DEPARTMENT OF THE INTERIOR

UNITED STATES GEOLOGICAL SURVEY

CHARLES D. WALCOTT, DIRECTOR

GEOLOGIC ATLAS

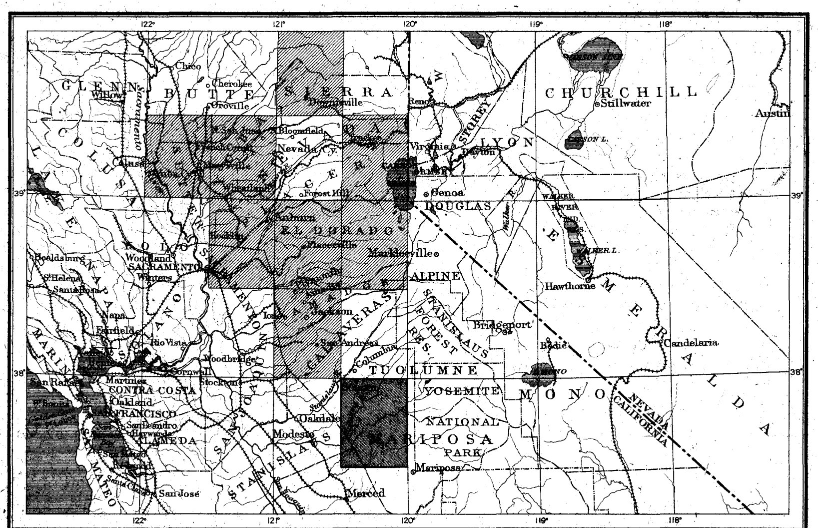
OF THE

UNITED STATES

SONORA FOLIO

CALIFORNIA

INDEX MAP



SCALE: 40 MILES = 1 INCH

AREA OF THE SONORA FOLIO

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FOLIO 41 | LIBRARY EDITION | SONORA

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BAILE LLIS. EDITOR OF GEOLOGIC MAPS S.J. KÜBEL. CHIEF ENGRAVER

EXPLANATION.

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

THE TOPOGRAPHIC MAP.

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

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

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

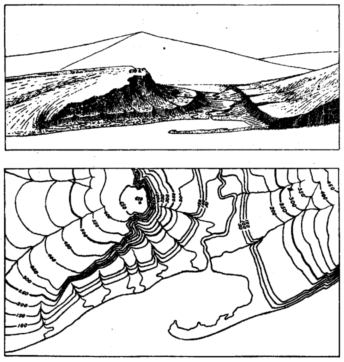


Fig. 1.—Ideal sketch and corresponding contour map.

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

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

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

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

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

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

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

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

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

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

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

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

THE GEOLOGIC MAP.

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

KINDS OF ROCKS.

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

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

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

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

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

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

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

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

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

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

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

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

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

AGES OF ROCKS.

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

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

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

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

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

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

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

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

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

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

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

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

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

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

THE VARIOUS GEOLOGIC SHEETS.

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

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

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

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

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

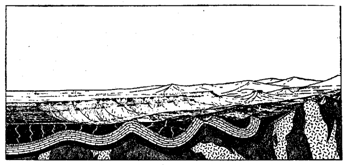


Fig. 2.—Sketch showing a vertical section in the front of the picture, with a landscape beyond.

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

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

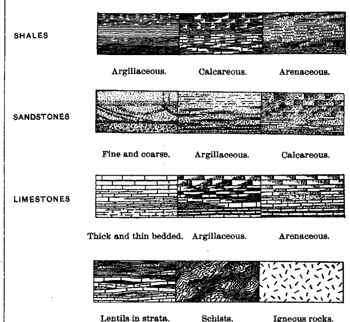


Fig. 3.—Symbols used to represent different kinds of rock.

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

CHARLES D. WALCOTT,
Director.

Revised June, 1897.

DESCRIPTION OF THE GOLD BELT.*

GEOGRAPHIC RELATIONS.

The principal gold belt of California includes a portion of the Sierra Nevada lying between the parallels of 37° 30′ and 40° north latitude. It is bounded on the west by the Sacramento and San Joaquin valleys, and on the east by a diagonal line extending from about longitude 120° 40′ in the neighborhood of the fortieth parallel to longitude 119° 40′ in the neighborhood of parallel 37° 30′. There are other gold-bearing regions in the State, both to the north and south of this belt, but by far the largest quantity of gold is produced within these limits. The area thus defined contains approximately 9000 square miles. At the northern limit the gold deposits are scattered over nearly the entire width of the range, while to the south the productive region narrows to small dimensions, continuing as a very narrow strip for some distance south of latitude 37° 30′. The whole southern part of the range is comparatively barren. North of the fortieth parallel the range is not without deposits, but the country is flooded with lavas which effectually bury the larger part of them.

GENERAL GEOLOGY.

The rocks of the Sierra Nevada are of many kinds and occur in very complex associations. They have been formed in part by deposition beneath the sea and in part by intrusion as igneous masses, as well as by eruption from volcanoes. All of them except the latest have been more or less metamorphosed.

The northern part of the range, west of longitude 120° 30′, consists prevailingly of clay-slates and of schists, the latter having been produced by the metamorphism of both ancient sediments and igneous rocks. The trend of the bands of altered sediments and of the schistose structure is generally from northwest to southeast, parallel to the trend of the range, but great masses of granite and other igneous rocks have been intruded among these schists, forming irregular bodies which interrupt the regular structure and which are generally bordered each by a zone of greater metamorphism. These slates and schists and their associated igneous masses form the older of two great groups of rocks recognized in the Sierra Nevada. This group is generally called the Bed-rock series.

Along the western base of the Sierra occur beds of sandstone and clay, some of which contain thin coal seams. These are much younger than the mass of the range and have not shared the metamorphism of the older rocks. They dip gently westward beneath later deposits, which were spread in the waters of a shallow bay occupying the Valley of California and portions of which have been buried beneath recent river alluvium.

Streams flowing down the western slope of the Sierra in the past distributed another formation of great importance—the Auriferous gravels. The valleys of these streams served also as channels for the descent of lavas which poured out from volcanoes near the summit. Occupying the valleys, the lavas buried the gold-bearing gravels and forced the streams to seek new channels. These have been worn down below the levels of the old valleys, and the lava beds, with the gravels which they protect, have been isolated on the summits of ridges. Thus the Auriferous gravels are preserved in association with lavas along lines which descend from northeast toward southwest, across the trend of the range. The nearly horizontal strata along the western base, together with the Auriferous gravels and later lavas, constitute the second group of rocks recognized in the Sierra Nevada. Compared with the first group, the Bed-rock series, these may be called the Superjacent series.

BED-ROCK SERIES.

PALEOZOIC ERA.

During the Paleozoic era, which includes the periods from the end of the Algonkian to the end of the Carboniferous, the State of Nevada west of longitude 117° 30′ appears to have been a land area of unknown elevation. This land probably extended westward into the present State of California and included part of the area now occupied by the Sierra Nevada. Its western shore was apparently somewhat west of the present crest, and the sea extending westward received Paleozoic sediments which now constitute a large part of the central portion of the range.

At the close of the Carboniferous the Paleozoic land area of western Nevada subsided, and during the larger part of the Juratrias period it was at least partly covered by the sea. At the close of the Juratrias the Sierra Nevada was upheaved as a great mountain range, the disturbance being accompanied by the intrusion of large amounts of granitic rock.

The Auriferous slate series comprises all of the sedimentary rocks that entered into the composition of this old range of Juratrias time. Formations representing the Algonkian and all of the Paleozoic and Juratrias may therefore form part of the Auriferous slate series.

Fossils of Carboniferous age have been found in a number of places, and the presence of Silurian beds at the northern end of the range, north of the fortieth parallel, has been determined. A conglomerate occurs in the foothills of Amador and Calaveras counties, interbedded with slates containing Carboniferous limestone; this conglomerate is therefore presumably of Carboniferous age. The conglomerate is evidence of a shore, since it contains pebbles of quartzite, hornblende-porphyrite, and other rocks, which have been rounded by the action of waves. The presence of lava pebbles in the conglomerate shows that volcanic eruptions began at a very early date in the formation of the range, for the hornblende-porphyrite pebbles represent lavas similar to the hornblende-andesites of later age.

The great mass of the Paleozoic sediments of the Gold Belt consists of quartzite, mica-schist, sandstone, and clay-slate, with occasional limestone lenses. On the maps of the Gold Belt these sediments are grouped under two formations:

(1) The *Robinson* formation, comprising sediments and trachytic tuffs. This contains fossils showing the age to be upper Carboniferous. The formation is known on the Gold Belt series of maps only in the Downieville quadrangle, a short distance south of the fortieth parallel.

(2) The *Calaveras* formation, comprising by far the largest portion of the Paleozoic sediments of the Gold Belt. Rounded crinoid stems, corals (Lithostrotion and Clisiophyllum), Foraminifera (Fusulina), and bivalves have been found in the limestone lenses, and indicate that a considerable portion at least of this formation belongs to the middle or lower Carboniferous. In extensive areas of the Calaveras formation no fossils have, however, been found, and older rocks may be present in these. It is not likely that post-Carboniferous rocks are present in these non-fossiliferous areas.

POST-CARBONIFEROUS UPHEAVAL.

After the close of the Carboniferous and before the deposition of at least the later Juratrias beds (Sailor Canyon, Mariposa, and Monte de Oro formations), an upheaval took place by which the Carboniferous and older sediments under the then retiring sea were raised above water level, forming part of a mountain range. The beds were folded and compressed and thus rendered schistose. Smaller masses of granite and other igneous rocks were intruded at this time.

JURATRIAS PERIOD.

The areas of land and sea which existed during the earlier part of this period are scarcely known. Fossiliferous strata showing the former presence of the Juratrias sea have been recognized in the southeastern portion of the range, at Mineral King, where the sediments are embedded in intrusive granite; at Sailor Canyon, a tributary of American River; in Plumas County at the north end of the range about Genesee Valley and elsewhere; and in the foothill region from Butte to Mariposa counties in the slates of the Mariposa nd Monte de Oro formations.

The land mass that originated with the post-Carboniferous upheaval became by gradual elevation very extensive toward the end of the Juratrias period. This continental mass of late Jurassic time probably reached eastward at least as far as the east base of the Wasatch Mountains. This conclusion is based on the fact that the latest Jurassic beds of California, the Monte de Oro and the Mariposa slates, are found only on the western flank of the Sierra Nevada. During the earlier part of the Juratrias period portions of the Great Basin were under water, as is shown by the fossiliferous beds of that age in Eldorado Canyon south of Virginia City and in the Humboldt Mountains, but nowhere from the foothills of the Sierra Nevada to the east base of the Wasatch, if we except certain beds near Genesee Valley, are any deposits known which are of late Jurassic age.

The following formations have been recognized on the Gold Belt maps:

(1) The *Mariposa* formation, which occurs in narrow bands along the western base of the range. The strata are prevailingly clay-slates, which are locally sandy and contain pebbles of rocks from the Calaveras formation. Tuffs from contemporaneous porphyrite eruptions also occur in them. The fossils of these beds, such as Aucella and Perisphinctes, have their nearest analogues in Russia, and indicate a very late Jurassic age.

(2) The *Monte de Oro* formation, occurring to the northeast of Oroville. This consists of clay-slate and conglomerate containing plant remains of late Jurassic age.

(3) The *Sailor Canyon* formation, which appears well up toward the summit of the range, and consists of clay-slates, altered sandstones, and tuffs. It is separated from the Mariposa formation by a broad belt of the Calaveras formation. The fossils indicate that the period of its deposition covered both the later part of Triassic and the earlier part of Jurassic time.

(4) The *Milton* formation, which has thus far afforded no fossils; it is lithologically similar to a portion of the Sailor Canyon series, and future research may show that it really was deposited at the same time.

THE POST-JURATRIAS UPHEAVAL.

Soon after the Mariposa formation had been deposited the region underwent uplift and compression. The result of uplift was the development of a mountain range along the line of the Sierra Nevada. The Coast Range also was probably raised at this time. The action of the forces was such as to turn the Mariposa strata into a nearly vertical position, and to fold them and other Juratrias beds in with the older Paleozoic strata. The Juratrias clay-shales, in consequence of pressure, now have a slaty structure, which appears to coincide in most cases with the bedding. This epoch was one of intense eruptive activity. The Mariposa and other Juratrias and older beds were injected with granite and other intrusive rocks. There is evidence that igneous rocks were intruded in varying quantities at different times; but that the intrusion of the great mass of the igneous rocks accompanied or immediately followed the upheavals is reasonably certain. Those beds that now form the surface were then deeply buried in the foundations of the range.

The disturbance following the deposition of the Mariposa beds was the last of the movements which compressed and folded the Auriferous slate series. The strata of succeeding epochs, lying nearly horizontal or at low angles, prove that since they were accumulated the rock mass of the Sierra Nevada has not undergone much compression. But the fact that these beds now occur above sea-level is evidence that the range has undergone elevation in more recent time.

THE GOLD-QUARTZ VEINS.

The extent of the gold deposits has been indicated in the introduction to this description. In character they may be classed as *primary*, or deposits formed by chemical agencies, and *secondary*, or those formed from the detritus produced by the erosion of the primary deposits. The primary deposits are chiefly gold-quartz veins,—fissures in the rock formed by mountain-making forces and filled with gold-bearing quartz deposited by circulating waters. The gold-quartz veins of the Sierra Nevada are found in irregular distribution chiefly in the Auriferous slates and associated greenstone-schists and porphyrites, but they also occur abundantly in the granitic rocks that form isolated areas in the slate series. While some gold-quartz veins may antedate the Jurassic period, it is reasonably certain that most of them were formed shortly after the post-Juratrias upheaval, and that their age, therefore, is early Cretaceous.

SUPERJACENT SERIES.

CRETACEOUS PERIOD.

Since no beds of early Cretaceous age are known in the Sierra Nevada, it is presumed that during the early Cretaceous all of the present range was above water.

