GEOLOGY AND MINERAL DEPOSITS OF THE JULIAN DISTRICT, SAN DIEGO COUNTY, CALIFORNIA *

By MAURICE DONNELLY **

OUTLINE OF REPORT

* Report submitted as part of a doctor's thesis to the Balch Graduate School of Geological Sciences, California Institute of Technology.

** Teaching Fellow in Geology, Balch School of Geological Sciences, California Institute of Technology.

OUTLINE OF REPORT—Continued

ABSTRACT

The Julian region, in the central part of San Diego County, California, includes the Julian, Banner, several other less important mining districts, and the Stonewall Mine on the Cuyamaca land grant. In addition to being one of the few areas in the Peninsular Range of southern and Baja California that have yielded notable amounts of gold, it constitutes geologically a diagnostic part of the range because of the land forms, structures, and rock formations exposed. Discovered in 1870, the Julian and Banner districts produced in the next several years $2,500,000 in gold from oxidized ore, having an average tenor of $50 a ton. This came from narrow veins which were only in a few instances mined below the water-table. The Stonewall Mine, worked continually from 1870 until shut down in 1893, produced $2,000,000 from a large orebody extracted to a depth of 600 feet. The Julian and Banner districts had a brief mining revival during the '90s.

The oldest rocks recognized are meta-sedimentary mica schist and quartzite of Juratrias(?) age. These are invaded on a batholithic scale by plutonic rocks that have an average composition of quartz diorite; in the terrane included in this survey, assimilation of material from the schist has rendered the batholith predominantly granodioritic. Near the contacts with schist masses, the granodiorite is closely foliated and this structure has probably been inherited from injected and incompletely assimilated schist. A coarse-grained granite intrudes the schist and an irregularly shaped body of fine-grained gabbro intrudes both schist and granodiorite. The granite was injected with considerable vigor; the gabbro was passively emplaced. All of the crystalline rocks have external or internal structures that trend northwest, parallel to the main alignment of the Peninsular Range.

The Juratrias (?) sediments were initially fine-grained marine shales, argillaceous sandstones, and pure sandstones. During load-metamorphism, excellent fissility was developed in the argillaceous members. Regional metamorphism prior to the intrusion of the quartz diorite produced in the sediments a schistosity parallel to the stratification. As a consequence of heat, given off by the invading batholith, a secondary foliation controlled by poorly defined fracture cleavage was produced in parts of the schist. The schist exhibits other contact and thermal metamorphic effects of the intrusion of the granodiorite. The gabbro and granite on the other hand, have had little contact metamorphic effect on the schist or granodiorite.

Almost all of the gold-bearing quartz deposits are in schist, and with the exception of the Stonewall Mine occurrence, practically all of the deposits are inclosed wholly or partly in a single body of schist which extends continuously for a distance of twelve miles and has an

average breadth of a mile. This schistose mass is the eastern limb of a northwest-plunging anticline, in which the schistosity (which coincides with the stratification) strikes northwest and dips steeply northeast, except where superficially bent upon east-facing slopes of strong relief. According to their shape, the vein-quartz bodies are classified as lenses, lenticular veins, and rolls. Lenses and lenticular veins are generally conformable to the attitude of the schist. The singular structures known as rolls are U-shaped bodies of vein quartz in which the sides of the "U" roughly conform to the schistosity and the curved part cuts across it. The roll structures represent deposition of quartz along directions of least resistance, partly conforming to and partly transecting the schistosity. The directions of least resistance were developed during regional folding and are related to minor or drag-folding with which they are associated. Although the rolls simulate folded veins they have not been formed by the folding of initially tabular veins.

The quartz bodies are usually 'frozen' tight to the schist country rock and well-defined fissures or gouge-walls are in the main absent. Stringers and thin layers of schist or *septa* are common in the quartz and form the typical banded or ribbon-ore of the Julian-Banner district. The deposits are high-temperature in type, corresponding to the hypothermal class of Lindgren. The paragenesis is quartz (predominant gangue), tourmaline, mica, pyrite, pyrrhotite, arsenopyrite, gold, and petzite. There is no evidence of secondary solution and redeposition of the gold. The differences in the purity of the native gold in various parts of the region may be accounted for by enrichment due to removal of part of the silver content by supergene leaching or to a closer position of some of the deposits to the magmatic source. This magmatic source is related to the batholithic intrusion of quartz diorite.

Physiographically, most of the area is an erosional surface of low relief, an uplifted peneplain, with many monadnocks, some of which possess elevations exceeding 5800 feet and relief in excess of a thousand feet. Cuyamaca Peak, loftiest of these monadnocks and the highest summit in San Diego County, owes its eminence—in common with the related Middle and North Peaks—to the underlying chonolithic mass of gabbro which, under the prevailing erosional conditions, is more resistant than the surrounding granodiorite and schist. The peneplain has been warped and broken by uplift and faulting. The general trend of the major faults is northwest and one of them, Banner fault, is a local segment of the Elsinore fault zone, a major tectonic feature of southern California. Erosion along fault zones and belts of weaker rocks has produced youthful valleys in parts of the area.

The region is readily accessible the year round to motor vehicular traffic from the coast cities of southern California. Julian, the principal town of the region, lies at the summit of the Peninsular Range in a saddle between Volcan Mountain and the Cuyamaca Peaks. This saddle together with Banner Canyon, forms a pass over the range, on one of the two direct routes from Imperial Valley to the coast of San Diego County.

The future of gold mining operations in the area will depend on the extent to which modern methods of mining and milling are applied.

INTRODUCTION

LOCATION AND TOPOGRAPHY

The name Peninsular Range has been given to the mountainous belt extending 300 miles southeast of an irregular northern boundary formed by San Gorgonio Pass and the Santa Ana River. The northern one-third of the belt is in Riverside, Orange, and San Diego counties;

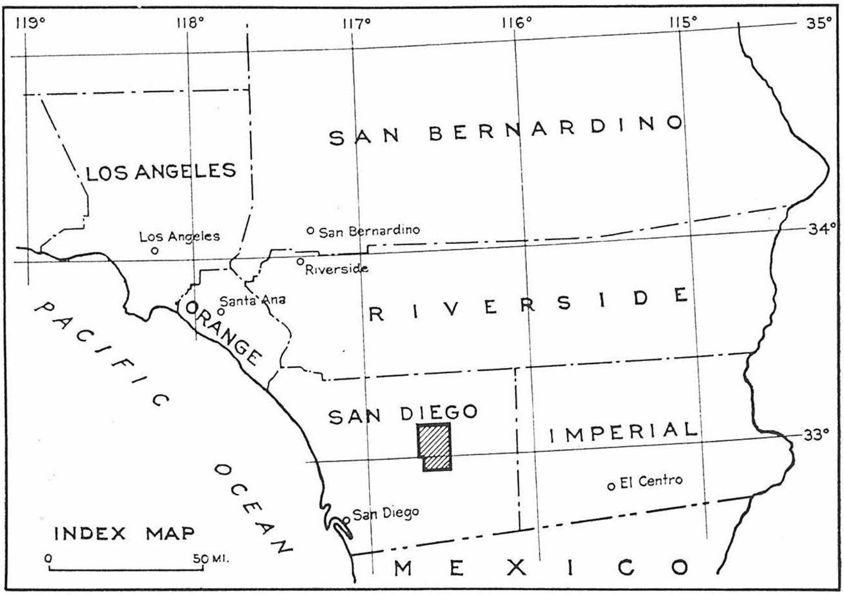

FIG. 1. Index map of southern California showing location of the area mapped in the report on the Julian district.

the remainder is in Baja California. In San Diego County, the range attains, by step-like ascents from the coastal strip, elevations exceeding 5000 feet, and, in the central east-west segment of the county, reaches a width of about 50 miles.

That part of the Peninsular Range, herein called the Julian region, lies near the geographic center of San Diego County, about 40 miles in an airline from the city of San Diego. It includes the rolling upland country—the Julian Mesa—about Cuyamaca and Julian, which lie near the crest of the Range, and the rugged area drained by Banner and Chariot creeks. The boundary between these two topographic entities is an east-facing scarp, in places remarkably steep. The relief on the Julian Mesa is commonly a few hundred feet, exceptionally, as in the case of the Cuyamaca Peaks, over a thousand feet. Much of the upland area around Julian represents a saddle between Volcan Mountain on the north and the Cuyamaca Peaks on the south. Cuyamaca Peak, loftiest of these eminences, is noteworthy in being the highest peak (6515 feet) in San Diego County.

Several land grants are partly in or near the Julian mining district; the boundaries of the district (1881) were determined largely by three grants, San Felipe on the northwest, Cuyamaca to the south, and Santa Ysabel on the northeast. A large Indian reservation, Santa

Ysabel, lies just outside the northern boundary of the area mapped, and two small Indian reservations, Cosmit and Inaja, are a short distance southwest of the western limit of the area. Knowledge of the location of these land grants and reservations is important to those interested in prospecting for minerals in the region.

The largest town in the area is Julian (elevation 4219 feet) with a permanent population in 1932 of 150. On the Julian Mesa are many summer resorts, of which Kentwood-in-the-Pines, Pine Hills, and Whispering Pines are the most important. Power, telephone, and bus lines from San Diego terminate at Julian. The town of Banner (elevation 2717 feet), once a thriving mining and milling center of several hundred people, was partially destroyed by floods in 1916 and 1926. It is now (1932) nearly deserted. Paved highways connect Julian with San Diego and Los Angeles. An improved road runs eastward from Julian by way of Banner Canyon to the Imperial Valley. Although the road in Banner Canyon is sometimes very difficult to traverse in wet weather, it is seldom impassable to light automobiles. A radiating network of secondary and mining roads exists.

CLIMATE AND VEGETATION

In the upland valleys and ridges of the Julian Mesa the climate is temperate, the rainfall varying between 25 and 45 inches a year. Eastward and westward the rainfall diminishes, the decrease being gradual to the west, sharp and sudden to the east so that at Banner, three miles east of Julian, the rainfall is estimated to average 12 inches a year, while two miles farther east in the lower part of San Felipe

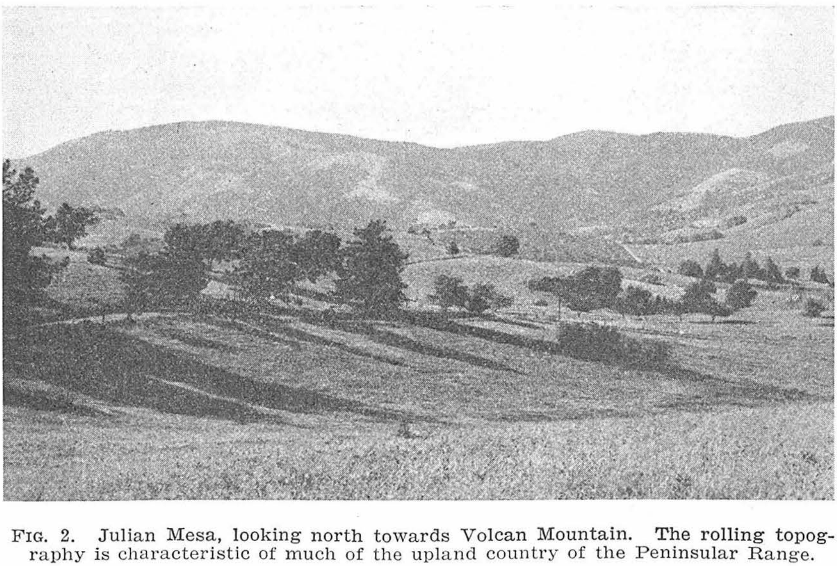

FIG. 2. Julian Mesa, looking north towards Volcan Mountain. The rolling topography is characteristic of much of the upland country of the Peninsular Range.

Valley it is under 10 inches a year. Thunderstorms occur during the summer months, although seasons may pass without one. The vegetal zones are very clearly defined. Open stands of oak, pine, and cedar, with fringing clumps of manzanita, that grow on the Julian Mesa and on Volcan Mountain, give way to the east to thickets of chaparral, which in turn are supplanted by sage-brush thinning to the eastward. Pear and apple orchards are successfully cultivated in the broad valley bottoms and on the slopes of the low hills of the Julian Mesa.

Timber for mining use was formerly cut from local stands of trees, now largely gone. In recent years all dimension lumber for mining and other purposes has been trucked into the district from tidewater at San Diego, although considerable wood is cut for fuel to supply local needs and for shipment to the coast cities of San Diego County.

FIELD WORK AND ACKNOWLEDGMENTS

This paper is a result of field studies carried on in the summer of 1932 and during various short visits in 1933. Airplane photographs and an enlarged portion of the Ramona and Cuyamaca sheets of the U. S. Geological Survey were used in field mapping. The accompanying map is a compilation of data plotted on the engineer's base map prepared by Allen and Rowe, Inc., of San Diego. It is not possible to mention by name the many persons who have assisted in the survey, but the writer wishes to especially acknowledge the courtesies extended by Mr. Sidney Dodge, Mr. Fred Farmer, and Mr. Arthur Blanc of Julian, and Mr. R. Robinson Rowe and Mr. Ernest Childs of San Diego.

The work was made possible by a grant of funds from the California State Division of Mines and a cooperative grant from the San Diego Board of Supervisors, part of which provided the assistance of Mr. J. E. Morrison in the field for three weeks. To Messrs. Rene Engel, Ian Campbell, F. L. Ransome, and J. P. Buwalda, of the Balch Graduate School of the Geological Sciences in the California Institute of Technology, the writer is particularly indebted for helpful suggestions and criticisms.

