lithological grounds. The presence of limestone, the frequent occurrence of cherty beds, and the micaceous character of the slates are features not found in any of the areas of known Mariposa rocks. Just southeast of Jackson, however, it is difficult to draw the line sharply between the Calaveras and Mariposa slates. It is certain that the unaltered clay slates of the Mariposa formation are wholly cut off, just west of Scottsville, by micaceous slates, cherts, and limestone of thoroughly Calaveras aspect, and having a line of strike different from that of the belt of Mariposa slates underlying the town of Jackson.

Unconformity between Calaveras and Mariposa formations.

The relation just shown between the Calaveras and Mariposa slates carries with it a strong suggestion of unconformity between the two formations. While not in itself conclusive, this case is in line with several other occurrences which indicate the same unconformity.

The several tongues of Calaveras schists lying southeast of Middle Bar do not call for detailed description. Some difficulty was experienced in drawing the boundary between the Calaveras and Mariposa formations southward from Middle Bar. This, however, is not at all uncommon whenever the two formations are directly in contact. It was encountered in delineating the tongue of Calaveras cherts, siliceous conglomerates, and micaceous slates which, passing 1½ miles west of San Andreas, extends northward across the Calaveras River toward Golden Gate Hill. It was also met with on Cherokee Creek, 4 miles west of Angels Camp.

Lenses of tuff in Calaveras formation.

An important area of Calaveras rocks begins about 4 miles northwest of Angels Camp and extends across the Stanislaus River, past French Flat, Rawhide, Jamestown, and Quartz Mountain to a point a little beyond Sullivan Creek. West of Angels Camp this area consists of clay slates, micaceous slates, slaty mica-schists, squeezed conglomerates, and sandstones, with some chert and limestone. There are also occasional thin lenses of altered basic tuffs, or amphibolite-schist. At Robinsons Ferry, on the Mokelumne River, the micaceous slates and schistose conglomerates are connected with the main mass of Calaveras rocks to the eastward. For at least half a mile down the river from Robinson Ferry the Calaveras is represented by a squeezed, flaky, schistose conglomerate. The pebbles of this conglomerate consist largely of chert, quartz, and slate, with apparently a little material of igneous origin. Just southeast of the ferry a tongue of the Calaveras conglomerate extends into the Tuttletown area of amphibolite-schist. This conglomerate is accompanied by slaty mica-schists and is itself much more altered than that exposed along the river. It has become a mica-schist in which, however, the original pebbles still show on weathered surfaces. The same belt of Calaveras rocks is also well exposed along the open bottom of Mormon Creek, where the rocks consist of slates, usually somewhat micaceous, squeezed conglomerates, and cherts, with limestone lenses. The latter contain round crinoid stems, indicating that they are of Paleozoic age. Near French Flat, hard, "blocky," dark slates make up the mass of the belt. Small lenses of limestone are exceedingly abundant northwest of French Flat, and the formation contains also some bands of conglomerate, and streaks of basic tuff and talc-schist, usually not large enough to map.

Relation of Calaveras rocks to Mother Lode veins near Rawhide.

This belt of Calaveras rocks is of unusual interest from the fact that it swings directly across the line of the Mother Lode, between Tuttletown and Rawhide, and from lying to the west of the main veins, comes to lie on their eastern, or hanging wall, side. This feature will be again referred to in the discussion of the Mother Lode veins. Northeast of Rawhide, and northwest of Table Mountain, this area of Calaveras is again directly connected with the main eastern area of these rocks. It is difficult to account for the irregularity of the contact between the dark, slaty schists of the Calaveras and the amphibolite-schist on both sides of Table Mountain northeast of Rawhide without supposing that the original folding of the rocks in this region was of a decidedly complex character.

Gradation into amphibolite-schist.

In the vicinity of Jamestown, particularly to the south and west, the ordinary Calaveras slates grade frequently into amphibolite-schists in such a manner that the absolutely accurate separation of the two rocks upon the map is impossible. The amphibolite-schist in this case was originally a somewhat basic tuff or volcanic ash, which was deposited at the same time that the clayey sediments from which the slates were formed were being laid down upon the sea bottom. In such a case not only would there sometimes be an actual mingling of materials, but there would also be a certain amount of overlapping of the layers of clay and tuff, due to changes in supply and shifting of currents. With the subsequent folding, compression, and truncation of the beds, there has resulted the intricate relationship exposed on the surface to-day.

Character of rocks.

Mariposa formation.—The rocks making up the Mariposa formation consist chiefly of very cleavable and homogeneous clay slates, with locally varying amounts of sandstone and conglomerate. Slates, sandstones, and conglomerates sometimes alternate in well-defined beds, but very frequently the last two form irregular lenses in the slates and have but little linear persistency. In the vast majority of cases the original bedding planes and the planes of cleavage are parallel, so that the strike and dip of the slaty cleavage corresponds also to the strike and dip of the beds. Speaking broadly, the rocks of the Mariposa formation constitute a remarkably persistent narrow belt that, with the exception of a sweep to the southwestward, southwest of Fourth Crossing, which carries it for a distance outside the limits of the area mapped, traverses the district from end to end. Looked at more closely, this belt is seen to be sometimes very irregular. It branches or divides into two or more belts and at one point, possibly at two, its continuity is interrupted. As in the case of the Calaveras formation, northwest-southeast strikes and steep northeast dips greatly predominate; but both dip and strike are subject to wide local variation.

Fossils.

The Mariposa rocks as a whole contain very few organic remains. Sufficient fossils have been found, however, at various points to establish the Jurassic age of the main belt shown on the maps (see Jackson and Sonora folios). In the case of smaller isolated belts or detached lenses, the lithological character is as a rule the chief factor which determines whether such small areas shall be mapped as Mariposa or Calaveras. Thus it is always possible, though scarcely probable, that the future discovery of fossil remains within any small area of slates may change the designation given that area upon this map.

Near the town of Plymouth the belt of Mariposa rocks has an average width of about a mile, and consists almost wholly of homogeneous clay slates with very uniform strike and dip. Some conglomerate occurs near the western edge of the belt and continues down past New Chicago and New Philadelphia almost to Amador. The conglomerate occurs usually in two or three beds interbedded with clay slates and schistose sandstones. The pebbles consist of quartz, chert, slate, and schist, and as a general rule are not noticeably distorted by pressure. Between the conglomerate and the meta-andesite area to the west there is usually a narrow strip of clay slate.

Near Amador the main belt of slates contracts to a width of about one-eighth of a mile. For a distance of a mile, however, northeast of the town, the Mariposa clay slates occur in close association with the tuffaceous and more coarsely clastic rocks of the meta-andesitic volcanic series. From Bunker Hill to a point just east of the town of Sutter Creek the exposures show that the basic tuffs and clayey sediments from which the Mariposa slates were formed were deposited practically contemporaneously, and under similar conditions. Sharp contacts sometimes occur, but often slate and tuff grade into each other, or alternate in such thin beds that it is impossible to separately delineate them on a map of this scale. Where gradation occurs the fact is indicated by omitting the line separating the colors of the two rocks upon the map. Where the alternating streaks are too small to map the structure is somewhat generalized.

Just southeast of the town of Jackson, the main belt of Mariposa slates is cut off, as already described, by supposedly Calaveras rocks. A quarter of a mile southwest of the town, however, is a very narrow strip of Mariposa slate which is noteworthy in containing the important Kennedy and Argonaut mines. There is at present no means of telling whether this narrow strip really connects to the northward with the broader band of slates lying east of it, as it passes beneath andesitic breccia east of Martell. They probably do unite however. Toward the south this narrow ribbon of slate continues without break to the Mokelumne River. Before reaching the river, however, it joins the spur-like projection of slates extending up Black Gulch and so merges into the wider slate band of Rich Gulch, in which is located the Gwin mine. Thus the Kennedy, Argonaut, Alma, Anita, Amador No. 2, Mammoth, and Gwin mines, all occur in the same remarkably narrow and continuous strip of black slate. Miners are inclined to draw from such a fact deductions not warranted by a comprehensive study of the Mother Lode district. At present attention is directed simply to the distribution of the slate, the discussion of its bearing upon mining problems being reserved.

The main belt of Mariposa slates, after being cut off west of Scottsville for an interval of about a quarter of a mile, reappears and crosses the Mokelumne at Middle Bar with a width of half a mile. It passes beneath the andesites of Golden Gate Hill and finally wedges out about a mile south of San Andreas. Clay slates predominate in the greater portion of this area, but southwest of San Andreas the slates are largely replaced by conglomerate. This conglomerate varies from a grit or very coarse sandstone to a conglomerate with pebbles 4 or 5 inches in diameter. The latter consist of quartz, chert, schist, slate, and probably a little volcanic material, and usually show the result of intense pressure Near the contact with the Calaveras on the east is a breccia composed chiefly of fragments of chert and quartz and apparently derived from the adjoining chert beds of the Calaveras. A similar conglomerate occurs 1½ miles southwest of San Andreas in the belt of Mariposa rocks which is shown just on the edge of the map.

Southwest of Angels Camp this western belt of Mariposa rocks again swings within the area mapped, with a width of 1½ miles. It occupies the southwestern border of the district as a broad band which extends across the Stanislaus and beneath the lava of Table Mountain. Slates, sandstones, and conglomerates, with lenses of basic tuff, are the prevailing rocks of this area, the slates largely dominating all other rocks in amount.

Exposures on Woods Creek.

On Woods Creek the belt of slate contracts somewhat in width, and toward the southeast is well defined and much simpler in outline than farther north. The bed of Woods Creek and the ravines opening into it afford the best exposures in the whole area for studying the structure and character of the Mariposa beds in detail. As usual, slates predominate, but there are numerous beds of sandstone and conglomerate. The sandstone is often somewhat schistose, the schistosity being usually parallel to the bedding planes and to the cleavage of the slates. The beds of conglomerate are not always persistent, but often pass irregularly into sandstone and slate. On Sullivan Creek, for five-eighths of a mile from its mouth, there is exposed an excellent section of the Mariposa slates, with but little sandstone or conglomerate. Along much of this section it is apparent that the principal slaty cleavage makes a considerable angle with the planes of original bedding. This is a very uncommon occurrence in these rocks, as far as known.

Intrusive serpentine.

The Mariposa rocks along Moccasin Creek call for no particular description. They resemble in general character those composing part of the same belt on Woods Creek. Four miles northwest of Coulterville the belt is cut in two by an intrusive mass of serpentine a mile in width. West and south of Coulterville, the Mariposa rocks consist chiefly of clay slate, with uniform dip and strike, constituting a belt about a mile in width. Conglomerates and sandstones, however, are not present. A coarse conglomerate with pebbles 5 to 6 inches in diameter occurs on the ridge west of Whites Gulch, while along the Merced River is much hard, fine-grained, thin-bedded sandstone. This main bed of Mariposa rocks extends far beyond the limits of the area mapped, and in Hell Hollow, just south of the Merced River, were found the fossils which first determined its age as Jurassic.

IGNEOUS ROCKS.

Under this heading are included not only such members of the Bed-rock complex as preserve the original structure and mineralogical constitution of eruptive rocks, but also those which have been directly derived from igneous masses through various processes of change (metamorphism). Between these two classes of rock no perfectly sharp line can be drawn in the Mother Lode region. In this district it is exceedingly uncommon to find in any portion of the Bed-rock complex an igneous rock mass which microscopic study does not show to have undergone considerable alteration. The ancient volcanic tuffs (meta-andesites) have been rendered roughly schistose, and contain secondary amphibole, chlorite, epidote, and calcite. Even the freshest-looking of the granular intrusive rocks are generally full of secondary minerals and frequently pass into schistose peripheral modifications. The feldspars are commonly altered to aggregates of epidote (or zoisite), white mica, and more obscure secondary products. Since Tertiary time the streams have in some places cut down into these older igneous rocks to a depth of over 1000 feet without exposing unaltered rock, whereas the Tertiary lavas are, as a rule, fresh and unchanged. Thus this general alteration of the older igneous rocks is not a mere superficial phenomenon, but is profound in its character, and is a result of the stresses to which the region has been subjected, and of the passage of solutions through the rocks similar in character to those which deposited the Mother Lode veins. Such widespread alteration of the country rock is not peculiar to the Mother Lode district. It is common in many mining districts, and is a natural accompaniment of the conditions which produce large and productive veins.

Mother Lode.

Deep-seated alteration.

Amphibolite.—Rocks embraced under this head occur in both massive and schistose forms. They have been derived from igneous rocks, of basic or intermediate chemical composition, by processes of metamorphism, through which the augite and plagioclase of the original rock have been obliterated, and green amphibole, biotite, chlorite, white mica (sericite), feldspar, epidote, zoisite, calcite, quartz, and other minerals have been formed by secondary crystallization. The characteristic mineral of such metamorphosed rocks is a bright-green amphibole and the universal greenish tint of the amphibolites is, in almost all cases, due to the presence of abundant slender prisms of this mineral.

Component minerals.

Typical facies.

The typical schistose amphibolite, or amphibolite-schist, (the so-called "gray-slate" of the miners) shows, as a rule, no trace of the minerals or structure characteristic of the igneous rock from which the schist was derived. Occasionally, however, remnants of the original structure remain, and not infrequently areas of amphibolite grade into masses of comparatively little altered igneous rock.

Origin of amphibolites.

The amphibolites were, in part, derived from massive igneous rocks. But by far the greater proportion of them, and especially the thoroughly schistose or slaty facies (varieties), were derived from tuffs and volcanic breccias originally similar to the Neocene andesitic tuffs and breccias which cap many of the present ridges.

Occurrence.

Practically all of the amphibolite-schist of the district is comprised in a very irregular and frequently interrupted belt lying northeast of the main strip of Mariposa rocks. Sometimes the amphibolite-schists separate the Mariposa from the Calaveras areas, but in many places they are so irregularly involved with the Calaveras schists as to indicate that the two rocks have been folded and compressed together and that they are essentially of the same age. The amphibolite-schists are readily distinguished from adjacent Calaveras schists or slates of sedimentary origin by their invariable greenish tint when fresh or only slightly weathered, and by the red color of the soil resulting from their decay. The Calaveras rocks, containing as a rule but little iron, generally give rise to a gray soil.

Description of areas in detail.

The strip of amphibolite-schist which enters the area mapped northeast of Plymouth and extends southeastward to a point about 2½ miles south of Mokelumne Hill is composed almost wholly of the greenish, thoroughly schistose rock, of somewhat fibrous texture, which represents the most widespread and characteristic facies of the amphibolite-schists. From place to place the rock varies in degree of schistosity, in coarseness or fineness of grain, in hardness, and in the relative proportions of the minerals already enumerated. The hornblende is sometimes porphyritically developed, as in an epidote-rich facies forming a narrow band just west of the Mokelumne Hill meta-diorite area, and well exposed in the canyon of the Mokelumne, about a mile above the bridge at Middle Bar.

East of Golden Gate Hill there is a break of about 2 miles in the amphibolite-schist belt. At San Andreas, however, the green schists have again attained a width of over a mile. Between San Andreas and Angels Camp the amphibolite-schists occupy an extensive and very irregular area. A broad tongue of them extends to the eastward up San Antonio and Indian creeks, and another large mass extends into the main area of Calaveras rocks northeast of Angels Camp. The rock composing these tongues is, as a rule, recrystallized and thoroughly schistose. The strike of the green schists is generally conformable with that of the enclosing Calaveras rocks. The schistosity near contacts is always approximately parallel to the latter. These relations, taken in connection with the varying strikes and dips of this portion of the area, indicate originally complex folding. Southeast of Lower Calaveritas and northeast of the narrow strip of Calaveras rocks which extends southeastward toward Bunker Hill the fine-grained amphibolite-schists are associated with numerous narrow streaks of black slate. A portion of these schists appears, moreover, to have been derived from material consisting only in part of igneous detritus. This portion of the area, like that already referred to near Jamestown, probably preserves the record of a time when comparatively fine volcanic tuffs and argillaceous mud were mingled together on the sea bottom, or deposited thereon in overlapping layers.

As already stated, the rocks comprising the large eastern area of the Calaveras formation are as a whole more altered than those of the western area. A similar statement may be made with reference to the amphibolite-schists As a rule, the thoroughly recrystallized and typically schistose facies occur in the middle or on the eastern side of the irregular amphibolite belt. Along the western edge, however, southwest of San Andreas and west and south of Fourth Crossing the amphibolite-schists pass into less altered facies which still retain more or less of the original igneous minerals and structure. Such facies not uncommonly show porphyritic hornblendes and might be taken for some of the porphyritic meta-andesites presently to be described. The microscope shows, however, that the groundmass of the rock has undergone recrystallization and has the character of an amphibolite-schist.

Typical fine-grained amphibolite-schist underlies and surrounds the town of Angels Camp, and extends down to Carson Hill and the Stanislaus River. On the south side of Carson Hill and in Indian Gulch the amphibolite-schists are bleached and light-colored in superficial exposures and separable with some difficulty from the Calaveras rocks lying to the west of them. Tuttletown lies in an area of the green schists, which, while evidently a portion of the main belt of these rocks, has yet been completely isolated by the complex folding. A rather coarsely crystalline fibrous facies showing abundant remnants of augite crystals is common in this area. The large mass of amphibolite-schist folded in with the Calaveras rocks northeast of Jamestown has been derived from igneous rocks of more than one kind. Much of it, particularly just east and southeast of Jamestown, is fine-grained, with slaty cleavage, and was probably originally a fine tuff. About 1½ miles northeast of Jamestown, on the road to Columbia much of the schist has been derived from a volcanic breccia. Although the original minerals have given place to new mineralogical combinations, yet the grosser structure of the originally fragmental rock still remains. In the central part of the area a finely fissile schist occurs which is composed chiefly of quartz and a pale-green sericite. This schist may be well seen on the road between Jamestown and Sonora, about a mile southwest of the latter town. It was evidently derived from a much less basic rock than most of the amphibolitic series, and is not, strictly speaking, an amphibolite-schist. On the eastern edge of this area, south of Sonora, the amphibolite-schists comprise unusually hard and rather massive rocks, which appear to be altered diorites. They are completely recrystallized and when examined under the microscope differ from the more common facies of the schists in the larger size of the green hornblende crystals. There is the usual granular mosaic of quartz, feldspar, and calcite. Epidote is frequently very abundant, and in some portions of the mass a paragonite-like mica and small garnets are plentiful. The maximum width of this mass of interesting schists where crossed by Sullivan Creek is about half a mile.

Between Jamestown and Stent fine-grained, slaty amphibolite-schists are intricately dovetailed or interleaved with the Calaveras slates. These amphibolites were at one time igneous tuffs deposited over the sea bottom synchronously with the Calaveras muds and afterwards folded up together with the latter.

Southward from a line connecting Stent and Algerine fine-grained facies of imperfect schistosity are closely associated with the more common amphibolite-schists. These have in some cases been derived from tuffs of various kinds, from volcanic breccias, and perhaps in some cases from massive lavas. Thus considerable variety in texture and color may be observed in the amphibolites west of the Algerine meta-diorite area; but they manifestly are all part of the main amphibolite-schist belt, and grade into more nearly typical facies toward Jacksonville.

On Rattlesnake and Jackass creeks, south of Priest, the fine-grained altered peripheral portions of the meta-diorite can not be sharply separated in the field from the amphibolites to the west, which are here much restricted in width, owing to the intrusion of the diorite.

Southeastward from Jackass Creek the belt of amphibolite broadens toward Coulterville. Although consisting in the main of recrystallized, more or less schistose amphibolite, this portion of the area contains other fine-grained green rocks which are very much altered and uralitized basic tuffs or eruptives. The recrystallization in such rocks has not been so complete as in the typical amphibolite-schists. Although composed almost wholly of secondary minerals, they are turbid and obscurely crystallized when examined under the microscope. The typical amphibolites, on the other hand, have been clarified by thorough recrystallization, and their component minerals are fresh and clear.

Relation to meta-andesites.

Southeast of Coulterville the amphibolite-schists pass, without definite contact, into the meta-andesite area of Buckhorn Flat. This area is to be regarded as a residual mass which has escaped metamorphism into amphibolite-schist.

Quartz-muscovite-schist. — This is a rather coarsely crystalline schistose rock consisting of quartz, calcite, and muscovite, with abundant small cubes of pyrite. It occurs as a lenticular mass inclosed within the Calaveras slaty schists about 4 miles a little north of east from San Andreas. On account of its striking difference from the ordinary schists of the Calaveras formation and its probable derivation from a granitic dike, the mass has been indicated on the geological map.

Definition.

Meta-andesite. — The name *meta-andesite* is applied to andesites which have undergone distinct alterations, but which still retain in large part their original structure and mineralogical composition. In the earlier Gold Belt folios such rocks have been termed *porphyrites* (a name in common use by German petrographers for andesites of pre-Tertiary age), *diabase-porphyrites* and *diabase-tuffs*. The meta-andesites of the Mother Lode district, as will be shown, are chiefly fragmental or clastic rocks. They are old volcanic tuffs and breccias. The original character of an ancient altered tuff is not always exactly determinable, so that it is not to be understood that every variety or facies of igneous rock within the areas mapped as meta-andesite was originally an andesite. It is very probable that basaltic tuffs were laid down in subordinate amount with those of andesitic character. Basaltic flows and sheets appear also to have played a part, although a small one, in building up these great igneous accumulations. None of the material, however, so far as is known, contained olivine, and the series as a whole presents andesitic rather than basaltic characters. These older volcanic rocks must at one time have been very similar to the andesitic tuffs and breccias of Neocene age which cap so many of the present ridges of the Sierra Nevada. But they were probably on the whole more basic, and among themselves more variable, than the Tertiary lavas.

Clastic origin.

Occurrence.

The meta-andesites occupy extensive areas, not only within the district, but also just outside its southwest border. They occur in broad bands parallel with the general trend of the sedimentary series and in smaller lenticular masses in the Calaveras and Mariposa sediments. As a general rule, bands of meta-andesite are less persistent, and more variable in width, than the belts of clay slates with which they are associated. The clastic origin of the great bulk of the meta-andesites is evident merely from a careful study of the shape of the areas, and of their relation to the belts of clay slate and conglomerate.

Green color.

Some shade of grayish-green is characteristic of all the meta-andesites. The green color, however, is not original, but is due to the alteration of the rock, and to the development of such secondary green minerals as chlorite and uralitic amphibole. These rocks were once gray, like the Neocene andesites. A very common facies of the meta-andesite is a breccia composed of fragments up to 3 or 4 inches in diameter embedded in a finer matrix. The fragments usually show small porphyritic crystals of augite, or more rarely, of hornblende. As a rule the breccia has become so thoroughly indurated that its clastic structure is apparent only on weathered surfaces or under the microscope. All gradations can be found, from the coarse breccias down to the finest tuffs, and in nearly every case the induration has been such as to convert a once loose mass of fragments into a hard, tough rock. A rude schistosity is of very frequent occurrence, particularly in the finer tuffs, and is probably in most cases coincident with, and partly determined by a rough original bedding. The surface exposures of such schistose facies show the usual steep northeasterly dip common in the sedimentary series, and project from the soil in long, parallel, comb-like outcrops — the so-called "gravestone slates." The meta-andesitic breccias and tuffs are more resistant as a whole than the neighboring Mariposa or Calaveras sediments, and form some of the boldest mountain masses of the foothill region. They decompose to a red soil which supports a growth of oaks and grass, and is much more fertile than the gray soil derived from the clay slates of the Mariposa or Calaveras formations.

Induration.

Outcrops.

Description of areas in detail.

One of the largest areas of meta-andesite occurring within the limits of the area mapped is the broad belt lying west of Jackson, Sutter Creek, Amador, and Plymouth, and separating the main eastern belt of Mariposa slates from the western belt of Calaveras rocks. This area (the same one that farther south includes the elevations of Mount Joaquin and Bear Mountain) is made up chiefly of volcanic breccia of the kind described, with some finer tuffs, and a very subordinate amount of massive meta-andesite. The latter appears to have been erupted as surface flows, generally contemporaneous with the tuffs and breccias. Along the western edge of the area occur conglomeratic facies, which, by the addition of non-volcanic pebbles, often pass into the siliceous conglomerates of the Calaveras formation. On the northeast the contact between the meta-andesite and the Mariposa clay slates is usually sharply enough defined. Yet the occurrence within the meta-andesitic area of long, thin lenses of dark clay slates, (often too small to map), which resemble in every way the known Mariposa slates, and the projecting tongue of Mariposa slates and sandstones extending northward from the Gwin mine up Black Gulch, all point to a close age relationship between the Mariposa rocks and at least a portion of the meta-andesites.

A second regular belt of meta-andesitic rocks lies just northeast of Jackson, Sutter Creek, and Amador. This is composed in large part of rather fine tuff which is so intimately associated with the Mariposa slates east of Amador as to show that clayey silts, which were ultimately to form the slates, were laid down simultaneously with the tuffs.

Numerous lenses of meta-andesitic tuffs and breccias occur in the broad belt of Calaveras rocks in the northwest corner of the district. Not uncommonly these lenses are composed of waterworn pebbles of volcanic rock. It is difficult or impossible in many cases to discriminate sharply between the purely igneous conglomerate and the ordinary siliceous conglomerates of the Calaveras. The two grade into each other, and were deposited at the same time and under like conditions. These relations are well seen south and west of Sugarloaf.

Age of meta-andesites.

It will be seen from the foregoing that the meta-andesites can be assigned neither wholly to Calaveras nor wholly to Mariposa times, but that their eruption took place both in the Carboniferous and in the Juratrias period. No certain criterion has yet been discovered for discriminating between the meta-andesites of these two periods. It seems probable that the broad belt of tuffs and breccias lying west of Jackson, Sutter Creek, Amador, and Plymouth may consist in part of rocks erupted in Carboniferous time, and in part of those erupted in Juratrias time.