During the late Cretaceous the range subsided to some extent, allowing the deposition of sediments in the lower foothill region. These deposits are known as the Chico formation, and consist of sandstone with some conglomerate. In the area covered by the Gold Belt maps this formation is exposed only near Folsom on the American River up to an elevation of 400 feet, and in the Chico district at elevations of from 500 to 600 feet. Since their deposition these strata have been but slightly disturbed from their original approximately horizontal position, but the larger part of them has been eroded or covered by later sediments.

Auriferous gravels are found to some extent in the Chico formation—for instance, near Folsom—showing that the gold-quartz veins had already been formed before its deposition.

EOCENE PERIOD.

In consequence of slow changes of level without marked disturbance of the Chico formation, a later deposit formed, differing from it somewhat in extent and character. The formation has been called the Tejon (Tay-hone′). It appears in the Gold Belt region at the Marysville Buttes, in the lower foothills of the Sonora district, and it is extensively developed in the southern and western portion of the Great Valley of California. During the Eocene the Sierra Nevada remained a separate, low mountain range, erosion continuing with moderate rapidity but no great masses of gravels accumulating.

NEOCENE PERIOD.

The Miocene and Pliocene periods, forming the later part of the Tertiary, have in this atlas been united under the name of the Neocene period. During the Neocene a large part of the Great Valley of California seems to have been under water, forming perhaps a gulf connected with the sea by one or more sounds across the Coast Ranges. Along the eastern side of this gulf was deposited during the earlier part of the Neocene period a series of clays and sands to which the name Ione formation has been given. It follows the Tejon, and appears to have been laid down upon it, without an interval of disturbance or erosion. Marine deposits of the age of the Ione formation are known within the Gold Belt only at the Marysville Buttes. Along the eastern shore of the gulf the Sierra Nevada, at least south of the fortieth parallel, during the whole of the Neocene formed a low range drained by numerous rivers. The shore-line at its highest position was several hundred feet above the present level of the sea, but it may have fluctuated somewhat during the Neocene period. The Ione formation appears along this shore-line as a brackish-water deposit of clays and sands, frequently containing beds of lignite.

The Sierra Nevada during this period was a range with comparatively low relief. The drainage system during the Neocene had its sources near the modern crest of the range, but the channels by no means coincided with those of the present time. Erosion gradually declined in intensity and auriferous gravels accumulated in the lower reaches of these Neocene rivers, the gold being derived from the croppings of veins. Such gravels could accumulate only where the slope of the channel and the volume of water were sufficient to remove the silt while allowing the coarser or heavier masses to sink to the bottom with the gold.

During the latter part of the Neocene period volcanic activity, long dormant, began again, and floods of lavas,[1] consisting of rhyolite, andesite, basalt, and plagioclastic glassy rocks chemically allied to trachyte, were ejected from volcanic vents, and these eruptions continued to the end of the Neocene. These lavas occupy

*Jointly prepared by Geo. F. Becker, H. W. Turner, and Waldemar Lindgren, 1894. Revised January, 1897.

[1] The term "lava" is here used to include not only such material as issued from volcanic vents in a nearly anhydrous condition and at a very high temperature, but also tuff-flows and mud-flows, and, in short, all fluid or semifluid effusive volcanic products.

small and scattered areas in the southern part of the Gold Belt, increasing in volume to the north until, north of the fortieth parallel, they cover almost the entire country. They were extruded mainly along the crest of the range, which still is crowned by the remains of the Neocene volcanoes. An addition to the gold deposits of the range, in the form of gold-quartz veins and irregular thermal impregnations, attended this period of volcanic activity.

When the lavas burst out they flowed down the river channels. The earlier flows were not sufficient to fill the streams, and became interbedded with gravels. They are now represented by layers of rhyolite and rhyolite-tuffs, sometimes altered to "pipe-clay." The later andesitic and basaltic eruptions were of great volume, and for the most part completely choked the channels into which they flowed. The rivers were thus obliged to seek new channels—substantially those in which they now flow.

Fossil leaves have been found in the pipe-clay, and in other fine sediments at numerous points. Magnolias, laurels, figs, poplars, and oaks are represented. The general character of the flora is thought to indicate a warm and humid climate, and has been compared with the present flora of the South Atlantic Coast of the United States.

THE NEOCENE UPHEAVAL.

In the latter part of the Neocene period a great dislocation occurred along a zone of faulting at the eastern base of the Sierra Nevada, and the grade of the western slope of the range was increased. These faults are sharply marked from Owens Lake up to Honey Lake. There was also a series of faults formed apparently at the very close of the Neocene within the mass of the range in Plumas County. Near the crest the Sierra Nevada is intersected by a system of fissures, often of striking regularity; it is believed that these fissures originated during the Neocene upheaval.

PLEISTOCENE PERIOD.

During Cretaceous, Eocene, and Neocene times the Sierra Nevada had been reduced by erosion to a range with gentle slopes, and the andesitic eruptions had covered it with a deep mantle of lava flows. The late Neocene upheaval increased the grade of the western slope greatly, and the rivers immediately after this disturbance found new channels and, rejuvenated, began the work of cutting deep and sharply incised canyons in the uplifted crustal block.

A period of considerable duration elapsed between the emission of the lava flows which displaced many of the rivers and the time of maximum glaciation. In this interval most of the deep canyons of the range were formed. Such, for example, are the Yosemite Valley on the Merced River, the great canyon of the Tuolumne, and the canyon of the Mokelumne. The erosion of these gorges may have been facilitated by the fissure system referred to above, for many of the rivers of the range appear to follow one or another set of parallel fissures for a long distance.

At what point the limit between the Neocene and the Pleistocene should be drawn is a somewhat difficult question. On the maps of the Gold Belt the great andesitic flows are supposed to mark the close of the Neocene, and this division is in fact the only one that can be made without creating artificial distinctions. But it is not positively known that this line corresponds exactly to that drawn in other parts of the world between these periods.

The Sierra, from an elevation of about 5000 feet upward, was long buried under ice. The ice widened and extended the canyons of preexisting topography and removed enormous amounts of loose material. It seems otherwise to have protected from erosion the area it covered and to have accentuated the steepness of lower slopes. Small glaciers still exist in the Sierra.

During the earlier part of the Pleistocene period the Great Valley was probably occupied for a time by a lake dammed by the post-Miocene uplift of the Coast Ranges. Later in the Pleistocene this lake evidently was drained and alluvial deposits were spread over the valley. There is no valid reason to believe that the central and southern part of the Sierra has undergone any important dynamic disturbance during the Pleistocene period, but renewed faulting with small throw has taken place along the eastern base of the range in very recent times.

IGNEOUS ROCKS.

Rocks of igneous origin form a considerable part of the Sierra Nevada. The most abundant igneous rocks there found are of granitic character. Rocks of the granitic series are believed to have consolidated under great pressure and to have been largely intruded into overlying formations at the time of great upheavals; they are thus deep-seated rocks, exposed only after great erosion has taken place.

The rocks called diabase and augite-porphyrite on the Gold Belt maps are not usually intrusive, but largely represent surface lavas which have been folded in with the sedimentary rocks and correspond to modern basalt and augite-andesite. In like manner hornblende-porphyrite corresponds to hornblende-andesite, quartz-porphyrite to dacite, and quartz-porphyry to rhyolite. In the Sierra Nevada the diabases and porphyrites are of pre-Eocene age, and contain in most cases secondary minerals, such as epidote, zoisite, uralite, and chlorite. The unaltered equivalents of these rocks—basalt, andesite, dacite, and rhyolite—are, in the Sierra Nevada, chiefly of Neocene or later age.

Tuffs are volcanic ashes formed by explosions accompanying the eruptions. Mixed with water, such material forms mud flows; and when volcanic ashes fall into bodies of water they become regularly stratified like sedimentary rocks and may contain fossil shells. Breccias are formed by the shattering of igneous rocks into irregular angular fragments. Tuffaceous breccias contain angular volcanic fragments cemented by a consolidated mud of volcanic ashes.

GLOSSARY OF ROCK NAMES.

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

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

Serpentine.—A rock composed of the mineral serpentine, and often containing unaltered remains of pyroxene or olivine. Serpentine is usually a decomposition product of rocks of the peridotite and pyroxenite series.

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

Gabbro.—A granular intrusive rock consisting of soda-lime or lime feldspars and pyroxene, or more rarely hornblende.

Diabase.—An intrusive or effusive rock composed of soda-lime feldspar (often labradorite) and pyroxene (more rarely hornblende). The feldspars are lath-shaped. The pyroxene is often partly or wholly converted into green, fibrous hornblende or uralite. From this change, also frequent in gabbros, rocks result which are referred to as uralite-diabase or uralite-gabbro.

Diorite. A granular intrusive rock consisting principally of soda-lime feldspar (chiefly andesine or oligoclase) and hornblende or pyroxene (sometimes also biotite).

Quartz-diorite.—A granular intrusive rock composed of soda-lime feldspar and quartz, usually with some hornblende and brown mica.

Granodiorite.—A granular intrusive rock having the habitus of granite and carrying feldspar, quartz, biotite, and hornblende. The soda-lime feldspars are usually considerably and to a variable extent in excess of the alkali feldspars. This granitoid rock occupies a position intermediate between a granite and a quartz-diorite, and is in fact closely related to the latter. The large areas occupied by it and the constancy of the type justify the special name.

Granite.—A granular intrusive rock composed of quartz, alkali and soda-lime feldspars, mica, and sometimes hornblende.

Aplite (also called *Granulite*).—A granitoid rock usually occurring as dikes, and consisting principally of quartz and alkali feldspar.

Syenite.—A granular intrusive rock composed chiefly of alkali feldspars, usually with some soda-lime feldspars and hornblende or pyroxene.

Amphibolite, amphibolite-schist.—A massive or schistose rock composed principally of green hornblende, with smaller amounts of quartz, feldspar, epidote, and chlorite, and usually derived by metamorphic processess from augite-porphyrite, diabase, and other basic igneous rocks.

Augite-porphyrite.—An intrusive or effusive porphyritic rock with larger crystals of augite and soda-lime feldspars in a finer groundmass composed of the same constituents.

Hornblende-porphyrite.—An intrusive or effusive porphyritic rock consisting of soda-lime feldspars and brown hornblende in a fine groundmass.

Quartz-porphyrite.—An intrusive or effusive porphyritic rock consisting of quartz and soda-lime feldspar, sometimes with a small amount of hornblende or biotite.

Quartz-porphyry.—An intrusive or effusive porphyritic rock, which differs from quartz-porphyrite in containing alkali feldspars in excess of soda-lime feldspars.

Rhyolite.—An effusive rock of Tertiary or later age. The essential constituents are alkali feldspars and quartz, usually with a small amount of biotite or hornblende in a groundmass, which is often glassy.

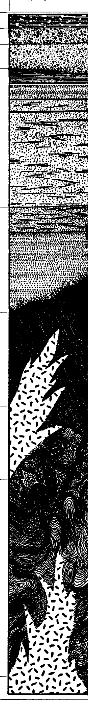
Andesite.—An effusive porphyritic rock of Tertiary or later age. The essential constituents are soda-lime feldspars (chiefly oligoclase and andesine) and ferromagnesian silicates (hornblende, pyroxene, or biotite), in a groundmass of feldspar microlites and magnetite, usually with some glass. The silica is ordinarily above 56 per cent. When quartz is also present the rock is called a dacite.

Basalt.—An effusive rock of Tertiary or later age, containing basic soda-lime feldspars, much pyroxene, and usually olivine. The silica content is usually less than 56 per cent. It is often distinguished from andesite by its structure.

Trachyte.—An effusive rock of Tertiary or later age, composed of alkali and soda-lime feldspars, with biotite, pyroxene, or hornblende.

GENERALIZED SECTION OF THE FORMATIONS OF THE GOLD BELT.

	Period.	Formation Name.	Formation Symbol.	Columnar Section.	Thickness in Feet.	Character of Rocks.
SUPERJACENT SERIES	Pleistocene	Recent.	Pal		1–100	Soil and gravel.
		River and shore gravels.	Pgv		1–100	Sand, gravel, and conglomerate.
	Neocene	River and shore gravels.	Ng		10-400	Gravel, sandstone, and conglomerate.
		Ione.	Ni		10–100	Shale or clay rock.
					10–100	Sandstone.
					....	..Coal stratum.
					50–800	Clay and sand, with coal seams.
	Eocene	Tejon.	Et		10–300	Sandstone and conglomerate.
	Cretaceous	Chico.	Kc		50–400	Tawny sandstone and conglomerate.
						GREAT UNCONFORMITY
BED-ROCK SERIES	Juratrias	Monte de Oro. Mariposa. Milton. Sailor Canyon.	Jo Jm Jml Js		1000 or more	Black clay-slate, with interbedded greenstones and some conglomerate.
						UNCONFORMITY
		Intrusive granitic rocks.	gr grd			
	Carboniferous and Older	Robinson. Calaveras.	Crb Cc		4000 or more	Argillite, limestone, quartzite, chert, and mica-schist, with interbedded greenstones.
		Intrusive granitic rocks.	gr grd			



DESCRIPTION OF THE SONORA QUADRANGLE.

GEOGRAPHIC RELATIONS.

The Sonora quadrangle is bounded by the parallels of latitude 37° 30′ and 38° north and the meridians of longitude 120° and 120° 30′ west. **Extent of quadrangle.** It thus covers a quarter of a square degree, being about 27.4 miles wide and 34.5 miles long and embracing approximately 944 square miles. The quadrangles immediately adjacent to it are the Oakdale on the west, the Big Trees on the north, the Yosemite on the east, and the Merced on the south. At its northwest corner it is in contact with the Jackson quadrangle, which, owing to the nearly northwest-southeast trend of the structural axis of the Sierra Nevada, lies in the general line of strike of the auriferous formations and is in natural continuity, both geographic and structural, with the Sonora district.