PREVIOUS GEOLOGIC WORK

Previous detailed geologic study of the Julian region is confined to an investigation, mainly petrographic, by F. S. Hudson [1] who gave the gold-bearing quartz deposits only a passing examination. Carl Sauer [2] has written his views on the genesis of the land forms as developed in this and neighboring region to the north. Certain reports of the State Mineralogist [3] of California contain general mining information of the region. The reports of R. W. Raymond [4] contain accounts of the early and productive epoch of the camps.

[1] Hudson, F. S., Geology of the Cuyamaca Region, of California, with special reference to the origin of the nickeliferous pyrrhotite: Bull. Univ. Cal., Publ. Dept. Geol. Sci., vol. 13, pp. 175–252, 1922.

[2] Sauer, Carl, Land forms, Peninsular Range of California: Univ. Cal. Publ. in Geography: vol. 3, pp. 199–290, 1929.

[3] State Mineralogist's Reports VI, VIII, IX, X, XI, XII, XIII, XIV, XVII, XVIII, XX, XXI contain information on Julian district.

[4] Raymond, R. W., Mineral resources of the States and Territories west of the Mississippi, Reports for 1870 to 1875, inclusive. Washington, 1872–1877.

GEOLOGICAL FORMATIONS

JULIAN SCHIST

General Features and Distribution.

Isolated bodies of metamorphic rocks of sedimentary origin have been reported from many places in the Peninsular Range. They occur mainly as roof pendants or flanking bodies having the same general strike as the northwest trend of the range; all have steep dips. Apparently the bodies lying within the batholiths of the range owe their preservation to downfaulting or downfolding. They are found both in valleys and along the summits of the present-day topography. The dominant tectonic lines of the range bear northwest and almost all of the structural units of the range—granitic intrusions, bodies of slates and schists, major pegmatite dikes, sedimentary beds of Cretaceous and Tertiary age—are related to these lines.

Numerous bodies of schist are found in the Julian region; the largest, most continuous, and economically most important schistose mass is an elongated, curved body which extends without a break from northeast of Wynola to the vicinity of Rattlesnake Valley, somewhat over twelve miles. The width of this body varies from a maximum of a mile and a half just southeast of Julian to about a half a mile near the trail from the Gold Queen Mine into Chariot Canyon; the average width is a mile. This will be referred to as the main Julian schist body. Of the other mapped masses, an important one extends almost due north four miles from the base of Stonewall Peak to the vicinity of Harrison Park. The abandoned and caved workings of the once productive Stonewall Mine are located in the lobate end of this body of schist which like many of the schist masses in the vicinity of Pine Hills, occurs as a screen between the Cuyamaca Basic Intrusive and the Stonewall granodiorite. There are many small bodies of schistose rock southwest and northeast of the main Julian schist which are not sufficiently large to have warranted field mapping.

Constituents of the Formation.

The main constituents, making up more than nine-tenths of the bulk of the main body, are (1) fissile quartz-muscovite-biotite schist, (2) slightly to highly contorted quartz-muscovite-biotite schist, (3) quartzite, more or less impure, and (4) coarse schist, including paragneiss and injected gneiss. Less abundant constituents are actinolite and amphibolite schist, and blunt-end lenses of a quartzose pyroxene-hornblende rock.

The fissile quartz-muscovite-biotite schist is composed of biotite, muscovite, and quartz in fissile schistose layers. Minor minerals are plagioclase, graphite, iron oxides, and scanty rutile and apatite. Quartz is very often concentrated in tiny veins, in knots or clumps of venous appearance, and in flattened quartzitic lenses. Because of the ease with which the rock disintegrates, exposures are poor where removal is relatively slow, as on the Julian Mesa. Much of the biotite has been hydrothermally altered to bleached biotite. The middle portion of the main schist mass is chiefly the fissile quartz-mica schist above described. It probably makes up more than half of that body, The fissility, schistosity, and bedding are parallel, as evidenced by (1) the concordance of attitude of these structures, particularly on weathered outcrops, (2) the lithologic variation across the strike of the schistosity, and (3) the agreement in attitude between the quartzite beds and schistosity.

Fine-grained schist similar in composition to the fissile variety but more or less contorted and poorly or nonfissile is common in the middle portion of the main body. It probably ranks with coarse schist and paragneiss in the relative order of abundance, being exceeded by fissile schist and by quartzite. Mica (biotite and muscovite) is developed in about equal proportions with quartz in a considerable part of this rock.

Intercalated within the fissile schist, as well as forming important masses itself, are numerous thin beds of a more or less impure quartzite, containing essentially quartz and subordinate quantities of biotite and muscovite. Graphite and iron ores occur to a small extent. All gradations from a relatively pure quartzite to a fissile and nonfissile quartz-mica schist are found. Quartzite forms extensive bodies in the vicinity of the Ready Relief Mine; in the middle of the main body near Kentwood-in-the-Pines and elsewhere; and along the western border of the main body, where a bed several hundred feet thick is exposed for a distance of over two miles. By virtue of its superior resistance to erosion the quartzite beds affect the topography markedly; many of the elongate ridges with a northwest trend are underlain by these rocks. Some of the quartzite breaks into rectangular blocks that could be used for building purposes.

At many of the contacts between schist and granodiorite are found coarse-grained schistose rocks designated coarse schist in the field. They are commonly more resistant than surrounding rocks and yield ridge-like outcrops. Along the western border of the main body they form a zone varying from a few hundred feet to a half-mile, on the eastern border a thinner zone occurs wherever mica schist makes up the bulk of the schist near the contact. In numerous places throughout the interior of the main mass, foliated rocks coarser than the typical fine-grained fissile schist are found. These rocks may be divided into coarse schist, secondary-cleaved schist, paragneiss, and injection gneiss. They have all apparently been formed by the contact metamorphic effect of granodiorite intrusion. Coarse schist contains essentially quartz, biotite, and muscovite, in a coarser-grain size and with a closer-knit texture than in the fissile schist. The secondary-cleaved schist very frequently contains in addition to these minerals, the thermal metamorphic mineral, andalusite, in long white prisms. The structure of this rock, in which a secondary foliation at variable angles with the primary banding has been developed by thermal effects, possesses much petrographic interest and significance. Paragneiss and injection gneiss, including pegmatitic gneiss, contain large amounts of injected igneous material, largely acid plagioclase, orthoclase (in some of the rock specimens), and quartz. Tourmaline and andalusite are also present in certain of these rocks, particularly in the paragneiss.

Layers of amphibolite and actinolite schist intercalated in the schist series are common and in places form bodies of considerable size. Coarse, long-fibered, green antinolite, with or without quartz, plagioclase, and apatite. make up the actinolite schist. The amphibolite schist consists largely of fine-grained green hornblende and basic plagioclase.

Origin of the Julian Schist.

(1) The presence of beds of quartzite paralleling the primary banding, (2) the lithologic variation normal to this banding, indicative of sedimentary bedding, and (3) the mineralogic composition, point unmistakably to the initial sedimentary nature of the Julian schist. Many weathered outcrops of the less metamorphosed fissile schist resemble thin-bedded sediments more than weathered crystalline schist. The Julian schist series represents the product of load, regional, and contact metamorphism of relatively pure quartz sandstones, clayey sandstones, and clay-mudstones. The fissility parallel to the bedding is believed to have been developed by processes induced by superincumbent load. The layers of amphibolite and actinolite schist are interpreted as the products of metamorphism of andesitic and basaltic lavas.

Structure of the Julian Schist.

The schistosity (which is parallel to the stratification) of the main body of the Julian schist strikes northwest in varying degrees, the westward component increasing as one goes northward along the outcrop from the southern limit near Rattlesnake Valley. The strike almost uniformly agrees with the direction of the nearby schist-granodiorite contact, a generalization that holds good for most of the smaller bodies of schist. The dip of the rocks of the main body, as they are encountered in going from west to east is first steeply northeast (70–80°), then steeply to gently inclined southwest (average 60–70° SW., but varying from horizontal to vertical), and still farther east again steeply northeast (75–80°). This change in dip has been interpreted as indicating the existence of several outcropping limbs of sharply compressed folds. The writer has observed, however, that the pronounced southwestward dips are all on east or northeast facing slopes. The evidence collected is conclusive that southwest or nearly horizontal dips in the schist of the main body are due to downhill creep or bending. The effect is superficial and diminishes rapidly beneath the surface, so that in depth the schistosity dips in the whole body northeast at a high angle.

A study of the drag folding in the main Julian schist body leads to the conviction that the axes of most of the major drag folds plunge northwest at low angles, up to 25°. Taken in conjunction with the effect of downhill creep, such a generalization permits the following interpretation of the broad structure of that body.

In summary, the main body of the Julian schist is structurally the eastern limb of a northwest-plunging anticline in which the rocks strike northwest and dip at high angles northeast except where superficially bent southwest by downhill creep on east-facing slopes of strong relief. Contact metamorphism following the intrusion of Stonewall granodiorite has affected the body, particularly the margins, both structurally and mineralogically, and broad warping, probably during the same intrusion, has produced the crescent shape now seen in plan. Beneath the schist the contact between it and the granodiorite dips at low angles from both sides, the result being a wedge-shaped cross-section of schist of no great depth. This bottom contact with granodiorite appears to be irregular, judging by the presence of contact metamorphism well within the body.

Age of the Julian Schist.

The age of the Julian schist has not been definitely and accurately determined on the basis of paleontological evidence. Because of lithologic and structural features it is tentatively assigned to the Juratrias. By various writers it has been correlated with the Calaveras formation (mainly Carboniferous)[5] of the Sierra Nevada and with the Santa Ana slates (upper Triassic)[6] of the Santa Ana Mountains.

MAJOR IGNEOUS ROCK BODIES

The predominant rocks of the Peninsular Range are coarse-grained intrusives, in places more or less gneissic, which vary in composition from gabbro to granite. The average rock of the batholith is probably a quartz diorite.

In the Julian region three kinds of intrusive rocks occupying rather large areas have been mapped; namely, quartz diorite-granodiorite, norite-gabbro, and a true granite. Following Hudson in part these rocks are called (1) Stonewall granodiorite, (2) Cuyamaca basic rocks, and (3) Rattlesnake granite. Certain of the aplite dikes and pegmatite bodies have also been mapped.

Stonewall Granodiorite.

The Stonewall granodiorite rock is typically exposed in Stonewall Peak, from which the name has been taken. The areas mapped as granodiorite include rocks that compositionally are quartz-dioritic and granodioritic, and structurally are massive to rather highly gneissic. The rocks weather to rounded, knob-like forms that frequently project from the thin detrital and soil cover in monolithic shapes. These low eminences are especially common in the neighborhood of Lake Cuyamaca. They are not due to glaciation.

Megascopically these rocks are medium to coarse-grained aggregates of feldspar, quartz, and biotite, and in the more basic varieties, hornblende. Swarms of orthoclase phenocrysts are found in the granodioritic facies, usually near schist. Good exposures of such porphyritic granodiorite occur in the Oriflamme Mine.

Microscopically all of these rocks were found to contain plaioclase having a composition varying from oligoclase to andesine. In a majority of the rocks primary orthoclase is present in varying amounts but always less than the plagioclase. Quartz is an essential constituent in all the microscopic slides examined. Biotite occurs in greater or lesser amounts in all the specimens studied microscopically. Green hornblende is present as a minor constituent in the rocks determined as quartz diorite and scant amounts of pyroxene were also noted. Minor quantities of muscovite were found in orthoclase-bearing rocks near schist-granodiorite contacts.

A striking feature of most of the microscopic slides examined is the development of secondary textures by deformation and by replacement due to post-consolidation processes. In the main, the first process in which cataclastic textures are produced, goes on hand in hand with

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[5] Merrill, F. J. H., Geology and mineral resources of San Diego and Imperial Counties: 14th Rept. State Mineralogist, pp. 653–662, 1914.

[6] Fairbanks, H. W., Geology of San Diego; also portions of Orange and San Bernardino Counties: 11th Rept., State Mineralogist, pp. 76–120, 1893.

the second, in which new minerals are formed by solutions introduced into the rock. However, specimens were examined that showed as secondary textures only one or the other. The solutions that effected replacement at first, apparently deposited quartz, later inter-growths of albite and quartz known as myrmekites, and finally fine-grained intergrowths of quartz and alkali feldspars. Tourmaline and abnormal orthoclase, or isorthoclase, have been recognized in a few of the thin sections of rocks that have been subjected to corrosion by replacing solutions.

The volume distribution of orthoclase, considered in connection with the structural evidence given below, lends probability to the statement that the granodioritic phases have been derived, at least in part, through assimilation by quartz dioritic magma of schistose material. The extent of post-consolidation replacement depends, apparently, on the closeness of foliation in the granodiorite, which in turn depends on the nearness to schist bodies.

The Stonewall granodiorite has intruded the Julian schist as evidenced by (a) the foliation developed within the granodiorite near the schist contact, (b) the presence of numerous oriented xenoliths of schist in the granodiorite, (c) the presence of igneous material in the schist near the contact, (d) the zones of pneumatolitic and normal contact metamorphism at the margins of the schist bodies where they are in contact with granodiorite, (e) the finer grain size of the granodiorite in places near the schist contact.

The character of the foliation in granodiorite may be said to be a function of the nearness of schist bodies. Along the immediate contact with such bodies the foliation in the granodiorite is sharp, the layers are thin and have the same general trend as those of the contiguous schist. Away from the contact the folia in the granodiorite increase in thickness and decrease in sharpness. From (1) the increased percentage of orthoclase in the granodiorite nearest the schist contact, (2) the presence of oriented xenoliths, especially of quartzite, in granodiorite near the contact, and (3) the very close relation between the attitude of the gneissic texture and of the schistosity; it is concluded that the gneissic texture in granodiorite is relict after the schist.