The belt of meta-andesitic tuff which separates the Mariposa and Calaveras rocks west of Carson Hill consists of a hard, fine-grained rock containing occasional fragments of black shale. A rather fine indurated tuff is the prevailing rock of this area, although some portions of it may possibly be massive. Toward the northwest the strip becomes narrow, and passes into an area of amphibolite-schist.

On the extreme edge of the area mapped, southwest of Angels Camp, a narrow area of meta-andesite is shown. This is merely the eastern edge of the Bear Mountain mass and a portion of the broad belt west of Jackson already described. It is largely a breccia, made up of fragments of porphyritic meta-andesite.

Between the Stanislaus River and Table Mountain, several lenticular areas of meta-andesitic breccia and tuff occur in the Mariposa slates. They are more numerous than shown, as many of them are mere narrow streaks, too small to map. The large lens crossing Mormon Creek is composed in part of rather coarse breccia, and in part of finer tuffs. There is also a massive porphyritic facies exposed where the creek cuts through the lens, which occurs in what are apparently thin contemporaneous flows interbedded with the tuffs. This rock is full of chlorite and other secondary minerals, but appears to have consisted of labradorite-feldspar and augite, with probably some glass, and may be a meta-basalt rather than a meta-andesite. The second considerable area, on Bear Creek, is composed chiefly of tuff and breccia, often alternating with thin streaks of clay slate. The mass contains also some altered andesitic or basaltic (meta-andesites or meta-basalts) dikes, which also cut the adjoining Mariposa slates.

The largest area of meta-andesitic rocks in the district extends from the vicinity of Chinese Camp across the Tuolumne River, and thence southeastward, constituting a region of much ruggedness, in which Moccasin Peak, the Penon Blanco Ridge, and the Horseshoe Bend and Hunter Valley mountains are the dominant features of topographic relief. Indurated breccias of the character already described occur with monotonous persistency throughout the area. Almost equally abundant are finer indurated tuffs, with frequent rough schistosity, and sometimes distinct bedding.

West of Penon Blanco, near the contact with the Mariposa slates, the meta-andesite contains irregular grains of quartz, visible with the unaided eye. West of Coulterville, on the road to Horseshoe Bend, a small lens of Mariposa slate is shown within the meta-andesite area. The exposures along this portion of the road afford good examples of the close relationship frequently observed between tuffs and clay slates. The two rocks are so intimately interbedded in the neighborhood of this slate lens that neither rock can be mapped separately.

Fine tuffs and cherts.

Fine, even-bedded tuffs which pass on the west into banded cherty rocks of chocolate, red, white, and green colors occur on the southwest slope of Hunter Valley Mountains. These cherts are mapped separately. Similar cherts occur about 5 miles west of Coulterville.

Several small areas of meta-andesite breccias and tuffs, including also a little massive meta-andesite or meta-diabase, occur in the neighborhood of Quartz and Stent. These, however, call for no special description. They are altered greenish rocks, easily distinguished from the serpentine and Calaveras rocks with which they are here associated.

A considerable mass of meta-andesite breccia and tuff occupies the southeast corner of the district, forming Buckhorn Flat. This is probably a residual portion of a much larger area of similar rocks of which the greater part have been transformed into amphibolites.

Meta-hornblende-andesite (*"Hornblende-porphyrite" of earlier folios*).—Meta-andesitic rocks in which the principal dark mineral is hornblende instead of augite, are not common in well-defined masses. One area of such rock occurs on Moccasin Creek not far from its mouth, while another lies just southwest of Moccasin Peak. Both areas are composed largely, if not wholly, of indurated breccia. Hornblendic facies also occur at various other places within the meta-andesite areas, but do not occur in sufficient quantity, or with sufficiently definite boundaries to make it practicable to map them separately.

Meta-diabase.—By *meta-diabase* is understood an altered rock of the gabbro-basalt family possessing a holocrystalline ophitic structure. Such rocks are composed essentially of basic plagioclase (labradorite or anorthite) and augite, with sometimes olivine. The prefix *meta-* indicates that these minerals may be largely altered to secondary minerals.

The meta-diabases of the Mother Lode district are closely associated with the meta-andesites and belong to the same general period (or periods) of eruption. They appear to have been flows, or intrusive masses or sheets.

Chinese Camp area.

The area about Chinese Camp consists of a medium-grained rock composed of an ophitic aggregate of plagioclase, augite, and biotite. The rock is much altered and contains abundant secondary hornblende, chlorite, quartz, and carbonates, as well as a serpentinous alternation product which may possibly represent former olivine. It was not found practicable to separate this massive intrusive meta-diabase by a definite line from the meta-andesitic breccias to the southeast.

On the right bank of the Tuolumne River, just above Jacksonville, is a small area of fine-grained meta-diabase which was either a surface flow or a sheet intruded at no great depth beneath the then existing surface.

The third area which has been separately mapped as meta-diabase lies in the extreme southern corner of the area mapped, in Hunter Valley. This is a fine-grained green rock, which the microscope shows to be an altered diabase. It was probably a lava flow.

Granodiorite.—The name granodiorite has been used in the earlier Gold Belt folios to designate a granular igneous rock mineralogically and chemically intermediate between the granites and the diorites, and as later defined, very close to quartz-monzonite. Rocks of this general character occupy wide areas in the higher portions of the range, but they are not characteristic of the Mother Lode district, as will be presently shown. The name has been retained, however, for the area which just enters the district about 2 miles northeast of Algerine, because it is directly connected with the main intrusive masses of the higher sierra. As only a small peripheral portion of the mass appears in the present map, it was deemed best not to revise, on so slender a basis, the name by which the mass as a whole has been indicated in the Sonora folio. As indicated in that folio this whole mass is exceedingly variable in character and passes into dioritic and even gabbroitic facies.

Big Oak Flat area.

Quartz-diorite.—The village of Big Oak Flat lies near the middle of a basin-like hollow floored with granitic rock and surrounded by hills of Calaveras schists. This granite-like rock has not undergone deep-seated alteration to anything like the extent of the originally similar rocks described under the next heading as *meta-diorites*. It is a somewhat altered quartz-diorite, consisting of feldspar, quartz, hornblende, and biotite. It is traversed by numerous quartz veins, and its upper portion, which is weathered to a crumbling mass 30 or 40 feet deep, was formerly extensively hydraulicked for gold. Such rotten rock in place has been called *saprolite*.

Quartz-diorite also occurs at Parrott Ferry, but as it is here merely a small part of a larger area of more altered rock, meta-diorite, it is described under the next head.

Meta-diorite (*chiefly altered quartz-diorites*).—The meta-diorites of the Mother Lode district are usually medium-grained granular rocks, commonly termed "granite" by the miners. They occur in areas of variable size and irregular form and are in all cases intrusive into, and therefore younger than the other rocks of the Bed-rock complex which surround them. These masses are in all probability genetically related to the great quartz diorite, granodiorite, and granite areas of the higher sierra slope, and belong to the same general period of intrusion. In the Jackson and Sonora folios this relationship was expressed by mapping all of these areas as "granodiorite," although it was realized at that time that as a whole they are far more closely related to the diorites than to the granites. In the present folio it has been thought best to map them as meta-diorites, or altered diorites, reserving for the text the explanation that they are probably somewhat basic facies of the same magma which has solidified to the eastward as typical granodiorite. The intrusive character of the meta-diorite is sufficiently shown by the very irregular outline of the areas, together with evident local disturbance and contact metomorphism of the invaded rocks. As a rule the intruded masses grow larger with depth, and if the surface of the country were more deeply eroded than at present, the existing areas of meta-diorite would be much larger, and in all probability some masses would be uncovered which are now still concealed.

Relation to granodiorite areas.

Algerine area.

The area of meta-diorite near Algerine is particularly instructive in illustrating the points just referred to. Its outline is curiously irregular. This is largely due to the fact that erosion has only partly stripped the Calaveras schists from an intruded mass which grows rapidly larger with increasing depth. The contact of the meta-diorite with the siliceous schists of the Calaveras is well exposed at several places. One of the best of these is half a mile northeast of Algerine, where slaty schists of the Calaveras formation can be seen striking generally into the meta-dioritic area, but becoming curled and twisted as the contact is approached and so indurated as to resemble compact quartzites or hornstones (hornfels). The Calaveras rocks were evidently softened near the contact, and were kneaded like putty. Ragged fragments and wisps of the schists are included in the intrusive rock, and the intrusion was accompanied, at least to some extent, by a fusion and assimilation of the invaded schists by the molten magma. Contact phenomena may also be well studied on Rancheria Creek, 2 miles east of Drytown.

Various facies in one mass.

Most large bodies of intrusive igneous rocks are composed of rocks of more than one kind. There is usually a facies or variety which makes up the bulk of the mass and constitutes its central portion. But associated with this facies, particularly around the edges of an area of eruptive rock, there often occur, in minor amounts, rocks which are very different from the main type of the mass and yet which really belong to it—grade into it in fact. Such variations of the principal type are commonly called *peripheral facies*. The great masses of granodiorite to the eastward present many such local variations ranging from granite to gabbro. The smaller, and usually isolated masses of the meta-diorite which occur in the Mother Lode region may perhaps be regarded as somewhat basic facies of the great granodiorite intrusion. But they are in themselves by no means perfectly uniform or homogeneous. Each mass has its local variations from the type of rock which may be regarded as characteristic of the mass as a whole. Thus the meta-diorite frequently becomes very rich in hornblende near contacts, so much so that the rock sometimes becomes almost a pure hornblendite. Disregarding, however, for the present such minor facies, the meta-diorite areas are all composed of very similar rock. This is an evenly granular rock of moderate coarseness, which is popularly termed "granite." The unaided eye usually recognizes hornblende, feldspar, and sometimes quartz as the most prominent constituents. The rocks are thus, strictly speaking, meta-quartz-diorites. The feldspar has almost invariably the dull-white appearance which denotes alteration. Biotite, or black mica, sometimes occurs, but is often lacking, and is always subordinate in amount to the hornblende. Examined in thin sections under the microscope the rock usually shows abundant green hornblende in rather irregular areas, and usually some biotite. Occasionally the outlines of the original feldspar areas are preserved, but more often the hornblende is surrounded by a somewhat confusedly crystallized groundmass composed of epidote, secondary feldspar, quartz, and muscovite. In such a rock it is often difficult to determine which minerals are primary and which are secondary. In many cases it is believed that accessory titanite and apatite, and possibly some of the hornblende, are all that remain of the original igneous constituents of the rock. It is thus seen that the meta-diorites, even where not superficially decomposed, are much altered from their original dioritic character. They have undergone deep-seated alteration throughout the Mother Lode region, and it is probable that this alteration is connected with the rock-fissuring and the passage of solutions through the country rock during the period of ore deposition. In part also the alteration is due to mechanical stresses. It is evident through a close examination of the meta-dioritic masses that the forces which have produced the prevailing schistosity of the Bed-rock sediments continued to be operative subsequent to the dioritic intrusions, or perhaps recurred, for the latter are frequently schistose, particularly near their peripheries or where they send out relatively narrow tongues into the surrounding schists. Excellent examples of this may be seen northeast of Amador, north of Butte City, three-quarters of a mile northeast of Middle Bar on the Mokelumne River, and on Jackass Creek, a tributary to Moccasin Creek, in Tuolumne County. In some of these cases it is difficult to distinguish the schistose hornblendic facies of the meta-diorite from the ordinary amphibolite-schists of the region.

Main type of meta-diorite.

Alteration.

Schistosity.

Description of areas in detail.

Most of the separate areas of meta-diorite call for little special description. The Mokelumne Hill area is notably irregular in outline and the meta-diorite shows considerable variety. Surface exposures are usually decomposed, and the rock is markedly schistose along its western border. South of Butte City a facies occurs consisting almost wholly of hornblende, and is in contact with Calaveras schists showing somewhat more crystallinity than usual. The contact between the meta-diorite and the Calaveras schists is well exposed in the spillway at the head of the Blue Lakes Water Company's pipe line, one mile southeast of Jackson Butte. The intrusive nature of the contact is here beautifully shown. The meta-diorite is a rather hornblendic facies, and locally carries red garnets. The siliceous schists of the Calaveras are not conspicuously metamorphosed at the contact. The microscope shows the schists to consist chiefly of quartz in very irregular interlocking grains, small pink garnets, a little mica, and an undetermined mineral of high refractive index. Just north of Mokelumne Hill and on the west slope of French Hill occurs a fine-grained green meta-diorite which is apparently merely a hornblendic facies of the coarser meta-diorite of the area.

The considerable area of meta-diorite east and southeast of San Andreas is interesting in that at one point erosion has spared a small mass of the Calaveras schists which probably at one time covered the intrusive body. A small lens of limestone within the patch of schist has been metamorphosed to marble.

East of Angels Camp, and about Parrott Ferry most of the meta-diorite is of the usual character, with frequent highly hornblendic facies occurring in patches, especially about its perimeter. In the canyon of the Stanislaus at and above Parrott Ferry there occurs a facies so little altered that it may be termed a diorite (quartz-hornblende-mica-diorite). This is a medium-grained gray rock showing abundant crystals of hornblende and biotite, and rather fresh triclinic feldspar. The microscope shows that the rock consists of fresh labradorite-feldspar, quartz, hornblende, and biotite, with accessory muscovite, apatite, zircon, and iron ores. The structure is the usual one found in granitic rocks. In spite of the general freshness of the rock, epidote is a conspicuous constituent, often cleanly and sharply intergrown with the primary minerals, and it might be regarded by some petrographers as a primary constituent of the rock.

A mile and a half south of Parrott Ferry an augitic facies occurs which may be termed meta-augite-diorite. Near the southern border of the area the normal meta-diorite passes into dark, coarse-grained, hornblendic facies—a very common modification in this and in the other areas of the meta-diorite.

Coarse hornblendic facies.

The Algerine area of meta-diorite is petrographically interesting on account of the very coarse hornblendic facies which abound near Algerine, particularly just south of the village. The rock at this point contains crystals of dark-green hornblende up to 2 inches in length lying in a white, finely granular matrix made up of nearly colorless epidote with a little quartz and muscovite. This aggregate has probably resulted from the complete alteration of the original feldspars. In the creek bed, half a mile northeast of Algerine, fragments of a similar coarse hornblendic facies can be seen included in the normal medium-grained meta-diorite, showing that the coarse basic facies was an early and local crystallization from the main molten magma.

The large area of meta-diorite lying between Big Oak Flat and Coulterville is usually a rather dark rock of moderate coarseness showing abundant hornblende, dull white feldspars, quartz, and usually chlorite and epidote. The feldspars are generally completely altered to an aggregate of epidote (or zoisite) and white mica. Apatite is sometimes an abundant accessory mineral.

Three miles a little south of west from Jackson is an area of intrusive rock which probably belongs with the meta-diorites. It is composed of a grayish-green granular rock of medium grain which the microscope shows to be apparently a much altered diorite. The feldspars are clouded and decomposed, and calcite, chlorite, and epidote are abundant. The exact original character of the rock is therefore somewhat in doubt.

Decomposed, rather basic areas.

Another area of somewhat similar kind occurs west of the Rawhide serpentine. The rock composing this area is generally considerably decomposed. It varies from gray to green in color and is usually fine-grained and traversed by veinlets of epidote. The whole area, however, shows much streakiness and variability, and some coarse hornblendic facies occur, recalling the rock already described at Algerine.

Northwest of Horseshoe Bend is a cluster of rounded hills covered with grease wood, surrounded on the north, east, and south by the higher and more rugged ridges of meta-andesitic breccias. The rock which underlies this area of gentler topography is chiefly an altered, rather fine-grained diorite—a meta-diorite, usually deeply decomposed. The freshest specimens obtainable show clouded, decomposed feldspars, green hornblende, and sometimes augite, with secondary quartz, epidote, chlorite, amphibole, and calcite. The medium-grained rock is often intimately associated with dark-green fine-grained facies, as well as with coarse hornblendic varieties. Sometimes the contacts are sharp, but in general there is an intimate mingling, as if the entire mass had solidified from a heterogeneous or streaky magma. The meta-diorite is probably intrusive into the meta-andesites, but owing to the prevailing decomposition of both rocks near the contact, and the depth and similarity of the resulting soils, the line separating the two is only approximately correct. This rather basic and augitic meta-diorite can be well studied near the mouth of Picture Gallery Gulch, at Horseshoe Bend.

Serpentine.—This rock has resulted from the alteration of basic gabbros, or of ultra basic rocks of the peridotite family, which were originally intruded into the rocks which now inclose the serpentine. In general it occurs in elongated dike-like masses of irregular shape and extremely varying width.

The process of alteration whereby serpentine results from basic rocks rich in magnesian silicates is essentially one of hydration. The amount of water thus chemically combined with the serpentine renders it considerably more bulky than the original igneous rock, and the increase in volume must be accommodated by squeezing and movement throughout the mass. Thus serpentine masses are usually full of irregular surfaces along which crushing and movement have taken place. It is almost impossible for regular open fissures to be formed within such a rock, and it is accordingly a most unpromising material in which to look for continuous and paying veins.

Internal movements.

The serpentine of the district is fairly constant in character and the separate areas call for no special petrographic description. The rock is usually readily recognized by the miners and given its proper name. A dark facies with glistening cleavage faces of bastite is rather common and the serpentinization as seen in hand specimens is usually complete. In nearly every serpentine area of any size, however, there occur isolated masses of gabbro and of peridotitic rocks. In most cases these seem to represent facies of the original basic igneous mass which have escaped complete serpentinization.

The original rocks from which serpentine has been derived were intrusive into the sediments, volcanic rocks, and amphibolite-schists of the Bed-rock complex. The intrusions seem to have had a very general tendency to take place along contacts. This is illustrated by the large area of serpentine west of Rawhide, but, best of all, by the almost continuous line of intrusions extending from the Tuolumne River down past Coulterville.

Character of intrusions.

There is usually little or no evidence of contact metamorphism about the peripheries of the serpentine masses, the conditions being rarely favorable to its detection. There has usually been movement along the contacts subsequent to the intrusion, and the rock in the immediate neighborhood is generally decomposed and soil-covered.

It does not appear from a study of this district whether the serpentines preceded or followed the great dioritic and granitic intrusions which are so prominent a feature of the region lying northeast of the Mother Lode. The detailed evidence, as far as it goes, is rather conflicting. The serpentine is in some cases apparently intrusive into the rather basic meta-diorites with which it is in contact, while in other cases dike-like masses of similar meta-diorite traverse the serpentine. The conclusion is that the meta-diorite areas do not represent wholly simultaneous intrusions, and that they and the serpentine belong to the same general intrusive period.

Relative age of serpentine and meta-diorite.

Soda-syenite-granophyre and related rocks.—These rocks occur as dikes, of which the most remarkable lies just east of Moccasin Creek. This dike has a length of about 6 miles and a width varying from a few feet up to about 200 yards. It is easily visible from most points along the road up Moccasin Creek, on account of its conspicuous white outcrop along the steep hill-slope. In the main it follows the contact between serpentine on the west and amphibolite-schist on the east, although some serpentine occurs to the east of the dike near the mouth of Grizzly Gulch.

Moccasin Creek dike.

The variations in the texture and mineralogical composition of different portions of this long dike are remarkable. At its northern end it is composed of a rather coarse granular rock consisting chiefly of albite, quartz, and muscovite, and may be termed a soda-granite. About a mile farther southeast the rock is a soda-syenite-granophyre, consisting chiefly of albite and ægerine with accessory zircon, titanite, and apatite. Still farther southeastward, about a mile south of Priest, muscovite and quartz are abundant and the rock is a soda-granite-porphyry. It is possible that the dike at this point may be a multiple dike, i. e., a dike consisting of two or more branches, but the exact relations are obscured by the amount of sliding that has taken place on the steep slope.

Smaller dikes of similar soda-syenite-granophyre occur north of the Tuolumne River and eastward from Jacksonville. Of the three dikes here shown on the map the two nearest Jacksonville are composed of nearly white rocks with minute faint-blue mottlings. The microscope shows that the chief constituent of both dikes is the soda feldspar, albite, and that the blue mottlings are due to beautiful little tuft-like clusters of slender crystals of blue amphibole. The rock also contains ægerine, apatite, zircon, and specks of iron ore. The most easterly of the three dikes is more decomposed than the others and darker in color. It consists chiefly of albite and biotite, the latter in great part decomposed to chlorite.

Dikes near Jacksonville.

Other dikes closely related to the syenitic dikes just described occur at various other points, as, for example, about $1\frac{1}{2}$ miles northwest of Penon Blanco Point and about one mile south of Coulterville, but they are small and usually considerably altered. Special interest attaches to the Moccasin Creek dike, and to those east of Jacksonville, from the fact that they are locally auriferous.

Other localities.

Miscellaneous dike rocks.—Dikes, usually of small size, are fairly abundant in the Mother Lode district. Like the other intrusive rocks, however, they are nearly always considerably altered and are not of great petrographical interest. Certain of them, from their close association with the gold-quartz veins, have great importance, as will be more fully shown when these latter are described. The greater number of the dikes are altered diorite-porphyries, or fine-grained diorites. The serpentine areas, however, are sometimes cut by dikes of more basic character, and by nearly white dikes. One of the latter, cutting coarse, rotten gabbro within the serpentine, about half a mile northwest of Penon Blanco Point, was found to consist of a nearly colorless amphibole (tremolite), epidote, and albite. The rock is altered, and all the minerals may be secondary.

THE SUPERJACENT SERIES.

This series consists of late Cretaceous, Eocene, Neocene, and Pleistocene sediments, together with volcanic rocks of the same periods, lying uncomformably upon the Bed-rock complex. In the Mother Lode district the marine sediments of the late Cretaceous and the Eocene are wanting, and the Superjacent series is locally represented by the Neocene auriferous gravels, the Neocene volcanic rocks, and the Pleistocene gravels and alluvium.

NEOCENE PERIOD.

Auriferous river gravels.—The oldest Neocene gravels are those which lay in the stream-ways before the outbreak of the Neocene volcanic eruptions. Such gravels represent the material which had accumulated along the stream beds in the course of the long erosion of Cretaceous, Eocene, and earliest Neocene times. During that period a high, rugged mountain range had been worn down to a range of comparatively low relief, with a broad, gently graded western slope. Thousands of feet of rock had been disintegrated, reduced to sand and silt, and carried down by the streams to fill the depression of the Great Valley. The rock masses which have been worn down and removed as sediments were traversed by quartz veins carrying gold. In part these were the upper portions of veins which are being mined to-day, but in part also they were small "pocket veins," containing occasional masses of free gold. As the rocks decayed and were washed down into the streams, the gold also found its way more slowly into the channels. Thus in the course of time the gold originally scattered in countless veins, of all sizes and degrees of richness, became concentrated in the beds of the streams. Rock fragments, when subjected to constant grinding and solution in rapidly running water, do not all behave alike. The softer and more soluble kinds are soon worn to sand or dissolved by the water and carried away. Ordinary weathering is also effective in disintegrating many of the pebbles, especially if the gravels are for a time deposited and exposed to the atmosphere. Finally, pebbles composed of the most resistant rocks come to far outnumber all other kinds in the bed of a long established stream. Thus, as might be expected, the earliest Neocene gravels are composed chiefly of well-rounded pebbles of quartz, compact quartzite, siliceous schists, close-grained granitic rocks, or hard, dense porphyries derived from small acid dikes.

Origin of the gravels.

The deposition of gravels did not cease with the beginning of the rhyolitic eruptions which opened the period of volcanic activity. Beds of rhyolitic tuff often occur in the siliceous gravels, sometimes as small lenses, and sometimes as beds of considerable horizontal extent. These relations indicate that at the beginning of the volcanic period there was considerable shifting and rearrangement of the earlier formed siliceous gravels, due either to an increase in the grade of the streams or an augmentation in their volume, or to both causes combined. These causes alone would ultimately have swept the streams clear of the greater part of their accumulated gravels had they not been hampered, clogged, and finally buried by the products of the rapidly succeeding volcanic eruptions of the late Neocene.

Relation of gravels to rhyolitic eruptions.

In discussing the geology of the western slope of the Sierra Nevada the Neocene is generally considered as being brought to a close with the cessation of the great volcanic eruptions. It was a period of rapid accumulation, chiefly of volcanic materials, during which the streams, overburdened and choked with the amount of débris thrown into them, were unable to establish stable channels. At intervals, however, there were lulls in the volcanic activity, during which some streams were able to erode channels of considerable depth and in some cases to cut down into the Bed-rock complex. With the close of the Neocene began the process of erosion which has continued without general interruption to the present day. A classification of the auriferous river gravels is possible in the light of this history. Such gravels as occur beneath volcanic accumulations are manifestly of Neocene age, as that age is understood for the Sierra Nevada. Moreover, gravels which, although not at present covered by lava, occur in positions where they could not have been deposited by streams belonging to the present cycle at some earlier period of their history, are also classed as Neocene gravels. Probably in most cases such gravels were once covered by volcanic materials which have been carried away by erosion. Occasionally masses of gravel are met with in such positions as to make the question of their Neocene or later age a matter of doubt. The mapping of such areas is determined by the probabilities of the case as deduced from general position, elevation above the present stream beds, and the character of the gravel itself.

Classification of the auriferous river gravels.

The material included in the Neocene gravels varies considerably in the size of the separate particles. In the gravel proper the pebbles may range from diameters of a fraction of an inch up to a foot or more. As a rule, large and small pebbles occur in the same bed, not infrequently mixed with sandy or clayey material. These gravels are sometimes irregularly interbedded with light-gray or yellowish quartzose sandstones, or impure rhyolitic tuffs. Cross bedding is a characteristic feature of such deposits.

Materials of the gravels.