The Sonora quadrangle embraces the southern end of the Gold Belt, as that region is defined in the preceding general description. **Southern end of the Gold Belt.** The belt in this case may be regarded as a rather arbitrary zone, about 10 miles in width, traversing the quadrangle diagonally from its northwest to its southeast corner, and containing a section of the remarkable linear system of gold-bearing quartz veins known both locally and in geologic literature as the Mother Lode. Its natural termination is not, however, exactly at latitude 37° 30′, but a few miles farther south, where the auriferous slates of the Mariposa formation are cut off by granitic intrusions.

The larger part of the quadrangle lies within the western foothill region of the Sierra Nevada. The southwestern portion, however, to the west of Lagrange and Merced Falls, **Three topographic divisions.** is properly a part of the Great Valley, and another portion, of about the same size, in the northeast corner, is allied more closely with the thoroughly mountainous tracts of the Big Trees and Yosemite quadrangles.

TOPOGRAPHY.

Relief.—The lowest land within the quadrangle is in the southwest corner, and forms the alluvial plain of the Merced River, with an altitude near Snelling of less than 250 feet. **Range of altitude.** Toward the northeast the elevations steadily increase until the summit of Duckwall Mountain is reached, at 5859 feet, in the northeast corner. This is the greatest elevation recorded on the sheet. Taken as a whole, the area may be said to have the character of a plateau, sloping gently southwestward. This plateau represents the old surface to which the long-continued **The Neocene peneplain.** erosion of Cretaceous, Eocene, and Neocene times had degraded this portion of the Sierra Nevada. Its present irregularities are due to two causes. In the first place, the former cycle of erosion was interrupted before reaching maturity, so that the surface was never quite reduced to a peneplain. Obdurate masses, such as Duckwall Mountain and Moccasin Peak, being composed of more resistant rocks, still stood above the general level, and the streams were as a rule separated by low rounded divides. Secondly, the interruption of this cycle of erosion was brought about by the Neocene upheaval, by which the old worn-down surface appears to have been tilted to the southwest. The activity of the streams was greatly intensified, and they at once began with renewed energy to carve from the older and simpler land forms the deep narrow canyons and all the intricate details of the present topography. Thus, ancient irregularities never subdued and more recent vigorous dissection combine to obscure the approximation to a peneplain which the district, in common with most of the western slope of the Sierra Nevada, once attained. **The peneplain farther north.** Farther north, beyond the boundaries of the quadrangle, the peneplain character is better preserved, owing largely to the protective covering of great sheets of andesitic tuff-breccias, while farther south it is apparently much less distinct, if it can be detected at all in the rugged region west of Mount Whitney. The Sonora quadrangle seems to stand somewhat in the character of a transition ground between the two regions.

In the northern part of the quadrangle the most conspicuous remnant of the old topography is found in the lava-capped ridge of Table Mountain. This is an old stream channel, which once confined one of the principal rivers draining the Neocene surface. During one of the later volcanic eruptions which closed that period, a lava flow, descending from the **A preserved Neocene stream channel.** crest of the Sierra, filled this channel and buried its gravels under a stream of molten basalt. This covering has since effectually resisted the erosion which has worn down the surrounding country, so that to-day the former stream channel stands out as the most imposing, although not the highest, elevation of the whole western portion of the quadrangle. Its long, nearly horizontal crest and bounding cliffs of black columnar basalt make Table Mountain the most conspicuous feature in the landscape for miles around. The remnants of this lava flow are not limited to the area of the Sonora quadrangle, but can be traced from the edge of the Great Valley up to the summit region of the Sierra Nevada, a distance of more than 60 miles. This length is important, as showing that the stream whose waters the lava displaced constituted one of the main drainage trunks, and traversed the gentle slope of that time from a point not far west of the present crest. Such a stream probably flowed on a uniform grade a little below the level of the surrounding country, and for this reason the stretches of its channel preserved beneath the lava furnish a convenient datum plane in determining how much of the present surface has always stood above that level and how much has since been degraded below it. If the plane determined by the flat top of the lava stream be in imagination projected over the immediately surrounding region, many summits will be found to stand above it, but the greater part of the country will be distinctly below it. In case vestiges of the former Neocene peneplain remain, they should consist of nearly level or gently undulating plateaus, standing somewhat above the plane of the Table Mountain flow and surmounted by occasional higher residual hills, or monadnocks. Approximately level areas, whose floors are formed of the truncated edges of the steeply dipping slaty or **Level areas of upturned strata.** schistose formations, are found at various points, notably between Table Mountain and Chinese Camp, between Tuttletown and Rawhide, southeast of the Crimea House, north of Fortynine Gap, and at the head of Corral Creek; but with the exception of the last two, these flat-floored areas appear to be too low to have formed a portion of the surface at the time the basalt of Table Mountain was erupted. Had they then existed, the lava would have inundated them. They probably represent eroded surfaces of a somewhat later date.

Other fragments of the Neocene surface are preserved, particularly in the northeast portion of the quadrangle, beneath various areas of andesitic tuff and breccia, sometimes **Neocene tuffs and river gravels.** associated with Neocene river gravels. A series of these small patches extends from the neighborhood of Soulsbyville in a southeasterly direction to within about 2 miles of Colfax Gate. This line is parallel with the general trend of the range, and, as would be expected in such a case, the deposits show a general agreement in altitude. They rest upon the eroded edges of the more ancient rocks at an elevation not far from 3000 feet. To the northeast of this line similar deposits occur at steadily increasing altitudes up to 5000 feet, in the corner of the quadrangle, while to the west a few small areas of andesitic tuff and breccia occur in association with the basalt of Table Mountain, near Mountain Pass, at about 1500 feet. They underlie the basalt at this place. These scattered remnants are all that remain of once far more extensive volcanic deposits which were spread over the eroded Neocene surface. Like the Table Mountain flow, they furnish a datum plane for estimating the former character of its topography and the **Restoration of the Neocene surface.** advance made in its partial destruction by the forces of denudation. The two datum planes are not strictly identical, for there is unequivocal evidence, drawn chiefly from beyond the bounds of the quadrangle, that a large portion of the andesitic deposits had been laid down and considerably eroded before the eruption of the basalt; but so far as the Sonora quadrangle is concerned they may be taken together in the endeavor to restore the old surface of erosion. The outcome of such an attempt is the conclusion that the surface was never quite reduced to the state of a typical peneplain, **Not a complete peneplain.** and that, since the cessation of the volcanic activity which brought the Neocene to a close, it has been greatly modified through dissection by the present streams. The quadrangle as a whole is a region of hills and canyons, with but little level land, and the evidence of former approximation to a peneplain must be sought in the fairly regular character of the slope as a whole, in the regular altitudinal disposition upon it of the remnants of the Neocene volcanic cover, and in the general and common truncation of rocks of varied character and origin, many of them formed at great depths and exposed only through the removal of thousands of feet of overlying material.

The degree of recent dissection is naturally more pronounced toward the northeast, the larger streams having established themselves on grades that are distinctly flatter than the general slope of the surface. Thus their gorges grow deeper as they are followed into the mountains to points far beyond the limits of the quadrangle. The most rugged canyons are those of the **Rugged canyons.** northeast portion, in the watershed of the Tuolumne River, where there are steep slopes with a vertical range of more than 2000 feet. At some points, as at the end of the east spur of Duckwall Mountain and just north of Colfax Gate, the slopes are very precipitous.

From Lagrange southward, low rolling hills predominate, carved from the soft Tertiary beds and intersected by occasional shallow stream-valleys filled with alluvium. Being practically treeless, and covered with a scanty **Bare, rolling country.** gravelly soil upon which a sparse and fugitive growth of grass springs up in the wet season, these undulating hills present a particularly parched and cheerless aspect during the dry months of summer. Their surfaces are often rendered extremely uneven by successive alternations of small hillocks and hollows, locally known as "hog wallows," although the term is an evident misnomer. Similar mounds and hollows have been described in other regions of scanty vegetation and gravelly soil, but no completely satisfactory explanation of their origin has yet been advanced.

Drainage.—Excepting the northwest corner, where the streams north of Table Mountain flow into the Stanislaus River, and a narrow area on the south border, extending from Hornitos to Bullion Mountain, the entire region is drained by two rivers, the Toulumne and Merced. The former of these is the larger, having a good flow of water at all times of the year. In summer both streams are partially fed by melting snow along the crest of the range.

There is a marked connection between the drainage system and the structure of the region. In a general way the courses of the two main rivers may be said to follow **Relation of drainage to structure.** either the prevailing northwest-southeast strike (direction of the lines of stratification and schistosity) of the rocks, or to cut directly across the strike toward the southwest. This is to a certain extent likewise true of the larger tributaries. The courses of the minor streams have been chiefly determined and controlled by the northwest-southeast lines of structure, after the manner of subsequent streams (i. e., streams that have eaten back their valleys along belts of weak strata).

Vegetation.—The valley lands in the southwest corner are largely barren of any natural vegetation other than grass and other small herbs. There is usually, however, a line of poplars and sycamores along the rivers. The lower foothills, up to an elevation of about 1000 feet, are dotted with Douglas oak and live oak (*Quercus wislizeni*), and there are occasional patches of *Ceanothus cuneatus*, a thorny shrub. The middle foothill region, from 1000 to 2500 feet elevation, is especially characterized by large areas of an evergreen shrub often called greasewood (*Adenostoma fasciculatum*), which **Vegetation at various altitudes.** remains a deep green during the hot and dry summer, affording relief to the eyes and adding greatly to the picturesqueness of the landscape. Manzanita and Christmas berry (*Heteromeles arbutifolia*) are also common. The most abundant trees of this zone are digger pine (*Pinus sabiniana*) and Douglas oak.

In the upper foothill region, from 2500 to 3500 feet, the yellow pine (*Pinus ponderosa*) is perhaps the most characteristic tree, and as this is valuable for timber, it may be said to form the lower border of the timber belt, while in the northeast section of the quadrangle, above an altitude of 3500 feet, sugar pine (*Pinus lambertiana*), black oak (*Quercus californica*), and a cedar (Librocedus) are abundant.

There is thus a marked relation between the vegetation and altitude. The species above mentioned, while not confined to the limits noted, may be said therein to reach their maximum development.

There is, however, some relation between the vegetation and the underlying rock. Thus, on serpentine areas, digger pine, Christmas berry, and greasewood are common, **Effect of underlying rocks.** while oaks are rarely to be noted. On the ridge east of the lower part of Solomon Gulch, and the plateau-like ridge of which Texas Hill is the culminating point, there are groves of the narrow-cone pine (*Pinus attenuata*) and patches of a low-growing plant of the rock-rose family (*Helianthemum scoparium*) which were not noted elsewhere. The underlying rock in both these cases is a fine-grained and thin-bedded quartzite. The digger pine often wanders out of its normal zone to dry ridges of higher elevation. It occurs, together with *Ceanothus cuneatus*, on andesite-breccia areas up to an altitude of 4000 feet.

GEOLOGY.

BED-ROCK SERIES.

The Bed-rock series consists of sedimentary rocks which were turned into a nearly vertical position during or before the post-Juratrias mountain-building disturbance, together with the associated igneous rocks. The sedimentary rocks of this period represent beds of fine silt, sand, and gravel which since their **Origin of the older rocks.** deposition have been hardened and metamorphosed. These beds were originally horizontal, but have been folded and compressed by forces acting chiefly from north-northeast to south-southwest. They have also been subjected to extensive erosion, so that the upper parts of the folds have disappeared. Intercalated in these sediments are layers of metamorphic lavas and tuffs, showing that volcanic eruptions occurred while the beds were forming. Irregularly intruding the sedimentary rocks with their included volcanic layers are masses and dikes of various granular igneous rocks, such as granite and gabbro. The Bed-rock series is therefore made up of sedimentary rocks and igneous rocks.

SEDIMENTARY ROCKS.

Calaveras formation.—With the exception of a few lenticular areas along the line of the Mother Lode, the sediments that have been referred to the Calaveras formation form one large area which comprises about one-third of the quadrangle. The kinds of rock chiefly represented are quartzite, mica-schist, clay slate, chert or fine-grained quartzite, and limestone. Of these, only the limestone has been found to be even occasionally fossiliferous. **Age of Calaveras formation.** That this rock is not younger than the Paleozoic era is indicated by the occurrence of cylindrical crinoid stems in the limestone lenses on Mormon Creek, in the northwest corner of the quadrangle, while the main limestone belt, extending with interruptions from Sonora to Bower Cave, is in the line of continuation of a similar belt in the Yosemite quadrangle in which Foraminifera (Fusulina) of Carboniferous age have been found.

East and south of Sonora the limestone,

together with the sediments on either side of it, has been displaced by a large intrusion of granodiorite. The bedding and schistosity of the sedimentary series have been forced into approximate parallelism with the eruptive contact, as is strikingly shown by the manner in which the long limestone mass curves eastward south of the granitic area. Another interesting feature of this body of limestone is the way in which its eastern extremity divides into long diverging fingers. At Bower Cave a small cavern of some interest has been dissolved out of the limestone by percolating waters.

Limestone lenses.

Siliceous mica-schist and quartzite.

Lying to the east and north of the Sonora and Bower Cave limestone belt is a considerable mass of sedimentary rocks of which Duckwall Mountain is the culminating point. The mountain itself is composed mainly of quartzite, while between it and the limestone siliceous mica-schists prevail. This entire siliceous series is regarded as probably older than the Carboniferous, although no fossils have been found within it. The supposition rests upon lithologic grounds and upon the fact that the series lies to the east of the known Carboniferous limestone. Its displacement by the intrusion of granodiorite east of Sonora has already been described.

Between Coulterville and Bower Cave the rocks belonging to the Calaveras formation are probably of Carboniferous age, as indicated by the fossils in the limestone lenses already referred to. They are chiefly fissile clay slates, often micaceous, and sometimes nearly black from the abundance of finely disseminated carbonaceous material. Some fine-grained and thin-bedded quartzites form the ridge east of the lower part of Solomon Gulch, and also a portion of the plateau east of the North Merced River, of which Texas Hill is the culminating point.