Cuyamaca Basic Intrusive.

The Cuyamaca Peaks are made up almost wholly of basic rocks, principally norite and gabbro. These rocks have no apparent relation to gold deposition and are considered summarily here. In brief, they are fine-grained basic rocks containing basic plagioclase, pyroxene (hypersthene, augite), olivine, hornblende, small amounts of pyrrhotite, along with certain other minor minerals.

The Cuyamaca basic mass intrudes the granodiorite and schist and hence is younger than these. Several small isolated bodies of gabbroic rocks are mapped as being contemporaneous with the main mass of the Cuyamaca Peaks. The endomorphic and exomorphic effect of the basic rocks near their contact with others has been slight, some freezing denoted by decreased grain size has been the chief endomorphic change. The walls of the Cuyamaca basic intrusive dip under it, so that in cross-section the body has the shape of a downward-pointed wedge. In horizontal plan the body is irregularly elongated north and south.

Such an injected igneous mass is termed a chonolith; in this case the intrusion took place rather quietly.

Rattlesnake Granite.

A true granite, consisting of very coarse-grained orthoclase, quartz, and muscovite, and exiguous biotite, outcrops near the southeastern limits of the map. Orthoclase is commonly developed in white or pinkish white carlsbad twins and the quartz in some of the specimens collected has a pronounced bluish tinge.

The formation has no apparent relation to the gold quartz deposits and has not significantly metamorphosed the schist it has intruded. The intrusion has been somewhat vigorous as attested by variations in the dip of the schist nearby.

DIKE ROCKS

Aplite.

In the eastern part of the Cuyamaca Grant, an aplite dike, broken in the middle, averaging 10 feet in width and 2 miles in length, has been injected into the schist series. The attitude of the dike coincides with that of the encasing schist; the strike is slightly west of north at its northern end and the dip steeply east. The dike stands out sharply from the country rock. Minor off-shoots strike to the northeast and disappear in the schist. Microscopically the aplite is made up of corroded phenocrysts of quartz and andesine, with subordinate orthoclase, in a fine-grained, parallel-textured groundmass of quartz and scanty muscovite and hornblende. Megascopically the rock is sugary in texture, possesses a rude foliation, and is white in color except where slightly iron-stained.

Pegmatite.

Pegmatite dikes cut all the crystalline rocks in the Julian region and in places, as along the old Banner road, form large irregular-shaped masses. Most of them may be classified as simple granite pegmatites, containing quartz, orthoclase, and muscovite. Well crystallized black tourmaline is found along with quartz in bands and clumps in some of the dikes. Lithia pegmatites, similar to those of Pala and Mesa Grande outcrop on the southwest slopes of Granite Mountain, east of the boundaries of the map. A close relation exists between the pegmatites and the gold-quartz deposits, the deposition of the gold-quartz bodies being here viewed as lower temperature phenomena than the pegmatites in the same general post-consolidation processes. Some of the pegmatites have been prospected and occasionally contain up to 2–3 pennyweights of gold per ton.

Barren Quartz Veins.

The gold-bearing quartz deposits will be discussed under the section on ore deposits. The other type of quartz vein or 'dike,' the barren quartz or 'bull' quartz of the miner, occurs extensively in the schist and granodiorite; it may be regarded as a siliceous end phase injection associated with granodiorite intrusion, as opposed to the presumably hydrothermal phase of gold-bearing quartz deposition.

A close relation exists between these barren quartz veins and pegmatite veins or dikes. Transitions along the strike from barren quartz veins to pegmatite veins are found. The quartz phase may be interpreted as being a pegmatite-like injection in which quartz has been the only mineral deposited. Some of the 'bull' quartz is not wholly barren, but contains a few pennyweights in gold per ton.

Dark-colored Dikes.

Dark-colored dikes are found cutting the basic rocks and granodiorite. The composition is variable. One specimen collected from a dike cutting gabbro contains hornblende and labradorite, with a small amount of magnetite; this rock may be called a camptonite. Another specimen from a tabular body in granodiorite contains hornblende (green), quartz, and acid plagioclase, with some pyroxene. It appears probable that the two dikes here cited are not genetically related.

AGE OF THE IGNEOUS ROCKS

All of the igneous rocks are younger than the Julian schist which they intrude. They are probably upper Mesozoic in age and, on the basis of regional considerations, to be correlated with the post-Mariposa intrusions of the Sierra Nevada.

The relative ages of Stonewall granodiorite, Cuyamaca basic intrusive, and Rattlesnake granite are in the order of intrusion: (1) granodiorite, (2) granite and basic rocks. The relation between the Cuyamaca basic intrusive and Rattlesnake granite is not clear; the probabilities are that the basic rocks are younger. The evidence pointing to such a view is the inferred lesser depth of cover during the intrusion of the basic rocks, as deduced from their much finer grain size and more quiet mode of intrusion in comparison with the Rattlesnake granite.

RECENT ALLUVIUM

In many of the depressions throughout the region recent unconsolidated alluvium has been deposited. In the open valley to the north of North Peak one of the branches of Cedar Creek has cut deeply into alluvium and cliffs 20 feet or more in height are exposed. Laid open in these cliffs are rudely-stratified, poorly-sorted layers of angular and subangular fragments, which in the upper two-thirds are largely weathered to a dark brown soil. A few feet from the top are lenses of boulders at an accordant level. Intercalated in the alluvium is a bed of dark, carbonaceous material, apparently the result of the burial of vegetal material. This last feature is seen in the tract in a number of stream cuts. The recent deposits of San Felipe Valley are also alluvial, the result of inwash from the surrounding higher lands.

Throughout the Peninsular Range the alluviated bottoms of many of the upland valleys are being dissected, in some cases very rapidly. This may mean rejuvenation of streams due to a very recent seaward tilt, or increased erosion because of deforestation and cultivation. It is much more likely that cultivation and deforestation are responsible. The makeshift devices that have been installed in places to decrease erosion generally aggravate the situation.

STRUCTURAL GEOLOGY—FAULTING

One of the principal fault zones of southern California, called the Elsinore fault zone because of its remarkable development near the town and lake of that name, passes through the Julian region. In the little-known country south and east of Julian the location of the trace of this fault zone is conjectural.

BANNER FAULT

The section of the Elsinore fault zone in Banner, Ranchita, and Rodriquez Canyons is called here the Banner fault. The evidence for faulting along the Banner-Rodriquez line is divisible into three headings: namely, (1) physiographic, (2) structural, and (3) seismic.

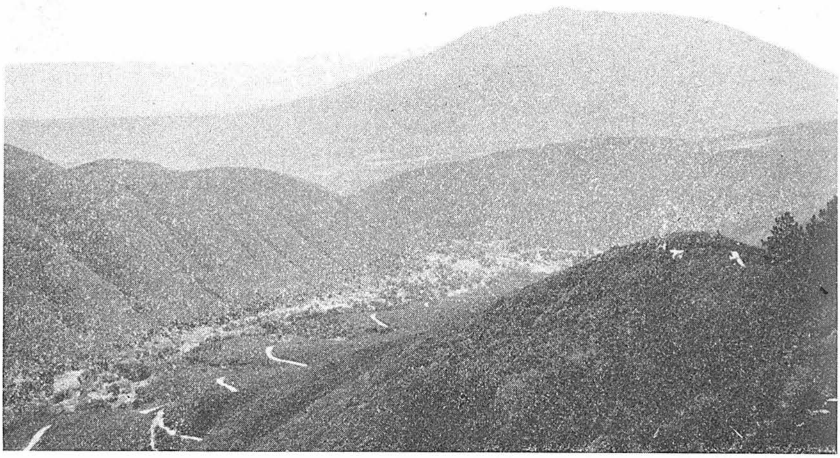


FIG. 3. Looking down Banner Canyon, the local expression of the Elsinore fault zone. The site of Banner town lies in the alluviated floor in the middle of the picture.

Physiograhic Evidence.

a. Remarkable straightness and linear continuity of the three canyons involved, Banner, Ranchita, and Rodriquez. The straightness is even more striking in aeroplane photographs than on topographic maps.

b. Asymmetry of the canyons, especially Banner Canyon, the east side of which is little dissected and has little debris at its base, the western side is much dissected. This evidence is complicated in places by different rock types occurring on opposite sides of the fault-controlled canyon.

c. The suggestion of depressed, poorly drained blocks, or small grabens along the fault zone.

d. Springs along the fault trace, as in Ranchita Canyon southwest of Ranchita Mine. Hot springs are reported in Rodriquez Canyon.

e. Correlation of two old-age erosion surfaces—(a) the Julian Mesa, and (b) the summit portions of Volcan Mountain, now separated by a vertical distance in excess of a thousand feet.

f. Sliced benches or parallel ridges on the eastern side of Banner Canyon. They are not continuous nor at the same level. Some of them do not slope downstream.

In addition to the above evidence may be emphasized the prolongation of the Rodriquez-Banner line northwestward to localities of known active faulting.

Structural Evidence.

Gouge and brecciated zones found (1) in road cuts on the Foster grade near the upper part of Banner Canyon, (2) in the Ranchita Mine, (3) in road cuts just east of Banner. The Ranchita gouge zone dips northeast at a high angle, parallels the strike of the fault trace, and has been metallized.

Seismic Evidence.

In the period 1899–1906, for example, 25 earthquake shocks were reported at Cuyamaca. It appears probable that many of them originated from movements on the Elsinore fault zone as no faults in the immediate neighborhood of Cuyamaca have been found, and many of the shocks were reported on dates when the middle and northern parts of California were seismically inactive. Although the evidence shows conclusively that the Elsinore fault zone has been less active in recent time than the San Jacinto fault zone, it appears probable that the sparsely-settled nature of the country through which the Elsinore zone passes has been responsible for the lack of accumulated information on its activity.

The summary of evidence on the Banner fault supports the view that it is an ancient structural feature along which movement has been in progress for a long time. The fault plane apparently dips under the upthrown block, hence the vertical movement has been of a thrusting nature and the fault is reverse in type. Although no movement resulting in earthquake shocks can be proved to have occurred within the mapped area, it seems probable that movements are to be expected in the future.

There are several other physiographic lines in and near the region that suggest[7] the presence of faults and for most of them faulting is a likely explanation. For the one formed by Chariot and Sweetwater canyons the geologic evidence, however, precludes faulting as an hypothesis of origin.

MINOR FAULTING

Minor faulting at the contact between schist and granodiorite on the east margin of the main body is common. Where exposed by Golden Chariot Mine workings it is stepped and reverse in type; each

[7] Ellis, A. J., and Lee, C. H., Preliminary geologic map of San Diego County. Geology and ground waters of the western part of San Diego County: U. S. Geological Survey, Water-supply Paper 446, 1919.

succeeding step in depth is flatter than the one higher, so that the fault surface as a whole is curved concave upward and dips under the eastern member, granodiorite. Gouge, quartz, sericite, and occasionally calcite and pyrite are developed in the faulted areas. No important cross faults, i. e., those which if existing would have a strike nearly at right angles with the regional or northwest trend, were

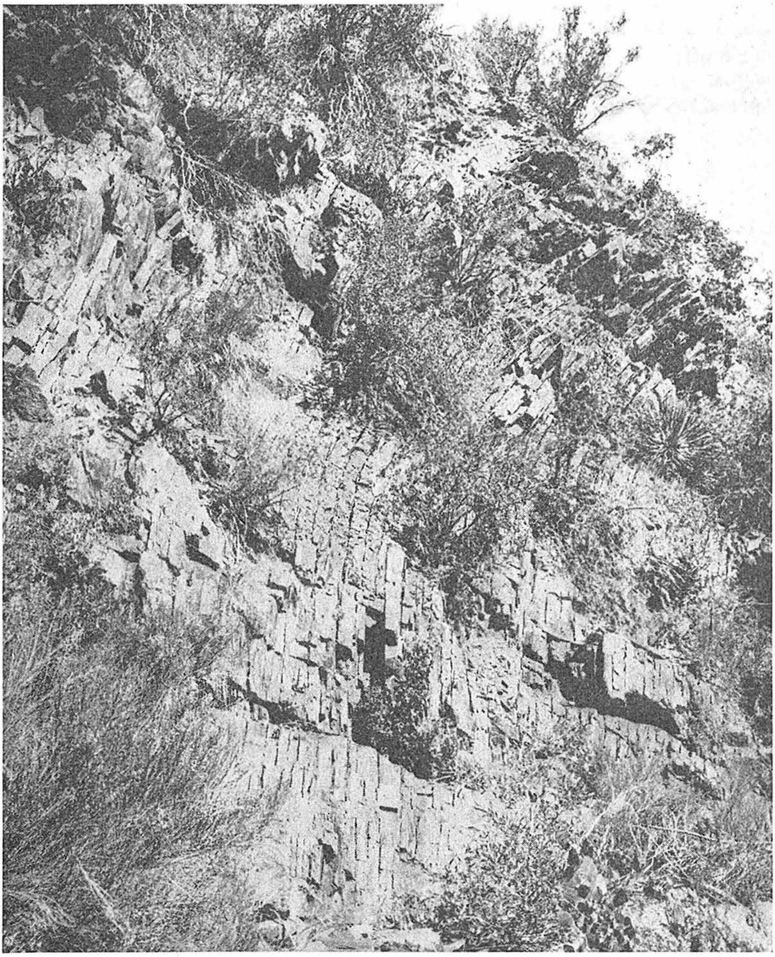


FIG. 4. Bending in schist. Looking northwest along the strike, where the schist dips northeast. This effect is most pronounced where the slopes face east, causing a reversal of dips near the surface to the southwest.

observed in granodiorite. A cross fault said to occur near the Ranchita Mine could not be found by the writer. Minor faults occur within the schist series, with displacements of a few inches or feet. A few minor cross faults in schist exposed in mine workings in the Ready Relief and North Hubbard Mines strike N. 75 E. and dip at a steep angle (70°) northward.