In some localities, where the gravels rest upon the upturned edges of the Calaveras formation, their lower portion contains large, imperfectly rounded masses of the siliceous Calaveras schists, often several feet in diameter. Such material may have been deposited during the time of rapidly changing conditions at the opening of the volcanic period; but it is difficult to conceive exactly the conditions which must have governed such deposition. Such blocks may be well seen in a patch of gravel, which has been extensively hydraulicked, one mile northeast of Fourth Crossing. The gravels at this point are 30 to 40 feet in thickness and rest upon a rather coarse-grained and massive amphibolite-schist. They are light-colored, the pebbles being quartz, acid porphyries, rhyolite, granitic rocks, and chert. A lens of soft white rhyolite tuff, about 12 feet in maximum thickness, containing fragments of silicified wood, is interbedded with the gravels above the large subangular blocks of schists. Similar masses of schist were observed in the gravel areas north of Lower Calaveritas, where they may have been derived directly from the underlying bed rock. They can not be regarded as of morainal character.

Large masses of schist in the gravels.

Rhyolite tuff in gravels.

The most extensive development of auriferous gravels within the area is found along the former course of a Neocene river channel which extends across the district in a northeast-southwest direction, past Mokelumne Hill and Golden Gate Hill. In the neighborhood of Mokelumne Hill these early siliceous gravels are overlain at many points by rhyolitic and andesitic tuffs. Where covered by a hard capping of tuff they have been extensively exploited by drifting, and by hydraulicking when the absence of a capping rendered this method practicable. On the ridges inclosing Spring Gulch, Chili Gulch, and Old Woman Gulch an upper stratum of the gravels has been cemented into a hard conglomerate stained with oxide of iron. A number of relatively small patches of gravel testifies to the former continuity of the Mokelumne Hill gravels with the large area 3 miles northwest of San Andreas known as the Central Hill area. All these small patches have been worked in the past by the hydraulic method and evidently proved remunerative. Good exposures of these gravels can be studied on the road to Mokelumne Hill, about $4\frac{1}{2}$ miles northwest of San Andreas. Some lenses of rhyolite tuff may be seen inclosed in the gravels left standing by the miners. These gravels, in spite of the considerable area of country that they formerly covered, were in places laid down in channels possessing steep and well-defined banks cut in the rocks of the Bed-rock complex. Much of the gravel in these smaller areas contains more fine material than usual and is often red and rusty in color. The gravel of the large Central Hill area is light colored and of the usual siliceous character. It has been extensively hydraulicked in several places, and is now being exploited by drifting.

Gravels near Mokelumne Hill.

Well-defined channels.

Extensive gravel deposits occur north and northeast of Angels Camp. These gravels are of the usual siliceous character and are sometimes capped by and sometimes interbedded with rhyolite tuff. Gravels and rhyolite are in several places overlain by andesitic conglomerates and breccias. About half way between Altaville and Dogtown the siliceous gravels pass upward into impure andesitic gravels which might perhaps be as appropriately mapped with the auriferous river gravels as with the andesites. It was in a shaft

The Calaveras skull.

sunk beneath the rhyolite of Bald Mountain, half a mile northeast of Altaville, that the famous Calaveras skull was found in 1866. If there were no doubt of the authenticity of this and similar discoveries in the Neocene auriferous gravels, they would prove that man had inhabited the earth for a vastly longer period than there is conclusive evidence for in the other portions of the world.

The Table Mountain channel.

South of the Stanislaus River the auriferous river-gravels are of much less importance as regards area and former economic value than the deposits farther north. A well-defined channel is known to exist beneath the greater part of the massive black lava (latite) capping Table Mountain. These gravels, however, are much older than the dark lava which caps the mountain. They represent an early Neocene stream channel which was buried under andesitic conglomerate and breccia. During a pause in the volcanic eruptions a new stream cut a channel in the andesite and flowed for a portion of its course above the old buried gravels. This stream was busy eroding its bed, and did not deposit auriferous gravels. It was this newer channel which was found and usurped by the liquid lava, now congealed and forming the cap of Table Mountain. Thus the fact that the lava has covered and protected the more ancient gravel-filled stream bed may be looked upon almost in the light of a curious coincidence. Above this deep gravel occur deposits of fine light-colored silts, "pipe-clay" of the miners, which have been found at many points within the mountain to be rich in fossil plant leaves. The study of these plant remains, and of those from other similar deposits in the Gold Belt, has afforded the best evidence yet adduced of the Miocene age of the auriferous gravels which immediately underlie these silts. In Tuolumne Table Mountain the silts grade upward without any stratigraphic break into coarser andesitic sediments.

Pipe-clay and fossil leaves.

Gravels near Montezuma.

North and east of Montezuma are considerable areas of gravels, which, although not capped by volcanic material, are probably of Neocene age. They are composed chiefly of pebbles of quartz and chert, with considerable light-yellow quartzose sand. As shown in the extensive pits left by hydraulic workings they rest upon an uneven erosion surface of the nearly vertical Mariposa slates. A similar but smaller mass of gravels occurs just east of Chinese Camp.

Rhyolite.—Rhyolite does not occur in the Mother Lode district in the form of massive lava flows, but as volcanic ashes or rhyolitic tuffs. These tuffs are white or pink and are sometimes consolidated into a firm though somewhat porous rock. The microscope shows them to be composed of crystals and crystal fragments of sanidine, plagioclase, quartz, and biotite in an abundant groundmass made up of glass spicules and shreds of pumice. The groundmass is usually more or less altered by secondary silicification.

Original distribution of the rhyolite tuff.

The rhyolite tuffs were thrown out in the first volcanic eruptions of the Neocene period. They appear never to have been so widespread as the later andesitic breccias and tuffs, but probably were confined to the broad stream-ways of the early Neocene. The andesites, on the contrary, appear to have completely filled the old valleys and to have buried the greater part of the region beneath their cover. Between Mokelumne Hill and Golden Gate Hill the rhyolite tuffs overlie the earliest auriferous gravels and are in turn overlain by the andesites. The rhyolitic tuffs were thrown into the air as volcanic ashes from volcanoes near the crest of the range, washed into the streams, and deposited by them over the earlier quartzose stream gravels. The streams of that time probably flowed slowly, in broad valleys, and may have been choked by the volcanic débris and forced to spread locally into broad, lake-like expansions in which the tuffs were laid down as sediments. There is evidence that the tuffs thus deposited were considerably eroded before the eruption of the andesites.

At Butte City occurs an area of very impure rhyolitic tuff, full of foreign fragments, including some pebbles of andesite. This material is probably of late Neocene, possibly of Pleistocene age, and was washed into the nearly inclosed basin in which it now lies.

Nature of the andesitic material.

Andesite.—The post-Neocene erosion of the Mother Lode district has been so extensive and general in its character that comparatively few fragments remain of the mantle of clastic andesitic rocks which once nearly covered the region. Thus flat-topped ridges capped with andesitic tuff and breccia are less prominent features of the topography than they become a little higher up the slope of the range. The ordinary fragmental andesites of the region may be divided into breccias, conglomerates, and fine tuffs. Of these the breccias are perhaps the most common and characteristic. They are composed of fragments of very unequal size firmly cemented by a matrix of finer andesitic particles. The fragments are frequently porphyritic, in which case the phenocrysts may be either hornblende, augite, or plagioclase. The microscope shows that augite and hornblende are usually both present in varying abundance. The groundmass consists of labradorite or andesine feldspar, augite, bronzite, glass, and the usual accessory magnetite and apatite. It is believed that these breccias were deposited as floods of thick mud, which poured down from volcanic vents situated to the eastward, near the crest of the range. Whether the material issued from the vents as mud, or was thrown out and subsequently washed down by the floods which often accompany volcanic outbursts, is not known. The latter is believed to be more probable.

The conglomerates are composed of well-rounded, waterworn pebbles of andesite, cemented by andesitic sand. The pebbles vary in size from coarse sand up to bowlders a foot in diameter. Such conglomerates are old stream gravels which differ from the ordinary auriferous gravels merely in the nature of their material, which is andesitic throughout. These conglomerates are usually found to underlie the breccias, but in a thick series they may occur at various horizons intercalated with the breccias. They sometimes contain quartzose pebbles and so grade into the non-volcanic auriferous gravels which they often overlie. The andesitic conglomerates indicate that within the volcanic period there were intervals during which temporary, shifting streams wandered over the desolate lava-covered plain, as if striving to rediscover their buried channels or to establish new ones. The finer andesitic material occurs in beds of sand or tuff made up largely of small, angular particles. Between these beds and the breccias and conglomerates no hard and fast line can be drawn. As a rule these finer beds occur at the base of the andesitic series, but are not everywhere present. They usually consist in part of andesitic sand consolidated into a porous crumbling rock. Scattered andesitic pebbles, as well as lenses of andesitic conglomerate, occur in this sand. Below the sand there is sometimes found a deposit of fine silt, the so-called pipe-clay of the miners. This material often directly overlies the older auriferous gravels and is noteworthy as sometimes containing fossil leaves. Collections of these leaves have been made at various points and they are considered by paleobotanists as indicating Miocene age.

The Table Mountain section.

All three kinds of andesitic deposit are well exposed in Table Mountain, particularly along its southwestern side. Two miles a little south of west from Jamestown, the cap of the mountain is a flow of solid latite about 60 feet in thickness. Below the latite occurs a bed of rather coarse andesitic breccia in which many of the fragments are subangular. Then come 200 feet of andesitic conglomerate, sand, and pipe-clay. The conglomerate is most abundant near the top, and the pipe-clay near the bottom, but they are interbedded somewhat irregularly, and grade more or less into each other. The fine silt is here probably derived chiefly from andesitic material, as it is interbedded with and passes into undoubted andesitic sands. But in some other localities the so-called pipe-clay is probably chiefly of rhyolitic origin. The andesitic beds at the point described rest upon the edges of the Mariposa slates, but it is known that gravels underlie the pipe-clay in many portions of the mountain.

Relation of andesites to the auriferous gravels.

Most of the areas of clastic andesite call for no special comment. North of Altaville much of the material mapped as andesite is an andesitic gravel or conglomerate which contains a rather large proportion of foreign pebbles, and might therefore with almost equal propriety be mapped as Neocene gravel. Strictly speaking the andesitic conglomerates are Neocene gravels, but as it would be practically impossible to map them separately from the andesitic breccias with which they are so closely connected, and as they are rarely if ever auriferous, it seems best to include them with the volcanic series. Similar deposits, in which the andesitic material was laid down chiefly as sand and gravel, occur northwest of Montezuma and at a few other places in the area.

Massive andesite.

Massive andesite is known at only five points within the district. It forms the upper portion of the peak known as Jackson Butte, occurs on Golden Gate Hill, and caps three smaller hills about 1¼ miles northeast of Golden Gate Hill. The highest of the latter is sometimes known as Tunnel Hill.

Jackson Butte andesite.

Jackson Butte owes its conspicuous and picturesque outline to the mass of andesite, 400 to 500 feet in thickness, which forms its summit. The rock itself is rather light colored, with a slight reddish tint, and shows small porphyritic crystals of dark hornblende. Under the microscope it is seen to be a fresh hornblende-andesite, consisting of labradorite-feldspar, bright-brown hornblende, and glass, with a little magnetite and apatite. The groundmass shows flow structure. The form and isolated position of this andesitic mass have suggested that it may be a volcanic plug which has been intruded from below through the Calaveras rocks. The latter, however, appear to be undisturbed in the vicinity of the mass, and it is known that gravels and fine tuffs occur beneath at least a portion of the lava. It is probable, therefore, that the andesite is a remnant of a thick flow, and merely rests upon the Calaveras rocks.

Golden Gate Hill andesite.

Golden Gate Hill consists in the main of andesitic breccia and conglomerate of the ordinary type, capped by a thick mass of hornblende-andesite similar to that of Jackson Butte, although somewhat richer in porphyritic crystals of hornblende. Although included with the massive andesite to distinguish it from the ordinary clastic andesites, this rock is in part a breccia of rather peculiar kind. The fragments fit closely together, and are held by a matrix of the same general character as the fragments. The brecciated portions grade into parts which are perfectly massive, and the phenomenon is probably to be explained as a case of partial brecciation during the movement of the lava while still hot and semi-fluid. Some of the hornblende-andesite is also exposed on the south slope of the hill, underlying the ordinary andesitic breccia and conglomerate. It is probable, although not demonstrable, that the hornblende-andesite of Golden Gate Hill was erupted in place through the underlying rocks.

Relative age of massive and clastic andesites.

Tunnel Hill, 1¼ miles north of Golden Gate Hill, is capped by a very light-gray hornblende-andesite which under the microscope resembles the hornblende-andesite of Jackson Butte and Golden Gate Hill. The hornblende, however, is less abundant and is greenish instead of brown. Similar hornblende-andesite caps the two hills half a mile east and half a mile northeast of Tunnel Hill. Hornblende-andesite of the character described at these five localities has not been recognized in the ordinary fragmental andesites of the region. The date of eruption of the massive andesites, with the possible exception of the small mass on the south side of Golden Gate Hill, is later than that of the clastic andesites of the vicinity.

Latite.—The name latite has been given to a group of lavas which in petrographical character stand between the andesites and the trachytes. They correspond to the granular intrusive (plutonic) rocks called monzonites, which occupy a position between the syenites and diorites. The lava capping Table Mountain, although commonly called a basalt, belongs to this group. It is characterized by abundant porphyritic crystals (phenocrysts) of labradorite-feldspar lying in a dark-gray fine-grained matrix. Vesicular facies occur in the upper portion of the flow, the vesicles being often partially filled with clear colorless opal (hyalite). Examined under the microscope, thin sections of the Table Mountain lava show phenocrysts of labradorite, augite, and usually a little olivine in a groundmass of lath-shaped labradorite crystals, grains of augite and olivine, and some glass filled with the incipient crystal forms termed globulites. There is always a little accessory magnetite and apatite present. Three chemical analyses of specimens taken from portions of this lava flow 15 to 20 miles apart, show it to contain from 56.1 to 59.8 per cent of silica, 5. to 6.5 per cent of lime, 2.5 to 3.9 per cent of soda, and 3.4 to 5. per cent of potash.

Table Mountain lava flow.

The largest area of latite in the district is that forming the dark massive cap of Table Mountain. Other areas occur to the northward in the vicinity of Parrott Ferry. These separate masses were at one time connected and formed part of a single long lava stream which poured from some unknown vent near the crest of the range down to Knights Ferry on the edge of the Great Valley — a distance of more than 60 miles. Portions of this flow must have attained a thickness of about 300 feet, as shown in the columnar cliffs which constitute a picturesque feature of portions of Table Mountain.

PLEISTOCENE PERIOD.

In the Mother Lode district, the Pleistocene, or, more strictly, that portion of the Pleistocene which Professor LeConte has proposed to call the Sierran epoch, has been essentially a time of erosive activity. Such deposits as occur are merely incidental to the action of the streams in carving and shaping the surface of the land into its present form. They comprise small areas of alluvium bordering some of the streams or washed down into valleys from the surrounding hills, as well as patches of gravel left by the streams above their present high-water mark as they have sunk their beds deeper into the bed rock. These last, like the Neocene gravels and the gravels of the present streams, are usually auriferous.

GEOLOGICAL STRUCTURE.

The problem of the detailed structure of the Bed-rock complex is an exceedingly intricate one, and has never been solved. It is known that the long belts of slaty and schistose rocks have been folded from nearly horizontal into nearly vertical positions and closely compressed by forces acting generally in a northeast-southwest direction. But the internal structure of the belts has yet to be fully unravelled. There is no doubt that prior to their final compression the sediments and volcanic rocks of the Bed-rock complex were intricately folded, and not, as formerly supposed, simply tilted as a whole into their present position. Evidence of such folding is found in a careful study of the geological map. Actual minor folds may be seen in the excellent exposures of Mariposa rocks along Woods Creek. But such data have not yet been sufficient to reconstruct the original folds in detail and to determine whether a given belt of rock now possessing monoclinal structure was evolved from an original anticline or an original syncline, or from a combination of synclines and anticlines. The lack of characteristic and persistent stratigraphic horizons, joined with the compression and metamorphism of the beds and with the effects of igneous intrusions, has hitherto baffled efforts to interpret the detailed structure. A long course of patient observation, with analysis of a high order, can alone solve this problem, which, however, has no immediate economic bearing.

The part played by igneous intrusions in the Bed-rock complex has already been sufficiently described and need not be repeated.

The structural relation of the Superjacent series to the older complex should also be sufficiently clear from what has gone before.

GENERAL GEOLOGICAL HISTORY OF THE MOTHER LODE DISTRICT.

Carboniferous time.

The oldest rocks known in the Mother Lode region are those comprising the Calaveras formation. They are, in part at least, of Carboniferous age. It is possible, however, that the Calaveras formation as a whole may include some rocks older than the Carboniferous, but such have not yet been definitely recognized. Little is known of the origin of these oldest rocks of the district. They must have been derived from a land mass which probably lay to the eastward of the present mountain range, and which was composed in part of crystalline and metamorphic rocks. The region of the Mother Lode was then sea bottom upon which accumulated con glomerates, sands, fine mud, and limestone. This sea bottom was apparently subject to oscillations, sometimes rising and sometimes slowly sinking. The pebbles and sands must have accumulated in shallow water, not far from shore, while the limestones were deposited in relatively deep, clear water in which crinoids flourished. There were active volcanoes during this time, and the volcanic ashes thrown out from their vents formed the beds of tuff which accumulated in the Paleozoic sea or spread out as mud-flows on the land. At present these old tuffs are represented by the amphibolite-schists.

At the close of the Carboniferous there was apparently a change in the relative distribution of sea and land. We know practically nothing of the details of this disturbance. There is, however, conclusive evidence that the Mesozoic rocks of the district were laid down unconformably upon Paleozoic rocks, and from this fact it is concluded that the latter were in part elevated above the sea and exposed to subaerial erosion before the former were deposited.

Juratrias time.

During the portion of Juratrias time represented by the Mariposa beds, at least the Mother Lode region of the Sierra Nevada was sea bottom. Upon this sea bottom there accumulated, as formerly in the Paleozoic sea, gravels, sands, and muds. The Juratrias sea was probably shallow and muddy and the conditions appear to have been unfavorable for luxuriant marine life. Unlike the Paleozoic sea, it did not deposit limestone. The volcanic eruptions of Juratrias time were, however, very considerable. In the enormous masses of ancient andesitic and basaltic lavas, breccias, and tuffs which are colored upon the geological map as meta-andesites, there has been preserved a record of vigorous and prolonged volcanic activity.

Post-Jurassic folding.

At the close of the Juratrias occurred the great geological revolution whereby the Calaveras and Mariposa rocks were folded by forces acting along northeast-southwest lines and gradually raised above sea level until the former sea bottom had become a lofty mountain range. This folding was so intense and the folds so closely compressed that the sediments were transformed into slates and schists possessing cleavage and schistosity generally approximately parallel to their original bedding and dipping northeasterly at a high angle. Accompanying and following the folding there were great intrusions of igneous rocks—granites, granodiorites, diorites, and gabbros—into the folded sedimentary and volcanic beds. These were deep seated intrusions, originally far beneath the surface, and it is only by enormous later erosion that these intrusive masses have been exposed to our view and to-day constitute part of the surface of the sierra slope. By these intrusions and through subsequent erosion the rocks of the Calaveras formation have been cut off from the shore line to the east, against which they were probably laid down. These rocks are, as far as known, everywhere bounded on the east by the eruptive contact of the granitic rocks. It is certain that, at many places, when those intrusions took place, the adjacent Calaveras sediments had already been closely folded and rendered approximately as schistose as they are to-day. Moreover the intrusive rocks themselves are often locally schistose. Thus we see that the geological processes did not act suddenly and simultaneously over large areas. The elevation of the range was probably slow, and the erosive forces attacked it at once without waiting for it to reach its full altitude. The folding and compression of the beds probably occupied very many thousand years, and the granitic and other intrusions may have taken place at any time during that period. While considered geologically as one period of intrusion, considerable time may in reality have intervened between the intrusion and solidification of different masses—as for example the Algerine area of meta-diorite and the Parrott Ferry area.

Thus at the close of the Juratrias, the Mother Lode region was part of a high and rugged mountain range, with lofty peaks and narrow V-shaped canyons.

Cretaceous and Eocene erosion.

All through Cretaceous and Eocene time this mountain range was being slowly worn down by the action of air, frost, rain, and streams until at the beginning of the Neocene this portion of it had been reduced to a gently rolling surface, upon which the drainage was shed from low divides into broad, open stream-ways. The eye, sweeping over such a region from one of its higher points, would gain the impression of a great undulating plain with here and there an occasional hill of hard rock (a monadnock) rising above its surface. The youthful topography of the lofty mountain range, with its sharp peaks, narrow canyons and rushing torrents, had given place to gentle curves and broad, slowly flowing streams characteristic of topographic old age.

Neocene volcanic eruptions.

During the Miocene there came a change, and the long period of continuous erosion ended. Volcanic eruptions to the east of the Mother Lode region broke the long interval of quiet, and rhyolitic pumice came floating down the streams from the summit regions. The streams soon became overladen with the rhyolitic tuff which was thrown out by the volcanoes and washed into their channels and they were forced to deposit it along their broad courses. Finally the eruptions of rhyolite ceased, and the streams at once began to cut through the tuff which filled and choked the old channels. There was probably at this time a beginning of the elevation which has increased the western slope of the Sierra Nevada and transformed the old surface once more into a high mountain range. The grade of the streams was thereby increased and their erosive power augmented. But their cutting was again interrupted by the andesitic eruptions, which far exceeded the rhyolitic outbursts in the volume of the material thrown out. The streamways were filled with andesitic detritus, partly in the form of flows of thick volcanic mud, partly as water worn andesitic conglomerate and sand, and partly as fine tuff. The Mother Lode region must have been part of a great desolate plain of fragmental andesitic material. Beneath the lava were buried the low hills and shallow valleys of the pre-Neocene topography, above it projected an occasional monadnock of hard rock which had never been worn down. Over this plain the streams, choked and encumbered with volcanic débris, flowed in shifting courses, sometimes spreading into lake-like expansions in which finer material came to rest, and again gathering into temporary channels and forming deposits of andesitic gravel.

Neocene elevation and tilting.

During the period of andesitic eruptions, the crest region of the sierra was probably gradually rising, thus increasing the grade of the western slope. There were pauses within the general period of andesitic eruptions, during one of which a stream draining the high sierra eroded its channel in, and in part through, the andesitic cover. This channel was usurped, however, by the long flow of lava (latite) the remnants of which now form Tuolumne Table Mountain. Subsequently this lava was covered, in the high sierra, by fresh accumulation of clastic andesites. In the Mother Lode region proper, however, it is the youngest lava of which any remnants are preserved. With the cessation of volcanic activity the streams, no longer overladen with débris, were free to begin cutting down into the tilted lava-mantled plain. As the slope of this plain to the southwest was now considerably increased, the streams cut energetically through the volcanic covering and have since developed the topography which we see to-day.

Similarity of volcanic products in each geological period.

It is interesting in looking back over the geological history of the region, to note the similarity in the chief volcanic products of the Paleozoic, the Mesozoic, and the Tertiary volcanoes. The ancient tuffs associated with the Calaveras rocks are now transformed in great part to amphibolite-schists, but these schists grade into less altered tuffs and breccias of meta-andesitic character, which are in no noticeable way different from those of Juratrias time. During Mariposa (Juratrias) time andesitic tuffs and breccias were piled up in thick accumulations and they form the meta-andesitic areas of to-day. Lastly, the Neocene was marked by the eruption of enormous quantities of andesitic tuff and breccia. Were these nearly horizontal beds folded, compressed, and subjected to such slow operation of chemical and physical agencies as have altered the volcanic rocks of Calaveras and Mariposa times, they would undoubtedly resemble them closely in general character. Thus in Carboniferous, in Juratrias, and again in Neocene times the Mother Lode region received extensive accumulations of andesitic tuffs and breccias.

DEVELOPMENT OF THE PRESENT TOPOGRAPHY.

The topography of the Mother Lode district is the direct result and expression of the mature dissection, by the present streams, of the uplifted rolling Neocene surface and its cloaking lavas. The hills remain, merely because they are composed of resistant rocks, while the valleys have been carved below them in weaker rocks. Thus the relatively soft Mariposa slates and sandstones form valleys or low hills, as may be seen by following the principal belt of these rocks southeastward from Plymouth down past Coulterville. On the other hand the meta-andesite breccias ("porphyrites") are not easily eroded, and form hills and mountains, such as Moccasin Peak, the Penon Blanco Ridge, Horseshoe Bend Mountains, and Hunter Valley Mountains. The mountains of to-day may even have been valleys of Neocene time, as is most strikingly shown by Tuolumne Table Mountain. The flow of lava which poured down the old Neocene stream-way has proved so resistant to decay and erosion that it still remains long after the low hills, which once confined it, have been washed away by rain and streams. This erosion has gone so far that the old stream-bed now stands above the surrounding country as a mountain, while to the north of it the modern Stanislaus River has cut a canyon a thousand feet in depth.

The erosion of Pleistocene time (Sierran epoch) did not proceed with perfect uniformity. North west and south of Table Mountain there are stretches of nearly level country incised by the present streams. Thus Mormon Creek has cut its channel below a former surface of near 1500 feet elevation, remnants of which remain at French Flat, Rawhide, and Tuttletown. Similarly, south of the mountain, Jamestown, Quartz, Montezuma, and Chinese Camp are all situated upon a surface which would be almost a plain were it not for the ravines of Woods and Slate creeks which intersect it. These surfaces show that at one time during the Pleistocene the streams draining this portion of the area were interrupted in their energetic downward cutting (or corrasion) and began to erode laterally with the aid of their tributaries, producing local peneplains. The cause of this interruption is not certainly known, but it is probably connected with some obstacle formerly encountered by the Stanislaus and Tuolumne rivers in the process of corrading their channels to the westward of the Mother Lode district. With the removal of this obstruction, Mormon, Woods, and Slate creeks again began to cut rapidly downward, and carved their present canyons and ravines.