Some difficulty was experienced in separating the area of Calaveras slates in the extreme northwest corner of the quadrangle from the Mariposa slates adjoining them on the west. The line as drawn is somewhat arbitrary, but fairly defines the boundary between slates of rather heterogeneous character on the east, including lenses of limestone, and the ordinary uniform clay slates of the Mariposa formation on the west. Moreover, this portion of the quadrangle is one of complexity, the various sediments of the Calaveras formation being associated in the most intimate manner with amphibolite-schists and intrusive igneous rocks.

Structure of the Calaveras formation.

The general strike of the schistosity and bedding of the Calaveras formation is northwest and southeast, while the dip is usually northeasterly at an angle greater than 65°. Irregularities frequently occur, however, particularly in the vicinity of large intrusive masses of granodiorite. Practically vertical dips are common, and the inclination is sometimes to the west. The lateral compression of the whole series in a northeast-southwest direction has been so severe, and the absence of characteristic and persistent beds is so marked, that only by the most patient and detailed study could one hope to reconstruct the original folds of the beds as they were before their subjection to such great pressure and to such deep truncation by erosion.

Mariposa formation.—This formation attains its maximum development in the Mariposa County portion of the quadrangle, and it was here that the first fossils were found which determined its Jurassic age. These came from the slates northwest of Bear Valley, in the ravine known as Hell Hollow. Since their discovery similar fossils have been collected at other points in the same belt of slate.

Eastern belt of Mariposa clay-slates.

There are three bands of sediments which have been colored on the geologic map as belonging to the Mariposa formation. Of these it is the longer and eastern one which has been found to be fossiliferous. This extends across the middle of the quadrangle in a northwest-southeast direction, and is remarkable in containing a large number of rich gold-quartz veins, forming a portion of the Mother Lode. The rocks of this main belt are chiefly clay slates and shales, of uniform appearance, with a subordinate amount of sandstone and some coarse grit and conglomerate. As a rule the general strike of the slates, as determined by their cleavage, is nearly parallel with the trend of the belt, and their dip is northeasterly at a high angle. The sandstone occurs usually in thin beds intercalated with the slates. The existence of these beds permits the observation to be made that with rare local exceptions the slaty cleavage is parallel with the original bedding planes. Such an exception is found at the mouth of Sullivan Creek, where the shales show numerous small irregular folds, in some of which slaty cleavage can be seen cutting the planes of both stratification and shearing. The sandstones themselves usually show marked fissility parallel with their bedding planes. A considerable mass of conglomerate, containing pebbles of quartzite, black siliceous argillite, porphyrite, muscovite-granite, and granite-porphyry, is exposed near the mouth of Sullivan Creek. The prevailing dip of the slates and sandstones is northeasterly at considerable angles. On Woods Creek, near Jacksonville, the beds have an anticlinal attitude, those on the western side of the creek dipping westerly while those on the eastern side dip easterly. In general, however, the beds, closely compressed in a northeast-southwest direction, do not allow the recognition of anticlinal or synclinal structures.

Anticlinal structure.

The middle belt.

The middle belt of the Mariposa formation is separated from the one just described by extensive areas of augite-porphyrite, amphibolite, and serpentine. Its rocks are generally similar to those of the eastern belt. The sandstone is usually fine-grained, but at times contains small pebbles. It nearly always shows evidence of strong compression. As can be seen by reference to the map, this middle belt includes some elongated areas of porphyrite and porphyrite-tuff, and some patches of granodiorite. The tuffs and porphyrites were evidently formed contemporaneously with the slates and sandstones, but the granodiorite is later and intrusive. At Don Pedro Bar the intruded boss of granodiorite has not only caused a conspicuous displacement of the sedimentary rocks, compelling them to curve around it, but has also effected a marked contact metamorphism of the surrounding clay slates. In the southeastern extension of this belt, in the neighborhood of Hornitos, are some highly altered schists which appear to be of the same age, and perhaps owe their alteration to the effect of contact metamorphism produced by the intrusion of basic igneous rocks, in part typical diabase, of which there are numerous areas in this vicinity. However, the case is not a clear one. The diabase, although occurring in abundant dikes, and in irregular masses up to 3 miles in length and half a mile in width, does not seem to be sufficiently extensive to have metamorphosed nearly the entire mass of the schists northeast of Hornitos. There is the possibility, however, that the igneous masses are of much greater extent at a short distance below the surface, and have thus been able to effect an amount of metamorphism greater than that which might be expected from the size of their present exposures. It is likewise possible that the metamorphism is due to an underlying mass of granitic rock. On Cotton Creek, about 6 miles north of Hornitos, there is a lens of slaty limestone which has been used for making lime. This is the only limestone lens in the quadrangle in rocks supposed to belong to the Mariposa formation.

Highly altered schists.

Chert beds inclosed in the igneous rocks.

There will be noted on the geologic map some bands of chert (**ch**) intercalated in the igneous rocks which lie between the eastern and middle belts of the Mariposa formation. These are presumed to be of Juratrias age, as they appear to have been formed during the period of the eruption of the porphyrites with which they are associated.

No fossils have been found in the middle belt within the limits of the quadrangle, but it is considered to be part of the Mariposa formation on account of the little-altered character of its slates and sandstones and its actual continuity with the supposed Mariposa slates of Salt Spring Valley, shown in the Jackson folio.

The western belt.

The western belt of the Mariposa formation extends from Lagrange, on the Tuolumne River, to Merced Falls, on the Merced River, and is composed almost wholly of dark clay slates. It has a very irregular shape, partly due to the overlapping of the flat Tertiary beds and Pleistocene gravels upon the upturned and truncated edges of the slates, and partly to tongues of porphyrite which project into the slate area. In the latter case there is sometimes a gradation between the ordinary clay slates and the slaty or schistose porphyrites. It is probable that the latter were chiefly deposited as tuffs contemporaneously with the true slates. Near Lagrange the slates disappear entirely under the nearly horizontal Tertiary sandstones. No fossils were found in the western belt of slates except some obscure belemnite-like forms east of Lagrange, and their reference to the Mariposa rests chiefly upon their lithologic character.

IGNEOUS ROCKS.

Amphibolite.—Rocks included under this head are not so abundant in the Sonora quadrangle as they are farther north. They occur in both massive and schistose form, and have in all cases been derived from the alteration of more or less basic igneous rocks through a process of recrystallization.

Origin of the amphibolite-schist.

The amphibolite-schists form a band of irregular width lying just east of the main belt of Mariposa slates, and frequently separating the latter from the rocks of the Calaveras formation. The band is not continuous, being interrupted near Campo Seco. Although the typical facies of these schists is a rather dark-green, fibrous rock, composed chiefly of slender prisms of green amphibole with some visible calcite and biotite, yet the megascopic and microscopic variation is rather great, indicating their derivation from rocks of extensive range in chemical composition and probably also of considerable original textural variety. Occasionally remnants of the original augite and plagioclase of the parent rock can be detected, but the transformation has generally been sufficiently thorough to obliterate the original igneous minerals and structure. The characteristic mineral of these schists, from which they derive both their name and their invariable greenish tint, is green amphibole, of more than one variety; but the microscope shows that quartz, plagioclase feldspar, chlorite, epidote, biotite, white mica, and calcite are all abundant constituents in varying proportions, although not all present in any one specimen. South of Coulterville the amphibolite-schist merges into augite-porphyrite, which was undoubtedly the original rock of the larger part of the belt.

Massive amphibolite.

The massive amphibolite is usually a dark-green, fine-grained rock, probably largely derived from a massive basalt. Two main areas of it are noted on the map. One of these lies just northwest of Horseshoe Bend; the other forms a considerable belt extending from Pleasant Valley, on the Merced River, to beyond Indian Bar, on the Tuolumne River. Although, as above stated, the larger part of the massive amphibolite is fine-grained, certain portions of these areas are composed of a coarser rock which appears to have been originally gabbro; but the feldspars are generally altered to saussuritic aggregates, and their exact original character has not been determined. Such rocks occur south of Indian Bar, west of Horseshoe Bend, and at other places.

Origin of the porphyrite.

Porphyrite.—Altered lavas having the composition of andesite are called porphyrite. The very large areas of these rocks indicate that the time of their eruption was one of great volcanic activity. Porphyrite occurs in the foothills of the Sierra Nevada, in long belts of irregular width, which are generally parallel with the belts of sedimentary rocks between which they lie. A schistose structure, in many cases determined probably by a rough original bedding, is not uncommon, and in such cases the superficial exposures show the usual steep easterly dip common to the sedimentary series, the rocks projecting from the soil in long, parallel, comb-like outcrops stretching over hill and dale. The most common facies is a greenish augite-porphyrite, showing porphyritic crystals of dark augite lying in a fine-grained groundmass. With a very few exceptions, all of the rocks of the porphyrite series were erupted as surface flows or as coarse tuffs and breccias that find their analogues in the andesitic breccias of Tertiary age which now cap many of the higher ridges of the Sierra Nevada. They were, on the whole, probably more basic than the latter, and at the same time less uniform in character. Their clastic texture is generally easily recognized in the field, and the microscope shows that the porphyritic crystals of augite are frequently embedded in a fragmental groundmass of which the original character is now largely obscured by secondary minerals, among which epidote and calcite are conspicuous.

Two main belts of porphyrite.

The porphyrites and the indurated tuffs immediately associated with them have a wide distribution in the Sonora quadrangle. In a general way they form two broad parallel bands, extending diagonally across the western portion of the district, and separated from each other by the middle belt of slates and sandstones of the Mariposa formation.

The eastern belt comes into the quadrangle near the northwest corner, being a continuation of the area forming the high western ridge of the Bear Mountains, and passes out of it near the southeast corner. For practically the entire distance it adjoins the main or eastern belt of the Mariposa slates on the west. Considerable variation exists within this mass. At its northern end, just north of Table Mountain, it is a typical augite-porphyrite. South of Table Mountain and about Chinese Camp the rock is a massive diabase with ophitic texture. Farther south the cluster of rugged hills dominated by Moccasin Peak and the almost equally rugged Peñon Blanco Ridge are made up of the ordinary augite-porphyrite-breccia or coarse tuff, now consolidated into a hard rock of massive appearance. Irregular grains of quartz are fairly abundant in the augite-porphyrite 2 miles northwest of Peñon Blanco, near the contact with the Mariposa slates.

The volume of these augite-porphyrites is very great. In the wider portions the belt has a width of about 5 miles, and this, allowing for a general easterly dip of 65°, which is less than that of the inclosing sedimentary rocks, would give the enormous actual thickness of 4½ miles. The nature of the material makes it impossible to be sure that there is no folding or repetition of the single members of the series, but no indication of such duplication was observed in the field. Nevertheless, it seems hardly possible that 4½ miles can represent the original thickness of the accumulations.

The large western area of porphyrite does not call for detailed description, as its rocks resemble in a general way those just described. They may be characterized, however, as exhibiting a rather pronounced schistose structure, whereby their outcrops, although more massive, resemble somewhat those of the clay slates. Moreover, by the disappearance of the grains of augite and an increasing fineness of the tuffaceous material, with the addition of nonvolcanic detritus, these porphyrites appear to grade locally into the ordinary clay slates of the Mariposa series.

Smaller isolated areas.

Two other considerable masses, which are largely augite-porphyrite, form the ridges of which Buckhorn Peak and Bullion Mountain are the culminating points. Smaller areas of porphyrite-tuff occur intercalated with the rocks of the sedimentary series. Such a strip is that lying east of Don Pedro Bar. At the Tuolumne River this is a nearly white quartz-porphyrite, but it appears to be in direct continuation with the ordinary augite-porphyrite-tuff which lies west of the large serpentine area near the Crimea House, and the two were not separated in mapping.

Although the porphyrites have been described as being chiefly fragmental in origin, it is probable that igneous intrusions in the forms of sheets and dikes helped in building up these thick volcanic accumulations, but they were subordinate in volume to the purely effusive and clastic material.

Hornblende-porphyrite.—Hornblende-porphyrite is an altered andesitic lava containing needles of hornblende.

The only area of hornblende-porphyrite indicated upon the map occurs just west of Marsh's Flat, on the south slope of Moccasin Peak, where it forms a small lenticular sheet within the augite-porphyrite series, and, like most of the latter, is of fragmental origin. The rock is gray in color, with dark idiomorphic hornblende crystals disseminated abundantly through it.

Gabbro.—Evenly granular rocks composed of basic lime-soda feldspar and a ferromagnesian mineral, usually pyroxene, are called gabbro. This rock is not abundant in the quadrangle. It is in general more or less altered, the feldspars being kaolinized and the pyroxene often converted into uralite.

The area shown east of the Phoenix Reservoir, at the north edge of the sheet, is surrounded by quartz-pyroxene-diorite, into which it may grade. The southern part of the large area east of Sonora, called granodiorite on the geologic map, is in reality a gabbro, some of the feldspar being labradorite, a feldspar rich in lime. This gabbro, however, grades over into the pyroxenic diorite that forms the larger part of this area, and is not separated from the dioritic rock on the geologic map.

Uralite-gabbro.

The irregular mass lying west of the Rawhide serpentine area and extending southward under the basalt of Table Mountain may be called a uralite-gabbro. It shows considerable variation and is generally so much altered that its original character can not be determined. It is usually a fine-grained green rock, which under the microscope shows green hornblende, altered feldspars, and abundant epidote and calcite. Quartz is sometimes present, and where it is original the rock seems to have been a quartz-gabbro, but generally it appears to be secondary. At a point on the road about 2 miles southwest of Jamestown a coarse facies of the rock is exposed; it is here made up of large, irregularly bounded crystals of dark-green hornblende and dull opaque feldspars. It is possible that the entire area mapped as gabbro may not be a strict geologic unit, but the general decomposed condition of the rock would render any further separation extremely tedious and unsatisfactory at best.