LANDSLIDING

The effect of downhill creep, which is a special case of landsliding, on the structure of the Julian schist has already been considered. The large amount of landsliding in quartz diorite and granodiorite even on gentle slopes is noteworthy. This is produced by the thorough soaking (during brief, heavy rainstorms) of the rather coarse mantle rock developed over these rocks. Landsliding is effected on an especially large scale when a heavy rain is followed within a few days by a second downpour. No landsliding was observed in the heavy, compact soil produced by weathering in the basic rocks.

PHYSIOGRAPHY

In this particular part of the Peninsular Range an intrusive-metamorphic complex, having a general northeast structural trend, was worn down by subaerial erosive processes—weathering and streaming—to a surface of low relief, a peneplain, on which the streams were adjusted to the structure of the underlying rocks. Monadnocks, of which the Cuyamaca Peaks carved in basic rocks are examples, jut above the rolling surface of this peneplain. The Cuyamaca Peaks owe their eminence to superior resistance to erosion compared to the surrounding areas of more acidic rock types—schist and granodiorite. The order of increasing resistance to erosion under the conditions obtaining in the Julian region of the three categories of rocks is granodioritic, schistose, basic. Low etching in rocks containing minerals, such as amphibole and pyroxene, show these minerals standing out in relief against a background of plagioclase, or quartz. Such an order of resistance is contrary to that usually given in textbooks, as for example, that of G. P. Merrill.[8] Renewed uplift along fault lines parallel to the established northwest trend broke up by the peneplain and tilted that portion of it herein called the Julian Mesa gently westward. The portion now preserved on top of Volcan Mountain was uplifted higher and probably in a scissors-like manner, the northern part being lifted higher than the southern part. As a consequence of uplift, westward-flowing streams have eaten headward into

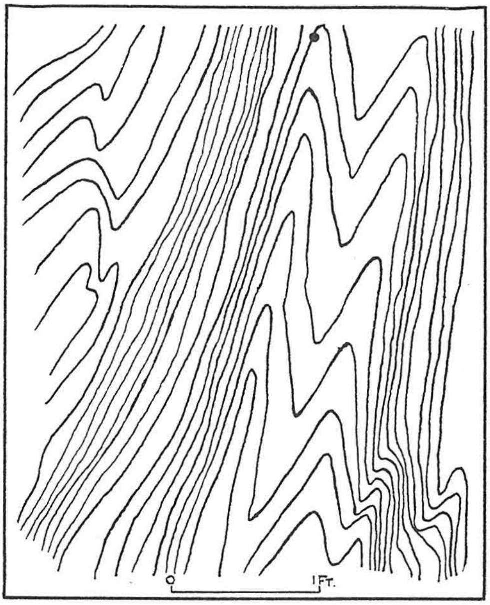


FIG. 5. Minor folding in quartzite exposed in the Ready Relief Mine. The axes of the folds plunge northwest. Observer is looking southeast along the strike.

[8] Merrill, G. P., Rocks, Rock Weathering and Soils: Macmillan, N. Y. (1921).

the peneplain and one, Boulder Creek, has cut as far back as the site of Cuyamaca dam. Because of increased erosion due to cultivation and deforestation, the smaller streams flowing into the Julian Mesa have in places cut deep trenches (up to 20 feet deep) in the unconsolidated alluvium of the upland valleys. From the east, streams of which Banner and Chariot Creeks are the most important, have eaten into and frayed and complicated the eastern border of the Julian Mesa, but in general there remains a steep eastward-facing scarp, locally quartzite-defended, that forms part of the main drainage divide between the Pacific Ocean and the Salton Sea. Banner and Chariot Creeks unite to form San Felipe Creek which has probably cut an antecedent gorge through the southern part of Volcan Mountain. The physiographic effects on the gold quartz deposits is discussed under ore deposits.

SUMMARY OF GEOLOGIC HISTORY

1. Deposition of mud, clay, and sand in a marine environment at some distance from the nearest land mass. Intercalation of basic lava flows, possibly submarine, in these sediments.

2. Transformation of the claystone and mudstone sediments by load into a fissile shale, in which fissility parallels the bedding.

3. Initiation of compressive forces that broadly folded the sediments, at first at a relatively low temperature.

4. Increase in vigor of folding, increase in temperature. Schistosity, and later, foliation, developed parallel to fissility and bedding. Minor folding increased, places of less compression developed.

5. Intrusion of Stonewall granodiorite. Normal and pneumatolytic contact metamorphism of schist. Gneissic texture developed in granodiorite near schist contacts.

6. Intrusion of Rattlesnake granite. Intrusion of Cuyamaca basic intrusive.

7. High-temperature hydrothermal deposition of gold-bearing quartz deposits.

8. Uplift and erosion, with the stripping of a cover several thousand feet thick.

9. Development of the peneplain by subaerial erosion.

10. Break-up by uplift along bounding faults of this peneplain. Renewed erosion, conditioned by uplift and structure.

ECONOMIC GEOLOGY

GOLD

Validity of the Information.

Any consideration of the gold-bearing quartz deposits of the Julian region must take into account several factors:

1. During the period of greatest mining activity, 1870–75, no detailed competent observations on the ore deposits were made that have come down to us.

2. The mines have not penetrated much beyond the oxidized zone, hence, no complete hypogene suite of minerals is available for study.

3. The most important mines on the Julian Mesa, Stonewall Owens, and Helvetia, are not accessible and little can be seen on the surface of these mines.

4. During the writer's first visit to the camp practically no mining work was going on, and even the recently-operated Golden Chariot Mine was inaccessible.

The specific remarks made in this report in application to the mineralogy, structure, and genesis are based on information which is certainly incomplete, and in some respects wholly inadequate. In spite of this, conclusions have been reached that are tenable and may prove valuable in prospecting in the district. On the whole, the report should be considered as a framework of highly probable geologic interpretation which may be amended and amplified by the future observations of all those interested.

History.

Toward the close of 1869 a party of ex-Confederate soldiers drifted into the vicinity of what is now the Julian district. Driven from their homes in Georgia by the economic collapse of the South during Reconstruction, Mike and Webb Julian, James and D. D. Bailey, had prospected in Montana and Arizona with little success. Placer mining on a small scale was by this time no longer profitable in these States, all the rich ground accessible without the expenditure of capital was worked out, and a general exodus to more remote districts took place. In November, 1869, these men and others organized the Julian or the Cuyamaca mining district and during December worked placers on Coleman Creek near Wynola in a small way, apparently attempting meanwhile to trace the origin of the float gold. It is related that on February 22, 1870, a boy in search of firewood in a small ravine north of Julian found gold under the roots of a blown-down tree on what was called, after the date of its discovery, the George Washington claim. The Van Wert, about a half mile northeast of Julian, was located the same day. The first town, Tent City, was laid out in the small valley east of Julian on the Volcan road.

C. C. Parry,[9] W. P. Blake,[10] Thomas Antisell,[11] and J. S. Newberry[12] made geological and topographical reconnaissances across the mountains from San Diego to the Colorado Desert in the decade 1849–59. Most of these exploratory parties followed the now little-traveled route: San Diego-San Pasqual-Santa Ysabel-Warners-San Felipe-Vallecito-Carrizo Creek, and the Colorado Desert. C. C. Parry, however, in the fall of 1849 followed a route now taken in part by the improved highway from San Diego to Julian and the Imperial Valley. Of his observations made while traveling down Banner Canyon to join the main road in San Felipe Valley, Parry records "the geological formation exhibited along the eastern slope (along the west wall of Banner Canyon) of the mountain range at this point shows a very sensible change, and in place of the usual forms of feldspathic or quartz granite we meet a more prevalent character of micaceous granite,

[9] Parry, C. C., Reconnaissance to the mouth of the Gila River from San Diego, California. Rept. U. S. and Mexican Boundary Survey: vol. 1, 34 Cong. 1 Sess. Ex. Doc. No. 135, pp. 125–130, 1857.

[10] Blake, W. P., Pacific Railroad Surveys: vol. V, Part II, 33 Cong. 2 Sess. Ex. Doc. 78, Chap. VIII, IX, and X, 1856.

[11] Antisell, Thomas, Pacific Railroad Surveys: vol. VII, 33 Cong. 2 Sess. Ex. Doc. 78, pp. 119–129, plate VIII, fig. 1, 1857.

[12] Newberry, J. S., Colorado River of the West (Exploration): 36 Cong. 1 Sess. Ex. Doc. No. 90, 1861.

in which the scales of mica are frequently of large size, and very confusedly intermixed. With this also occur mica and talcose slates, traversed by quartz veins. At this point, then, we have an approach to the gold formation, and in the section of country thus limited, exist the fairest prospects of mineral discoveries.'' Over twenty years after Parry made this note, gold was found in these quartz veins.

Up to August 30, 1870, records of 54 claims had been accepted for filing in the Julian mining district by M. S. Julian. These included the Owens, High Peak, Eagle, Van Wert, Hayden, George Washington, Shamrock (not the present claim), San Diego, and others.

The discovery of gold in the Banner district did not come, as one might suppose, from prospectors working southeastward from Julian along the strike of the veins. In August, 1870, a party of men from Julian while looking for wild grapes in southern San Felipe Canyon, as Chariot Canyon was then called, found the vein named from one of its discoverers, the Redman. Both the vein, 3 feet wide, and the sands of the nearby creek were rich in gold. In a few days after this discovery the steep and chaparral-covered slopes of Banner and Chariot Canyons were alive with prospectors and the Ready Relief, Hubbard, Kentuck, Madden, Antelope, Chaparral, and many other claims were located. Two of the most important mines in the area were among the last to be located, the Helvetia, about a mile east of Julian, was found late in 1870, and the Golden Chariot, two miles south of Banner, was discovered in February, 1871.

During the early and vigorous epoch of mining activity which brought at its peak 700 people to Julian and 300 to Banner, these towns constituted the centers of separate mining districts. In 1881 the two districts were consolidated into one and the boundaries of the newly formed Julian Consolidated Mining district were made to also embrace several unimportant districts, including the Desert Mining district, some miles southeast of Banner and containing the Oriflamme Mine, and the Indian Mining District, a short distance northwest of Julian. Later nearby discoveries, like the Gold King and Gold Queen, the Ranchita and Elevado, were grouped in the Julian district.

The absence of capital in the period 1870–1874 has been explained as a consequence of a suit brought in 1870 by the owners of the Cuyamaca grant who attempted to 'float' their boundaries to include the Julian district. The United States Land Office finally decided in July, 1874, in favor of the Julian miners. Another cause for the scarcity of foreign capital at the same time has been assigned to the prejudice existing during this period in northern and middle California against the 'lower' country or southern California.

Production reached a maximum in the Julian and Banner districts in 1874 and declined very rapidly thereafter. The greatest annual production, that of 1874, was probably slightly in excess of $500,000. The production estimates include the returns from the Stonewall Mine, which although not a part of the Julian Mining district at any time during its history, is reported in the meager literature with the mines of the Julian belt and is described in this report. In 1876 the Golden Chariot closed down, and according to the report of R. W. Raymond for 1875 most of the mines and mills were idle.

The discovery of the Gold Queen and Gold King mines four miles southeast of Julian in 1888, almost twenty years after the main discoveries, infused new vigor to prospectors. The development and the building from San Diego to Foster of the Cuyamaca Railroad, under construction in 1888, probably also helped to stimulate mining activity, so that in 1889 work was resumed on many of the Julian mines and some rich ore discovered. In 1890 many of the mines were taken over by more or less strongly financed companies and although it is probable no large amount of gold was produced by them, their exploratory work, coupled with the system of leasing inaugurated about this time, and the general industrial condition of the Nation, resulted in considerable gold production during the nineties. In 1891 the first claim map of the district was compiled by D. D. Bailey, J. E. Chamberlin, and W. A. Sickler; a revision of this map was made in 1896. In 1894, 20 mines were operating in the Julian district and some time in the following year the Ranchita and Elevada mines were discovered. The Stonewall after attaining a depth of 600 feet and a production record of $2,000,000 closed down in 1893 and has never been reopened. The Owens Mine, abandoned in 1889, was unwatered and reconditioned at considerable expense in 1890–91, but this attempt at reopening failed; in 1896 operations had been resumed and some good gold-bearing quartz was found.

In the first two decades of the twentieth century almost no substantial mining ventures were under way in the Julian district. A small amount of ore was found in 1910 on the southwest slope of Granite Mountain in what was called the Granite Mountain Mine. During 1913–14 attempts were made to work the Golden Chariot. In March, 1923, the Golden Chariot Mine was taken over by the Golden Chariot Mining Corporation and a formidable program of exploration was projected. In the latter part of 1923 the Ready Relief and contiguous mines were consolidated and considerable prospecting is reported to have been done in the next few years. A number of smaller mines were being worked in this same period. The total amount of gold produced in the Julian district by the mining operations in the years 1923–33 was 2057 fine ounces, value $42,940, about 10 per cent of which was from placers. In the fall of 1932, after an alleged expenditure of $300,000 with only a small return in gold production, most of the surface plant of the Golden Chariot Mine was dismantled and removed from the property.