In connection with the topography the fact which is of most importance in an intelligent comprehension of the conditions governing the occurrence of gold is the salient one that the hills and valleys of to-day are in no sense due to local uplift or disturbance, but are the result of the very processes of atmospheric etching or carving which are now slowly transforming the rocks into soil, washing the loose materials into the streams, and carrying them down to the sea.

ECONOMIC GEOLOGY.

GOLD.

The gold of the Mother Lode district occurs both in the gravels of the Superjacent series and in veins in the Bed-rock complex. As in other portions of the Gold Belt, the gravels were the first to be exploited and were formerly actively worked. At the present day gravel mining has almost ceased and the available capital and energy are chiefly directed to the development of mines located upon the gold-quartz veins.

Origin of fissures.

Gold quartz veins.—Internal stresses in the earth, due primarily to imperfectly understood causes, produce compressive strains in the outer rocky portion of the globe which find relief in cracks or fissures. These cracks are never perfectly straight and there is usually some tangential movement of the two surfaces, or walls, of the fissure. Thus at certain points they touch and grind together while elsewhere they are separated by empty spaces. Fissures thus "open and pinch." Such fissures become natural conduits for the circulation of underground waters. The waters rising from the deeper, hotter portions of the earth's interior carry in solution quartz, carbonates, gold, metallic sulphides (sulphurets), and other mineral substances. These materials are deposited within the empty spaces of the fissure and constitute a vein.

Filling of fissures.

A vein thus occupies a crack or fissure in the rocks, filled usually from below by materials brought up in an aqueous solution. In all probability the waters which carried the Mother Lode ores in solution were originally meteoric waters, which, after gathering up their mineral freight in the course of downward and lateral movement through the rocks, were converged in the fissures as upward-moving mineral-bearing solutions. It is unlikely that such waters ever attained a depth much greater than 30,000 feet. Veins are not always simple, for the rock may be fractured along more than one general plane, giving many branching and interlacing fissures.

Stringer leads.

Thus there may be many small veins or stringers, together constituting what has been called a *stringer lead* or *stringer lode.* Most of the large mines of the Mother Lode district are upon leads of this character, and their veins are really aggregates of many veinlets. After a fissure has been formed and filled with ore or gangue, it is usually still a line of weakness, and is very likely to be again partly opened by renewed movement.

Banded ore.

This process may take place several times, and explains the formation of much of the "banded ore" of the district. The action of the ore-bearing solutions is not limited to the deposition of material within the walls of the fissures. Rocks are porous, and the solutions circulating in the fissures penetrate to a certain extent the inclosing walls and produce chemical changes in the country rock.

Alteration of country rock.

Thus the country rock of a vein is always an altered rock, and may consist almost wholly of secondary minerals, such as calcite, sericite, and quartz. Such altered wall rock is often highly impregnated with metallic sulphides, especially pyrite, deposited by the solutions which have soaked into it from the fissure. When, as is sometimes the case, the altered wall-rock adjacent to the fissure is impregnated or enriched in such a way as to constitute ore, it is convenient and customary to include it within the term "vein." The wall-rock sulphurets in this district, however, are usually worthless, and are never so rich as those found in the vein itself. When worked, they usually afford a bullion containing considerable silver.

Gold confined to veins.

It is a fact of much scientific and economic importance that the gold of this district has been chiefly deposited within the walls of the fissures and has not migrated to any great extent into the porous country rock.

Pay shoots.

Not all portions of a vein are equally productive. Those portions, often of irregular form, which contain ore sufficiently rich to pay for extraction are termed *pay shoots.* In the Mother Lode district these pay shoots usually extend to great depths (in the Kennedy mine 2500 feet) without any appreciable regular or progressive change in tenor. They are usually nearly vertical, but may pitch or "rake" slightly to the northwest or southeast.

Date of fissures.

The fissures which the veins fill were formed after the post-Jurassic folding of the Bed-rock complex and after the granitic and dioritic intrusions. They have probably continued to be a zone of movement and readjustment ever since their first dislocation, and such movements are still in progress. It should not be forgotten that when the veins now accessible to us were formed the surface of the country was far different from what it now is. The outcrops of to-day were then several thousand feet below the surface.

Mother Lode.

The Mother Lode is not a single vein, but is a remarkable linear system or chain of interrupted and overlapping veins which traverses the district embraced in the accompanying map from end to end, and extends beyond its boundaries.

The Mother Lode a system of veins. Toward the south, veins belonging to this great system extend down past Benton Mill, Bear Valley, and Mount Bullion to near the town of Mariposa. Toward the north the line of veins running up past Placerville to the Middle American River, and perhaps beyond, undoubtedly belongs to the same system. It is erroneous to suppose, as some do, that a continuous drift might be run along the whole length of the "lode" without losing sight of the vein. Although one of the veins may be traced for miles, yet it will finally die out entirely and be succeeded by an interval where no noticeable veins occur; or else its place will be taken by a second perhaps overlapping vein lying some distance to the east or west of it. In some cases there may be several approximately parallel veins a mile or more apart, as near Angels Camp or Coulterville. The usual tendency of the miner or engineer who wishes to represent the Mother Lode system in diagrammatic form is to exaggerate a continuity in itself sufficiently remarkable and draw imaginary connections and "branches," where there is no evidence for their existence.

Origin of Mother Lode system due to a belt of weak rocks. The veins of the Mother Lode system are not confined in their occurrence to rocks of any particular kind or of any particular age. Nevertheless a study of the whole district very strongly suggests that the position of the Mother Lode is determined by the general character of the rocks which its veins traverse. Briefly, the veins of this system are confined to a belt of weak rocks. This structural weakness is due to a combination of at least three main causes: (1) The prevailing slaty cleavage or schistosity of the rocks, itself a manifestation of strain; (2) their occurrence in narrow belts and in small masses, giving many contacts, which are seldom if ever as strong as homogeneous rock; and (3) the great length of this individually and collectively weak zone of rock masses and its general parallelism with the structural features of the range. It appears highly probable that much of the movement which has affected the Sierra Nevada since the close of Jurassic time has been localized along this weak zone, and has resulted in the linear fissure system of the Mother Lode.

Character of faulting. The veins of the Mother Lode, without any known exception, dip northeastward, generally at a flatter angle than the inclosing slaty rocks. They usually strike nearly with the inclosing slates or schists; but there are exceptions to this general rule. The dislocations by which the fissures were originally opened, were of the kind known as thrust faults, i. e. the hanging wall moved up relatively to the foot wall. The present structure of the veins shows that the original displacement was followed at intervals by further movement of the same kind. There has very probably been subordinate displacement of reverse character, i. e. a downward movement of the hanging wall relative to the foot wall, producing local crushing of earlier-formed veins, and resulting in ore bodies of irregular and brecciated character. There is evidence that this latter movement is still in progress, producing the gouges and slickensided surfaces which accompany most of the veins. With the possible exception of serpentine there is no indication that the character of the wall rock has any direct influence upon the richness or poverty of the vein. **Influence of wall rock on tenor.** Nevertheless, the veins traversing different rocks possess certain distinctive features which will be briefly outlined.

Veins in the sedimentary slates. The veins occurring in the dark clay slates of the Mariposa formation or the slaty schists of the Calaveras formation are usually complex stringer leads, without conspicuous surface outcrops. The vein material is chiefly quartz, with a little calcite or dolomite, and sometimes nests of albite. The metallic components of the ore are pyrite and free gold, with small amounts of galena, zinc blende, arsenopyrite, and chalcopyrite. The ore body is generally a complex mass of stringers of varying sizes, mingled with slate, and separated by heavy gouges of crushed slate from the country rock, which usually shows little chemical alteration. The larger stringers are frequently banded, as a result of reopenings and renewed filling of the vein. Each time such a widening of the fissure takes place, a little of the slate wall rock adheres to the portion of the vein already formed, and finally forms a narrow, irregular slaty seam in the widened vein. As the richest portions of these veins are as a rule near the walls, it is evident that such banded ore is almost invariably of more than average value. The ores of the slates are free milling, and a large percentage of the gold is usually caught by amalgamation.

Veins in amphibolite-schists. The veins in the amphibolite-schists resemble those in the slates by being in the main complex stringer leads. But the country rock is usually much more altered, and may be heavily impregnated with pyrite near the vein. It is often changed to a soft grayish rock consisting chiefly of carbonates of lime and magnesia, with sericite, and sometimes a little chlorite. Such altered and pyritized country rock is too poor in gold to pay for working alone, but is often run through the mills for the sake of the rich stringers which intersect it, and from which it can not be economically separated. These veins are usually richer in carbonates than those in the black slate areas, and in certain parts of the district are rich in tellurides. With the exception of these last, they are all free-milling ores.

Veins in serpentine. Veins occurring in or alongside serpentine areas are characterized by conspicuous outcrops of massive white quartz. These quartz masses, however, constitute but a part of the whole vein, which may be 200 or 300 feet in width, and usually consists of a more or less schistose aggregate of dolomite, mariposite (a bright green chromium mica), and talc. The quartz occurs as intersecting stringers or great, thick lenticular bunches in this dolomitic mass, which is without much doubt an alteration product of the serpentine adjacent to the original fissure. No paying mine has yet been worked on a vein wholly within the serpentine, although rich ore bodies occur in contact veins of which the serpentine forms one wall. Even within the serpentine areas it will usually be found that the large veins are accompanied by one or more decomposed dikes. Otherwise probably no open fissure would have formed, or remained open, for a time sufficient for the deposition of a quartz vein.

Contact veins. Contact veins (i. e. veins occurring between rocks of different kinds and origins) are an important feature along the Mother Lode, and are often thick plates of quartz, with bold outcrops. Such massive veins are usually of low grade, and it is a very common thing to find that mines originally located upon these prominent croppings are really working a smaller vein, or a stringer lead, on one side or the other of the large "bull" vein as it is sometimes called by the miners. Small dikes also play an important part in some of the ore deposits, as will be more fully shown in the notes on the principal mines which follow. These notes are necessarily brief.

Empire, Pacific, Lucile, and Pioneer mines. The Empire, Pacific (Plymouth Consolidated), Lucile, and Pioneer mines all lie in the broad belt of Mariposa slate south of the town of Plymouth. Their ore is of the usual character found in the black slates, and shows some banded quartz, containing pyrite, gold, calcite, and a fine-leaved, pearly-white mica, which is a variety of muscovite (sericite or margarodite). These mines were closed in 1898, and their workings were not accessible. The first two were formerly large producers.

A number of claims have been located on Dry Creek, north of New Chicago, near the northern termination of the Bunker Hill area of meta-andesite ("diabase"). The Cosmopolitan has been extensively worked, and is said to have a curved vein following the contact with the meta-andesite. There are not at present any producing mines in this vicinity.

Amador, Bunker Hill, and Mayflower mines. Between Dry Creek and Amador, the principal vein of the Mother Lode system follows in a general way the contact between the Bunker Hill area of meta-andesite and the principal belt of Mariposa slates lying to the west. Several important mines, such as the original Amador, the Bunker Hill, and the Mayflower, were formerly extensively worked, but are now idle.

Keystone mine. The Keystone mine in Amador has been worked almost continuously from the early fifties, and is said to have produced from $12,000,000 to $13,000,000. It is located on a contact vein of massive white quartz, from 12 to 200 feet in thickness, lying between meta-andesite ("diabase") on the east and Mariposa slates on the west. The latter are here unusually narrow. This vein carries from a few cents up to $7 per ton, but is not at present worked. The ore bodies now being mined are a series of parallel stringer leads lying in the foot-wall slates, and dipping eastward into the main contact vein at angles of about 47°. When carefully followed up, these leads are found to expand from a thin seam of gouge (country-rock ground up by movement along the fissure and reduced to the physical condition of clay) into larger lenticular ore bodies consisting of many large stringers with crushed and impregnated slate. The middle portion of these lenses is generally occupied by a large and solid quartz vein. The ore of the Keystone contains quartz, pyrite, free gold, and a white sericitic mica.

South Spring Hill mine. The South Spring Hill mine adjoins the Keystone on the south, and is mining the main contact vein—probably here of somewhat higher grade than in the Keystone. Some of the quartz shows ribbon structure, and contains pyrite, free gold, and a little zinc blende. The banding is partly due to the original deposition of the quartz and pyrite. The proportion of free gold to gold contained in the sulphurets averages about five to one.

Medean mine. The ore of the Medean mine, east of the South Spring Hill, contains a little chalcopyrite, but this mineral is never abundant in the ores occurring in the Mariposa slates.

Wildman mine. The Wildman mine lies in the northeast corner of Sutter Creek on a vein whose general course is about N. 19° W., true. The ore-body as a whole is in the black Mariposa slates, but is associated with some amphibolite. It is divided by the miners into three distinct portions, viz., the "granite bowlder," the "main lead," and the "magpie." The main lead is a well-defined vein of solid quartz, with some banding near the walls. These banded portions are generally richer than the rest of the vein. Frequent irregularities are shown and the vein sometimes passes into a stringer lead, or locally pinches. The "granite bowlder" lies on the foot wall, or western side of the main vein, between the latter and the foot-wall slates. It is a body of amphibolite-schist which is traversed in all directions by stringers of quartz and is itself locally impregnated with sulphurets. Explicit statements as to the value of this portion of the lead were not obtainable; but it has been extensively stoped, and is undoubtedly a valuable portion of the ore-bearing ground, although varying much in tenor. The "magpie" is a somewhat similar mass of stringers and country rock, lying on the hanging-wall side of the main vein. The impregnated country rock in this case, however, is black slate. This portion of the lead is of little value, running only about 50 cents per ton. The ore of the Wildman is generally low grade, and is said to cost less than $2 to mine and mill. Some rich ore occurs, usually in streaks scattered through the ore body, with no regular arrangement so far as known. The vein minerals observed were quartz, pyrite, free gold, and small quantities of chalcopyrite, zinc blende, and galena. Some streaks of sericitic mica occur occasionally in the quartz.

Mahoney mine. In the Mahoney mine, which adjoins the Wildman on the northwest, the ore body is a stringer lead in black slate with a foot wall of amphibolite, or altered meta-andesite tuff. This latter is probably continuous with the amphibolite-schist of the "granite bowlder" in the Wildman, and broadens out into the considerable area of greenstone and greenstone tuff (meta-andesite) forming the hill just northwest of the town. The ore of the Mahoney is very similar to that of the Wildman.

Lincoln mine. Northward from the Mahoney the lode appears to divide, the Lincoln mine, now being reopened, being located upon the western and apparently more continuous branch.

Eureka mine. South of Sutter Creek lies Hayward's old Eureka mine, once the deepest mine in the State (2200 feet) and famed for the great quantity of high grade ore that was extracted from it. This mine, with the associated claims constituting the Amador Consolidated, has been idle many years. The mines are in Mariposa slates, but these contain many thin lenses of meta-andesite tuff (greenstone). Some of the larger ones are shown on the map, but many are too small to indicate.

The general pitch or rake of the ore shoots in the Sutter Creek district is said to be to the south.

South Eureka mine. The South Eureka mine, a little more than a mile south of Sutter Creek, lies in Mariposa slates and is on the northern extension of the Oneida, Kennedy, and Argonaut lead. There are no croppings at this point, the slates of the Bed-rock complex being covered by Neocene andesite. The mine was located by means of surveys, and through certain shrewd deductions drawn from the record of mines north and south of it. It is an example of bold yet legitimate and successful prospecting. The strike of the vein is N. 18° W. true, and the dip easterly, with the slates. For a short distance north of the shaft, however, the vein has a strike of N. 3° W. true, and locally cuts across the more westerly strike of the slaty cleavage. The real fissure vein in this portion is about 10 inches wide, but the slates are impregnated with pyrite and filled with stringers for a width of 4 feet. Occasional thin lenses of amphibolite-schist or meta-andesite tuff (greenstone) are met with in cross cutting the black slates. The pay ore is usually found near the foot wall, the hanging wall being frequently a large body of nearly barren (50 cents to $1 per ton) solid white quartz. The ore is generally high grade (by this is usually meant ore running over $10 per ton). The component minerals are quartz, pyrite, arsenopyrite, gold, with a little galena and zinc blende. These last are regarded as indicating good ore.

Oneida mine. The Oneida vein lies in Mariposa slate, near the contact with the meta-andesite breccia on the west. The general strike of the vein is about N. 27° W., true. The average dip is about 62° E. This mine was then closed after being worked to a depth of 1350 feet on the incline. It is now being reopened by a vertical shaft sunk to the eastward of the old shafts. At the 1500-foot level in this new shaft, a crosscut of 250 feet has been run west to the vein, which here shows banded ore consisting of quartz, pyrite, and free gold.

Kennedy mine. Adjoining the Oneida claim on the south is the Kennedy, one of the most important mines in the district. This mine has been a steady producer of high-grade ore for many years and is now the deepest mine on the Mother Lode (2250 feet). The Kennedy vein outcrops in meta-andesite ("diabase") but soon passes into a narrow belt of black Mariposa slates, within which the dip of the vein becomes much steeper. The vein is usually strong and well defined but varies considerably and is sometimes a stringer lead. Near the south end of the 2100-foot level the vein consists of from 4 to 5 feet of banded quartz, with a heavy lenticular mass of solid white quartz on the hanging-wall side. The banded quartz is worth about $20 per ton but the white quartz is very poor. The sulphurets in the banded quartz are most abundant in and near the thin slaty seams which produced the banded or ribbon effect. The vein follows in the main the eastern contact of the clay slates with the meta-andesite ("greenstone" or "diabase" of the miners), but does not strictly conform to it at all points.

The pay shoots in the Kennedy are considered to pitch northward. The ore consists of quartz, pyrite, gold, arsenopyrite, galena, and a silvery fine-grained mica (sericite or margarodite). The last three are not generally abundant. The pyrite often occurs in bunches of rather large crystals, especially in the massive white hanging-wall quartz, but such large crystals are usually not of much value as ore. Galena is regarded as a good indication. The pay is generally near the walls, particularly near the foot wall, where there is a persistent black gouge derived from the crushed slates.*

Argonaut mine. The Argonaut mine adjoins the Kennedy on the south, and is on the same vein, which here, as in the Kennedy, outcrops in meta-andesite ("diabase"), and dips about 40° E. Just above the 290-foot level the vein passes eastward into the Mariposa clay slates, and its dip rapidly increases to 68° or 70°. At the point where the vein passes into the slates it can be seen that the fissure was originally opened by a thrust fault of at least 120 feet throw, the hanging wall having been thrust upward over the foot wall to at least that distance. **Overthrust fault.** As far as known, this is the only place along the Mother Lode where the displacement can be actually seen and measured. The meta-andesite becomes an amphibolite-schist near the contact with the clay slates.

The Argonaut vein is on the whole a remarkably regular and continuous body of quartz which in the lower levels is from 8 to 14 feet in thickness. Much of it, especially on the hanging-wall side, is a firm, white quartz showing little sulphurets. Some of this unpromising-looking material is said to yield as much as $16 per ton, mostly in free gold. The richest ore is a firm, banded quartz containing gold, pyrite, galena, and zinc blende, the last two in small amount and lying next to the foot wall. There is no sharp separation, however, between this rich ore and the poorer white quartz next the hanging wall.

Veins near Jackson. In the vicinity of Jackson, the veins of the Mother Lode system are divisible into two nearly parallel secondary or subordinate systems. A western line, comprising the Kennedy, Argonaut, Alma, Anita, Amador Queen No. 2, Mammoth, and others, follows the narrow strip of Mariposa slates already described as passing west of Jackson and extending down through Murphy Gulch to the Mokelumne, which it crosses at Rich Gulch. A second line, locally called "the east vein of the Mother Lode," is that upon which the Jackson Gate, Zeila, and Amador Queen No. 1 are located. This system of veins is confined to the vicinity of the contact between a narrow strip of slaty Calaveras schists on the west and the main belt of amphibolite-schist on the east. Passing just west of Jackson Gate, it runs east of Jackson, just west of Scottsville, and down Hunt Gulch to the Mokelumne River, which it crosses near the bridge. There is absolutely no trace of any direct connection between these two sets of veins by "spurs" or branches, and they are an excellent example of the essentially compound character of the Mother Lode system as a whole.

Zeila mine. The Zeila mine, which has been worked nearly continuously for thirty years, lies about half a mile southeast of Jackson on the eastern line of the Mother Lode veins. The vein is essentially a stringer lead in amphibolite-schist, and has a general dip of 50° to 60° E. It is separated from the black slates (Calaveras formation) of the foot wall by a heavy gouge. The width of the vein where stoped is 40 to 50 feet, but the general average is somewhat less. A fine-grained, altered dike, from 4 to 6 feet wide, probably originally a diorite, accompanies the vein. The ore is low grade—less than $4 per ton. Pyrite is the principal sulphide, but there is sometimes a little molybdenite, and small quantities of galena and zinc blende are said to occur, and to indicate good ore. Calcite is quite abundant, both as stringers and crystallized with the quartz.

Gwin mine. South of the Mokelumne River, the Gwin mine is situated in a belt of Mariposa slates which is directly continuous with the slates of the Kennedy and Argonaut mines. The Gwin vein strikes with the slates and is generally parallel with their cleavage. It is accompanied by stringers, and varies in width, but on the whole is entitled to be called a simple vein rather than a stringer lead. The vein minerals are quartz, pyrite, arsenopyrite, free gold, and a little chalcopyrite, galena, zinc blende, albite, sericite, and calcite. Galena and zinc blende, when present in small amount, are considered to indicate good ore. The arsenopyrite occurs in both large and small crystals. The former are particularly prized, as they inclose beautiful arborescent masses of crystallized gold. All the free gold in the ore is coarse, and is easily caught on the plates after passing a No. 16 screen on the mortars; the tailings are said to average only 12 cents per ton. If true, this indicates a saving of about 98 per cent of the gold, which is a remarkably high average. Common pyrite is by far the most abundant sulphide in the ore. The average value of the ore is said to run from $5 to $7 per ton. The slates near the vein are impregnated with sulphurets, but these sulphurets are not so rich as those in the vein and are said to contain a larger proportion of silver. A conglomerate similar to many such beds occurring in the Mariposa formation, lies on the foot-wall side of the vein, and is said to carry gold up to 50 cents per ton, as shown by several assays. The ore shoot in the Gwin appears to be pyramidal in form and to be nearly vertical as far as exploited. The present depth of the mine is 1400 feet.†

In the neighborhood of San Andreas the original fissuring, which elsewhere resulted in a more or less linear and parallel arrangement of the Mother Lode veins, appears to have been irregular

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* Since this was written a new vertical shaft has been started 1950 feet east of the vein, designed to cut the latter at a depth of 3500 feet.

† Since the Gwin mine was visited the 40-stamp mill has been increased to one of 80 stamps, and other extensive improvements have been made. The shaft also has been sunk to about 1800 feet in depth.

in character. Veins were formed, but they are neither continuous for a long distance nor strikingly parallel in direction. In 1898 no mines were established upon a paying basis in this vicinity, although active prospecting was going on at the Ford mine, east of San Andreas.

Irregular fissures near San Andreas.

The vein here exposed is a stringer lead of much irregularity as regards ore-bearing portions. The ore shows free gold, pyrite, galena, and a little chalcopyrite. It is notable as containing a telluride (petzite) in small amounts, an uncommon occurrence in this portion of the district.

Subordinate divisions of the Mother Lode system near Angels Camp.

In the neigborhood of Angels Camp the Mother Lode system is represented by numerous important veins which fall naturally into two main groups: (1) the group of veins immediately around Angels Camp and Altaville, which are in amphibolite-schists; and (2) the groups of veins lying about a mile west of these towns, chiefly in dark slates belonging to the Calaveras formation. The veins nearest Angels Camp and Altaville have proved large producers, and are typical examples of ore bodies occurring wholly within amphibolite-schist. Several distinct lines of veins may be distinguished, in some cases running nearly parallel, and in others diverging at considerable angles. It is not known, however, whether such converging veins do in most cases actually meet and join. They are all equally members of the Mother Lode system. It is customary among the miners to distinguish one single vein as "*the Mother Lode.*" Not only does such a terminology lead to endless and unprofitable discussion, but, in the light of what is known of the complex character of the Mother Lode, the restriction of that name to any single vein of the system is misleading. All the Angels Camp mines are working what have been called stringer leads — a complex network of quartz stringers traversing a zone of fissured, altered, and impregnated country rock. In some cases the stringer lead is accompanied by a heavy vein of massive low-grade quartz, usually on the hanging-wall side. The lode upon which are located the Utica, Stickle, Lightner, and Bovee mines has proved exceedingly productive. Considerable calcite ("spar") occurs in the stringers composing the ore bodies. The richest ore is said to be the so-called "brown quartz" which is a fine granular aggregate of quartz, dolomite, and sometimes albite, thickly speckled with small crystals of pyrite. This "brown quartz" does not always form well-defined veins or stringers, but is very intimately associated with the country rock, and is in part an altered form of the latter. The other vein minerals are free gold, sericite, and a little chalcopyrite. Gold is not visible in most of the ore, but occurs in considerable masses in certain rich streaks.

The Utica lode.

Utica mine.

The ore body of the Utica mine is in the form of a stringer lead, consisting usually of numerous lenticular stringers lying nearly in the planes of schistosity of the amphibolite-schist, and separated by varying thickness of fissured and veined country rock. The stringers are largely quartz, but carbonates are also abundant, especially in the smaller fissures. The wall rock near the stringers is impregnated with pyrite, but the gold is said to occur chiefly within the quartz of the veins. The stringers dip easterly, as a rule, but are nearly vertical. Some rich specimens were seen in which the gold was embedded in a gangue of calcite. Pyrite was the only sulphide noted in the ore. Unfortunately, the attitude of those having the mine in charge was such that no satisfactory scientific examination of it could be made in 1897.