Dikes and masses of typical diabase. **Other diabases.**

Diabase.—The rocks that have been designated diabase (db) on the Sonora geologic map are dark, medium- to fine-grained rocks which occur as dikes and laccolith-like masses, chiefly to the northeast of Hornitos. An analysis of a specimen from a dike by the road to Bear Valley 1½ miles northeast of Hornitos shows that some of these rocks are chemically typical diabases. They contain less silica than any of the diabases which form portions of the areas that have been described under porphyrite. Moreover, they are without doubt later than the porphyrite series, for they cut that series in distinct dikes. They are made up of augite, amphibole, labradorite and other feldspars, and in part show a diabase-granular texture, a term used when there is interstitial pyroxene or amphibole between the feldspars. The largest area has a length of about 3 miles and a maximum width of about one-half mile, but a considerable part of this mass may be called diabase-porphyry; augite, and sometimes feldspar, being porphyritically disseminated in a fine-grained groundmass. The original composition of this groundmass is in many cases uncertain, as there is almost universally present a large amount of hornblende in ragged fibers, usually brown in color, but nevertheless presumably secondary. In a small area 4 miles east of Hornitos there is but little feldspar present, and at other points olivine occurs in the rock, so that these basic diabases grade over into rocks of the peridotite family. In some cases the original pyroxene is entirely replaced by brown hornblende. In some specimens, however, the hornblende may be partly primary, forming a hornblende-diabase. Under the head of Mariposa formation, the greatly altered condition of schists to the east and northeast of Hornitos is reservedly ascribed to metamorphism caused by these intrusive diabases, but the evidence of this is not satisfactory, there being no zones of greater metamorphism around even the largest area of the diabase. It is not impossible that the metamorphic condition of these schists, and of some of the diabases themselves, is due to an underlying mass of granitoid rock.

Occurrence of the serpentine.

Serpentine.—This rock is an alteration product of basic gabbros or of ultrabasic igneous rocks of the peridotite family. In general the serpentine occurs in broad, well-defined areas of rather irregular shape, or as elongated dike-like masses of greatly varying width. By far the largest area of serpentine in the district is that lying to the west and south of Chinese Camp, having a width of 4 miles and a length within the quadrangle of 12 miles. The usual rock of this area is a dark-brown serpentine, which forms rather rugged hills of an uninviting aspect, being very sparsely covered with vegetation and weathering to a rusty red color. Other portions of the mass, particularly near its periphery, weather to the greenish-gray color usual with the serpentines of the Sierra Nevada. North of the Crimea House the serpentine is quite schistose, sufficiently so to allow of good observations being taken for dip and strike. In general the rock of this area appears to be completely changed to serpentine. A specimen taken about 1½ miles northeast of the Crimea House, however, showed apparent remnants of a rhombic pyroxene under the microscope, while another specimen, taken from a small outcrop in the serpentine about one-half mile southwest of Chinese Camp, is made up of diallage and olivine and may be called a diallage-peridotite. Loose pyroxenic bowlders also occur scattered over various portions of the serpentine area. The mapping would indicate that the latter represents an originally intrusive mass of peridotite and related rocks. There is apparently little or no evidence of contact metamorphism about the periphery of the mass, but the exposures are not favorable to its detection.

Serpentine associated with gabbro.

Another considerable tract of serpentine is that near Rawhide, in the northwestern portion of the quadrangle, and which continues southward under the basalt of Table Mountain, down to Sullivan Creek. The rock of this tract is chiefly a dark massive variety, showing glistening cleavage faces of bastite. Near the western edge of the tract the serpentine is intimately associated with a rather decomposed gabbro, in a manner strongly suggesting that the gabbro is a portion of the original mass of basic igneous rock from which the serpentine was derived. A similar close association of serpentine and gabbro occurs on the south side of Table Mountain, about a mile southeast of Rawhide.

Another area of serpentine extends from a point a little northwest of Coulterville in a northwesterly direction past Peñon Blanco to Moccasin Creek. This is merely a portion of an interrupted and very irregular belt which extends from a point 1 mile east of Jacksonville down to the southeast corner of the quadrangle, near Mount Bullion, and lies generally just east of the eastern belt of Mariposa slates. The serpentine west of Rawhide is also directly in the line of this irregular belt, although separated by a longer interval than are any of the other detached portions. The serpentine of Peñon Blanco resembles that near Rawhide, being dark and massive, with large cleavage faces of bastite. Here also it is closely associated with gabbro, a portion of the latter being mapped as a distinct area. About 2 miles northwest of the village of Peñon Blanco, the great quartz veins of the Mother Lode lie wholly within the serpentine, and, by their resistance to weathering and erosion, have determined a series of little, sharply pointed spurs or knobs, upon whose summits the white quartz is seen in conspicuous croppings. Small basic dikes are fairly abundant in the serpentine between Peñon Blanco and Moccasin Creek, and were sometimes observed alongside the quartz veins.

Granodiorite and granite.—No distinction has been made on the geologic map between the different quartz-feldspar rocks belonging to the quartz-diorite and the granite families. It may be said in a general way, however, that there is very little true granite represented. There are also certain gneisses mapped with the granites. These are found in small amounts only, as on the east slope of the hill a mile northeast of Carter.

The largest area of granodiorite. **Small isolated masses.**

The large granitic area in which are the mines of the Soulsbyville district is neither a true granite nor a typical granodiorite. Much of the area contains pyroxene and grades over into rocks some of which may be quartz-gabbro. Others may be called pyroxene-diorites, the pyroxene being both augite and hypersthene. In nearly all of them more or less quartz is present. To the east of the Phoenix Reservoir is a very basic mass, probably a gabbro, the relation of which to the quartz-pyroxene-diorite that surrounds it was not determined. There are very numerous dikes of diorite-porphyry in these granitoid rocks. It will be noted on the map that there are a number of small irregular shaped areas inclosed in porphyrite and in the sediments of the Auriferous slate series. In general, the rock of these smaller masses has a somewhat different character from typical granodiorite. It is characterized by its richness in hornblende, the scarcity or absence of visible quartz grains, and the absence of recognizable orthoclase. Biotite is very rare, while it is abundant in typical granodiorite. All the specimens examined under the microscope show a more or less advanced stage of decomposition. The feldspars are changed into fine-grained aggregates of secondary products, but sometimes show remnants of twin lamellæ, indicating that they are plagioclase. Secondary quartz is abundant, and epidote is also common. Apatite and titanite occur as accessory minerals, particularly the former, included in the hornblende crystals. The prevailing decomposition renders an accurate determination of the rocks difficult, but they are in the main quartz-diorites, with frequent more basic dioritic facies.

Large area north of Coulterville.

Excepting the area east of Sonora, the largest single mass of quartz-diorite is that lying between Coulterville and Bigoak Flat, nearly in the middle of the district. This 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 clouded aggregates composed largely of a nearly colorless epidote or zoisite and scales of white mica. Apatite is sometimes a very abundant microscopic constituent, especially as inclusions in the hornblende crystals. On the east fork of Moccasin Creek, 3 miles due south of Bigoak Flat, a facies occurs which contains no hornblende, but is made up of feldspar, quartz, and small nests of epidote grains. The microscope shows that this rock has been subjected to much secondary action. The feldspars, where they are not completely decomposed, are recognizable as plagioclase.

The very irregular area just west of Indian Bar shows some variations, but in the main is a basic-looking, dioritic rock with abundant dark-green hornblende, dull feldspars, and some quartz. The microscope shows only occasional remnants of plagioclase and a prevailing abundance of epidote. This rock is intrusive on the east into a fine-grained green rock, which is evidently a somewhat altered member of the porphyrite series, and is described under that head. The association of the two rocks is at times so intimate that it becomes necessary to separate them by a more or less arbitrary line.

The granodiorite of the area about 2 miles east of Don Pedro Bar resembles closely that just described.

Interesting area at Don Pedro Bar.

The most interesting area of granodiorite is perhaps that at Don Pedro Bar, where the intrusion has not only metamorphosed the adjacent clay slates but has effected a marked displacement of the invaded rocks. The intrusive rock varies from a quartz-diorite, made up of hornblende, a predominating soda-lime feldspar, and quartz, to a quartz-mica-diorite, and resembles more closely the typical granodiorite of the Sierra Nevada than any other rock in the area. The feldspar (oligoclase?) occurs in semiporphyritic crystals more than a centimeter in length.

Age of the granitic rocks.

Nearly all the granitoid rocks in the district may be regarded as intrusive and of later age than the inclosing sedimentary and volcanic rocks. The various facies are probably to a large extent more basic peripheral portions of the large batholithic mass of granodiorite which underlies a part of the Sierra Nevada, and which is exposed over wide areas to the east of the Sonora quadrangle.

Soda-feldspar rocks. **Some auriferous dikes.**

Soda-syenite and soda-syenite-porphyry.—Along the belt of quartz veins known as the Mother Lode are numerous dikes which are made up chiefly of albite or soda feldspar, and may be classed as soda-syenites. Some of the larger of these dikes are shown on the geologic map. The most important one lies east of Moccasin Creek. At its north end, near the mouth of the creek, the rock contains quartz and muscovite in addition to the soda feldspar, and may be called a soda-granite, but the larger part of it is a porphyry whose groundmass is composed of grains of albite in which are embedded porphyritic crystals of plagioclase, which in part are likewise albite. Locally an olive-green ægirite-like mineral is present, and beautiful little stars made up of radiating needles of a blue amphibole are likewise common. Near its south end, to the north of the road to Priest's hotel, this dike contains pyrite and gold, the latter in sufficient quantity to have induced extensive prospecting. At the Bachelor quartz mine, on the north bank of the Tuolumne, are several small dikes, in part replaced by quartz, dolomite, and pyrite; and farther northwest, about due east of Jacksonville, is a dike about 100 feet wide in part made up of coarsely granular albite. At one point this dike has been mined extensively for gold, a large mass having been quarried out.

Dikes southeast of Coulterville.

Dikes of syenite-porphyry were also noted in siliceous argillite or thin-bedded quartzite of presumably Paleozoic age to the north of the Merced River on the ridge east of Solomon Gulch. One of these dikes, about 9 miles southeast of Coulterville, much decomposed, can be traced for a mile or more with a strike to the west of north. The soft dike material has apparently been auriferous, as numerous cuts have been made in it, and claims located. Along the borders of the serpentine area from 6 to 7 miles southeast of Coulterville are several soda-syenite dikes. Some of them follow quite closely the contact of the serpentine and the adjoining rock, which to the east of the serpentine is a greenstone, or augite-porphyrite-tuff (altered augite-andesite), and to the south is the same belt of siliceous Paleozoic (?) argillite or quartzite before noted. One of these dikes apparently forms the lode of a gold deposit, as it had evidently been mined. It is greatly altered in places, containing much quartz, calcite or dolomite, and sulphurets. There are some soda-syenite dikes in the greenstone itself, one of which contains primary hornblende needles.

Between the serpentine body above noted and the area of siliceous Paleozoic rocks is a white dike, 50 feet in width at one point, where it is crossed by the road from Buckhorn Peak to the bridge at the old Benton Mill on the Merced River. This dike, in following the contact, makes an S-shaped curve. It was supposed in the field to be a soda-syenite, but a chemical and microscopic investigation shows part of it to be made up of zoisite and orthoclase, both minerals being quite fresh. This peculiar dike is indicated on the geologic map.

Some syenite-porphyry dikes are also to be seen near the vein of the Red Bank gold-quartz mine, on the north side of the Merced River about halfway between Benton Mill and Split Rock Ferry.

About 2 miles west of Mount Bullion post-office, at the toll-gate, is a decomposed dike accompanied by some quartz. The rock contains a large amount of calcite or dolomite, and is quite like some of the dikes at the Bachelor quartz mine.

The lens 1½ miles south of Priest's hotel, called syenite on the map, is a porphyry containing quartz and muscovite. Strictly speaking, at least a portion of it is a granite-porphyry, but as it seems genetically related to the Moccasin Creek dike, it is given the same color and symbol.

Two narrow areas of diorite.

Diorite.—As noted below under "Dike rocks," diorite and diorite-porphyry dikes are very abundant in the Sonora district. There are two narrow masses of this rock shown on the geologic map. One of these lies in the limestone north of Sonora, and another, longer streak lies between the amphibolite-schist and the schists of Calaveras formation southwest of the town. The latter area is in reality a quartz-diorite-porphyry, there being free quartz in the rock in addition to the other constituents. All of the rocks grouped under the head of diorite contain primary hornblende, which usually shows its proper crystalline form.

Hornblende-pyroxene rock.—About 3 miles northeasterly from Coulterville, just north of the road to Dudley, is a small area of an interesting rock made up almost entirely of hornblende and augite. The hornblende forms conspicuous subangular crystals of a dark-greenish color, lying in a gray-green granular matrix of augite and hornblende. On fresh fracture the larger hornblendes exhibit brilliant cleavage faces and are sharply separated from the finely granular matrix. The microscope shows that the large hornblendes are pale-brown by transmitted light, with rather faint pleochroism, and are full of inclusions of the same colorless augite which makes up most of the groundmass. Three small areas of practically the same rock occur about 1½ miles northeast of Cherokee Camp.

Dike rocks.—Igneous rocks in the form of dikes are abundant in the Sonora district. There is a considerable variety of rocks represented in these dikes, a few of which are shown on the geologic map. It may be said in a general way that only those are indicated of which the exact course and position were noted in the field. **Dikes of various rocks.** The soda-feldspar dikes are referred to under the head of soda-syenite. In the quartz-pyroxene-diorite area east of Sonora, and in the limestone and other rocks of the Calaveras formation to the west, may be noted very abundant, rather fine-grained dikes, often showing to the unaided eye white porphyritic feldspars, and likewise minute glistening black needles, which the microscope shows to be hornblende. These rocks are diorites and diorite-porphyries and are among the latest of the pre-Tertiary intrusives. Similar dikes are also abundant in the granodiorite of the Don Pedro Bar area and in the surrounding slates. No distinction is made on the map between the dikes of diorite and of diorite-porphyry, both being marked di.