During the writer's visit in the summer of 1932 scarcely any mining work was being done. The moratorium on mining claim assessment work for the year ending July 1, 1932, and the expected continuation of this moratorium for the next year, virtually stopped all development work.

In the spring of 1933 the records of the Julian mining district were moved to the office of the county recorder in San Diego, and the legal existence of the district was by that act brought to an end, so that in common with most of the mining areas in California the term Julian mining district has lost its significance. The increase in the price of gold ($35 per troy ounce on January 31, 1934), from the former stable price of $20.67 per troy ounce, may cause a renewal of mining activity in the Julian region. A little work was going on in the Ready Relief group during the writer's visit in the fall of 1933.

Production.

The gold production during the early years of mining activity, from 1870 to 1876, can only be inferred. For the early production no records are available which are even approximately based on statistical information. The following figures represent estimates founded on fragmentary sources:

1870	$150,000	
1871	175,000	
1872	490,000	(10,000 tons of ore crushed)
1873	500,000	(10,500 tons of ore crushed)
1874	190,000	
1875	100,000	or less
1876	100,000	or less

Mr. Chester Gunn of San Diego, California, estimated the total production for 1869–1880 at over $2,500,000. As an indication of how the estimated amount of total production increased by passage of time, the Julian *Sentinel* in 1889 reported the total production of all mines at well over five million dollars, despite the small amount produced in the eighties.

In a publication issued by the San Diego Chamber of Mines in 1927 entitled "San Diego County Mines & Minerals" the total gold production of the Julian belt since 1880 is stated to be approximately $7,500,000, an amount about equal to the published production records of the State Mineraligist for San Diego County for the same period. The records of the State Mineralogist prior to 1907 include the gold production of what is now Imperial County, which was a part of San Diego County until that time, and, while there is no way of correctly allocating the production emanating from the Julian belt, the whole amount can not be credited to the Julian Mines.

The total production of all mines in the Julian-Banner-Cuyamaca region is believed to be between $4,000,000 and $5,000,000. The estimated production for individual important mines tabulated in appropriate order of rank is as follows:

Stonewall	$2,000,000
Golden Chariot	700,000
Ready Relief	500,000
Helvetia	450,000
Owens	450,000
Blue Hill or Gardiner	200,000
North Hubbard	200,000
Ranchita	150,000

The Antelope, Chaparral, Cincinnati Belle, Eagle, Elevado, Hidden Treasure, High Peak, Kentuck S., Madden, Redman, San Diego, Shamrock, Van Wert, Warlock, and Washington probably produced between $25,000 and $50,000 each.

The Cable, Chieftain, Eldorado, Ella, Fraction, Gold King, Gold Queen, Granite Mountain, Hidden Treasure, Homestake, Neptune, North Star, Oriflamme, Padlock, Ruby, South Hubbard, and Tom Scott are believed to have produced less than $25,000 each.

General Geologic Features of the Gold Deposits.

It has been shown [13] that most of the gold output of the Pacific coast belt has been derived from fissure veins or from deposits which possess close relationship to fissure veins. These fissure veins and allied deposits are believed to have been formed chiefly by ascending hot waters, which had their origin in batholithic intrusions of Mesozoic age. Such intrusion can be traced from Baja California, through San Diego, Los Angeles, and Kern counties, northwestward to Nome, Alaska, on the Seward Peninsula. It is obvious that the gold deposits of the Julian region are not the continuation or prolongation in southern California of the Mother Lode system of the Sierra Nevada. Instead it may be said similar conditions of ore deposition obtained in both areas at somewhat the same time.

The deposits contained wholly or partly in schist have been much more productive and are described in greater detail than those contained in fractured, sheared, or metamorphosed granodiorite.

Gold-bearing Quartz in Granodiorite.

Gold deposits in more or less metamorphosed granodiorite are represented by the Ranchita Mine, Gold Queen Mine, and a few other mines and prospects. They are much less important than those in Julian schist. At the Ranchita Mine, which was a large producer, a zone of granodiorite with what are probably schist xenoliths, has been converted by shearing into a mica schist now highly weathered and containing much black gouge. Lenses and stringers of quartz carrying free gold have been deposited in this shear zone, which has an average strike of N. 50° W. and dips about 60° NE. The Elevada prospect, just northeast of the Ranchita Mine, possesses a similar structure except that it dips southwest. The Gold Queen Mine is located near the contact between a small body of injected schist and gneissic granodiorite. Little is known of the mine except that it worked a small shoot of rich, free-gold ore. Other similar deposits of small highly-irregular gold-bearing quartz veins are not uncommon but have yielded a very small gold production.

Gold-bearing Quartz in Julian Schist.

The gold-bearing quartz deposits associated with Julian schist are mainly in a belt that cuts diagonally across the main schist body from the northwest nose of the hill just north of the town of Julian to the vicinity of Banner. Only two mines, but both of these important ones, are outside this belt, namely, the Golden Chariot Mine situated two miles south-southeast of Banner in the main schist body at the contact between gneissic granodiorite and schist, and the Stonewall Mine in the southern lobate end of a schist body entirely separate from the main Julian body. The distribution of the main belt led some of the earlier investigators to conclude erroneously that there were four main

[13] Lindgren, Waldemar, The geological features of the gold production of North America: Tr., A. I. M. E., vol. XXXIII, pp. 790–845, 1903.

veins traversing the district. There is no evidence whatever for the existence of four such veins.

Gold-bearing quartz occurs in all the various types of schist described, but it is more common and forms larger bodies in some types than in others. The bodies in richly-siliceous rock, as in the Ready Relief

FIG. 6. Quartz roll from the North Hubbard Mine.
The rock is silicified mica schist.

Mine and in the mines adjacent to the north and south, are the largest in size and the most continuous along the strike. Many of the others are encased in mica schist that shows evidence of contact metamorphism; e.g., those of the Madden, Helvetia, Owens, and nearby mines.

The richest and most characteristic ore consists of layers of quartz from a mere film to a few inches thick interlaminated with comparablysized schist layers, the whole carrying a subordinate amount of auriferous simple sulphides (or their oxidized derivatives) and free gold. The layers of quartz are commonly thicker and more persistent than those of schist. All gradations are known to exist from a very thin-banded ore to that in which quartz forms massive layers a foot or more thick. In much of the ore mined during the heyday of the camp, free gold is reported to have occurred in amounts visible to the unaided eye and the ore constituted what was then called 'specimen rock.'

Occurrence and Structure.

The gold-bearing quartz bodies are classified according to shape as (1) lenses, (2) lenticular veins, and (3) rolls. They have all been formed during the same period of ore deposition by related causes, but for convenience they are classified separately.

Lenses of vein quartz are abundant in the main schist body throughout its entire length. Although extremely variable in size, those an inch or so across and several inches long are most common. Insensible gradations exist between single lenses and lenticular veins on the one hand, and single lenses and incipient rolls on the other. These lenses are made up almost entirely of quartz that is clear and glassy except for cloudiness made by fractures, which may be so numerous as to completely destroy the transparence or translucence in the hand specimen. Where the lenses are gold-bearing, native gold is generally the only ore mineral present. Coarse interlocking anhedral quartz individuals, that are more or less strained, incipiently microbrecciated, and shredded are revealed microscopically. The shredding or parallel texture conforms in attitude to the general schistosity of the encasing rock. Usually a selvage of brown biotite a fraction of an inch thick encloses the lens. In the case of a large lens the selvage may simply be schistose country rock in which no biotite segregation has taken place. Puckering or plicating on the ends of the schist is common wherever the end of the lens is blunt. Where it pinches out in a more gradual fashion the encasing schist closes round the end without disturbance. A frequent occurrence consists of several lenses strung out along a layer in the schist and connected by small veins or films of quartz.

Many of the lenses have an *en echelon* arrangement along the strike and along the dip of the schist. In detail each lens is conformable with the schistosity, but the next succeeding one is offset from its neighbors, so that the strike of the lens system makes a small angle with the strike of the schist. Similar relations prevail along the dip of a lens system.

Microscopic evidence shows that the vein quartz has not been derived from the immediate vicinity, because schistose quartz is in immediate contact with it and the schist has been very often itself silicified.

Lenticular veins have furnished the bulk of the gold production in the Julian-Banner district. They are most strongly developed in the Owens, Helvetia, Blue Hill, Ready Relief, North Hubbard, and Golden Chariot mines. The veins are generally a few inches wide, occasionally one to four feet, and very exceptionally over the four feet. The Stonewall Mine deposit had the largest width—12 to 20 feet—of any on record, but its true geologic character is unknown.

Excluding the Stonewall Mine, most of the gold output has come from mines where the veins worked were 1½ to 5 feet wide. In the Ready Relief group where several limbs of rolls came together, widths up to 20 feet are recorded, but this represents the combined thickness of several quartz bodies. Individual veins have no great continuity. As in lenses the next vein is separated by an interval of schist which may carry numerous quartz stringers. The veins are usually conformable in dip and strike to the encasing schist; some cut across it at small

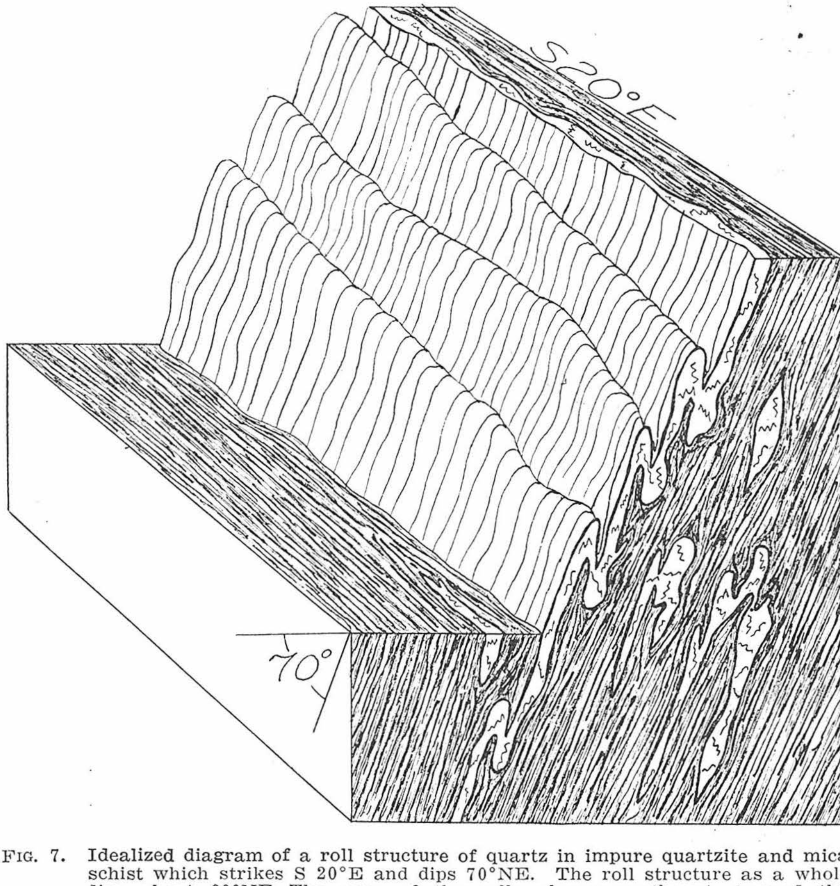


FIG. 7. Idealized diagram of a roll structure of quartz in impure quartzite and mica schist which strikes S 20°E and dips 70°NE. The roll structure as a whole dips about 60°NE. The axes of the rolls plunge northwest, toward the observer. For illustrative purposes, part of the hanging wall is not shown. The drawing is not to scale.

angles. They are most commonly made up of banded quartz gangue in which inconstant layers or septa of schist from a mere film to a fraction of an inch thick separate layers of glassy or translucent quartz. The boundaries between the quartz and the schist septa are both sudden and sharp, shadowy and indistinct. In the hand specimen an impression is often gained of the existence of a schist septa which proves under magnification to be merely discolored quartz. There is seldom the development of a gouge at the walls and the schist in the main adheres tightly to the quartz. Wherever gouge has been developed in association with a vein it appears to be later than the vein. The quartz in these veins has been apparently recrystallized since deposition, as it has a texture parallel to the walls. The boundaries as seen microscopically between gangue quartz and the schist septa are frequently irregular and suggest replacement.

The strike of the veins varies from N. 10°–20° W. in the vicinity of Banner to N. 50° W. near Julian. The dip is sharply northeast in the vicinity of Banner, southwest at varying angles on the steep slopes of the mines near the old Banner grade, and again steeply northeast in the mines on the Julian mesa. The southwest dips are due to the bending of the schist (and veins) downhill.

The broad relations of the lenticular veins of the main belt from Banner to Julian show an *en echelon* arrangement in plan. Commencing in the vicinity of the Ready Relief Mine and going northwestward a metallized belt is traversed in which the individual veins are parallel to the enclosing schist but each succeeding vein to the northwest is displaced a greater or lesser distance. Of course, overlapping along the strike occurs and the next vein to the northwest often begins before its southeast neighbor dies out.

FIG 8. Section of the end of a quartz roll, where it has split into a number of stringers. North Hubbard Mine.

The most remarkable structures in the Julian region are the rolls of gangue quartz found everywhere throughout the schist belt but exceptionally well developed in the mines near Banner in the claims now included in the group from the Warlock to the South-Hubbard. The wall rocks here are dominantly highly siliceous mica schist. A silicified, well-foliated biotite-muscovite-quartz schist is a common host for this structure. In the typical case, a tabular 2–5 feet thick quartz body conformable to the schistosity, when followed down the dip merges into a trough, transecting the schistosity, which connects with another straight vein parallel to the first but offset from it. This second tabular vein or body continues upward for a short distance and gives way to a saddle that connects with a third tabular vein likewise offset and running down the dip parallel to the first two veins. Thus the dip of the flat portions may be from 70°–80° NE., while the dip of the structure as a whole may be from 40°–60° NE.