The Stickles mine.

The Stickles mine adjoins the Utica on the south and is under the same management. As in that mine the country rock is amphibolite-schist, but it is in general more sheared and fissile than in the Utica. The ore body is a complex network of small stringers inclosing more or less impregnated country rock. True walls are lacking, and stringers occur in the country rock many feet away from the auriferous lead. The greater number of stringers follow approximately the planes of schistosity, but others traverse the schist in all directions. The ore body is separated into two longitudinal portions, or leads, by a horse of barren schist (and stringers) 30 to 50 feet in width. The westerly lead is the more important, being from 60 to 90 feet wide, while the eastern lead is only 20 or 30 feet. The leads and the horse, however, are very irregular.

The filling of the fissures is sometimes quartz, sometimes carbonates, and sometimes a mixture of both. Pyrite and a little chalcopyrite were the only sulphides noted, the former being usually finely disseminated in small crystals through the vein material, and particularly through the impregnated schist between the stringers The richest ore is said to be the so-called "brown quartz" already described.

At the 1000-foot level, the lowest worked in 1897, a mass of talc-schist was encountered near the shaft. This is apparently merely a portion of the amphibolite-schist series.

The Stickle is an important mine and is relied upon to contain the lower part of the rich ore shoot of the Utica, which is said to pitch southward.

The Lightner mine.

The Lightner mine adjoins the Utica on the north, and the general character of its vein is very similar to that of the Utica and Stickles mines. In 1897 it was simply a prospect 200 feet in depth, but in 1898 it was being actively developed with new machinery, and sufficient ore was being raised to run a new 40-stamp mill.

Madison and Gold Cliff mines.

East of the Utica lode is a line of veins called the Deadhorse lead. The Madison and Gold Cliff mines lie just west of Angels Camp and are working a large body of low grade ore. The ore body consists of a broad zone of fissile, chloritic amphibolite-schist heavily impregnated with pyrite, and intersected by abundant stringers of quartz which, as a rule, carry little sulphurets. The working hanging wall is a heavy vein of white quartz 4 to 6 feet in thickness, which is too poor to work. The Madison is on what is locally called the "main Mother Lode vein," while the Gold Cliff, which adjoins it on the north, is working chiefly on a short westerly branch of the main vein. The pay shoot is said to pitch southward from the Gold Cliff into the Madison ground. The general dip of the vein in the Gold Cliff is about 70° NE. In the Madison it is only about 40°. The Gold Cliff is worked entirely by open cuts. The greater part of the value in these two mines is said to lie in the impregnated schists, and not in the stringers themselves. This statement needs further confirmation. Something more than one-third of the total gold yield is obtained from the sulphurets by chlorination.

Carson Hill mines.

Southward from Angels Camp, no more important mines are met with until Carson Hill and Robinson Ferry are reached. On the south slope of Carson Hill there are at least three strong and distinct veins, all more or less curved. They lie chiefly within fissile amphibolite-schists, although some of the ore bodies are accompanied by small dikes and streaks of black slate. The Carson Hill mines were extensively worked in early days and the ore bodies were found to be very rich in their upper portions. There is at present, however, no deep mine in paying operation, although prospecting on an extensive scale is in progress, and it is likely that one or more large mines may soon be working in this noted locality, treating low-grade ores by modern processes.

Tellurides near Carson Hill.

The general occurrence of the ore in the Reserve mine, near the summit of Carson Hill, is very similar to that found in the Gold Cliff mine. It is a stringer lead on the foot wall of a massive vein of quartz. These mines contain tellurides of gold and silver. Petzite (telluride of silver and gold, silver about 40 per cent, gold about 25 per cent), calaverite (telluride of gold and silver, gold about 40 per cent, silver about 35 per cent), hessite (telluride of silver and gold, silver about 50 per cent, gold about 3 per cent), and altaite (telluride of lead), have all been described from the Melones and Stanislaus mines The latter mine is also noted as the locality of a rare telluride of nickel, melonite. The presence of these tellurides necessitates special treatment of the ores, as the gold contained in them can not be saved by the ordinary free-milling processes. The other vein minerals noted were quartz, dolomite, mariposite, albite, pyrite, chalcopyrite (Reserve mine), a little galena, and tetrahedrite or gray copper ore (Reserve).

Norwegian mine.

The Norwegian mine, about half a mile southeast of Robinson Ferry, is on a vein from 4 to 20 inches in width, which strikes N. 12° W., and dips 54° E. The country rock is a firm, tough amphibolite-schist. The vein is without gouge—"frozen to the walls," in miners' parlance. The ore is high grade, and exceedingly rich in tellurides. Pyrite, free gold, tellurides, and a little bornite and galena occur in a gangue of quartz, calcite, and dolomite, with a little albite and chlorite. The tellurides occur in rich masses with abundant free gold. They include petzite, hessite, the extremely rare telluride of mercury, coloradoite, and probably other species. The different tellurides are not readily distinguishable from one another without chemical tests. Chalcopyrite was not seen but is said to occur. During the month of August, 1897, the mine was stated to have produced $22,000, without reckoning the very rich slimes in the settling tanks.

Between the Stanislaus River and Mormon Creek the Mother Lode fissures are irregular and of little continuity. The Tuttletown area of amphibolite-schist, particularly at Jackass Hill, about half a mile northwest of the village, is noted for its "pocket mines." These are small, irregular veins of no great length which contain occasional nests or "pockets" of free gold. South of Mormon Creek the Mother Lode is represented superficially by a single large vein which outcrops boldly above the surface as far as Quartz Mountain. The outcrop is not continuous, however, for in several places the vein pinches and no quartz appears.

Alameda and Tarantula mines.

The Alameda and Tarantula mines, about a mile northwest of Rawhide, are exploiting the main vein, which is here of great thickness and composed chiefly of dolomite, mariposite, and talc, intersected by quartz stringers. It is thoroughly typical of such Mother Lode veins as occur near bodies of serpentine. The foot wall of the vein in these mines is partly black Calaveras slates and partly serpentine. Some dark slates occur in the hanging wall of the Alameda, but the characteristic feature of this side of the vein is a narrow dike of fine-grained greenstone—probably a much altered diabasic rock, which merges into the amphibolite-schists on the north. Both vein and dike cut across the strike of the Calaveras slates at this point, showing that although the original Mother Lode fissures took advantage of such planes of cleavage in the rocks as lay near their own general direction, yet they ceased to be controlled by these planes when the latter formed too great an angle with the general trend of the fissure system.

At the Rappahannock mine, which intervenes between the Alameda and the Rawhide mines, the fissure apparently traversed the serpentine, and no vein has yet been found.

Rawhide mine.

At the Rawhide mine the main vein practically follows the contact between the Calaveras slates on the east and the serpentine on the west, and is said to be about 70 feet wide. It strikes N. 34° W. true, and dips 62° NE. The dip of the slates is about 75° E. This vein is composed of dolomite, quartz, and mariposite, and is similar to that of the Alameda. The vein actually worked lies on the foot-wall side of the main vein, separated from it by a thin gouge. It is sometimes 20 feet wide. The ore shows pyrite and free gold, in a gangue of quartz, talc, dolomite, and mariposite. A gray telluride with rich ore is said to have occurred near the surface, but has not been recognized in the lower levels. A specimen of supposed telluride said to have come from the 900-foot level proved on examination to be tiemantite, or arsenical gray copper ore. The pay shoot is said to pitch south until the 800-foot level is reached, and then to turn northward. This mine has been, and continues to be, a large producer. It is a matter of regret that permission to enter this mine for disinterested scientific purposes could not be obtained. Fortunately for the advancement of useful knowledge, such cases are very rare.

Southeast of Rawhide the main vein passes beneath the lava of Table Mountain and reappears on the southern side in the Alabama mine, where the ore body lies on the hanging-wall side of the large vein. Although the latter outcrops boldly south of Table Mountain as far as Whiskey Hill, a mile southwest of Jamestown, there are no producing mines upon this section of the Mother Lode. At the Trio mine, at Whiskey Hill, a crosscut run through the main vein about 200 feet below the heavy surface quartz croppings shows that the latter have dwindled at this depth to a few stringers accompanied by gouge. The immediate foot wall is serpentine.

The conspicuous hill 2 miles south of Jamestown, known as Quartz Mountain, is due to the heavy quartzose croppings of the Mother Lode veins. Several important mines occur in its vicinity and southward as far as Sullivan Creek.

Dutch mine.

The Dutch mine lies just northwest of the little town of Quartz on the principal Mother Lode vein, here about 45 feet in thickness, with an average dip of about 60° E. This vein is a complex structure composed of dolomite, mariposite, and quartz, with numerous lenses of altered amphibolite-schist. Black slate of the Calaveras formation forms both walls. The workings have been irregular, but most of the ore has come from the foot-wall portion of the vein, which consists in part of ribbon quartz with dark slaty seams, resembling the ore characteristic of veins in black slates. There is no definite separation, however, between this ore and the more dolomitic portion of the vein. Good ore also occurs in the middle portion of the vein, and on the hanging-wall side. The ore shows quartz, dolomite, a little mariposite, pyrite, gold, and a little tetrahedrite (hanging wall). This last is frequently associated with free gold. The ore as a whole is medium grade, and the chlorination of the sulphurets affords but one-seventh of the total yield.

App mine.

The App mine adjoins the Dutch mine on the south. The great vein of the App is of compound structure, about 200 feet in thickness, and dips about 54° E. It is composed chiefly of dolomite and mariposite, but contains also abundant stringers and lenticular bunches of quartz, streaks of talc or talcose schist, and at least one dike of altered diorite. It is traversed, moreover, by several partings or "walls," usually roughly parallel with the vein, and frequently accompanied by thin attrition gouges. The east or hanging wall is dark Calaveras slate; the west or foot wall is partly slate and partly altered meta-andesite ("diabase" or "greenstone"). This great vein as a whole is very low grade, and is not now worked. The so-called "big vein" of the miners is a vein of quartz with some dolomite and mariposite lying within the great 200-foot vein, near its hanging wall. The quartz of this vein is white and massive, showing little sulphurets. It is low grade—about $5 per ton. Most of the development has been done on the so-called "west vein" or "foot-wall vein." This is a true stringer lead in the black slates and schistose greenstones of the foot wall, and is separated from the main vein by a thin streak of serpentine and talc. About 200 feet east of the great vein lies the Heslep vein, in the black slates of the hanging wall. This vein is not at present worked. The vein minerals noted in the ore of the App mine are quartz, dolomite, talc, mariposite, pyrite, and a little galena and free gold. The proportion of gold in the sulphurets to free gold is said to be as four to one.

Santa Ysabel mine.

In the Santa Ysabel mine, on the southern slope of Quartz Mountain, the ore is found on both sides of the main dolomitic and talcose vein. That in the hanging wall consists of numerous quartz stringers in dark Calaveras slates. These latter are cut by several small dikes of fine-grained greenstone, which are much altered diabases or diorites. The stringers are usually richest near the contacts of the dikes with the slates. The gold is mostly coarse and free—the sulphurets being worth only about $25 per ton. The ore is high grade, but variable in tenor. A gray telluride, probably petzite, accompanies some of the free gold, but is not abundant.

Golden Rule mine.

The Golden Rule mine, just south of Stent, is one of the oldest in Tuolumne County. The workings are all east of the main vein, which here preserves the general character already described in the App and Santa Ysabel mines, and is about 200 feet thick, with an altered dioritic dike on both foot and hanging wall. There are several veins east of this great complex vein, of which the Golden Rule is the most important. This is a stringer lead in black Calaveras slates, the fissured and impregnated zone of slate being accompanied with remarkable regularity by a small dike of the kind already described in the Santa Ysabel. This dike varies in width from a few inches up to a foot and a half, or more, but the general impression, in following it for over 800 feet, is that it is remarkably regular. The average width is about 6 inches. In general it follows the cleavage of the slates but occasionally cuts across it. The contact between the slates and the dike is perfectly sharp, and it is evident that the slates already possessed their characteristic cleavage before the intrusion of the igneous rock. The gold occurs coarse and free, often crystallized, in the small quartz stringers near the greenstone dike. The productive stringers are those that cut the slates and lie at a rather low angle. They grow poorer away from the dike. The ore is said to be richest and most abundant where the dike is largest. Both the dike and the adjoining slates are impregnated with pyrite, but it is not considered worth saving. The tellurides petzite and altaite have been reported from this mine, but they are not known in the present workings.

Jumper mine.

The Jumper mine, which lies just south of the Golden Rule, resembles the latter in the general character and position of its ore body. There is a similar relation of stringers of quartz and calcite, black slates, and greenstone dikes. The latter are themselves somewhat schistose in this mine. The best ore lies on the west side of the greenstone dike, and is high grade, containing much coarse free gold. A gray telluride occurs in small amount with the free gold.

South of Sullivan Creek the Mother Lode fissure (or fissures) pinches. No empty spaces were formed along that portion of the fissure which intersects the present surface of the country, and consequently no prominent vein could form. When, however, the Shawmut mine is reached, about 2 miles northwest of Jacksonville, the Mother Lode system is again represented by massive surface croppings.

Shawmut mine.

In the Shawmut there is a large low-grade vein about 33 feet thick, which dips 72° E., and which is composed chiefly of quartz with a subordinate amount of dolomite and mariposite. This is not worked. The vein now being exploited lies just east of it, usually about 30 feet back, in the black Calaveras slates of the hanging wall. In the Eagle claim, however, this eastern vein is close to the main vein, and it is here that the pay ore is found. The general dip of the pay vein is here about 63°, being thus flatter than the larger vein to the west of it. Its greatest width (in the Eagle claim) is about 12 feet. It is composed of quartz, dolomite, and mariposite. The ore is low grade as a whole, and the proportion of free gold to the gold in the sulphurets is about eight to one.

The Mammoth mine, on Woods Creek near Jacksonville, has exploited the main vein of the Mother Lode system but has found the ore of too low grade to be profitably worked.

From Jacksonville to Coulterville there is a long interval in which no large or profitable ore bodies are known. Along Moccasin Creek the long dike of syenite-porphyry lies in the general course of the Mother Lode fissures, but although locally auriferous, it is doubtful whether it will ever pay to work.

The syenite-granophyre dike.

Several claims have been located upon the white croppings of the dike. As far as is known none of these claims have ever been productive, and in the North Star and Black Warrior tunnels the dike is not at present regarded as the lode which is being sought. The North Star tunnel, 720 feet, has cut through the dike and encountered black slates of unknown thickness, which do not appear at the surface. It has not yet met with paying ore. In spite of such negative results, however, there is no question that the dike rock does at certain places carry some gold, although perhaps it may never be worked on a large scale. Thus at Grizzly Gulch it carries pyrite and contained enough gold to encourage considerable prospecting. North of the Tuolumne River the short, broad dike shown one mile southeasterly from Jacksonville (Willietta claim) was quarried some years ago and the ore run through a mill worked by water power. What success attended this venture is not known. Inspection of the quarry faces shows that the syenite-granophyre is traversed irregularly by small veins of albite with some quartz; it was apparently these that were mined. The more decomposed dike to the eastward of the one just mentioned is known to contain gold. It is decomposed to a depth of several feet and the decomposed rock contains free gold, as shown by panning. Below water level the rock is fresher but contains abundant small cubes of pyrite and soon crumbles on exposure. It is traversed by veinlets, usually of albite, which sometimes contain bunches of free gold. The largest "pocket" yet found in these veinlets is said to have amounted to $50.

South of Jackass Creek the line of the principal Mother Lode veins is defined by a line of massive croppings extending down to Coulterville, and giving rise to sharp-topped knobs of which Penon Blanco Point is a good example. These croppings are in, or on the contact of the large serpentine area shown on the map, and possess in full degree the character already described as typical of such veins. They are frequently associated with decomposed basic dikes in the serpentine. If they are ever worked as a whole, it must be on a far larger scale and under more economical conditions than have yet proved practicable in this region.

Two systems of veins near Coulterville.

In the neighborhood of Coulterville the Mother Lode system is represented by at least two distinct lines of fissuring. The more westerly one, which is locally referred to as "the Mother Lode," lies about a mile southwest of the town, near the western edge of the main belt of Mariposa slates. Its veins have the character already described as belonging to veins in the clay slates. They are stringer leads without prominent outcrops, and the vein matter is chiefly white quartz, often showing ribbon structure. They closely resemble the veins of the Plymouth district, in Amador County.

The easterly line of veins crosses Maxwell Creek just below Coulterville. It is here about 300 feet wide and has the usual complex character of veins in or near serpentine. It consists chiefly of dolomite and mariposite with stringers and lenses of quartz, streaks of talc, and horses of altered country rock.

Mary Harrison mine.

Considerable work has been done on the mines near Coulterville, but the only one which was running on a paying basis in 1897 and 1898 was the Mary Harrison, which is working a vein on the foot-wall side of the main dolomitic vein. This vein has a maximum width of about 20 feet, and dips 45° E. The ore averages about $10 per ton. Most of the value is in the free gold, the sulphurets running about $55 per ton. The ore consists of quartz, gold, pyrite, talc, mariposite, and dolomite. The gold often occurs in exceedingly thin films in streaks of talc or mariposite in the quartz.

Veins not belonging to Mother Lode system.

All the veins hitherto described belong strictly to the Mother Lode system; but the district includes many others, some of them productive, which lie to the east or to the west of the Mother Lode. The courses of these veins usually differ from the general trend of those composing the Mother Lode, and in some cases they constitute separate and local systems of fissures. They may or may not have been formed simultaneously with the long system of Mother Lode fissures, but it is probable that their genesis was not separated from that of the latter by any very great interval of time.

About 2 miles northeast of Amador a conspicuous vein outcrops on the southern slope of Quartz Mountain (not the Quartz Mountain in Tuolumne County) with so flat a dip (25°) that its hanging wall is largely eroded away and the vein forms the northern slope of a spur of the mountain. This heavy mass of quartz, 10 to 15 feet thick, has been extensively prospected, but it has not been profitably worked on a large scale. The vein is of interest on account of its northeast-southwest strike and low northwesterly dip.

The Baliol and Potazuba mines, about 1½ miles northeast of Sutter Creek, are examples of mines situated on minor fissure systems. The ore-bearing ground of the former consists of quartz stringers of various sizes which traverse the country rock on the hanging-wall side of a massive vein of barren quartz 12 to 13 feet in thickness. The veined and impregnated country rock is a light-gray, finely banded schist consisting of quartz, dolomite, sericite, and albite. It is probably an altered facies of the amphibolite-schist series, and was originally a tuff. Stringers and pyritized country rock are all sent to the mill, and the ore is low grade—usually less than $4 per ton.

The Potazuba mine is a prospect in dark Calaveras slates. The general strike of the vein is N. 43° W., true, and the dip 62° NE. The ore is unusually base, some of it assaying 70 ounces of silver per ton. It consists of a quartz gangue carrying pyrite, galena, zinc blende, chalcopyrite, and a little pyrrhotite. The vein is rich in spots, but small, and is irregular in tenor.

The Esperanza (or Boston) mine, about 1½ miles northeast of Mokelumne Hill, is on a 60-foot vein, dipping about 50° E. Altered diorite forms both foot and hanging walls. The ore is low grade.

About 2 miles northeast of Jamestown there is a small group of veins in amphibolite-schist, upon one of which the Golden Gate mine is operating. This vein dips about 66° E. The gold occurs chiefly in the pyrite, in a gangue of quartz and calcite.

Big Oak Flat veins.

An interesting set of veins occurs near Big Oak Flat. These are most abundant within the quartz-diorite ("granite"), but some veins lie at the contact between the dioritic rock and the inclosing schists, while others traverse both rocks. The Mississippi mine, just west of Big Oak Flat, is on a vein of solid milk-white quartz 3 to 4 feet wide. As shown on the map, this is a curved vein, and traverses both the quartz-diorite and the Calaveras schists. It dips at angles varying between 25° and 35° NE. Northeast of this vein are numerous small, approximately parallel veins in the quartz-diorite, which also shows similar low dips (20°–45°) to the northeastward. Northwest of the town the Longfellow and Mack mines are on a vein which crosses the contact between Calaveras schists and quartz-diorite. The portion of the vein included in the Longfellow claim is in the slaty schists, and dips 43° NE. The ore is white quartz, containing free gold, pyrite, a little arsenopyrite and galena, and some sericite. The vein of the Mack claim is partly in schist ("black slate") and partly in the quartz-diorite ("granite"). None of the Big Oak Flat mines have yet passed beyond the prospect stage.

Pocket mines.

Pocket mining is a characteristic feature of some portions of the Mother Lode district. This consists in the discovery and exploitation of small stringers, which, although not as a rule large enough or continuous enough to pay for extensive operations, may yet contain considerable masses of free gold. Men who follow this form of mining usually work alone or in pairs, and often display much practical skill and ingenuity in following up the indications of a pocket. The Jackass Hill area near Tuttletown has already been referred to, these veins being in amphibolite-schist. Another line of little pocket mines extends along the contact between the amphibolite-schist and Calaveras rocks between Priest and the Tuolumne River. The gold occurs usually in thin leaves, often showing triangular octahedral faces on the surfaces of the flat plates. The largest amount taken out of any one pocket along this contact is said to have amounted to $2500. There has also been considerable pocket mining in the amphibolite-schists south and east of Coulterville, in the meta-andesite east of Horseshoe Bend, and in Hunter Valley.

Generalizations applicable to the Mother Lode district.

A few generalizations, based upon a study of the Mother Lode veins of the area, and not necessarily applying to other areas, may be formulated as follows:

1. The ore bodies of the Mother Lode occur, almost without exception, in true fissure veins.

2. Paying veins may be found in any rock of the Bed-rock complex with the possible exception of serpentine. The most favorable rocks for the formation of large productive ore bodies are those possessing cleavage or schistosity.

3. In order to allow the deposition of ore, the country rocks must previously have been fissured in such a way as to produce open spaces. But many spaces of moderate size are more favorable to ore deposition than a single large one. Thus the stringer leads and impregnated zones of the fissile and schistose rocks are more uniformly productive than the large veins of solid quartz.

4. Very large solid croppings of white quartz are usually low grade, and likely to be lenticular, and to pinch out vertically or horizontally. They indicate, however, a strong line of fissuring and movement, and are often accompanied by smaller paying ore bodies on the foot or hanging wall.

5. The pay ore is not uniformly distributed through the veins, but is more or less concentrated into nearly vertical "shoots" or "chimneys," best referred to as pay shoots.

6. Veins must somewhere pinch vertically as well as horizontally. There is no evidence that any mine on the Mother Lode which has ever paid has been really worked out. A productive pay shoot followed down to a pinch will probably reappear again at greater depth. The extent to which it may be advisable to prospect for it must be determined by a thorough knowledge and study of the portion of the vein already exploited, and by the economic conditions of operating.

7. The gold usually occurs chiefly in the veins and stringers, not in the impregnated wall rock.

8. Quartz and pyrite are the only vein minerals always associated with the gold. When the pyrite occurs in large crystals of cubical form it is *usually* not auriferous. Zinc blende and galena in small quantities appear to indicate good ore. The free gold may occur embedded in pyrite, arsenopyrite, tellurides, tetrahedrite, quartz, dolomite, calcite, talc, or mariposite. There is but one way to determine the value of ore from a new prospect, and that is by assays. Experience is often sufficient to distinguish the signs of rich ore in a given mine, but the same indications may not hold in a mine a few miles away.

9. There is no evidence that mines grow suddenly richer at any arbitrary depth, such as 1000 feet, nor is there any recognizable regular change in the value or mineralogical character of the pay shoots with depth, when once the zone of superficial weathering is passed through. The depths of mines are measured from the present surface, which is irregular, and results from the erosion which has shaped the whole surface of the district *since* the ore deposits were formed. Thus of two separate ore bodies now about 1000 feet in depth, one may have been formed originally under several thousand feet of rock, while the other may have been deposited at only a half or a quarter of that depth. Or if both were originally formed at the same depth it would be a mere accident if at the present day the rich pay shoots should both be struck at the same distance below the croppings.

Treatment of ores.

There is neither need nor space to treat fully in this folio the processes by which the gold is obtained from the ores. Except in the case of a very few ores carrying tellurides, the universal practice is to employ rapidly dropping, moderately heavy stamps (850–1000 lbs.). The pulp passes through rather coarse screens over the amalgamating plates and thence to concentrators. The concentrates are chlorinated. The cyanide process is occasionally used on tailings. About 3 or 4 tons of ore per stamp is the usual daily capacity of a modern mill. The process is simple, and from the conditions in California there has been evolved a standard method of procedure known throughout the gold-mining world.

Auriferous gravels.—The occurrence and distribution of the Neocene and Pleistocene gravels have already been described. Their economic importance at the present day is comparatively insignificant. The Neocene gravels of the Mokelumne Hill district were formerly extensively worked by hydraulicking and drifting and were very rich. No work was in progress in 1898, although preparations were being made for drifting under the rhyolite near the head of Old Woman Gulch. Similar work was in progress at two points in the Central Hill area northwest of San Andreas, and some hydraulicking had recently been done about 2 miles southeast of San Andreas. The gravels just southwest of Dogtown were also being worked by the hydraulic method. Drift mining under the lava of Tuolumne Table Mountain has been practically abandoned, and never proved a remunerative venture on the whole. A little work is at present in progress near Montezuma, and a few Chinese are at work along some of the present river and creek beds, but beyond these minor operations there is no gravel mining going on in the district. The Pleistocene gravels along Moccasin Creek were formerly extensively worked, the material being raised by derricks and sluiced. But they are said to have barely paid expenses, and their poverty is an indication that there are probably no very productive veins in the vicinity. The former importance of the auriferous gravels diminished to the south in this district, and the region as a whole never possessed such extensive areas of rich Neocene gravels as were found farther north.

SILVER.