In the drainage of Big Creek east of Groveland dikes are very numerous. These consist of aplite or granulite, sometimes containing tiny garnets, feldspathic porphyries, and other rocks.

Near Hobron Mill, and southeast of Don Pedro Bar, dikes of quartz-porphyry are numerous in the slates.

SUPERJACENT SERIES.

This series consists of late Cretaceous, Eocene, Neocene, and Pleistocene sediments lying unconformably upon the Bed-rock series, together with volcanic rocks of the same periods. During late Cretaceous, Eocene, and Neocene times the Great Valley of California was under water and the Sierra Nevada was a mountain range. Rivers flowing down the western slope of this range deposited the Auriferous gravels. During the Neocene enormous quantities of lava issued from volcanoes situated chiefly along the crest of the range. In Pleistocene time, also, portions of the Great Valley were under water, but there were few, if any, volcanic eruptions.

EOCENE PERIOD.

Tejon formation.—The only rocks referable to this period are a few isolated patches of light-colored sandstone which occur capping some low hills in the southwest corner of the quadrangle. South and southeast of Merced Falls are two level-topped buttes capped by this sandstone, which rests almost horizontally upon the nearly vertical edges of the Mariposa slates. **Light-colored Eocene sandstone.** The basal bed is crowded with angular fragments of the slate and with abundant pebbles of white vein quartz, while the upper beds are composed of a light-colored quartzose sandstone with frequent bands of small quartz pebbles. Marine fossils (*Venericardia planicosta*) are fairly abundant in the upper bed at the west end of the butte that lies 1 mile south of Merced Falls. These sandstones are overlain to the west by the light-colored sandstones of the Ione formation. The two series are probably not absolutely conformable, as the Ione beds transgress onto the rocks of the Bed-rock series farther north.

NEOCENE PERIOD.

Ione formation.—The rocks referred to this formation in the Sonora quadrangle are a series of soft, usually light-colored, more or less tuffaceous beds which overlap the Eocene sandstones and the older rocks of the Bed-rock series in the southwestern portion of the district. **Soft tuffaceous beds.** The beds are apparently horizontal, but actually dip slightly to the west. The series exhibits considerable lithologic variety. Some of the beds are composed of a light-colored, fairly quartzose sandstone, others are stained brown or yellow with iron oxide, or striped with yellow, brown, or pink bands in fine wavy patterns; still others are composed of fine white rhyolite-tuff and of the decomposed tuff called clay rock in the Jackson folio. The more quartzose beds occur near the base of the series.

Andesitic sandstones.—Overlying the Ione formation is a series of sandstones and conglomerates which contain varying amounts of andesitic detritus. **Blue friable sandstone.** The sandstone is usually of a bluish color and is more or less friable. At some points it contains layers of light-gray pumice. The conglomerates are largely made up of andesitic pebbles. Portions of the areas shown on the map as belonging to the andesitic sandstone series contain very little recognizable volcanic material. Such is the rolling sandy country to the west and northwest of Snelling. Over this section there are practically no rocks exposed, and the exact nature of the underlying sandstone is not known. Moreover, it should be stated that no exact line of contact between the Ione formation and the andesitic sandstone series is shown on the map for the reason that the two formations were not separated in the field.

Auriferous river gravels.—The deposits of the Tertiary rivers have been largely removed by erosion. This is especially true in the southern half of the quadrangle, where scarcely a trace of a former river system is to be found. The best-preserved channel is that underlying Table Mountain. **Neocene river gravels of Table Mountain.** This may be said to represent the Stanislaus River of late Tertiary time. This river had its sources far to the northeast, possibly near the source of the present Stanislaus. It first appears in the Sonora district 2½ miles northwest of Sonora, and continues its southwesterly course to near Knights Ferry, in the Oakdale quadrangle. The basaltic rock which forms Table Mountain covers the old channel for this entire distance where not removed by erosion. The amount of gravel in this channel is not great, the river deposit being largely a soft, light-colored shale ("pipe clay") and andesitic sandstone. The gravels themselves are largely made up of andesite pebbles, some probably of late Neocene age. So far as known, the bottom gravels found in the channel with the gold are not volcanic.

Other areas of gravels, which, although not capped by volcanic material, are mapped as Neocene on account of their present elevation above the modern streams, occur in the northwest portion of the quadrangle, near Chinese Camp, Montezuma, and Quartz Mountain. These gravels are made up chiefly of quartzose pebbles.

On the crest of the plateau-like ridge a few miles east of Groveland, overlooking the deep canyon of the Tuolumne River, are some considerable bodies of river gravel, doubtless representing the Neocene Tuolumne River. **Neocene Tuolumne River.** These have been hydraulicked at several points, giving good exposures of the deposits. The area 3 miles west of Colfax Gate is made up chiefly of pebbles of the siliceous rocks of the Calaveras formation and of quartz. The deposit is 100 feet or more in thickness. The gravel bank 1¾ miles due north of Smith Station contains pebbles of black siliceous argillite, and also of rhyolite, the latter being common. All of the gravel areas of this ancient river representing the present Tuolumne appear to have been covered with andesitic breccia. What is probably a part of the same river deposit occurs 3½ miles northeast of Colfax Gate, at the edge of the quadrangle, and extends farther east into the Yosemite quadrangle. On the west side of Moore Creek is a small well-defined channel that has been traced for about 2 miles. Its elevation is less than that of the larger channel just described, and it is probably later in age. There are some small patches of river gravel and scattered pebbles at the head of Corral Creek, but no well-defined channel was found.

Rhyolitic beds.—No massive rhyolite occurs in this quadrangle. Interbedded with the soft sandstone of the Ione formation in the southwest corner of the quadrangle are beds of light-colored volcanic ash, which are probably rhyolitic with some admixture of ordinary sediments. Such a bed was observed on the south bank of the Merced River 1½ miles southwest of Merced Falls. As these are an integral part of the Ione formation they are not shown separately on the geologic map.

Andesite.—Andesitic tuff of the type so abundant over large portions of the Sierra Nevada occurs but sparingly in this quadrangle, being confined to the northern portion. In the vicinity of Table Mountain, near Mountain Pass, the andesitic tuff forms isolated tables which have been exposed by the erosion of the overlying basaltic cap. One mile south of Mountain Pass an outlier of the basalt rests upon the andesite. The uppermost bed of the andesitic series is a stratum of fragmental andesite made up of irregular and angular blocks of various sizes embedded in finer andesitic detritus. **Andesitic tuffs and breccias.** These blocks are commonly of hornblende-pyroxene-andesite, showing under the microscope phenocrysts of plagioclase, brown hornblende, colorless augite, and sometimes small prisms of hypersthene. The hornblende shows the usual corroded forms with dark borders characteristic of the andesites. Beneath this coarse andesitic breccia are beds of andesitic gravels and sandstones, which appear to have had a very local distribution and to have been less extensive than the overlying andesitic breccia.

There are considerable areas of andesitic tuff near Soulsbyville, east of Groveland, where it partly overlies river gravels, and on the ridge east of the Middle Fork of the Tuolumne. These are mere remnants of former large sheets that covered much of the northern part of the quadrangle.

Andesitic sandstones, as already stated, form considerable areas in the southwest corner of the district.

Basalt.—The only occurrence of basalt within the Sonora quadrangle is the massive flow, in places 300 feet thick, which forms the level top of Table Mountain, and its smaller outliers. This lava poured down an ancient stream channel in late Neocene time, burying the gravels and earlier clastic beds, and has since protected them from the erosion which has reduced the surrounding country to its present relatively low relief. **Massive basalt flow.** The edges of the flow, exposed through the undermining action of the erosive forces on the softer underlying rocks, form precipitous cliffs generally showing columnar structure. The rock forming the flow is dark, and basaltic in appearance, but is lighter in weight than most true basalt. It is spotted with porphyritic crystals of labradorite feldspar, sometimes nearly three-quarters of an inch in length. The microscope shows that the rock consists of large crystals of labradorite, smaller augites, and occasional olivines, lying in a fine groundmass which is made up of small lath-shaped crystals of plagioclase or soda-lime feldspar, grains and crystals of olivine, crystals of augite, some magnetite, and glass. In its field relations and general appearance this rock closely resembles ordinary basalt, and it has been so denominated by all the geologists who have hitherto written on this region. Even microscopic examination does not at once indicate the possibility of there being any impropriety in so naming it. But a chemical analysis shows that the rock contains an unusually high percentage of potash for a basalt, which, taken in connection with other peculiarities of composition, would assign it a chemical position between the andesites and the trachytes. **Chemical peculiarities of the basalt.** On account of its peculiar composition it has been given a special name, *latite*. (See Bulletin U. S. Geol. Survey No. 89.)

This basalt is evidently younger than a portion of the andesitic eruptions, as it overlies andesitic tuff and conglomerate.

ECONOMIC GEOLOGY.

Gold-quartz veins.—The veins comprising the Mother Lode system are usually larger and more persistent than those in other portions of the district, and the greater part of the capital and energy now engaged in gold mining has of late been turned toward their exploitation. **The Mother Lode system.** Many of these veins have been extensively worked in times past, and are now idle; for example, those on the Mariposa estate south of the Merced River. The fact that such mines are not now active by no means necessarily indicates that they are exhausted or are worthless. Work has seldom been carried far enough to accomplish the one result or to ascertain the other. Deep mining within this quadrangle is still in its infancy, and if the history of other portions of the Mother Lode is to be repeated here, more than one mine now closed will be reopened and made to pay by greater closeness in working combined with increased boldness and intelligence in prospecting. The Rawhide mine, the largest producer in the quadrangle, is one that had been worked with very indifferent success until it fell into the hands of its present owners. The southern portion of the district, never having possessed large deposits of high-level auriferous gravels, lacks the extensive systems of flumes and ditches which the profits of hydraulic mining made possible farther north, and which to-day are so useful in furnishing water for power and milling, particularly for prospecting purposes. Electric plants have, however, been established, the water of the rivers being used to run the dynamos.

The Mother Lode, so well defined in the Jackson quadrangle at Angels Camp and Carson Hill, enters the Sonora district west of Tuttletown. The old Patterson mine, near this town, is perhaps a little east of what is usually regarded as the line of the lode, but it lies within the same belt of amphibolite-schist as that in which the famous mines at Angels Camp occur. The veins of the lode are not limited in their occurrence to any particular kind of country rock. Their dip is almost without exception easterly, varying somewhat, but usually a little steeper than that of the inclosing rocks. The heavy vein of the Rawhide lies at the contact between serpentine and the dark clay slates of the Calaveras formation. **Rawhide vein.** It has produced a large amount of gold. As in the case of the majority of the mines along the southern portion of the Mother Lode, the vein actually worked lies alongside a much heavier vein composed largely of dolomite, talc, and mariposite (a green mica containing a small amount of chromium), with irregular stringers and bunches of quartz. It is this larger vein which usually gives rise to the conspicuous croppings that define the course of the lode across this section of the country. It is generally auriferous, but not sufficiently so to make its working profitable under existing conditions. To the southeast the Alabama, Crystalline, Trio, and other quartz claims connect the Rawhide with the Quartz Mountain mines, 2 miles south of Jamestown, where mining is also actively going on in the Dutch and App mines. **Quartz Mountain mines.** The App is located upon a vein which is partly within amphibolite-schist and partly on the contact between this schist and a narrow strip of clay slate, presumably of Carboniferous age. East of this vein lies the great low-grade vein of the Mother Lode, not at present worked, and east of this again a third vein, the Heslep, in a lens of black slate too small to appear on the map. Between Quartz Mountain and Sullivan Creek mining operations have recently been begun upon several claims. One of these, the Golden Rule, was quite extensively worked many years ago by a long drift connecting with the surface through a tunnel. The lead consists of small stringers of quartz in black Calaveras slates, and occurs along both sides of a small and remarkably regular diabasic dike which has been intruded into the slates in general parallelism with their cleavage. The large low-grade vein containing talc and carbonates here lies to the west of the productive lead. The Jumper mine, between the Golden Rule and Sullivan Creek, is working in ground of somewhat similar character, but the dikes are numerous and not so regular in their trend. In the Eagle mine, northwest of Jacksonville, the workable vein lies on the eastern or hanging-wall side of the main Mother Lode vein, with which it is at one place in contact. **Eagle and Mammoth mines.** At the Mammoth mine the main vein has been exploited. The vein here is in amphibolite-schist at the level of the workings. It is not yet in paying ore.

The soda-syenite dikes east of Jacksonville and Moccasin Creek carry gold at some points in sufficient quantity to have led to their exploitation. In the Willietta claim, at a point about one mile east of Jacksonville, a considerable quantity of the dike rock has been quarried out, and at the Wheeler and Grant mines, east of Moccasin Creek, and at other points, prospecting is being carried on. **Mines along soda-syenite dikes.** Gold had not been found in sufficient amount to lead to any extensive or permanent development up to 1895. At the North Star and Black Warrior mine, which is northwest of the Wheeler and Grant, good ore is said to have been found recently.

The Bachelor quartz vein, as seen at its north end, on the north bank of the Tuolumne River, is made up of quartz, dolomite, and mariposite. **Bachelor quartz vein.** Just east of the vein cutting the Calaveras slate are several soda-feldspar dikes in various stages of alteration. They now contain secondary quartz, and dolomite or calcite, with specks of iron disulphide. There is thus a suggestion here that the soda feldspar of the dikes is being replaced by silica, lime, and sulphides brought up by mineral waters. If such a process were carried further a vein deposit like the main vein might result.

Near Peñon Blanco the veins of the Mother Lode are very heavy, reaching a width of 250 feet. They are composed chiefly of dolomite, containing also some talc and mariposite. The dolomite is veined with quartz, which sometimes forms large and thick lenses. As the quartz is dazzling in its whiteness and resists erosion extremely well, it crops out very conspicuously on the hilltops along the course of the lode, and might readily be thought to have greater volume than the comparatively soft and soluble dolomite. The veins in this neighborhood have not proved productive.

Veins near Coulterville.