The folia of the schist wall rock are not folded around the rolls to conform with their shape, but they are disturbed somewhat at the contact. Where a roll along the strike pinches out, the schist folia merely curve and close together around the end, similar to the way they are bent around the end of a quartz lens. Likewise, in cross-section the schist folia usually bend around the curved boundary of the quartz roll.

The vein quartz adheres tightly to the schist walls and gouge has seldom been developed. Where gouge has been formed it appears to be later than the deposition of the vein quartz. The widths of the flat portions of these rolls is comparable with the widths of 'unrolled' veins, i.e., from a mere film up to several feet. Wherever they form a roll the tabular, conformable parts are often thickened and the curved transection part is commonly thickened so that combined widths up to 20 feet are attained in places. In length and depth rolls are perhaps the most persistent of any of the gangue quartz bodies. In the Hidden Treasure Mine a roll was followed continuously for 500 feet, a length probably to be regarded as near the maximum. It may be said that the horizontal extent of a good-sized (2–4 feet wide) roll may be anywhere from about twenty feet to several hundred. In vertical extent less persistence prevails. Along the dip the rolls pinch and swell very suddenly, even more so than along the strike. A roll continuous along the dip for more than 100 feet is exceptional, and dimensions of the order of tens of feet are the average. Like the lenticular veins, with which they are always associated, a roll frequently passes along the strike into a series of stringers, which retain for some distance the curved, transecting character of the main roll.

Some of the smaller rolls can be proved to merge into tabular veins along the strike. While it is true that the general tendency of the tabular parts of the rolls is to conform with the attitude of the enclosing schist, on a smaller scale many of them cut across the schistosity. The axes of the rolls generally plunge to the northwest or southeast at low angles, usually less than 25 degrees. Rolls with a northwest plunge predominate over those with a southeast one.

The predominant material in the rolls is vein quartz. Biotite, present in small, shining flakes in the quartz, has apparently been introduced or been recrystallized from local material. Varying amounts of schist are included in the quartz, as septa or residuals. Pyrrhotite and arsenopyrite constitute the principal ore minerals, with occasional specks of native gold.

The vein quartz occurs as interlocking, coarse-grained anhedra elongated roughly parallel to the axial plane of the fold. Microbrecciation is frequently seen. Quartz from rolls is found to be highly strained, but no more so than quartz from tabular veins.

The schist septa are made up principally of biotite, muscovite, magnetite, and occasionally graphite. Larger inclusions of schist contain in addition to these materials much schistose quartz. The mica schist wall rock is usually highly silicified and contains abundant pyrrhotite. The schistose quartz is not as highly strained as is the vein quartz in the nearby rolls.

Some of the rolls have been cut by radial and concentric tension fractures which are nonmetallized. Shear fractures, denoted in part by schist septa and probably inherited from the schist, are also present and these are metallized chiefly by pyrrhotite. Tiny rolls made up wholly of pyrrhotite occur. They have the same general shape as a quartz roll, but have been observed only in very small size.

The quartz rolls are believed to have been formed at the same time and by the same causes that resulted in the formation of lenticular veins and lenses. The genesis of the rolls is discussed in the following section.

Mineralogical Character.

The mineralogy of the ores is simple. Along with quartz, which is the only major introduced gangue mineral, arsenopyrite, pyrrhotite, and pyrite have been deposited in small amounts, free gold and petzite in still smaller amounts. The sulphides that occur in banded quartz deposits are apparently related to schist inclusions, or septa, in or around which they are generally clustered. Pyrite, pyrrhotite, and arsenopyrite also occur in the wall rocks. Unbanded, massive quartz commonly contains few visible sulphides. These are general relations and many unusual conditions may occur. From the little information available on the value of concentrates consisting of sulphides collected after amalgamation it is reasonably certain that the sulphides are auriferous. Many of the high-valued concentrates must owe a part of their gold content, however, to such gold-bearing minerals as petzite.

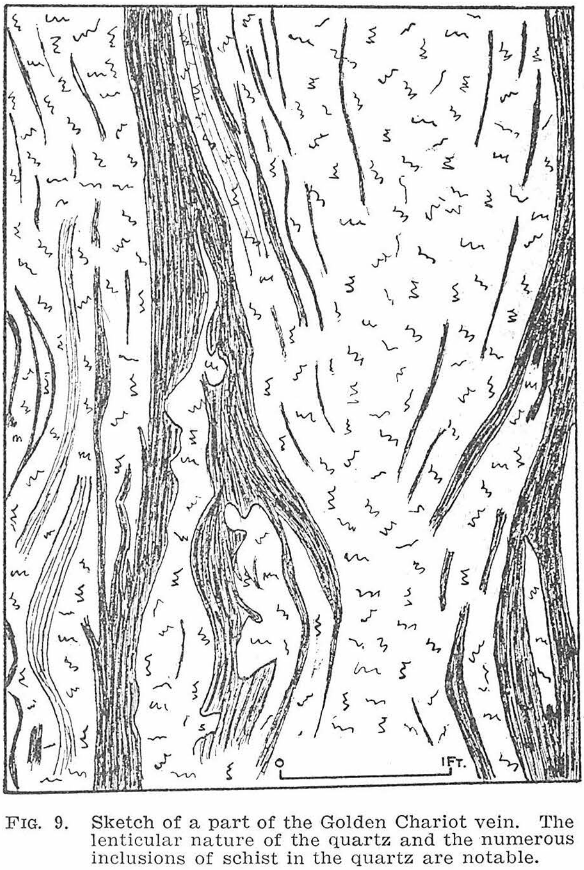


FIG. 9. Sketch of a part of the Golden Chariot vein. The lenticular nature of the quartz and the numerous inclusions of schist in the quartz are notable.

Ore Minerals—Native gold, alloyed with more or less of other metals, mostly silver, has been found in all the gold-quartz ores of the district. It occurs in masses from fine hair-like and plate-like particles of submicroscopic size up to coarse grains and nuggets measurable in fractions of inches. Native gold from the Golden Chariot Mine has a medium yellow color and is not appreciably different in depth of color from the gold of the Mother Lode system of northern California. Even though it is associated with simple sulphides, known to be active precipitants of gold, and with graphite present in the quartz veins after schist, it has not been deposited by them as large grains of native gold occur at some distance from the nearest sulphide or graphite.

Although native gold occurs chiefly in its coarse development in banded quartz ore, it is often found embedded within that ore in a layer of pure quartz with no associated minerals. This seems to indicate that part of the quartz and gold are contemporaneous. Unusual concentrations of native gold have been found associated with cleavage surfaces formed by schist septa in banded ore. In a specimen of this ore from the Golden Chariot Mine, gold is associated with brown and bleached biotite and in addition to being present in coarse irregular particles, occurs in very tiny, flat plates between cleavage surfaces of brown biotite.

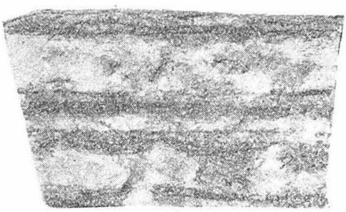


FIG. 10. (Upper) Typical banded (or ribbon) ore. The thin layers are schist septa; the white is quartz. North Hubbard Mine. One-half natural size.

FIG. 11. (Lower) Thin section of the quartz from the specimen shown in Fig. 10. The shredded and strained nature of the quartz is characteristic of much of the gold-bearing quartz. X-nicols. 13X.

The richness of the concentrates from the Golden Chariot ore and the presence of tellurium as shown by chemical tests, indicate that some of the gold occurs as a telluride. In a polished section of the ore a mineral was found which has the properties of petzite, although the criteria for the recognition of this mineral in polished section are not entirely accordant.

Pyrrhotite in granular and massive form is the commonest sulphide occurring in the ore. It is found both in the banded ore and in the wall rock. Where occurring in the banded ore it is usually related to schist inclusions. Gold occurs with it and no specimens containing visible free gold were found that did not have some pyrrhotite in them. In the polished section pyrrhotite does not show its own crystal boundaries, but has an irregular outline against the schist or quartz.

In one of the specimens examined from the North Hubbard Mine, about one-fifth of the pyrrhotite occurred in veinlets that strike off at nearly right angles to the banding in the ore; the other four-fifths is contained in stringers, elongated parallel to the banding and lying in or near schist septa. In another polished specimen from the Golden Chariot the pyrrhotite has a similar spatial relationship and is more nearly confined to the neighborhood of schist septa than is the accompanying gold.

Weathering leaches small cavities in larger grains of pyrrhotite and oxidizes the surface of grains to yield a 'peacock luster' or tarnish. This tarnish serves to help distinguish it from pyrite, moreover the pyrrhotite examined was all slightly magnetic, whereas pyrite is not.

Arsenopyrite occurs as a hypogene constituent in much of the ore. Rather large concentrations of it are found in the area in and near the Gold Cross No. 1 claim (the old Fraction claim). It is associated with visible pyrrhotite and schist septa in quartz. Arsenopyrite, which is a strongly idiomorphic mineral, is common in diamond-shaped and rectangular-outlined metacrysts that often transect the schistosity. No data are available on its gold content. Gold occurs with and without associated arsenopyrite. Weathering has frequently leached tiny cavities in the centers of arsenopyrite crystals.

Granular pyrite occurs, although not so extensively as pyrrhotite and arsenopyrite, as a constituent of the ore. It is rather common in the wall rocks, although much that in the past was thought to be pyrite is now known to be pyrrhotite. Small cubes of pyrite are found with calcite in gangue at the Golden Chariot Mine. Pyrite has also been found coating the walls of fractures in the vein quartz.

Gangue Minerals—The principal introduced gangue mineral is quartz. It is transparent or translucent in hand specimen except where highly fractured. Both the massive and banded varieties are common. The banded variety has yielded the largest amount of the gold production. Some of the quartz examined microscopically is highly fractured, some of it with two definite sets of fractures, one parallel to the banding and the other at a high angle, nearly 90°, to it. Thin slices reveal the quartz to be strained, elongated parallel to the banding or schistosity, anhedral to subhedral in outline, coarsely granular, and forming an interlocking texture described as 'shredded.' Faulting, as in the Golden Chariot Mine, has pulverized some of the quartz gangue and rendered it sugary. Much of the quartz gangue mined was coated with oxidation products and discolored. Because of the thinness of most of the veins, the quartz has not resisted erosion more than the containing rocks and does not commonly stand out against them. Euhedral quartz crystals are developed in small vugs collected from a few localities.

Associated with much of the quartz gangue is a lustrous, coarse-grained brown biotite. It occurs both in the wall rock near the quartz and along the schist septa preserved within the quartz. It is thought to have been deposited under high temperature, hydrothermal conditions.

Sericite is found rather abundantly in the veins and in the wall rock. It is considered a hydrothermal mineral, formed by reaction of solutions with the wall rock or schistose gangue minerals. Much that looks like sericite in the hand specimen is bleached biotite.

Tourmaline was found as a scanty gangue constituent. Its presence was definitely detected at the Owens, Madden, and North Hubbard mines. It does not make up any appreciable amount of the ore and is chiefly noteworthy as indicating the probable temperature of deposition of the quartz vein.

Calcite is found as stringers associated with gouge and small cubic crystals of pyrite in the Golden Chariot Mine.

The schist minerals embedded in vein quartz as residuals or septa of variable thickness are the same as those of the wall rock. They include, from place to place, biotite, muscovite (or sericite), graphite, bleached biotite likely produced by hydrothermal alteration, schistose quartz, magnetite, plagioclase, and a very scanty amount of the heavy minerals such as apatite and rutile. Graphite is noteworthy here because it frequently remains as a septa-forming mineral after all the other schistose minerals have been replaced. It has not influenced the precipitation of gold.

Supergene Minerals.—Kaolin, kalinite (or potash alum), iron oxides, and other oxidation products of the sulphides, gangue and wall rock are found near the surface in the mines. Kalinite, the birefringent potassium-aluminum sulphate, is very abundant as a supergene crust in the mine openings of the Ready Relief. Some of the kaolin from

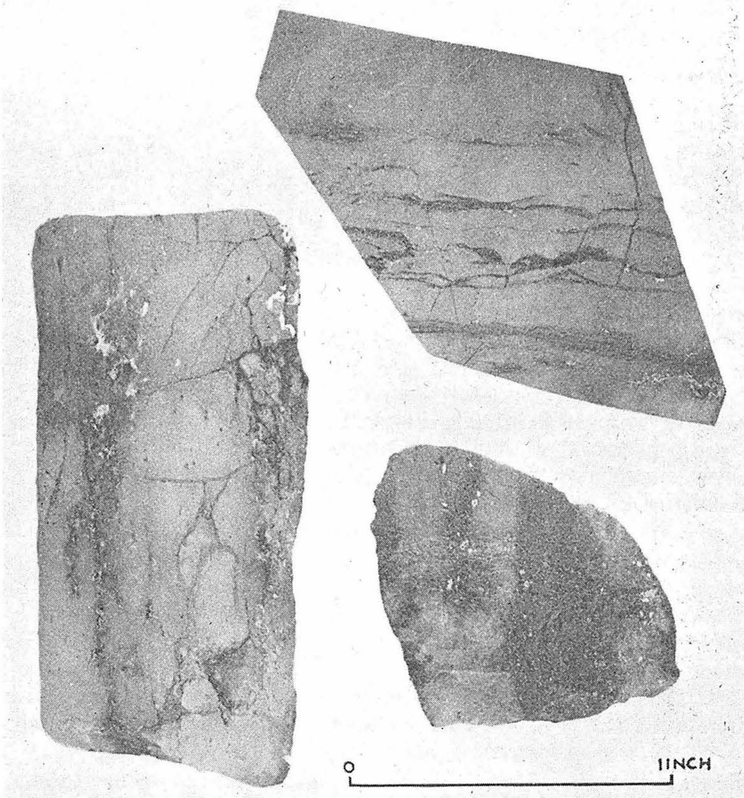


FIG. 12. Polished specimens of ore from the Banner district. In the specimen on the left the light spots are gold. Pyrrhotite in small, irregular grains is seen in the specimen on the upper right, where it is plainly associated with tiny schist septa. Arsenopyrite in somewhat rectangular grains is found, mostly in and near the schist septa, in the specimen on the lower right.

the Eagle Mine was studied and found to be an impure kaolin mixture. A dark brown, earthy, oxidation product, rich in iron, is common in some of the quartz veins. It does not contain manganese.