No silver ore is mined within the district, the appearance of this metal being merely incidental to the output of gold. The amount of silver is in many cases so small that it is disregarded in making up statistics of production. The silver occurs with the gold, chiefly in sulphurets, and particularly in the sulphurets in the country rock adjacent to the vein. It also occurs with gold in the form of tellurides.

PRODUCTION OF GOLD AND SILVER.

Accurate statistics of the production of the district included within the area mapped are not obtainable. The returns of the separate mines are often carefully guarded, and the only available data are those furnished by the reports of the Director of the Mint. In these reports the output is usually given by counties. The following table has been compiled from these sources, and gives the production from 1890 of the four counties which are, in part, included within the district mapped. The amount of silver is in nearly all cases too small to agree with the average fineness of California gold bullion. It is evident that the returns of the less valuable metal are very incomplete.

Table showing production of gold and silver from 1890 to 1897, inclusive.

Counties.		1890.	1891.	1892.	1893.	1894.	1895.	1896.	1897.†
Amador	Gold	$1,459,952	$1,395,962	$1,210,383	$1,505,974	$1,331,916	$1,391,929	$1,523,351	$1,324,473
	Silver	9,357	13,895	8,008	5,230	280	1,089	3,767	3,477
	Total	1,469,309	1,409,857	1,218,391	1,511,204	1,332,196	1,393,018	1,527,118	1,327,950
Calaveras	Gold	618,821	738,884	794,531	1,669,193	2,119,365	1,717,916	1,546,398	1,439,861
	Silver	2,499	4,861	24,441*	122	5,182	77	500	1,745
	Total	621,320	743,745	818,972	1,669,315	2,124,547	1,717,993	1,546,898	1,441,606
Tuolumne	Gold	1,500,629	1,384,950	1,092,549	354,734	547,448	666,754	1,070,142	1,809,572
	Silver	13,062	139	911	1,329	1,072	312	328	1,696
	Total	1,513,691	1,385,089	1,093,460	356,063	548,520	667,066	1,070,470	1,811,268
Mariposa	Gold	124,265	84,414	81,012	164,116	153,707	216,622	335,637	451,427
	Silver	22	......	67	307	38	7	180	660
	Total	124,287	84,414	81,079	164,423	153,745	216,629	335,817	452,087
Totals for district		3,728,607	3,623,105	3,210,902	3,701,005	4,159,008	3,994,706	4,480,303	5,032,911

* $22,000 from Satellite copper mine. Campo Seco.

† The silver is quoted for this year at its commercial value. The figures for previous years are coining values.

In the case of Amador and Calaveras counties the production of precious metals, as given in the table, probably does not greatly exceed the output from such portions of these counties as are within the limits of the area mapped. Deductions must be made, however, for a few mines lying to the eastward of the district, such as the Sheep Ranch mine, which produced nearly $131,000 in 1891, and is credited with $95,000 in 1892. The bulk of the product of these two counties for the years given in the table has come from the large mines developed along the Mother Lode vein system, from Plymouth to the Stanislaus River. The Kennedy mine, which has been a very steady producer for many years, had an output of more than $2,025,000 from 1890 to 1893 inclusive, and the Utica group of mines (Utica, Stickle, Gold Cliff, and Madison) afforded about $2,631,000 in the same period. The last-named group, which is under one management, ranked in 1894 as the largest producer of gold bullion in the United States.

Tuolumne County is noted for its pocket mines, some of which have been considerable, although erratic producers. The output of the county is therefore subject to fluctuations, and it is difficult to apportion the total yield among the different mines. The large product in 1897 was probably due chiefly to the general activity and development of the larger and more permanent mines, such as Rawhide, Shawmut, Jumper, Dutch, and App, along the Mother Lode, and the Golden Gate, near Sonora. But numerous smaller mines collectively make up a considerable part of the total, while several important mines, such as the Black Oak, lie to the eastward of the Mother Lode district.

It is impossible to say how much of the comparatively small output for Mariposa County can properly be apportioned to the district described in this folio. The development of the Mary Harrison mine, near Coulterville, is probably responsible for the considerably increased production of the last three years.

QUICKSILVER.

Cinnabar, or sulphide of mercury, occurs in small quantities at Marsh Flat, and in good crystals in a quartz vein east of Horseshoe Bend. (See Sonora folio). Neither deposit is of economic value.

MANGANESE.

A little psilomelane occurs in a small patch of serpentine about three-quarters of a mile west of French Flat. The deposit is not likely to be of economic importance.

LIME.

Most of the limestone of the area makes a fair lime, and has been burned at several points to supply local demand.

QUARTZ.

Large loose crystals of clear quartz, up to 19 inches in length, and suitable for cutting into ornamental objects and lenses, have recently been discovered in the Green Mountains gravel mine, near Mokelumne Hill. They occur abundantly in one of the Neocene gravel channels, and were found after drifting 900 feet from the surface.

BUILDING STONE.

There is practically no quarrying done within the district. White marble of fair quality occurs in a small patch of Calaveras schists included in the meta-diorite northeast of San Andreas, and has been used to a small extent for building in the latter town. About 2 miles northeast of Angels Camp a rhyolite tuff has been quarried in the past. It affords an easily worked and fairly durable stone. An inexhaustible supply of excellent building stone might be derived from the granitic masses just to the eastward of the area, but there is at present no demand for such material. A banded and ornamental serpentine has been quarried on a small scale 4 miles southwest of Plymouth.

GLOSSARY OF ROCK NAMES.

The sense in which the names applied to igneous rocks have been employed by geologists has varied, and it is likely to vary as knowledge increases. The senses in which the names are employed in this folio are as follows:

Peridotite.—A granular intrusive rock generally composed principally of olivine and pyroxene, but sometimes of olivine alone.

Pyroxenite.—A granular intrusive rock composed chiefly of pyroxene.

Hornblendite.—A granular intrusive rock consisting chiefly of hornblende.

Serpentine.—A rock composed of the secondary hydrous mineral serpentine. Serpentine is an alteration product of rocks of the peridotite and pyroxenite series, and sometimes contains unaltered remnants of pyroxene or olivine.

Gabbro.—A granular intrusive rock consisting of lime-rich feldspars (labradorite or anorthite), pyroxene (more rarely hornblende), and sometimes olivine.

Diorite.—A granular intrusive rock consisting chiefly of lime-soda feldspar (oligoclase, andesine, or labradorite) with hornblende or pyroxene, and sometimes biotite. If quartz is present the rock is called a *quartz-diorite.* A *meta-diorite* is a partly recrystallized or altered diorite.

Granodiorite.—A name used in the Gold Belt folios to designate a granular intrusive rock standing mineralogically and chemically between a granite and a quartz-diorite, but closely related to the latter, and yet more closely to quartz-monzonite.

Syenite.—A granular intrusive rock composed chiefly of alkali feldspars with amphibole, pyroxene, or mica. A *soda-syenite* is one in which a soda feldspar is prominent.

Granite.—A granular intrusive rock composed of soda or potash (alkali) feldspar, quartz, mica, and sometimes hornblende. Granites usually contain some soda-lime feldspar or plagioclase. A *soda-granite* is one in which albite or other soda-rich feldspars predominate.

Diabase.—An intrusive or effusive rock having a mineralogical composition like gabbro, but differing from the latter in structure. The feldspars are lath-shaped, and the rock is often porphyritic and usually less coarsely and evenly crystalline than gabbro. A *meta-diabase* is an altered diabase in which the pyroxene is often changed into fibrous green amphibole (uralite) and the feldspars into epidote and other secondary minerals.

Diorite-porphyry.—A rock possessing the general chemical and mineralogical character of a diorite, but with porphyritic instead of granular structure. Porphyry is merely a structural term.

Syenite-porphyry and syenite-granophyre.—A rock having the chemical and mineralogical character of a syenite, but with porphyritic instead of granular structure. A *syenite-granophyre* is a syenite-porphyry in which the groundmass is finely granular.

Basalt.—An effusive rock containing basic lime-soda feldspars, much pyroxene, generally olivine, and frequently considerable glass. The silica content is usually less than 56 per cent. The basalts are the effusive equivalents of the gabbros.

Andesite.—An effusive rock, usually of porphyritic structure, composed essentially of soda-lime feldspars (chiefly andesine and labradorite) and ferromagnesian silicates (hornblende, pyroxene, or biotite), in a groundmass of feldspar microlites and magnetite, with some glass. The silica is ordinarily above 56 per cent. The andesites are usually gray in color. A *meta-andesite* is an altered andesite. The andesites are the effusive equivalents of the diorites.

Latite.—An effusive rock, usually of porphyritic structure, which is mineralogically closely related to the andesites, but contains more potash and soda. The latites are the effusive equivalents of the granular intrusive rocks called monzonites. The latite of Table Mountain consists essentially of labradorite-feldspar, augite, olivine, and glass. It contains about 56 per cent silica, 6.5 per cent lime, 2.5 per cent soda, and 4.5 per cent potash.

Rhyolite.—An effusive rock, generally nearly white in color, consisting of alkali feldspars, quartz, and usually hornblende or biotite, in a groundmass which is often glassy. The rhyolites are the effusive equivalents of the granites.

Amphibolite and amphibolite-schist.—A massive or schistose rock composed principally of green amphibole, with quartz, feldspar, epidote, chlorite, calcite, and other minerals, and usually derived by metamorphic processes from andesites and diabases (often in the form of tuff), diorites, and other igneous rocks.

Tuff.—A rock composed of small fragments of lava (basalt, andesite, rhyolite, etc.) originally thrown into the air by explosive action of volcanoes, or erupted from volcanic vents in the form of mud flows. The finer tuffs are often bedded, and may become cemented into a hard rock.

Breccia.—A rock composed of angular fragments embedded in a finer clastic matrix. The breccias of the Mother Lode district are almost all of volcanic materials, and may be regarded as very coarse tuffs. If the fragments are waterworn and rounded the rock becomes a *conglomerate.*

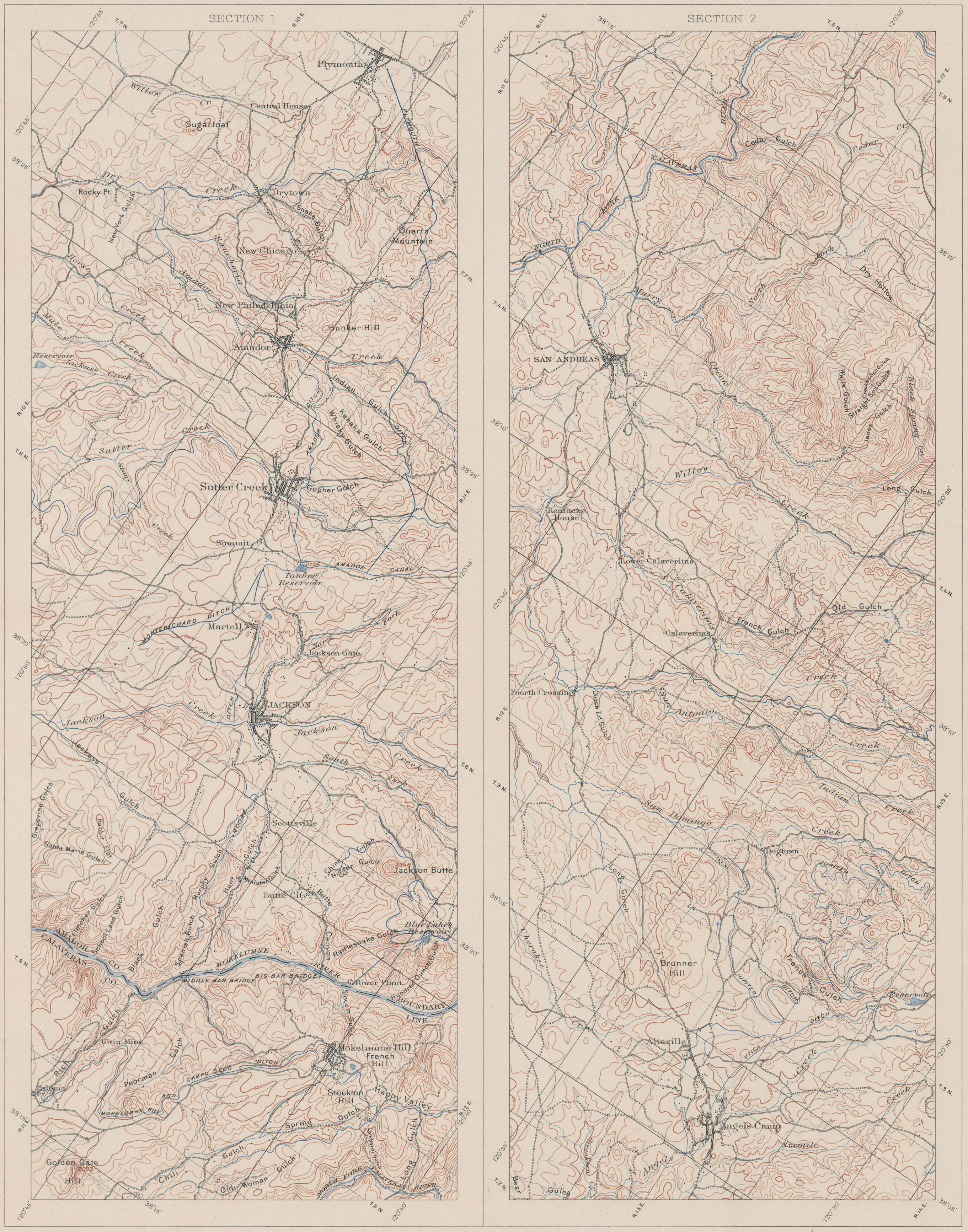
F. L. RANSOME,
Geologist.

April, 1899.

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

TOPOGRAPHIC SHEET 1

CALIFORNIA
MOTHER LODE DISTRICT



LEGEND

RELIEF
(printed in brown)

Figures *(showing heights above mean sea level instrumentally determined)*

Contours *(showing height above sea, horizontal form, and steepness of slope of the surface)*

DRAINAGE
(printed in blue)

Streams

Intermittent streams

Ditches, pipe lines, and flumes

Lakes and reservoirs

CULTURE
(printed in black)

Roads and buildings

Private and secondary roads

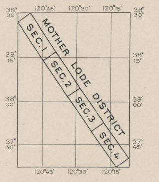
Trails

Bridges

County boundary lines

U.S. township and section lines

POSITION OF MAPS



R.U. Goode, Geographer in charge.
Topography by A.B. Searle.
Surveyed in 1897.

Scale $\frac{1}{63360}$

Contour interval 100 feet.
Datum is mean sea level.

Edition of Jan. 1900.

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

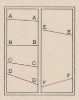
ECONOMIC GEOLOGY SHEET 1

CALIFORNIA
MOTHER LODE DISTRICT

LEGEND
(continued)

- 80° *Dip and strike of bedded rocks*
- *Vertical dip and strike of stratified rocks*
- 65° *Dip and strike of schistosity or cleavage*
- *Vertical dip and strike of schistosity or cleavage*
- *Quartz veins outcropping prominently on the surface*
- *Gold quartz mines*
- P *Shallow placer mines in auriferous gravels*
- H *Hydraulic mines in auriferous gravels*
- D *Drift mines in auriferous gravels*
- *Quarries of limestone, serpentine, and building stone*
- *Gold prospects, including pocket mines*

Sections

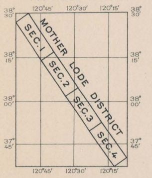


Known productive formations

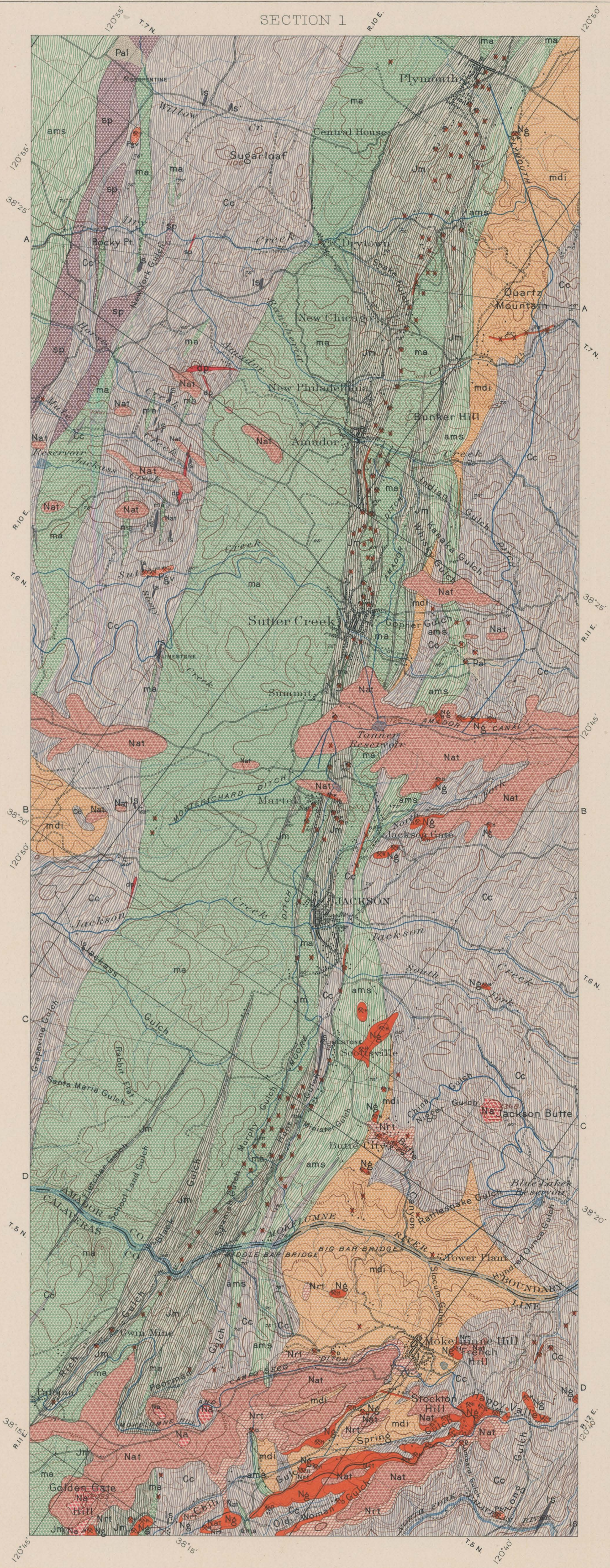
Auriferous river gravels

Limestone *(suitable for making lime)*

POSITION OF MAPS



SECTION 1



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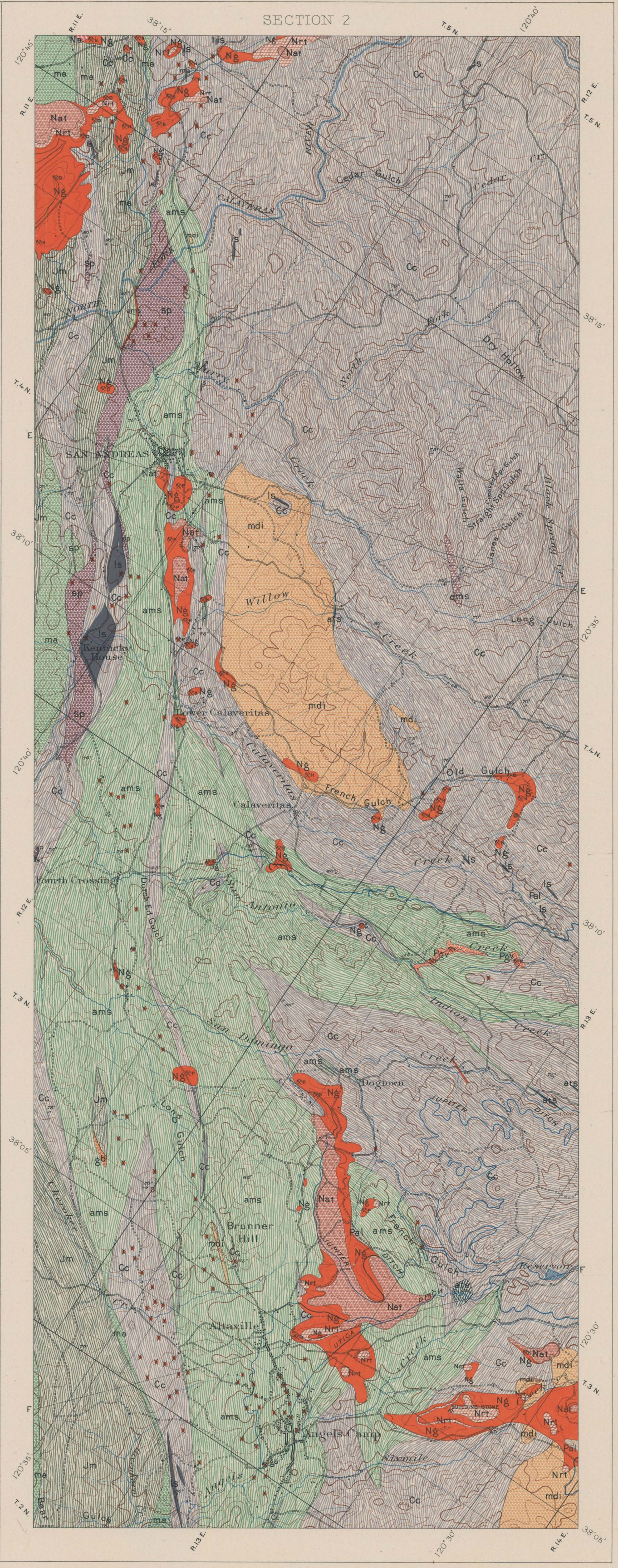


LEGEND

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

SUPERJACENT SERIES — PLEISTOCENE

- Pal — Alluvium *(bordering streams and filling small valleys)*
- Pgv — River gravels *(usually auriferous)*

SEDIMENTARY ROCKS
(Areas of Sedimentary rocks are shown by patterns of parallel lines. Wavy-line patterns show general direction of schistose cleavage.)

SUPERJACENT SERIES — NEOCENE

- Ng — Auriferous river gravels

BED-ROCK COMPLEX

JURATRIAS

- Jm — Mariposa formation *(clay slate, sandstone, and conglomerate)*

CARBONIFEROUS

- Cc — Calaveras formation *(slaty mica-schists, chiefly biotite-schist, quartzite, conglomerate, clay slate, chert, and limestone)*
- ls — Limestone *(lenses and irregular masses within the Calaveras formation)*

IGNEOUS ROCKS
(Areas of Igneous rocks are shown by patterns of triangles and rhombs. Wavy-line patterns show general direction of schistose cleavage.)

SUPERJACENT SERIES — NEOCENE

- Na — Andesite *(thick lava flows)*
- Nat — Andesite tuff, breccia, and conglomerate *(roughly stratified)*
- Nrt — Rhyolite tuff *(sometimes interstratified with gravel)*

BED-ROCK COMPLEX

JURATRIAS OR EARLY CRETACEOUS

- Small dikes of various rocks *(serpentine, sp, diorite-porphyry, dp, diorite, di, gabbro, gb, and altered rocks)*
- mdi — Meta-diorite *(altered diorites, largely quartz-diorites)*
- gb — Gabbro *(intrusive masses and dikes, usually associated with serpentine)*
- sp — Serpentine *(derived from peridotite and related basic intrusive rocks)*

CARBONIFEROUS OR JURATRIAS

- ma — Meta-andesite *(altered andesitic breccias, tuffs, and massive lavas, with some altered basalt and diabase)*
- ams — Amphibolite-schist *(derived from andesitic tuff and breccia, diorite, and other igneous rocks)*
- ats — Amphibolite-talc-schist
- qms — Quartz-muscovite-schist

Legend is continued on the left margin.

R.U. Goode, Geographer in charge.
Topography by A.B. Searle.
Surveyed in 1897.

Scale $\frac{1}{63360}$

1 ½ 0 1 2 3 4 Miles

1 ½ 0 1 2 3 4 5 Kilometers

Contour interval 100 feet.

Datum is mean sea level.