West of Coulterville the veins of the Mother Lode form two distinct lines. The eastern line, on which are located the Louisa, Mary Harrison, and Virginia mines, is characterized by the heavy croppings with the same abundance of dolomite and mariposite that are found near Peñon Blanco. Where cut by Maxwell Creek, just west of the town, this branch of the lode has a width of over 300 feet and is complex, being largely composed of dolomitic material, but containing some massive veins of quartz. The western line, on which are the Potosi, Malvina, Tyro, Anderson, and Red Bank mines, lies mainly within the slates of the Mariposa formation. These veins are not so massive, and do not outcrop so strongly, as those along the eastern line of fissuring. They are usually composed of numerous stringers of nearly pure quartz, and frequently show ribbon-structure, produced by the alternation of the quartz with thin black seams. In 1895 all the mines named, with the exception of the Virginia, were being actively exploited. On the south side of the Merced River the Josephine, Ophir, and Princeton mines are now idle, but may be reopened.

Free-milling ores.

The gold in the Mother Lode mines occurs partly free in the quartz and partly inclosed in the sulphurets, the latter being separated by concentrators and the inclosed gold obtained by chlorination. Such ores are termed free-milling. The invariable sulphide is pyrite, but chalcopyrite, galena, and zinc blende sometimes occur, usually in small amount. Tellurides of gold occur sparingly in the northwestern portion of the quadrangle, but have not been met with south of Sullivan Creek. Petzite, a telluride of gold, has long been noted in works on mineralogy as occurring at the Golden Rule mine, but it has not been recognized in the present workings. The green micaceous mineral known as mariposite is particularly abundant in the large veins containing much dolomite, and gives to the vein rock a characteristic green color. Both the dolomite and mariposite are usually most abundant where the line of the lode passes through, or close to, areas of serpentine. Such are the veins of the Rawhide, App, Louisa, Mary Harrison, Virginia, Red Bank, Josephine, and Mount Ophir mines.

Veins in the Soulsbyville granitic area.

The "East Lode."

Numerous mines are worked in the quadrangle which are not on the Mother Lode. In the Soulsbyville granitic area are several veins which have been exploited. In nearly all cases these ores are rich in sulphides, including pyrite, chalcopyrite, pyrrhotite, and sphalerite or zinc blende. They usually contain also a galena-like mineral giving blowpipe reactions for both lead and antimony. As a rule, therefore, they require a chlorination or other chemical process for the complete extraction of the gold. In mica-schist south of Carter, on the eastern border of the same granitic area, is the Eureka Consolidated mine (including the Dead Horse) which is now producing, and south of this the Seminole, also in schist. Farther southeast, on the ridge east of the North Tuolumne, are the Hunter and Buchanan mines, not now operating. The vein of the Buchanan mine is noteworthy as cutting across the strike of the schists. The veins from the Eureka to the Buchanan are on what is sometimes called the East Lode. The Golden Gate mine, just southwest of Sonora, is in amphibolite-schist, and the gold occurs chiefly in the sulphurets (pyrite), in a gangue of quartz with some calcite.

Pocket veins.

The region about Sonora and Tuttletown is remarkable in containing a great number of "pocket" veins, or small veins locally, and usually irregularly, rich in gold, with intervening comparatively barren stretches. The most famous of these mines is the Bonanza, situated at the north end of the town of Sonora. The ore is found accompanying a decomposed dioritic dike which cuts the clay slates and dips northwestward at 35°. The gold occurs with quartz in the native state, often beautifully crystallized and in the form of a telluride, probably petzite. The pockets are said to occur with some regularity, and to vary in richness from $4000 upward. They may be found above or below the dike, or within it. The exploitation is not carried straight down the dip of the vein, as usual, but follows both the dike and the cleavage of the slates. As a result the shaft has an incline of only 20°. The total product of the mine is given as $1,500,000. Numerous small pocket mines are scattered about in the amphibolite-schist of Jackass Hill, just north of Tuttletown.

Large veins at Bigoak Flat.

In the quartz-diorite area at Bigoak Flat are several large quartz veins which dip at small angles varying from 25° to 55°. These veins are not confined to the granite, but extend into the surrounding schists. Two of them — the Mississippi vein, which has a curved course, and the Mack — have been worked at different times. In the hard mica-schist to the north of Bigoak Flat are numerous gold-quartz veins, some of which have been exploited. As a rule the veins in these harder schists are not so continuous as in softer rocks, but the fact that much placer gold was obtained in the gulches throughout this district shows that at least some portions of some of these veins are rich in gold.

Extensive workings near Hornitos.

To the northeast of Hornitos quartz veins are abundant, and some of them, as the Number Nine, have been extensively worked. The Horseshoe mine, south of Hunter Valley, was being exploited in 1895. The vein of the Yellowstone mine, northwest of Bear Valley, has the unusual course of N. 70 E. The country rock is an altered augite-porphyrite and is brecciated along the line of the vein and recemented by quartz and calcite. Much of the gold in the upper workings is said to have occurred in the latter mineral as a gangue. The vein of the Whitlock mine, 3 miles northeast of Mount Bullion post-office, also has a northeast-southwest strike, and is in rock similar to that about the Yellowstone. Pocket mines are quite numerous in the areas of augite-porphyrite in the southeastern portion of the quadrangle, particularly in the vicinity of Chamisal, east of Bullion Mountain, and in the Buckhorn Peak area.

Hydraulic mines in Neocene gravels.

Gold-bearing gravels. — Nearly all the high gravels on the ridges, representing the Neocene river system, contain gold, usually in sufficient quantity to pay for mining by the hydraulic method. Such gravels have been hydraulicked at a point 3 miles northeast of Colfax Gate, and at three points on the ridge south of the Tuolumne River to the west of Colfax Gate. The last mines are known as the Dorsey claims. The old channel under Table Mountain is mined by tunnels. Most of the material called river gravel (**Ng**) on the map in the vicinity of Mountain Pass is andesitic gravel and fine friable sandstone. The pay gravel underlies these beds. The gravels at Quartz Mountain, Montezuma, and Chinese Camp have been extensively worked by hydraulic methods. Those of the latter place were exceptionally rich, but their washing was rendered difficult by the lack of an adequate water supply. The gravels of these three areas are composed chiefly of quartzose pebbles.

Auriferous gravels of recent age.

Most of the late Pleistocene gravels along the streams within the area of the older rocks belonging to the Bed-rock series have proved more or less auriferous, and have usually been carefully washed over. They may be well seen along Moccasin and Woods creeks. The early Pleistocene gravels, which occur on benches usually slightly elevated above the present rivers, have also proved auriferous and have generally been thoroughly washed.

The material that has been washed at Bigoak Flat is not true gravel, but auriferous detritus from the surrounding hills.

Placer mining along the modern streams has largely ceased. Some is being done, however, by the Chinese, who often rework gravels that have already been repeatedly washed.

Quicksilver deposits.

Cinnabar.—An interesting set of veins occurs on the steep slope of the ridge east of Horseshoe Bend. The country rock is "greenstone," an augitic tuff so indurated as to form a hard rock. There are two nearly parallel quartz veins, from 1 to 3 feet in width, which strike about N. 40 W. and dip 35° NE. The lower of these, called the Cabinet, contains chalcopyrite and a dark mineral which is apparently bornite. The upper vein is called the Lookout, and like the Cabinet, is somewhat auriferous. Cutting both these white quartz veins at nearly right angles is a third vein, with approximately vertical dip, known as the Crystal. This vein contains cinnabar, mostly in small grains and crystals, but occasionally in crystals two-tenths of an inch in diameter. Cinnabar is also found at Marsh's Flat in the form of distinct stains in a decomposed fine-grained augitic tuff. It is not likely that either of these deposits of quicksilver ore will prove of economic value.

Copper.—There is a copper deposit 1 mile southeast of Don Pedro Bar, known as the Salambo mine, and another in porphyrite about 2½ miles southeast of Baxter.

Chrome iron.—In this quadrangle, as elsewhere, chrome is found only in serpentine. No deposits were located, but abundant loose masses of small size were noted in the serpentine northwest of Mountain Pass.

Limestone.—All the limestone masses noted are shown on the geologic map. The rock is burned for lime at various points. Much of it is thoroughly crystalline, forming marble. Except a small lens on Cotton Creek in the Mariposa formation, all the limestone and marble in the quadrangle are in the Calaveras formation.

Building stone.—The sandstone of the Tejon formation south of Merced Falls and that of the Ione formation between Lagrange and Merced Falls form good building stone. About 3½ miles south of Lagrange, east of the road to Snelling, is a deposit of Ione sandstone ornamented with a concentric series of wavy red lines. This would make an ornamental building stone. Some of the granite and marble of the district will likewise make good building stone. The Maine and Mississippi marble quarries are located on the Sonora limestone or marble belt, about 7½ miles southeast of Sonora. So far as known no quarrying has been done there recently.

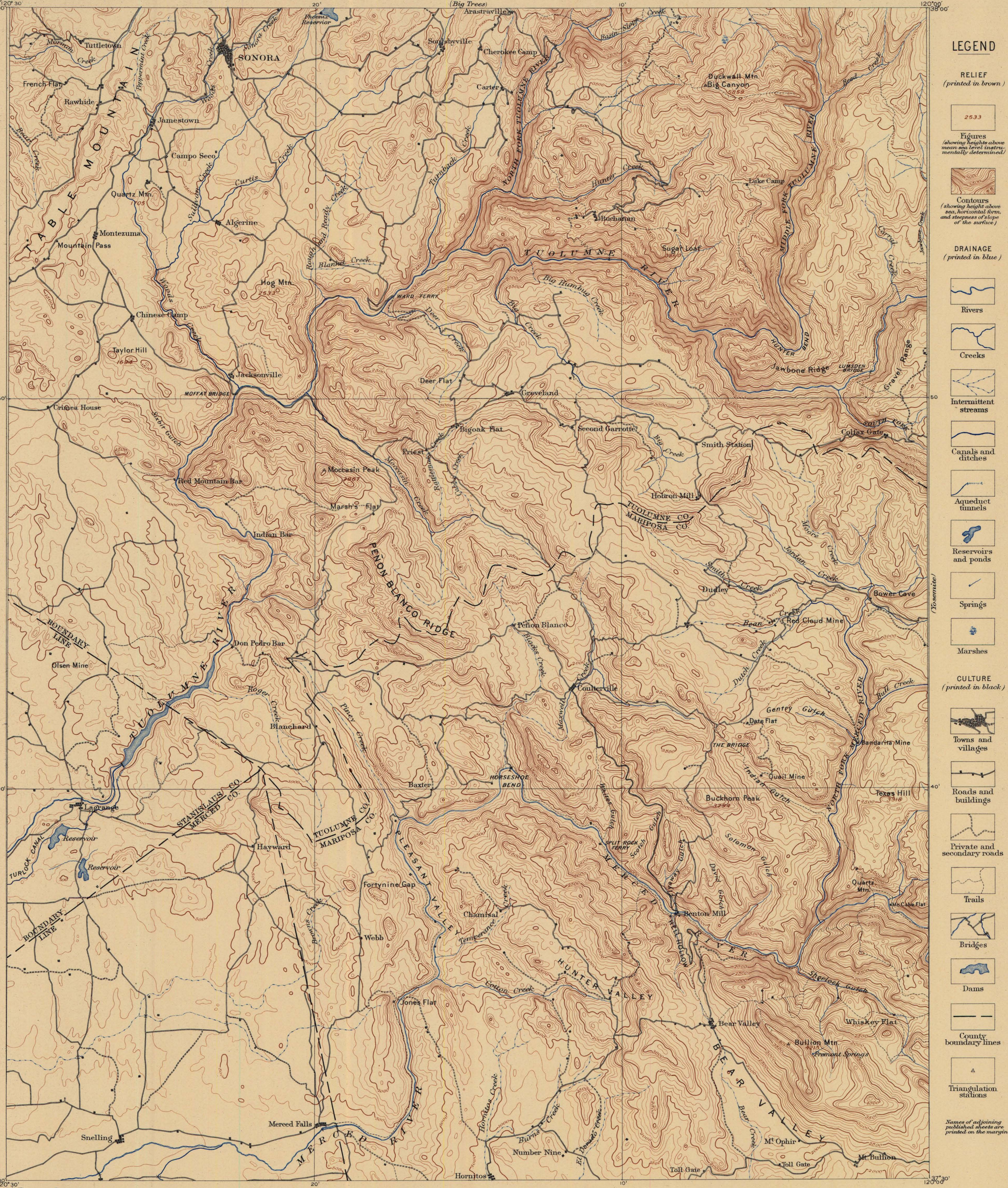
H. W. TURNER,
F. L. RANSOME,
Geologists.

December, 1897.

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

TOPOGRAPHIC SHEET

CALIFORNIA
SONORA QUADRANGLE



A.H. Thompson, Geographer.
E.M. Douglas, Topographer in charge.
Triangulation by H.E.C. Feusier.
Topography by R.H. Chapman.

Surveyed in 1891.

Scale $\frac{1}{125000}$

Contour Interval 100 feet.
Datum is mean Sea level
Edition of July 1897.