Age Relations of the Minerals.—To work out a well-founded paragenesis of the ore and gangue minerals would require many more specimens of hypogene ore than were available to the writer. Mica and tourmaline appear to be later than quartz. The simple sulphides and gold appear to be related in places to fractures in the quartz. Tiny plates of gold have been found between cleavage plates of brown biotite. Gold is also found as specks in pure quartz apparently unrelated to fractures and here seems to be contemporaneous with at least part of the quartz. On the basis of local evidence and comparison with the order of formation of minerals in similar veins the paragenesis has probably been: quartz, tourmaline, mica, pyrite, pyrrhotite, arsenopyrite, gold, and petzite.

None of the various hypotheses that have been advanced satisfactorily explain to the writer the association and distribution of the gold in the Julian deposits.

Ore-shoots.

For most of the information on ore-shoots the writer is indebted to the recollections of Mr. Al Frary, of Julian, who has operated many of the mines in the region. According to him the orebodies in the mines in the main belt—Julian to Banner—pitched north with one or two exceptions. The ore-shoots of the Golden Chariot also pitched north. The Stonewall Mine ore-shoots pitched steeply to the south.

The abrupt change in the character of the ore from rich to barren quartz is pronounced. It is reported that in following a roll-vein down the dip, a saddle would be encountered that contained ore carrying 10 oz. or more of gold per ton and in the next saddle below, in quartz of apparently the same character, no gold was found. Still farther down the dip on the same vein, quartz yielding about 4 oz. of gold was mined. A similar sudden transition along the strike also prevailed.

The size of ore-shoots on record may best be stated by giving a few examples: The Owens Mine worked an ore-shoot that had a stope length of about 400 feet and a vertical dimension of about 300 feet. The main ore-shoot in the Helvetia Mine was 150 feet in vertical length, 100 feet in stope-length, and pitched steeply south. The Stonewall Mine orebody had a stope-length in one place of 450 feet and a pitch-length of 800 feet maximum. One of the lenses or shoots of ore worked in the Golden Chariot Mine had a stope-length of 65 feet and vertical length of 185 feet. These are among the largest ore-shoots found, the majority were smaller.

No mineralogic indication for the presence of ore-shoots can yet be stated. A bluish-looking quartz is frequently mentioned in the record as being a favorable indication of gold content. It appears probable that most of the gold occurs with pyrrhotite, although ore is found in which the sum of the gold about equals the sum of the pyrrhotite. In the past, ore was prospected for by panning and assays were rarely obtained. It appears probable that much of the lower-grade ore that might have yielded a profit if it had been milled to recover the gold in the sulphides or gold compounds was thus lost.

Structural indications are a more likely source of guidance than mineralogic indications. In general the thinly banded ore has been more productive than the massive varieties. There seemed to have been a uniform supply of metallizing solutions and when this was deposited, a running foot of ore along the vein contained approximately the same amount of gold whether it was one or four feet wide.

Probable Persistence of Ore Zone in Depth.

Along a rather continuous belt or zone of ore deposition extending from the vicinity of Julian to the vicinity of Banner—a distance of about three miles—no notable change in the general character or tenor of the ore is found, despite a maximum vertical distance of

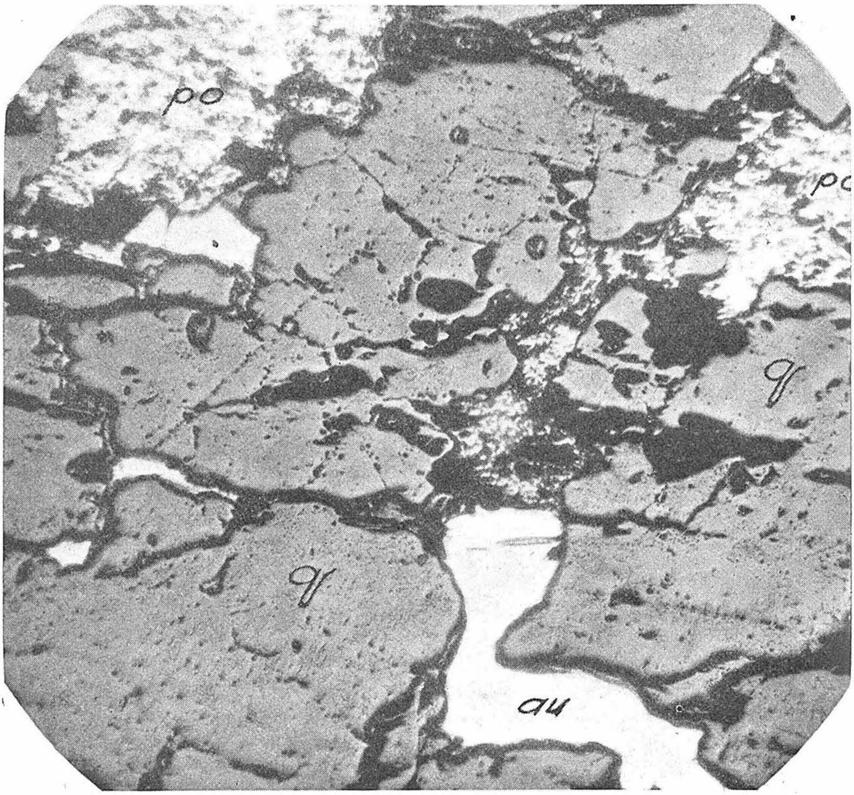


FIG. 13. Pyrrhotite (po) and gold (au) in banded quartz (q). Gold occurs as stringers and blebs, usually parallel or at high angles with the banding, which is parallel to the bottom of the photograph. Golden Chariot Mine, magnification 30 diam.

approximately 1800 feet between the highest and lowest surface points in the belt. The general character of the deposits, both their structure and mineralogy, indicates that they were formed at a great depth and over a wide vertical range. If the slope of the curve of the rate of change with depth of these and similar deposits be taken as a guiding principle, it seems likely that the zone of gold deposition persists with little change in primary character to a considerable depth below the present surface.

Supergene or Secondary Enrichment.

There is a decided trend in the recorded history of the camp toward an increased leanness in the ore in depth. This has been explained on the basis of secondary enrichment and it seems probable that some enrichment has taken place by removal of less valuable material, especially in the deposits on the Julian Mesa. This process may have taken place in the Stonewall, Owens, and Helvetia mines, and possibly in the uppermost zone of the Golden Chariot Mine.

It should be noted that orebodies formed by supergene enrichment involving solution and redeposition on a lower level may be expected to 'bottom' at a comparatively shallow depth, at or near the permanent ground water-level. It becomes a very practical question to determine, in so far as the evidence permits, whether the Julian gold veins have been enriched downward.

The experimental evidence tends to the conclusion that the dioxide of manganese is necessary both for the production of nascent chlorine essential to the solution of gold and for the inhibition of formation of precipitants of gold, which if formed simultaneously with the production of the soluble gold chloride would cause almost immediate redeposition of gold. Furthermore the sum of the observations on gold distribution the world over is that supergene gold—the richest gold ore—is usually found in the lower part of the oxidized zone, which was not the case in the Julian deposits. No manganese was found in the Julian ores, although much material was collected in the field that looked superficially like oxygen compounds of manganese.

Specimens of rich free-gold ore from the Ready Relief and Golden Chariot were examined in detail. These mines are associated with youthful erosional surfaces, of which the Ready Relief surface is much the younger, in comparison with the old age surface to which the mines of the Julian Mesa are related. Of the several applicable microscopic criteria to distinguish hypogene and supergene origin of ore minerals, none are at variance with the conclusion that the valuable ore minerals examined are wholly hypogene. The gold in the Golden Chariot and Ready Relief specimens is of the same generation, no gold deposition in fractures or openings associated with weathering has taken place. In the upper portions of these mines it is entirely probable that finely divided gold was formed from the breakdown of gold tellurides, but it is unlikely that this decomposition product or initially free gold has been carried downward in any large amount.

On the basis of local evidence and comparison with work done on this general problem, no significant amount of secondary or supergene enrichment is thought to have taken place in the Julian gold quartz deposits by the leaching or solution of gold from higher levels and its redeposition at lower levels.

Value of the Ore.

Based on the amount of gold per cubic foot of vein matter, the deposits have been very rich. Most of the profitable ore treated from the main belt has averaged around \$50 per ton in gold ($2\frac{1}{2}$ oz. of fine gold). Ore yielding \$100 to \$500 a ton was common. It appears probable that ore occurring in this type of vein (1–1½ feet wide) carrying less than an ounce of gold per ton did not pay to mine. The profitable Stonewall Mine worked ore yielding \$12–\$20 per ton in relatively pure (about 900 fine) gold, but the orebody was continuous for several hundred feet along the strike and dip and was up to 20 feet wide. Much of the wall rock carries a small amount of vein quartz and sulphides and on the basis of the few assays made is thought to contain from a trace up to about 10 pennyweights of gold per ton. Much of the gold in the wall rocks is not free and can not be recovered by amalgamation and very little of it can be recovered by regrinding and reamalgamating the concentrates.

Structural Features of the Vein Openings.

At the depth at which ore deposition is presumed to have taken place, continuous well-opened fissures are only exceptionally formed. A nonhomogeneous rock like the Julian schist—which had at the time of granodiorite intrusion a well-developed schistosity—tends upon being subsequently deformed to yield along planes parallel to the schistosity. Shearing in such a rock will take place, whenever possible, by slipping along the previously developed structural planes of the schist or by rendering such planes more permeable. The portions of schist rendered more permeable may be conceived as spaces in which compression is less than nearby spaces. If shearing stress acts in such a direction that relief across the folia must be accomplished, the resultant fracture will be jagged and for any shearing stress not at right angles to the schistosity, the fracture will alternately follow and cut across the folia. Fractures much like these, except that bending is involved, have been observed on steep hillsides where the pressure of overburden has fractured impure quartzite.

In the main body of Julian schist, which is regarded as the east limb of a northwest-plunging anticline, regional folding resulted in drag-folding in some of the beds and the production of incipient fractures and spaces of less compression in others. The largest of the drag folds and the strongest and most continuous fractures pitch roughly parallel to the plunge of the anticlinal axis of the main body of schist, i.e., northwest. The major axes of most of the elliptically-shaped lenses and lenticular veins trend northwest. Pressure of the granodiorite intrusion, which has a maximum effect on the bottom of the schist wedge, probably aided in opening or enlarging spaces for ore deposition. This concept of the production of vein openings may be compared in a general way to the behavior of a book placed under compressional stress by forces acting against the ends of the leaves and under shearing stress by forces tending to cause the leaves to slip past each other.

The genesis of the quartz rolls is one of the most important problems met in the investigation. Either they have been formed by deposition of quartz in fractures that partly follow and partly transect the schistosity or they have been formed by post-mineral folding of initially tabular quartz veins. The evidence in favor of their having an origin by deposition in fractures partly following, partly transecting the schistosity appears conclusive. The schist has not been folded to conform with the rolls; in some cases the curved part of the rolls transects the schist almost at right angles for a distance of several feet.

Some of the smaller rolls can be proved to merge within a few inches along the strike into tabular veins. Although quartz from the rolls is seen microscopically to be highly strained, it is no more so than quartz from tabular veins. No good examples of rolls were seen or have been reported in the Golden Chariot Mine, where post-mineral deformation has been more severe than in any of the other mines studied. Microscopic plates of biotite jut into the quartz from a base on the wall-rock selvage; this connection would have been broken by post-mineral deformation.

The development of rolls in especial strength in the Banner district is ascribed to the stronger nature of the rocks involved and to their position nearer the middle of the anticlinal limb, the place of maximum folding adjustment.

As previously described in the report, many of the lens systems and the lenticular veins of the main ore-zone from Banner to Julian have an *en echelon* arrangement. This has been caused by the development of spaces of less compression which are individually parallel to the schistosity, but which collectively cut across the schist at a small angle.

Deposition of the Ores.

From the coarseness of the grain of the gangue quartz, the mineralogic composition, and the general geologic relations, it is inferred that the deposits were formed at considerable depth. A rough estimate would be of the order of fives of thousands of feet. From this it is likely that much of the deposits have been removed by erosion and we are here dealing with the roots that have survived.

Following Lindgren, the deposits may be classed with the type called by him hypothermal. They are believed to have been deposited under temperature conditions higher than those obtaining during the formation of the mesothermal Mother Lode vein system. The hypothermal deposits of the Southern Appalachians [14] are very similar to those of the Julian region in shape, mineralogy, and genesis. The temperature prevailing during the deposition of hypothermal deposits has been estimated to be 300°–500° C. (plus or minus) and the pressures are believed to be very high.