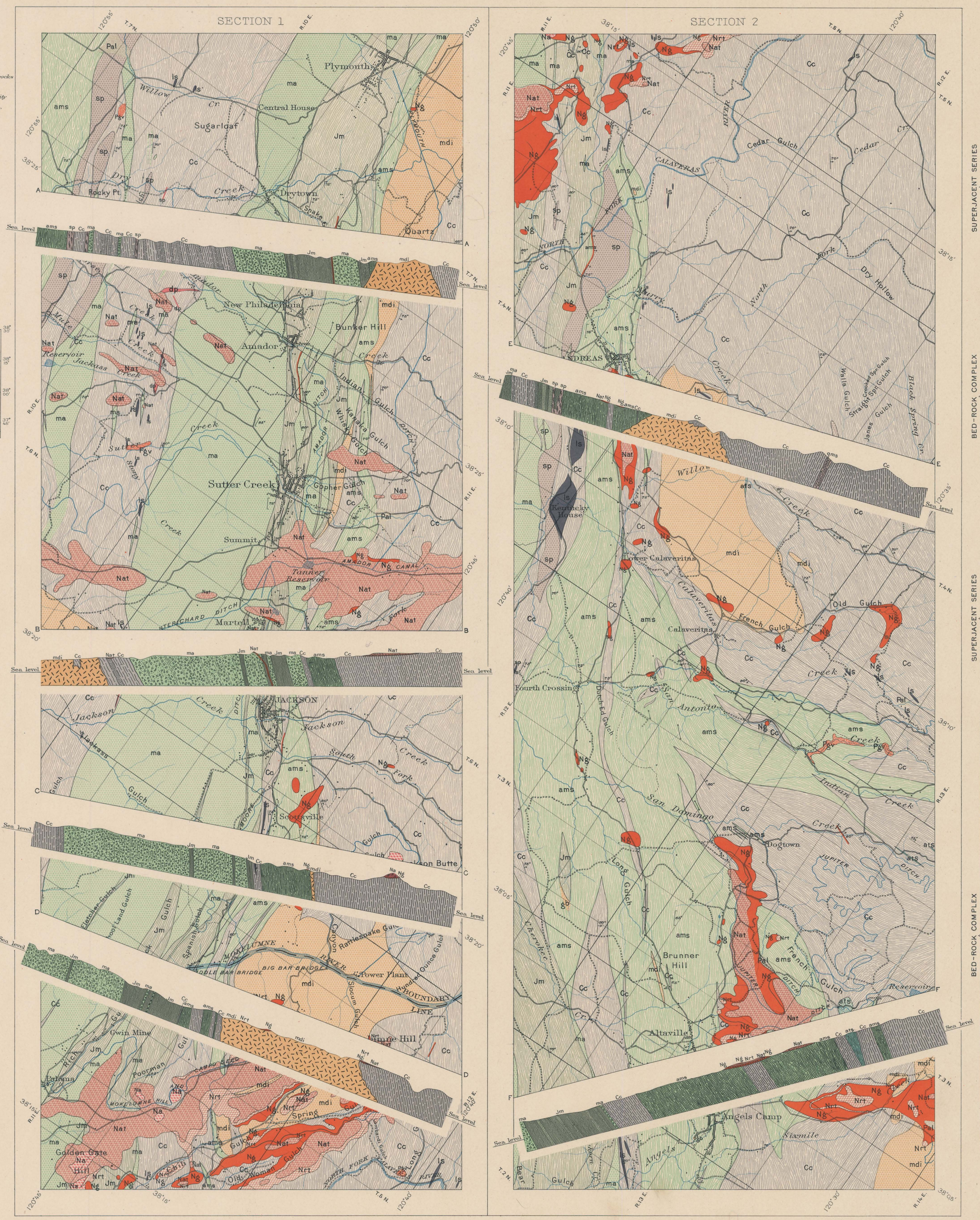
Edition of Mar. 1900.

George F. Becker, Geologist in charge.
Geology by F. L. Ransome.
Surveyed in 1898.

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

STRUCTURE-SECTION SHEET 1

CALIFORNIA
MOTHER LODE DISTRICT



LEGEND
(continued)

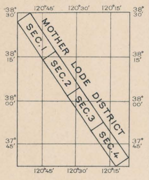
80° Dip and strike of bedded rocks
Vertical dip and strike of stratified rocks
65° Dip and strike of schistosity or cleavage
Vertical dip and strike of schistosity or cleavage
Quartz veins outcropping prominently on the surface

Known productive formations

Auriferous river gravels

Limestone
(suitable for making lime)

POSITION OF MAPS



LEGEND

SURFICIAL ROCKS

SHEET SYMBOL — SECTION SYMBOL

SUPERJACENT SERIES — PLEISTOCENE

- Pal — Alluvium *(bordering streams and filling small valleys)*
- Pgv — River gravels *(usually auriferous)*

SEDIMENTARY ROCKS

SHEET SYMBOL — SECTION SYMBOL

NEOCENE

- Ng / Ng — Auriferous river gravels

BED-ROCK COMPLEX

JURATRIAS

- Jm / Jm — Mariposa formation *(clay slate, sandstone, and conglomerate)*

CARBONIFEROUS

- Cc / Cc — Calaveras formation *(slaty mica-schists, chiefly biotite-schist, quartzite, conglomerate, clay slate, chert, and limestone)*
- ls / ls — Limestone *(lenses and irregular masses within the Calaveras formation)*

IGNEOUS ROCKS

SHEET SYMBOL — SECTION SYMBOL

SUPERJACENT SERIES — NEOCENE

- Na / Na — Andesite *(thick lava flows)*
- Nat / Nat — Andesite tuff, breccia, and conglomerate *(roughly stratified)*
- Nrt / Nrt — Rhyolite tuff *(sometimes interstratified with gravel)*

BED-ROCK COMPLEX

JURATRIAS OR EARLY CRETACEOUS

- Small dikes of various rocks *(serpentine, sp, diorite-porphyry, dp, diorite, di, gabbro, gb, and altered rocks)*
- mdi / mdi — Meta-diorite *(altered diorites, largely quartz-diorites)*
- gb — Gabbro *(intrusive masses and dikes, usually associated with serpentine)*
- sp / sp — Serpentine *(derived from peridotite and related basic intrusive rocks)*

CARBONIFEROUS OR JURATRIAS

- ma / ma — Meta-andesite *(altered andesitic breccias, tuffs, and massive lavas, with some altered basalt and diabase)*
- ams / ams — Amphibolite-schist *(derived from andesitic tuff and breccia, diorite, and other igneous rocks)*
- ats / ats — Amphibolite-talc-schist
- qms / qms — Quartz-muscovite-schist

Legend is continued on the left margin.

R. U. Goode, Geographer in charge.
Topography by A. B. Searle.
Surveyed in 1897.

Scale $\frac{1}{63360}$
1 ½ 0 1 2 3 4 Miles
1 ½ 0 1 2 3 4 5 Kilometers

Edition of May 1900.

George F. Becker, Geologist in charge.
Geology by F. L. Ransome.
Surveyed in 1898.

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

CLAIM SHEET 1

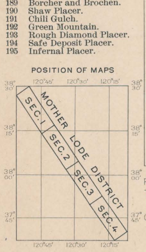
CALIFORNIA
MOTHER LODE DISTRICT

MINING CLAIMS.

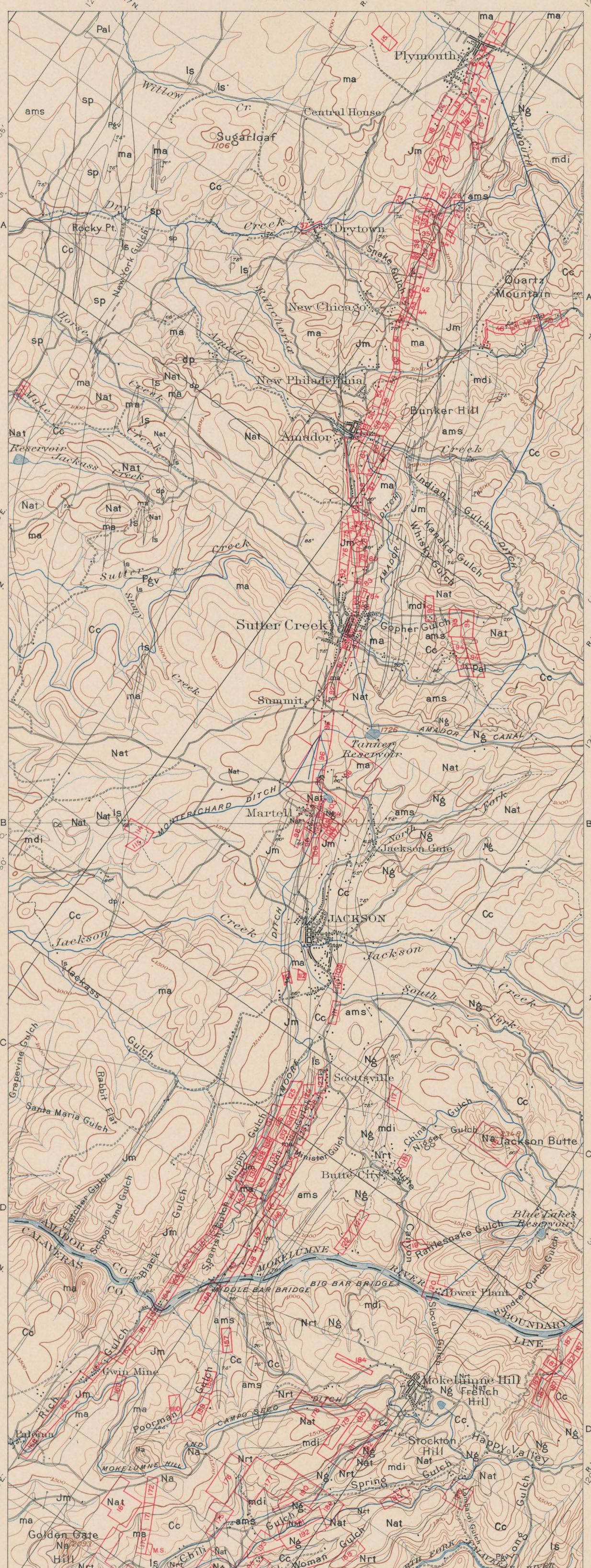
SECTION 1.

1 Hartford.
2 Wheeler.
3 Southerland.
4 Reese.
5 Phenix East.
6 Simpson and Aden.
7 Oaks.
8 Plymouth Gold.
9 Conville.
10 Chicago.
11 Giant.
12 Redoak.
13 Indiana.
14 New London.
15 Plymouth Rock.
16 Pioneer.
17 Shakespeare.
18 Victoria.
19 Fort John.
20 Bartlett.
21 Bruce.
22 Fortynine.
23 Hardscrabble.
24 Providence.
25 Hercules.
26 Dry Creek.
27 Centennial.
28 Atlantic.
29 Cosmopolitan.
30 Joe Davis.
31 Henry Clay.
32 Eureka.
33 North California.
34 Worley.
35 California.
36 Pocahontas.
37 Maryland.
38 Chili Joe.
39 Homestake.
40 Coulter.
41 Peerless.
42 Italian.
43 North Gover.
44 Poolepovich.
45 Loyal Lode.
46 Gold Mountain.
47 Gold Mountain Overplus.
48 White Mountain.
49 Gold Crown.
50 Gover.
51 Fremont.
52 Hazard.
53 Mayflower.
54 Nevada.
55 Bunker Hill.
56 Last Chance.
57 Crown Point.
57A Black Prince.
58 Original Amador.
59 East Amador.
60 Niagara.
61 Eclipse Extension.
62 Eclipse.
63 Keystone.
64 Spring Hill and Geneva.
65 East Keystone.
66 Eldorado.
67 Medean.
68 South Spring Hill.
69 South Keystone.
70 Talisman.
71 Wabash.
72 North Star.
73 Boyson.
74 McIntire.
75 West Side.
76 Granite State.
77 Occident.
78 Comet.
79 Golden Eagle.
80 North Lincoln.
81 Lincoln.
82 Beatrice.
83 Hubbard.
84 Capital.
85 Mahoney.
86 Lincoln South.
87 Mahoney South.
88 Wildman.
89 Maxwell.
90 Railroad.
91 Amador.
92 Summit.
93 Potazuba.
94 Baliol.
95 Maximilian.
95A South Eureka.
96 Oneida.
97 Kennedy.
98 Argonaut.
99 Muldoon.
100 Volunteer.
101 Clyde.
102 North Clyde.
103 Placer Mine.
104 Golden Gate.
105 Silva.
106 Silva Placer.
107 Stevich Placer.
108 Jackson.
109 Blue Jacket.
110 Zeila.
111 Meek.
112 Good Hope.
113 South Bright.
114 Monterichard.
115 Oaks.
116 Mineral Entry No. 613.
117 Alpi.
118 Alva.
119 E. A. Culver.
120 Kearsing.
121 L. K. Hall.
122 Confidence.
123 Etna.
124 Isaac Newton.
125 Law Lottier.
126 Ingalls.
127 Haley.
128 Doyle.
129 Amador Queen No. 1.
130 Sylvester and Bostwick.
131 ....
132 Millsite.
133 Loveridge and Lockwood.
134 Kruger.
135 McKay and Love.
136 Leavitt.
137 Empire.
138 Sylvester and Briggs.
139 Mahoney and Hall.
140 Mineral Point.
141 Valparaiso.
142 Wetzler.
143 Kelly Gold.
144 Vaughn.
145 Price and McNamara.
146 Vulture.
147 Hardenbergh.
148 Middle Bar.
149 Sargent.
150 Mammoth.
151 St. Julian.
152 Marlette.
153 McKinny and Grannis.
154 Farrell.
155 Baratini.
156 Hancock.
157 Fink.
158 ....
159 ....
160 ....
161 Oneto.
162 White Swan.
163 Flour Sack.
164 North Paloma.
165 Gwin.
166 South Paloma.
167 French Union Placer.
168 Indian Gulch Placer.
169 Red Hill Placer.
170 Macnevin.
171 Quaker City.
172 Hamby.
173 Pelletco.
174 Werle Placer.
175 Hughes Placer.
176 Sugal and Bernhard Placer.
177 What Cheer Placer.
178 Knell Placer.
179 Stockton Hill Placer.
180 Star and Mathison.
181 Porrel Placer.
182 Occidental.
183 Sullivan.
184 Union Placer.
185 Lamphear.
186 Mineral Entry No. 881.
187 Esperanza.
188 Empire Gravel.
189 Borcher and Brochen.
190 Shaw Placer.
191 Chili Gulch.
192 Green Mountain.
193 Rough Diamond Placer.
194 Safe Deposit Placer.
195 Infernal Placer.

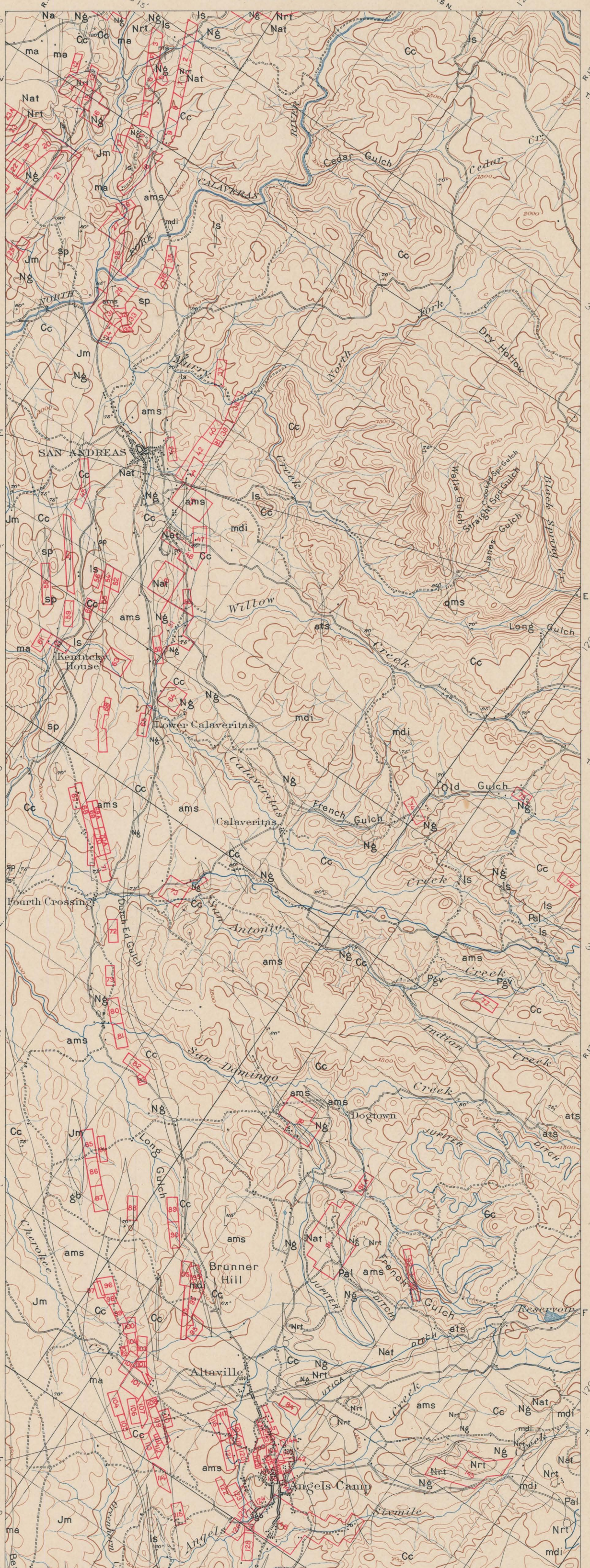
POSITION OF MAPS



SECTION 1



SECTION 2



MINING CLAIMS.

SECTION 2.

1 Edmonds.
2 South Africa.
3 Land Office.
4 Pine Peak.
5 Seattle No. 2.
6 Seattle.
7 Williams.
8 Edna.
9 Pocket Hill.
10 Diamond.
11 Williams and Hewes.
12 ....
13 ....
14 Berthot and Creton.
15 Prince.
16 Mineral Entry No. 79.
17 Three Brothers.
18 Pocket Hill.
19 Mineral Entry No. 709.
20 Rising Star Placer.
21 Mineral Entry No. 261.
22 Mineral Entry No. 288.
23 Lalla Rookh.
23A Last Chance Placer.
24 Putnam Gravel.
25 Mineral Entry No. 301.
26 Golden Hill.
27 Spinola.
28 Lookout.
29 Flamm.
30 Last Fraction.
31 Gottschalk.
32 Star.
33 Golden Gate.
34 Thornton.
35 Donellan.
36 Comet.
37 Leonard
38 Willie.
39 Lucky Find.
40 Iphigenia.
41 Manhattan.
42 North Ford Extension.
43 Fellowcraft.
44 Ford.
45 Everlasting.
46 Ford Extension.
47 Huberty.
48 Huberty.
49 Mineral Entry No. 149.
50 Bullion.
51 Hedrick and Co. Placer.
52 Ambrosia.
53 Golden West.
54 West Talcose.
55 Talcose.
56 Ninetyseven.
57 Holland.
58 Pioneer Chief.
59 Bismarck.
60 Kentucky.
61 Mineral Entry No. 797.
62 Mineral Entry No. 110.
63 Mineral Entry No. 683.
64 Scotts Placer.
65 Rathgeb.
66 Union.
67 Pedro.
68 Burgess.
69 London Extension or Gould.
70 Specimen.
71 Wells.
72 Backman.
73 Railroad Hill Placer.
74 Gertrude.
75 Valle Placer.
76 Elliotte.
77 Gold Hill.
78 Jupiter Placer.
79 Thorp.
80 Calaveras.
81 Ethel.
82 Bund.
83 Maloney.
84 Wiley.
85 Banner.
86 Ethel Mary.
87 Stony.
88 Garibaldi.
89 Top Notch.
90 Blackoak.
91 Jack Rabbit.
91A ....
92 German Ridge 1.
93 German Ridge 2.
94 Mineral Entry No. 243.
95 Curtis Consolidated.
96 Owensby and Minard.
97 Messer.
98 Brothers.
99 Bradley.
100 Osburn.
101 Gold Hill Mining Co.
102 Haywards.
103 Carpenter and Radcliff.
104 Curtis, Hendricks, and Eccleson.
105 J. B.
106 Gold Valley A.
107 Golden Robin.
108 Evening Star.
109 Blair Consolidated.
110 Eldorado or Bisbee.
111 Gold Valley B.
112 Gold Valley C.
113 Turner.
114 Adelia.
115 Pure Quill.
116 Tiberghein.
117 Pioneer.
118 Mineral Land.
119 Martinson.
120 Johnson.
121 Lindsey.
122 ....
123 Gold Cliff.
124 Anna.
125 Peachey.
126 Peachey.
127 Fairfax.
128 Centennial.
129 Democrat.
130 Oneida.
131 Fritz.
132 Bovee.
133 Doctor Hill.
134 Angels.
135 Crystal.
136 Jackson.
137 Lightner.
138 Utica.
139 Stickle.
140 Raspberry.
141 George Washington.
142 Dead Horse.
143 Billings.
144 Duffy.
145 Kentucky Placer.
146 Ghost.

Ditches, pipe lines, and flumes are indicated by solid blue lines.

Geologic formations, shown on the map by black lines and letter symbols, are explained on the Economic Geology Sheet.

R.U. Goode, Geographer in charge.
Topography by A.B. Searle.
Surveyed in 1897.
Claim boundaries compiled by A.B. Searle.

Scale $\frac{1}{63360}$

1 ½ 0 1 2 3 4 Miles

1 ½ 0 1 2 3 4 5 Kilometers

Contour interval 100 feet.

Datum is mean sea level.

Edition of Feb. 1900.

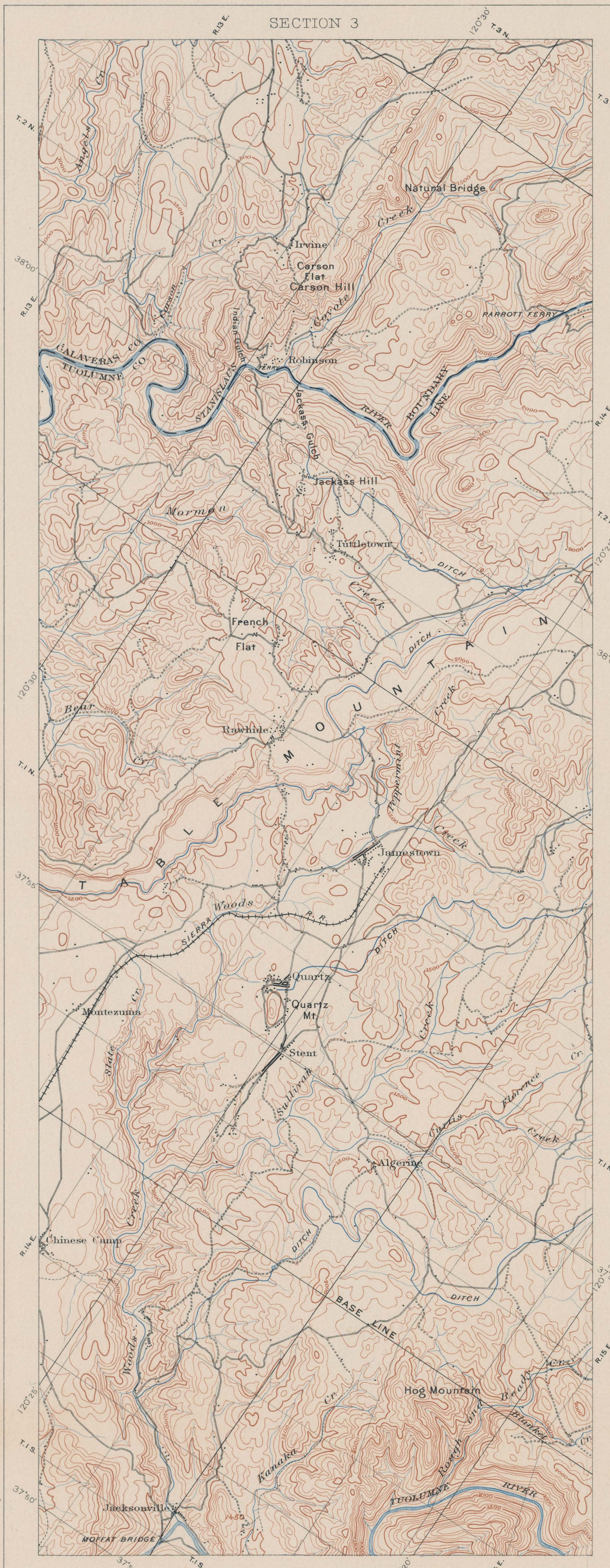
George F. Becker, Geologist in charge.
Geology by F. L. Ransome.
Surveyed in 1898.

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

TOPOGRAPHIC SHEET 2

CALIFORNIA
MOTHER LODE DISTRICT

SECTION 3



SECTION 4

LEGEND

RELIEF
(printed in brown)

Figures
(showing heights above mean sea level instrumentally determined)

Contours
(showing height above sea, horizontal form, and steepness of slope of the surface)

Depression contours

DRAINAGE
(printed in blue)

Streams

Intermittent streams

Ditches, pipe lines, and flumes

Lakes and reservoirs

CULTURE
(printed in black)

Roads and buildings

Private and secondary roads

Trails

Railroads and tramways

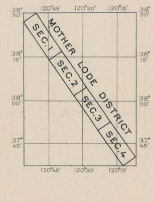
Bridges

County boundary lines

U.S. township and section lines

Triangulation stations

POSITION OF MAPS



R.U. Goode, Geographer in charge.
Topography by E.C. Barnard and A.B. Searle.
Surveyed in 1897.

Scale $\frac{1}{63360}$

Contour interval 100 feet.
Datum is mean sea level.

Edition of Jan. 1900.