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HISTORICAL GEOLOGY SHEET

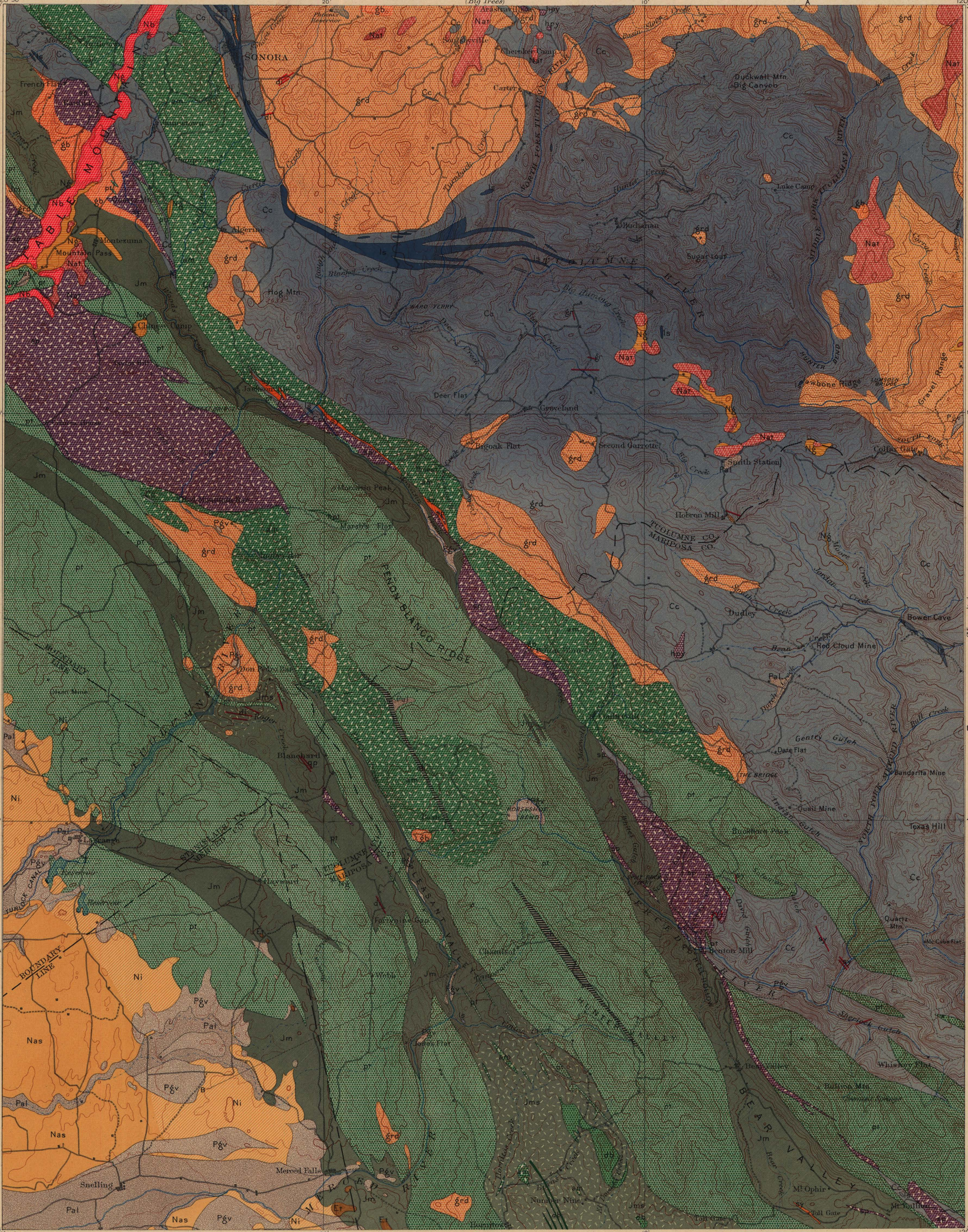
CALIFORNIA
SONORA QUADRANGLE

LEGEND (continued)

BED-ROCK SERIES — EARLIER THAN THE LATE CRETACEOUS, CHICO FORMATION

- Dikes of various rocks (soda-syenite, sy; diorite, di; granite, gr; quartz-porphyry, qp; and undetermined rocks)
- hpy — Hornblende-pyroxene-rock
- di — Diorite
- sy — Soda-syenite (and other related rocks rich in soda; contains gold in some places)
- grd — Granodiorite and granite
- sp — Serpentine (derived from peridotite and pyroxenite)
- db — Diabase
- gb — Gabbro
- pt — Porphyrite (augite-porphyrite with some quartz-porphyrite)
- hpt — Hornblende-porphyrite
- am — Amphibolite (schistose and massive, derived from porphyrite and other igneous rocks)

Sections



LEGEND

SURFICIAL ROCKS

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

PLEISTOCENE
- Pal — Alluvium
- Pgv — Shore and river gravels (in part auriferous)

SEDIMENTARY ROCKS

(Areas of Sedimentary rocks are shown by patterns of parallel lines. Metamorphism is indicated by short dashes combined with the parallel lines.)

SUPERJACENT SERIES

NEOCENE
- Nas — Andesitic gravel and sandstone (with some tuff)
- Ni — Ione formation (sandstone used for building, clay, conglomerate, and rhyolite-tuff)
- Ng — Auriferous river gravels

EOCENE
- Et — Tejon formation (sandstone and conglomerate, used for building)

BED-ROCK SERIES

JURATRIAS
- Jm — Mariposa formation (clay-slates and sandstone; contains rich gold quartz veins)
- Jms — Mariposa formation (mica- and andalusite-schists, contact metamorphic rocks)

JURATRIAS?
- ch — Cherty beds (enclosed in the porphyrite rocks)

CARBONIFEROUS
- Cc — Calaveras formation (argillite, limestone, quartzite, and mica-schist; contains gold quartz veins)
- ls — Limestone lenses (in Mariposa and Calaveras formations)

IGNEOUS ROCKS

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

SUPERJACENT SERIES — NEOCENE
- Nb — Basalt
- Nat — Andesitic tuffs and breccias

Legend is continued on the left margin.

A. H. Thompson, Geographer.
E. M. Douglas, Topographer in charge.
Triangulation by H. E. C. Feusier.
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Surveyed in 1891.

Scale 1/125000

Contour interval 100 feet.
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Geology by H. W. Turner.
Assisted by F. L. Ransome.
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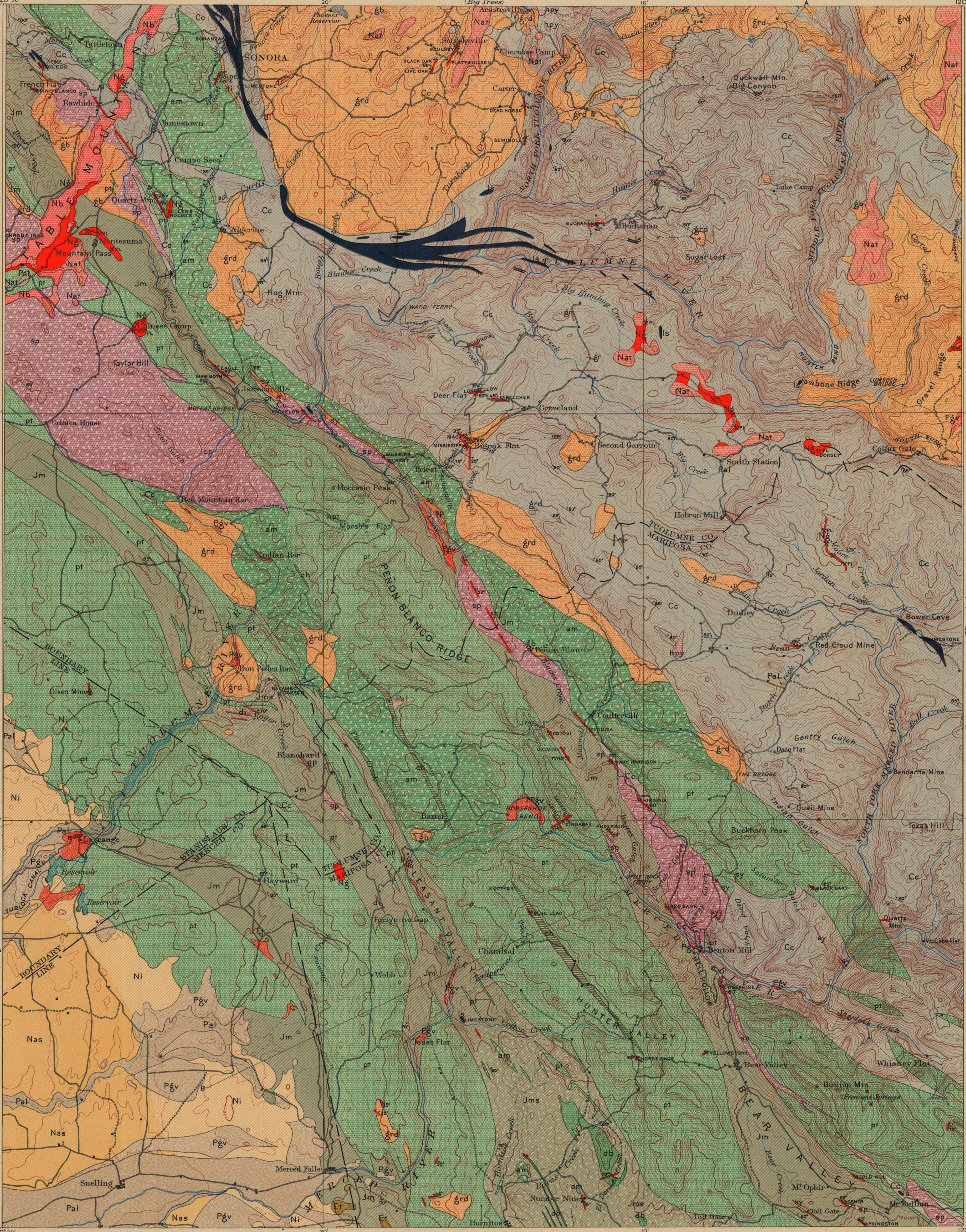
ECONOMIC GEOLOGY SHEET

CALIFORNIA
SONORA QUADRANGLE



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1 ½ 0 1 2 3 4 5 Miles

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Turner / Ransome / Turner

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(continued)

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Sections

A — A, B — B

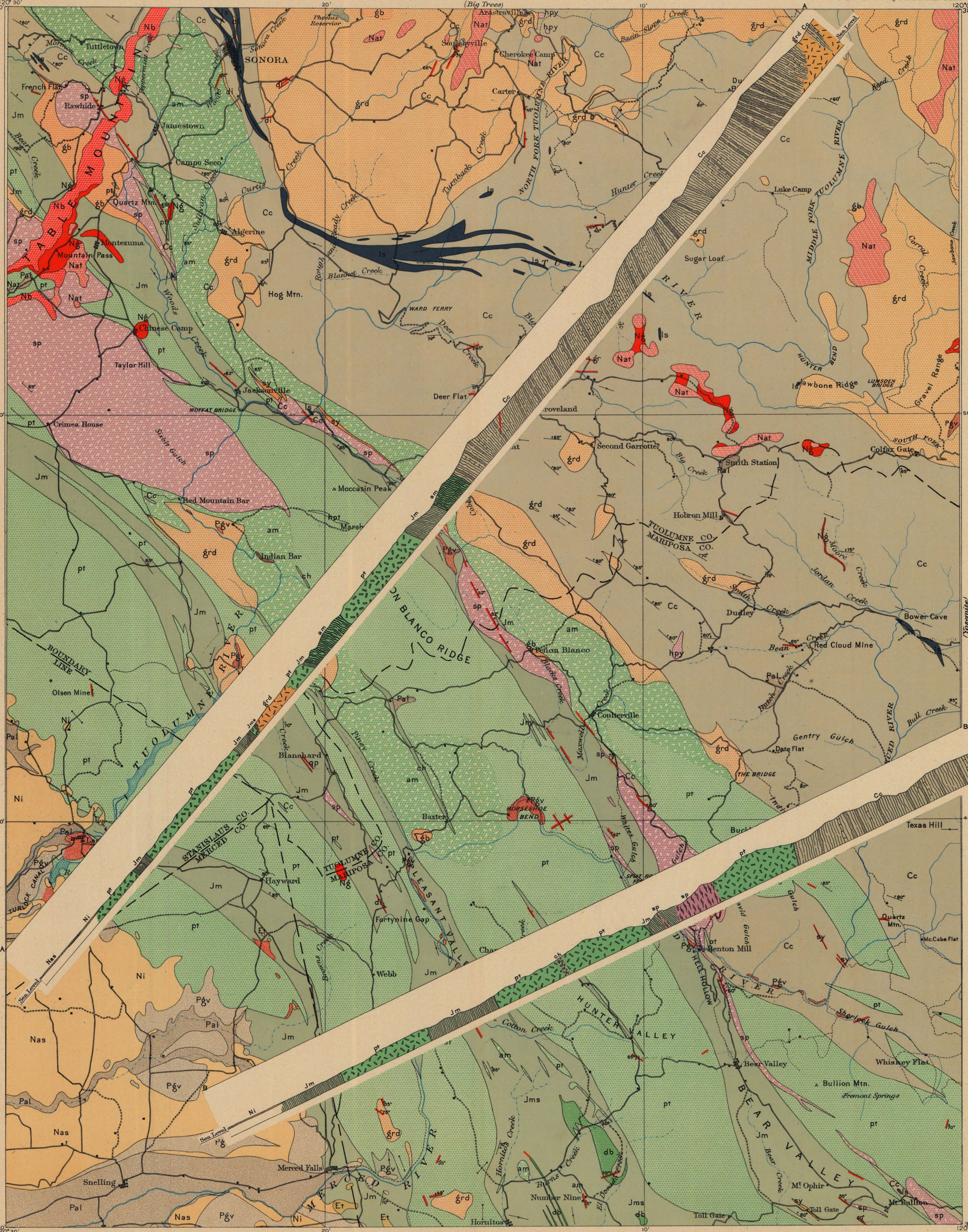
- 20° *Dip and strike of stratified rocks*
- *Vertical dip and strike of stratified rocks*
- 80° *Dip and strike of schistosity*
- *Vertical dip and strike of schistosity*
- *Gold quartz veins*
- *Gold quartz mines*
- PL *Placer mines in auriferous gravels*
- *Gold prospects, including pocket mines*
- *Other prospects*
- *Quarries*

Known productive formations
- *Auriferous gravels*
- *Limestone*

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

STRUCTURE-SECTION SHEET

CALIFORNIA
SONORA QUADRANGLE



LEGEND
(continued)

SHEET SYMBOL | SECTION SYMBOL

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Vertical dip and strike of stratified rocks
Dip and strike of schistosity
Vertical dip and strike of schistosity
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