The solutions which deposited vein quartz and the other hypogene ore and gangue minerals, presumably came from the same magmatic source that furnished the Stonewall granodiorite. They were introduced into the schist at a high temperature and under very high pressure. It is reasonably certain that this pressure aided materially in enlarging the openings by which the solutions could gain access. The force of crystallization may also have aided in enlarging openings in which ore was deposited. In addition to these two mechanical processes it appears clear that replacement of schist by vein quartz has gone on to an important extent. Some of the bands in vein quartz that appear to be schist septa prove upon close examination to be largely residual discoloration after the schist, or to be made up almost wholly of graphite spots. In many of the cases where a definite schist septa is present, it is bordered on both sides by discolored gangue quartz, which gives the

[14] Graton, L. C., Gold and tin deposits of Southern Appalachians: U. S. Geol. Survey, Bull. 293, 1906.

impression of the previous existence of a thicker septa, part of which has been replaced.

It is not possible to make a quantitative distinction between the relative volumetric importance to be ascribed to enlargement by pressure of solutions, enlargement by force of crystallization, or replacement. It is the writer's belief that replacement and enlargement have been of about equal importance, and enlargement by force of crystallization has been of secondary importance.

Post-mineral Deformation.

The vein quartz and to some extent the encasing schist has undergone metamorphism subsequent to the time of quartz deposition. In quartz this metamorphism is shown by the layering developed (as seen microscopically) and by the platy character visible in many of the hand specimens. This structure in vein quartz is parallel to the attitude of the schistosity.

Sometime after their formation many of the quartz bodies were deformed. In the Golden Chariot Mine and in prospects along the schist-granodiorite contact, the quartz has been highly fractured, the encasing schist has been broken and crushed, and gouge has been developed in places. All of the quartz examined, irrespective of origin, has been highly strained and most of it is more or less fractured. As this fracturing probably took place after deposition of the ore minerals it can not be used as an indication of gold content.

Age of the Deposits.

The age of the deposits is thought to be upper Mesozoic, being later than the consolidation of the exposed portion of the Stonewall granodiorite. Acid pegmatites are known to cut the Cuyamaca Basic Intrusive. This may indicate that the gold-quartz deposits are later than the basic rocks.

Water Supply.

A small flow of water was encountered by some of the mines in the main belt at a depth of from 100 feet to 250 feet. Many that are bordered on the east by lower ground were almost dry at the limit reached by mining operations. In the earlier history of the camp it is probable that even a small flow of water was troublesome. Much of the water pumped from mine shafts is not potable because of a high arsenic content. A perennial supply of water has been developed by the Ready Relief group by tunneling in coarse schist in the SE. $\frac{1}{4}$ of Sec. 10, T. 13 S., R. 4 E. The spring so developed is on the south side of what is here called Ready Relief Canyon, which drains a larger area than any of the other western tributaries of Chariot Canyon. By reason of faulting, the Golden Chariot Mine makes a supply of water probably ample for milling purposes. Any plan for the construction of mills on the Julian Mesa for the treatment of gold ores must carefully consider a supply of water. The depth to water in the domestic wells that supply the town of Julian is less than 60 feet.

Placer Deposits.

Analysis of the type of storm prevailing in the region that does most of the transportation of rock debris has led to an understanding of the absence of placers in an area that has yielded rather large quantities of free, coarse gold. Most of the precipitation comes during a few winter months and occurs in such a relatively short time that stream courses which are normally dry during most of the year bear raging torrents that carry everything before them. There has hence been no opportunity either to the east or the west of the district for the steady riffling action in good-sized perennial streams on gold-bearing gravels that might cause concentration of the gold in layers. Much gold-bearing gravel has been dumped during the geologic past into the fill of San Felipe Valley and is there unrecoverable, because of the low grade of material and the lack of an adequate water-supply. The Ballena placer,[15] lying east of Ramona in T. 13 S., R. 2 E., is part of the Poway marine conglomerate of Eocene age. The gold therein probably came from the Julian region.

Practical Conclusions.

1. Discoveries of many bodies of extremely rich oxidized ore occurring near or at the surface are not expected in the future. It may be remembered, nevertheless, that almost twenty years after the initial discoveries in the early seventies, rich masses of ore, such as those of the Ranchita, Gold Queen, and others, were found. Even after the long period of time during which the Julian gold deposits have been known, it can not be said that all of the favorable ground has been intelligently prospected.
2. Areas depicted on the map as representing schistose rocks should be well prospected. The ordinary method of prospecting by panning a stream course that heads in such rocks is worth while, but absence of colors should not be taken as indicating absence of lode deposits.
3. The ore zone may be expected to extend in depth considerably beyond any point attained by previous mining operations in the district.
4. The quartz bodies do not occupy fissures in the usual sense and well-defined gouge and fracture walls are generally absent. Thorough exploration of the ground on both sides of a vein or series of veins is necessary to verify the lateral extent of the metallized zone.
5. The mineralogic indications are (1) shiny, sometimes bluish, often transparent or translucent quartz, which may, however, be rendered opaque and sugary by fracturing, and (2) visible sulphides and free gold.
6. Ores mined in the future will probably contain less free gold and more auriferous sulphides and gold compounds than was the case during the previous history of the camp. Such ore can not be treated economically by amalgamation only. Everything considered, flotation in some form offers the best possibility for a high recovery of gold.
7. Assays must be run to determine the gold content of the quartz; panning is a valuable, although often misleading, guide.

[15] Merrill, F. J. H., Geology and mineral resources of San Diego and Imperial Counties: State Mineralogist's Rept. XIV, 1914.

8. Metallurgical treatment of unoxidized ores must take into account the known occurrence of gold in tiny plates between leaves of biotite, and of free gold, gold compounds, and auriferous sulphides in intimate association with tough, elastic schistose materials.

9. The richness of some of the ore makes necessary careful mining extraction to prevent losses. Sacking in stopes under supervision may be advisable.

10. The problem of water supply should be carefully considered before erecting reduction works.

OTHER MINERAL DEPOSITS

Nickel, Copper, and Iron.

Associated with the gabbroic rocks of the Cuyamaca massif are small deposits of nickel and copper-bearing pyrrhotite. Wherever they have been exposed on the surface, weathering has produced a gossan made up principally of iron oxide. The primary ore consists largely of pyrrhotite with lesser but megascopically visible quantities of chalcopyrite and minor amounts of nickel-bearing minerals, pentlandite $(Fe,Ni)S$; violarite $(Ni,Fe)_3S_4$; and possibly polydymite, Ni_3S_4. The discrimination of the nickel minerals is difficult, even in polished sections of the ore.

These deposits represent syngenetic magmatic concentrations of sulphides that have solidified at about the same time as the basic rocks that enclose them.

Various attempts have been made to exploit the deposits; only one, the Friday Mine orebody, has been worked to any extent. Several shallow pits have been dug in gossans at various places near the Friday Mine.

Lithia.

No lithia-bearing pegmatites have been found in the region mapped. One small lithia-bearing pegmatite deposit occurs on the southwest slope of Granite Mountain in Sec. 18, T. 13 S., R. 5 E., in what has been called the Royal Mine.

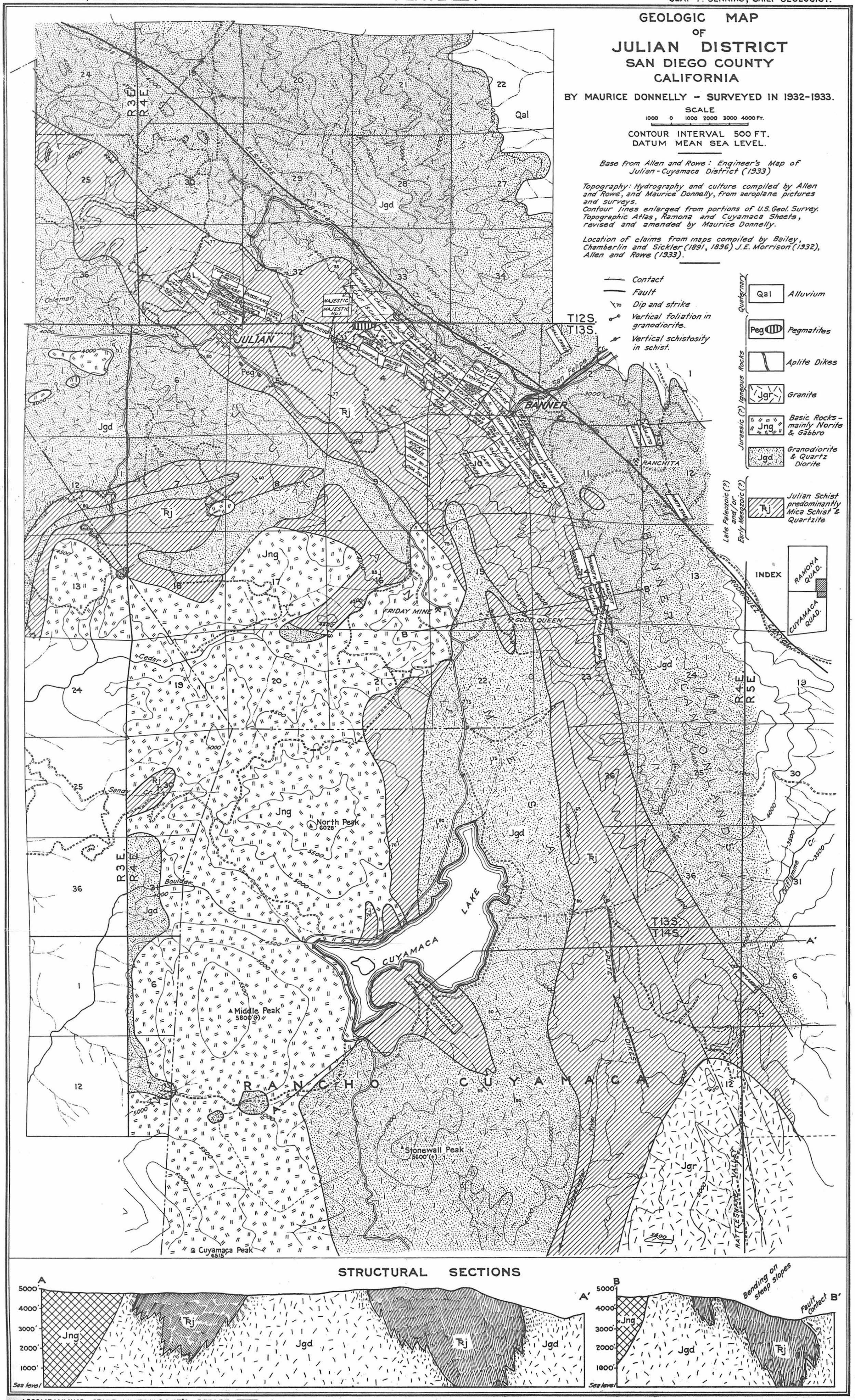
Graphite.

Graphite is found in small quantities in much of the Julian schist and hence is present in some of the schist septa in the gold-bearing quartz. The amount found in the schist in the region mapped is so small that it probably will never constitute a commercial source of the mineral. In Mason Valley, southeast of the area, graphite schist has been reported and a specimen of this material shows graphite to be present in considerable amount. In prospecting for this mineral it is well to remember that because of its opaque nature, graphite appears to make up a higher percentage of the mass than is actually the case.

Hot Springs.

Hot springs are found along the trace of the Elsinore fault zone in Rodriquez Canyon, at the eastern edge of the mapped area.

PLATE IV.


GEOLOGIC MAP
OF
JULIAN DISTRICT
SAN DIEGO COUNTY
CALIFORNIA
BY MAURICE DONNELLY - SURVEYED IN 1932-1933.
SCALE
1000 0 1000 2000 3000 4000 FT.
CONTOUR INTERVAL 500 FT.
DATUM MEAN SEA LEVEL.
Base from Allen and Rowe: Engineer's Map of Julian-Cuyamaca District (1933)
Topography: Hydrography and culture compiled by Allen and Rowe, and Maurice Donnelly, from aeroplane pictures and surveys.
Contour lines enlarged from portions of U.S. Geol. Survey. Topographic Atlas, Ramona and Cuyamaca Sheets, revised and amended by Maurice Donnelly.
Location of claims from maps compiled by Bailey, Chamberlin and Sickler (1891, 1896) J.E. Morrison (1932), Allen and Rowe (1933).
Contact
Fault
Dip and strike
Vertical foliation in granodiorite.
Vertical schistosity in schist.
Quaternary
Qal Alluvium
Jurassic (?) Igneous Rocks
Peg Pegmatites
Aplite Dikes
Jgr Granite
Jng Basic Rocks - mainly Norite & Gabbro
Jgd Granodiorite & Quartz Diorite
Late Paleozoic (?) and/or Early Mesozoic (?)
Ꞧj Julian Schist predominantly Mica Schist & Quartzite
INDEX
RAMONA QUAD.
CUYAMACA QUAD.
ELSINORE FAULT
JULIAN
BANNER
RANCHITA
FRIDAY MINE
GOLD QUEEN
BANNER CANYON
CUYAMACA LAKE
RANCHO CUYAMACA
North Peak 6028'
Middle Peak 5800(±)
Stonewall Peak 5600(±)
Cuyamaca Peak 6515
Coleman
Cedar Cr.
Boulder Cr.
San Felipe
Sandy Cr.
RATTLESNAKE VALLEY
T12S.
T13S.
T14S.
R3E.
R4E.
R5E.
STRUCTURAL SECTIONS
A
A'
B
B'
Sea level
Bending on steep slopes
Fault contact