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

ECONOMIC GEOLOGY SHEET 2

CALIFORNIA
MOTHER LODE DISTRICT

LEGEND

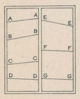
IGNEOUS ROCKS
(continued)

BED-ROCK COMPLEX — CARBONIFEROUS OR JURATRIAS

- am — **Amphibolite** *(derived from basalt, andesite, and other igneous rocks)*
- ams — **Amphibolite-schist** *(derived from andesitic tuff and breccia, diorite, and other igneous rocks)*
- ats — **Amphibolite-talc-schist**

- 80° *Dip and strike of bedded rocks*
- *Vertical dip and strike of stratified rocks*
- 65° *Dip and strike of schistosity or cleavage*
- *Vertical dip and strike of schistosity or cleavage*
- *Quartz veins outcropping prominently on the surface*
- *Gold-quartz mines*
- P *Shallow placer mines in auriferous gravels*
- H *Hydraulic mines in auriferous gravels*
- D *Drift mines in auriferous gravels*
- *Gold prospects, including pocket mines*
- × *Quicksilver prospect*

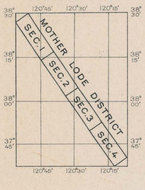
Sections



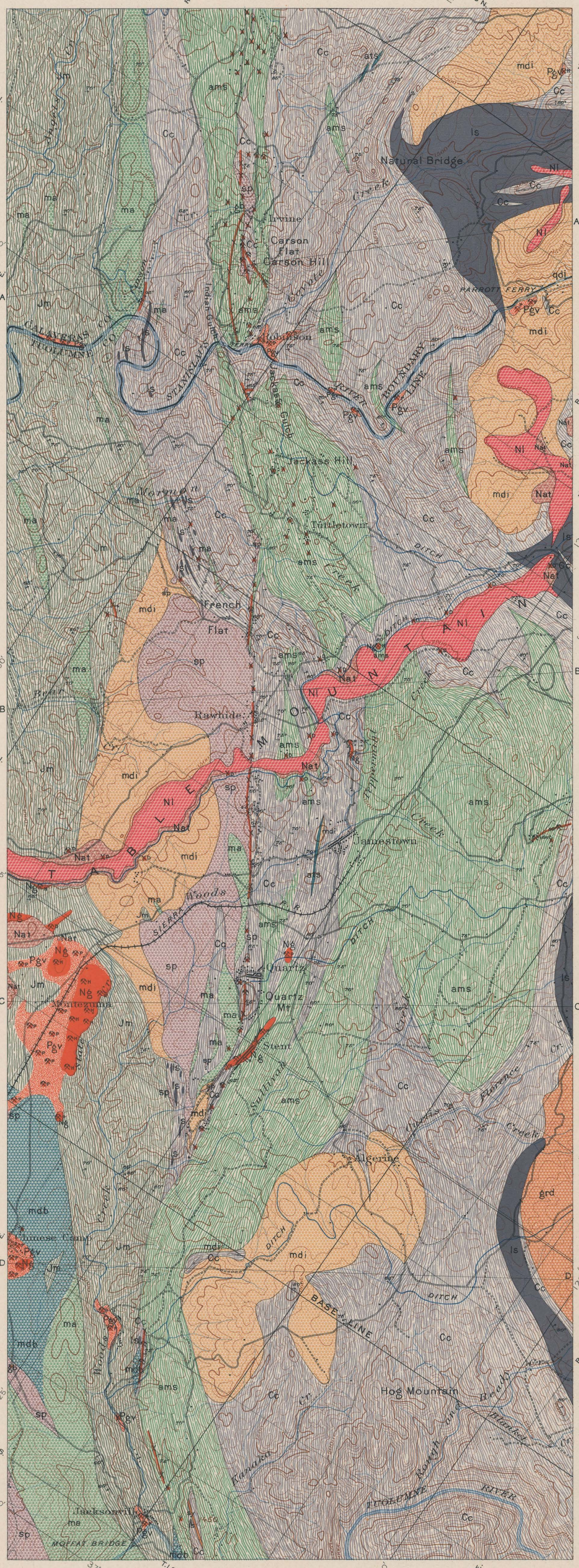
Known productive formations

- *Auriferous river gravels*
- *Limestone* *(suitable for making lime)*

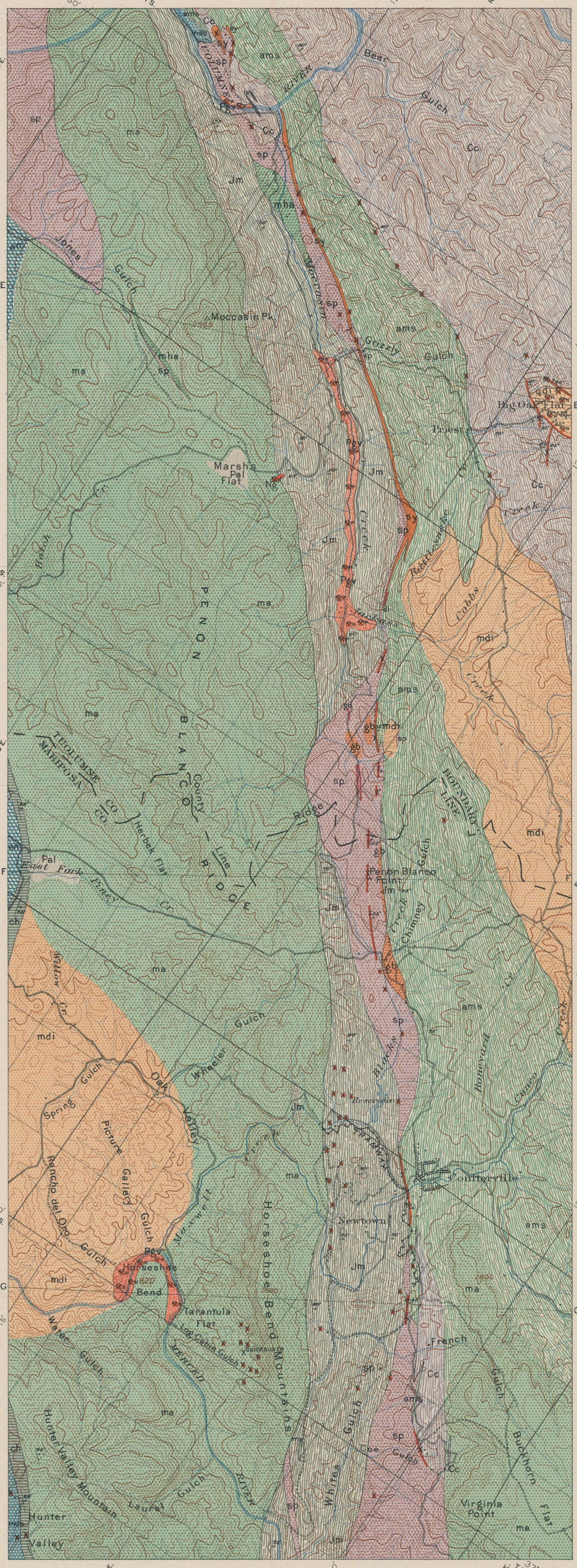
POSITION OF MAPS



SECTION 3



SECTION 4



LEGEND

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

SUPERJACENT SERIES — PLEISTOCENE

- Pal — **Alluvium** *(bordering streams and filling small valleys)*
- Pgv — **River gravels** *(usually auriferous)*

SEDIMENTARY ROCKS
(Areas of Sedimentary rocks are shown by patterns of parallel lines. Wavy-line patterns show general direction of schistose cleavage.)

NEOCENE

- Ng — **Auriferous river gravels**

BED-ROCK COMPLEX

JURATRIAS
- Jm — **Mariposa formation** *(clay slate, sandstone, and conglomerate)*

JURATRIAS ?
- ch — **Cherty beds** *(banded green and chocolate sediments closely associated with the meta-andesitic tuffs)*

CARBONIFEROUS
- Cc — **Calaveras formation** *(slaty mica-schists, chiefly biotite-schist, quartzite, conglomerate, clay slate, chert, and limestone)*
- ls — **Limestone** *(lenses and irregular masses within the Calaveras formation)*

IGNEOUS ROCKS
(Areas of Igneous rocks are shown by patterns of triangles and rhombs. Wavy-line patterns show general direction of schistose cleavage.)

SUPERJACENT SERIES — NEOCENE

- Nl — **Latite** *(a rock intermediate between andesite and trachyte, lava flows)*
- Nat — **Andesite tuff, breccia, and conglomerate** *(roughly stratified)*

BED-ROCK COMPLEX

JURATRIAS OR EARLY CRETACEOUS
- **Small dikes of various rocks** *(serpentine, sp, diorite-porphyry, dp, diorite, di, gabbro, gb, and altered rocks)*
- sy — **Soda-syenite-granophyre and related syenitic rocks** *(dikes)*
- mdi — **Meta-diorite** *(altered diorites, largely quartz-diorites)*
- qdi — **Quartz-diorite** *(batholithic intrusive masses)*
- grd — **Granodiorite** *(batholithic intrusive masses)*
- gb — **Gabbro** *(intrusive masses and dikes, usually associated with serpentine)*
- sp — **Serpentine** *(derived from peridotite and related basic intrusive rocks)*

CARBONIFEROUS OR JURATRIAS
- mdb — **Meta-diabase** *(altered intrusive diabase and lava flows)*
- ma — **Meta-andesite** *(altered andesitic breccias, tuffs, and massive lavas, with some altered basalt and diabase)*
- mha — **Meta-hornblende-andesite** *(altered hornblende-andesite breccia and tuff)*

Legend is continued on the left margin.

R.U. Goode, Geographer in charge.
Topography by E.C. Barnard and A.B. Searle.
Surveyed in 1897.

Barnard | Barnard, Searle

Scale $\frac{1}{63360}$

1 ½ 0 1 2 3 4 Miles

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Contour interval 100 feet.
Datum is mean sea level.
Edition of Mar. 1900.

George F. Becker, Geologist in charge.
Geology by F. L. Ransome.
Surveyed in 1898.

STRUCTURE-SECTION SHEET 2

LEGEND

IGNEOUS ROCKS
(continued)

BED-ROCK COMPLEX — CARBONIFEROUS OR JURATRIAS

SHEET SYMBOL	SECTION SYMBOL	
am	am	Amphibolite *(derived from basalt, andesite, and other igneous rocks)*
ams	ams	Amphibolite-schist *(derived from andesitic tuff and breccia, diorite, and other igneous rocks)*
ats		Amphibolite-talc-schist

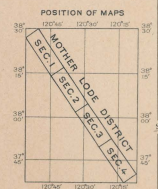
80° *Dip and strike of bedded rocks*
Vertical dip and strike of stratified rocks
65° *Dip and strike of schistosity or cleavage*
Vertical dip and strike of schistosity or cleavage
Quartz veins outcropping prominently on the surface

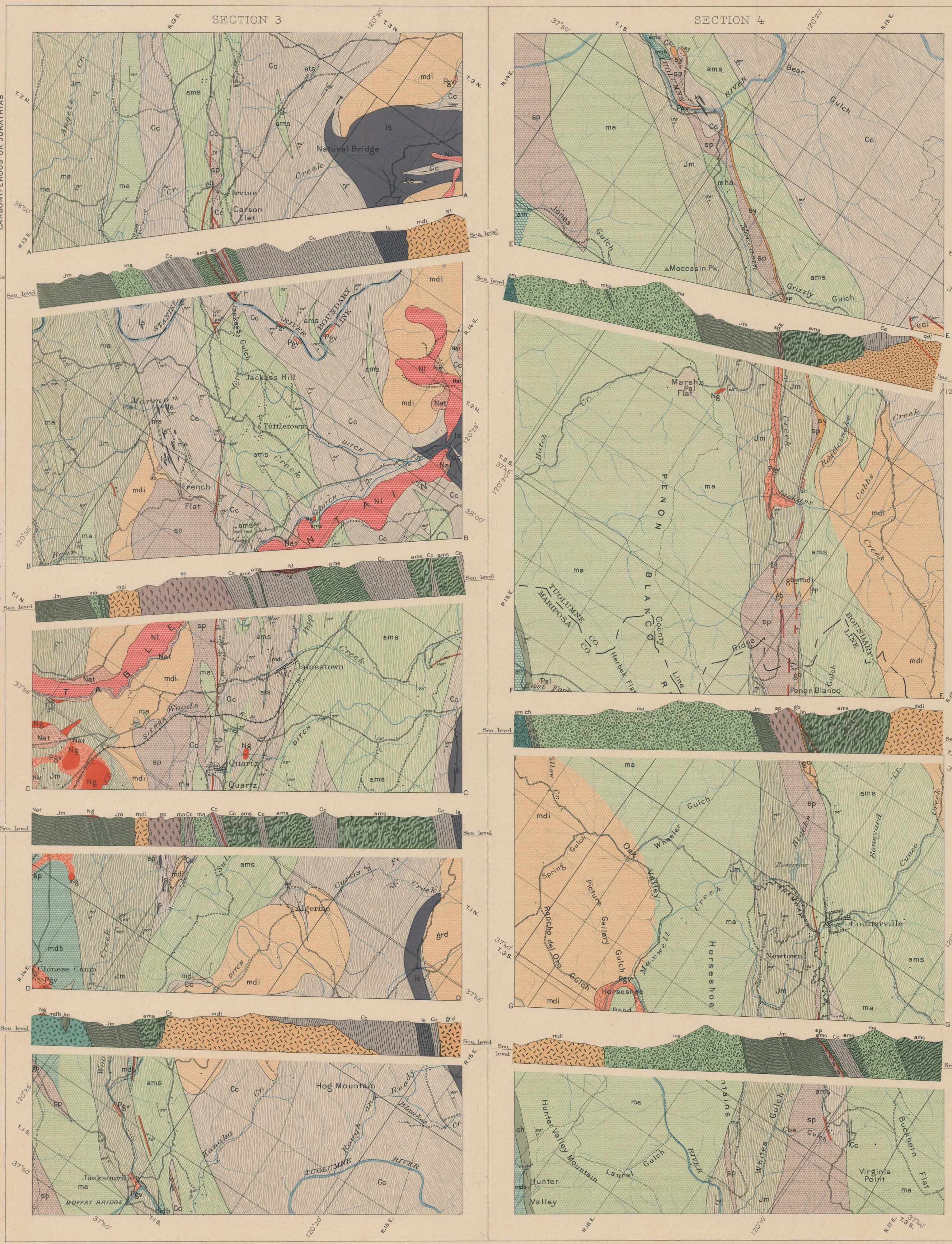
Known productive formations

Auriferous river gravels

Limestone (suitable for making lime)

POSITION OF MAPS





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Barnard | Barnard, Searle

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Edition of May 1900.

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Geology by F.L. Ransome.
Surveyed in 1898.

LEGEND

SURFICIAL ROCKS

SUPERJACENT SERIES — PLEISTOCENE

SHEET SYMBOL	SECTION SYMBOL	
Pal		Alluvium *(bordering streams and filling small valleys)*
Pgv		River gravels *(usually auriferous)*

SEDIMENTARY ROCKS

SUPERJACENT SERIES — NEOCENE

SHEET SYMBOL	SECTION SYMBOL	
Ng	Ng	Auriferous river gravels

BED-ROCK COMPLEX

SHEET SYMBOL	SECTION SYMBOL		
Jm	Jm	Mariposa formation *(clay slate, sandstone, and conglomerate)*	JURATRIAS
ch	ch	Cherty beds *(banded green and chocolate sediments closely associated with the meta-andesitic tuffs)*	JURATRIAS?
Cc	Cc	Calaveras formation *(slaty mica-schists, chiefly biotite-schist, quartzite, conglomerate, clay slate, chert, and limestone)*	CARBONIFEROUS
ls	ls	Limestone *(lenses and irregular masses within the Calaveras formation)*	CARBONIFEROUS

IGNEOUS ROCKS

SUPERJACENT SERIES — NEOCENE

SHEET SYMBOL	SECTION SYMBOL	
Nl	Nl	Latite *(a rock intermediate between andesite and trachyte; lava flows)*
Nat	Nat	Andesite tuff, breccia, and conglomerate *(roughly stratified)*

BED-ROCK COMPLEX — JURATRIAS OR EARLY CRETACEOUS

SHEET SYMBOL	SECTION SYMBOL	
		Small dikes of various rocks *(serpentine, sp, diorite-porphyry, dp, diorite, di, gabbro, gb, and altered rocks)*
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qdi	qdi	Quartz-diorite *(batholithic intrusive masses)*
grd	grd	Granodiorite *(batholithic intrusive masses)*
gb	gb	Gabbro *(intrusive masses and dikes, usually associated with serpentine)*
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BED-ROCK COMPLEX — CARBONIFEROUS OR JURATRIAS

SHEET SYMBOL	SECTION SYMBOL	
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ma	ma	Meta-andesite *(altered andesitic breccias, tuffs, and massive lavas, with some altered basalt and diabase)*
mha	mha	Meta-hornblende-andesite *(altered hornblende-andesite breccia and tuff)*

Legend is continued on the left margin.

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

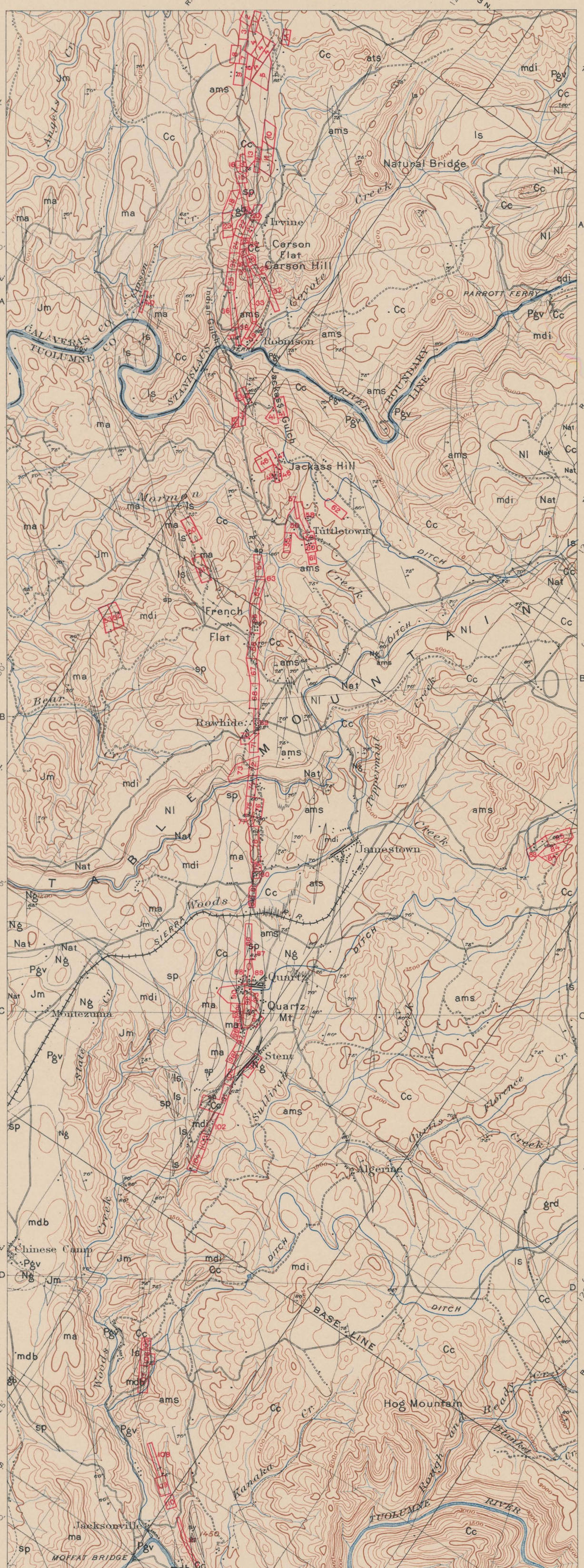
CLAIM SHEET 2

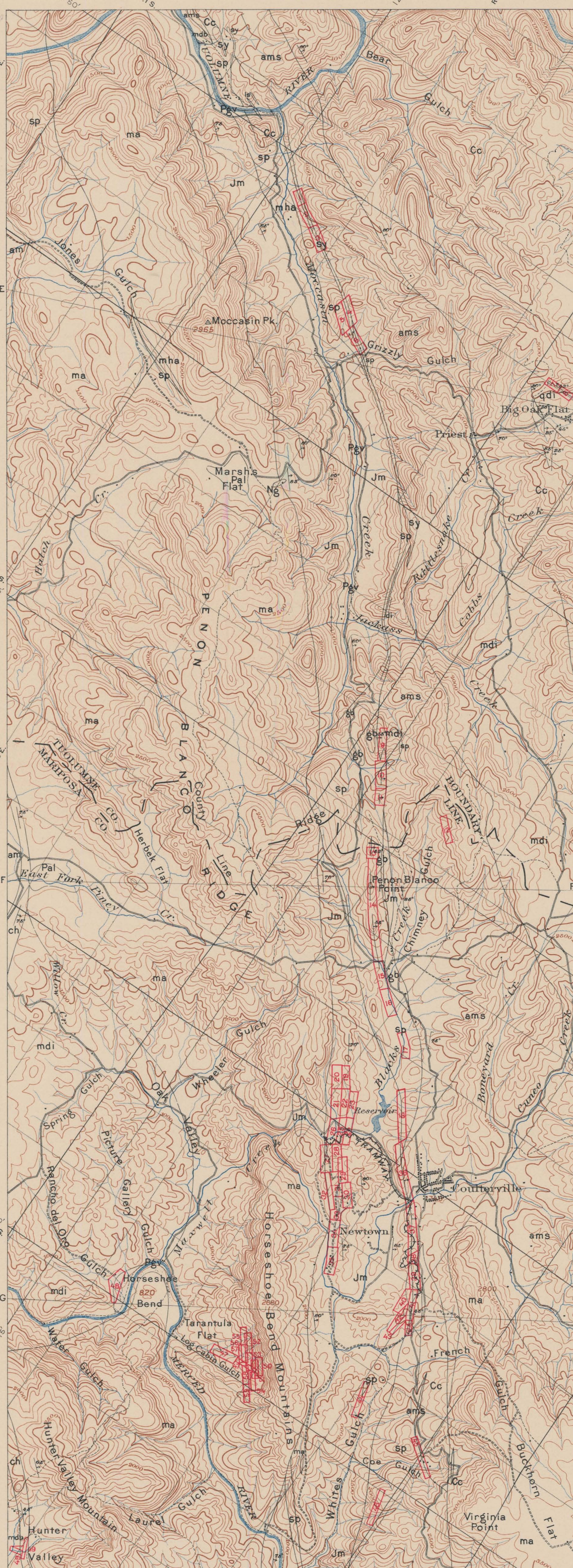
CALIFORNIA
MOTHER LODE DISTRICT

MINING CLAIMS.

SECTION 3.

1 Bolitho.
1A Tracy.
2 Excelsior and Rolleri.
3 Big Spring.
4 The Nellie Mining Co.
5 T. T. Lane and W. Garrard.
6 Victor.
7 Marble Springs.
8 Walter Tryon.
9 Bald Hill.
10 Missouri.
11 Missouri Extension.
12 Tulloch.
13 Felicia Placer.
14 Chaparral Hill.
15 Rothschild.
16 Vanderbilt.
17 Bright Star.
18 Luca.
19 Reed.
20 California Ophir.
21 Iron Rock.
22 Relief.
23 Luca Extension.
24 New Year.
25 Kentucky.
26 Union.
27 Morgan.
28 Reserve.
29 Enterprise.
30 Melones.
31 Point of Rocks.
32 South Carolina.
33 Mineral Mountain.
34 Stephens.
35 Brown.
36 Santa Cruz.
37 Calaveras.
38 Stanislaus.
39 Adelaide.
40 Carson Creek.
41 Norwegian Mining Co.
42 Bown.
43 Bown Millsite.
44 Gill and Carrington.
45 Gill and Carrington Millsite.
46 Waters Millsite.
47 Atlas.
48 Pine Tree.
49 Carrington.
50 Toledo.
51 Prospect.
52 Pena Blanca.
53 Sarah Francis.
54 O. K. Extension.
55 Arbona.
56 Paterson.
57 Lenman.
58 Paterson Millsite.
59 J. R. Gross.
60 Gagnere Extension.
61 Gagnere.
62 Grand Turk.
63 Combination.
64 O. K.
65 Tarantula.
66 Alameda.
67 Isabella and Gem Consolidated.
68 Rappahannock.
69 Rawhide.
70 Rawhide Millsite.
71 Rawhide No. 2.
72 Alabama Consolidated.
73 Table Omega.
74 Alabama Consolidated.
75 Crystalline.
76 Shore.
77 Ophir.
78 Trio.
79 Mooney.
80 McCann.
81 Vulture.
82 Pacific.
83 Golden Sulphuret.
84 Gerrymander.
85 Golden Gate.
86 Sweeney.
87 Sweeney Millsite.
88 Dutch.
89 Dutch Millsite.
90 App.
91 Hitchcock.
92 Heslep.
93 Heslep Millsite.
94 Knox and Boyle.
95 Gray Eagle.
96 Miller and Holmes.
97 Miller and Holmes.
98 Cloudman.
99 No. 1.
100 Erin-go-bragh.
101 Golden Rule.
102 New Era.
103 Jumper.
104 Mazeppa.
105 Bella Union.
106 Shawmut.
107 Eagle.
108 Mammoth.
109 Orcutt.
110 Republican.
111 Clio.





MINING CLAIMS.

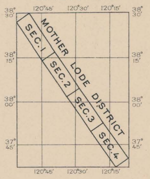
SECTION 4.

1 Black Warrior.
2 North Star.
3 Black Hawk.
4 Maverick.
5 Wheeler Hill.
6 Grant.
7 Longfellow.
8 Mack.
9 ....
10 McAlpine.
11 McAlpine Millsite.
12 Monroe.
13 North Penon Blanco.
14 Penon Blanco.
15 Old Judge.
16 South Judge.
17 Champion.
18 Black Hill.
19 Boston.
20 Mahoney.
21 Douglas.
22 Glendive.
23 Billings.
24 Livingston.
25 Miles.
26 D. Cook.
27 Potosi.
28 Helena.
29 Ninetyfour.
30 Bozeman.
31 Dillon.
32 Malvina.
33 Regina.
34 Malvina No. 2.
35 Rittershoffen.
36 Margaret.
37 Louisa.
38 Balance.
39 Venture.
40 Sheridan.
41 Mary Harrison.
41A Ely.
42 Choteau.
43 Dalia.
44 Midas.
45 Virginia.
46 Anderson.
47 Crystal.
48 Del Oro.
49 Barretta.
50 Sixteen-to-one.
51 Lookout.
52 Shelton.
53 Cabinet.
54 Blossom.
55 New Quartz.
56 Lost Friend.
57 Posly.
58 Horseshoe Bend.
59 Lawson.

Ditches pipe lines and flumes are indicated by solid blue lines.

Geologic formations shown on the map by black lines and letter symbols are explained on the Economic Geology Sheet.

POSITION OF MAPS



R.U. Goode, Geographer in charge.
Topography by E.C. Barnard and A.B. Searle.
Surveyed in 1897.
Claim boundaries compiled by
E.C. Barnard and A.B. Searle.

Scale $\frac{1}{63360}$

Contour interval 100 feet.
Datum is mean sea level.
Edition of Feb. 1900.

George F. Becker, Geologist in charge.
Geology by F.L. Ransome.
Surveyed in 1898.

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.