The Mojave Mining District of California.

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I. Location.

The Mojave mining district is situated in a group of small hills centering around Soledad peak, in the Mojave desert, Kern county, Cal. These hills are about 4.5 miles SSW. of Mojave, a railroad town at the junction of the Santa Fé and Southern Pacific railroads.

The town of Mojave is about 50 miles north of Los Angeles, to which it is connected both by telegraph and by rail. The distance on the Southern Pacific railroad is 102 miles, covered in 3 hr. and 45 min. by express train. A sketch-map of this region is shown in Fig. 1.

The Mojave district is relatively isolated. The only other mining towns in this section of California are Randsburg and Johannesburg, in a district (containing the well-known Yellow Aster mine) at the northern end of a low range of hills, which begins about 20 miles NE. of Mojave, runs nearly N. for 35 miles, and varies in width between 3 and 6 miles. As will be seen later, the origin and formation of these hills are not the same as those of Soledad peak.

II. Climate and Vegetation.

The climate and vegetation of the Mojave district are typical of the arid regions of the southwestern United States. During the winter and spring there is some rainfall, and the temperature is generally from 60° to 70° F. in the day-time. The rainfall in the spring is often very considerable for short spaces of time, and cloud-bursts are not infrequent. In summer there is continual sunshine, with temperatures, as a rule, exceeding 100° F. in the day-time, while 115° F. in the shade of a house is not at all unusual; but at night the temperature falls considerably. No rain falls during the summer. The vegetation consists of a very little desert grass, a little grease-wood, sage bush and a few yucca trees.

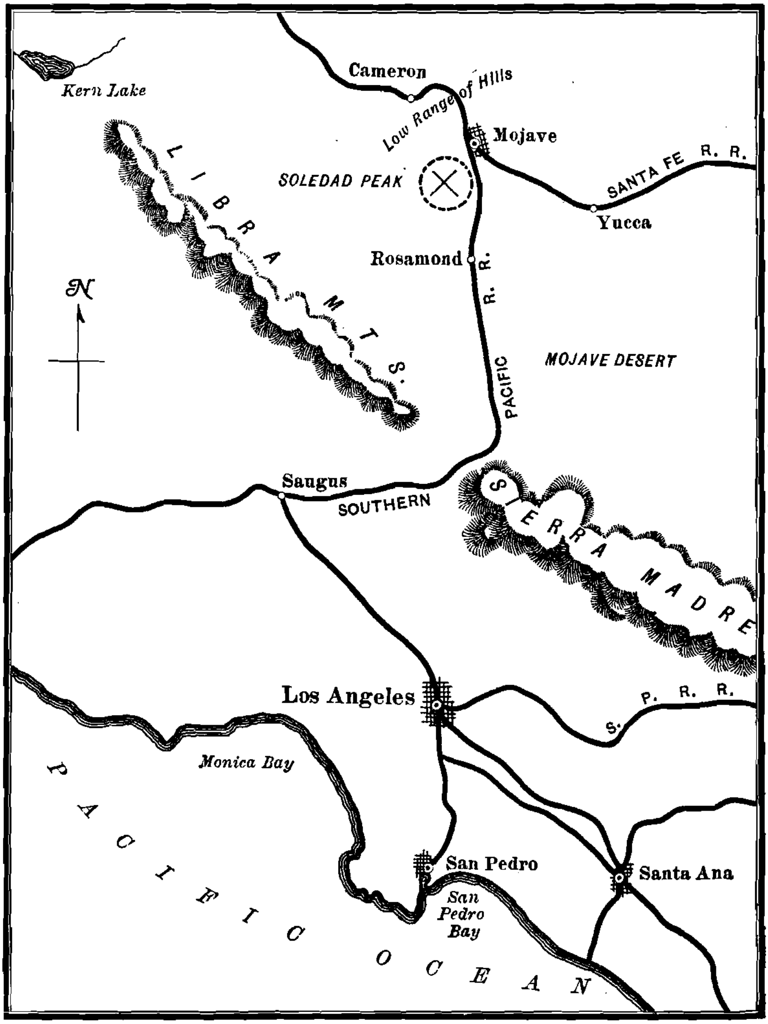

FIG. 1.—SKETCH-MAP OF SOUTHERN PART OF CALIFORNIA, THE CIRCLE SHOWING POSITION OF SOLEDAD PEAK.

III. TOPOGRAPHY.

The topography presents low ranges of hills and isolated peaks of igneous or volcanic origin, which seldom rise more than from 1,500 to 2,000 ft. above the level of the desert. The valleys, which are of much greater area than the hills, are the typical waste-filled interior basins characteristic of the desert.

Earlier in geological history, the valleys were deeper and the hills higher than they are now. The hills and ridges, being of igneous origin, were particularly susceptible to rapid disintegration, because the comparatively great change in temperature between day and night caused appreciable expansion and contraction in the outer crust of the rock, and the unequal rate of expansion and contraction of its constituent minerals produced stresses under which the rock-surface cracked and peeled off. The detritus, before any great amount of it could accumulate, was carried by the heavy rains into the gorges, where the water collected in great volume and swept it out into the valleys. This action exposed a fresh surface of the rock, to undergo the same cycle of disintegration.

The detritus was deposited at the mouth of the gorges as large alluvial fans, which increased in size until they met and merged into one another, forming detrital slopes. These slopes, extending outward and meeting the detrital slopes of adjacent ridges, formed detrital plains, which continued to grow until they completely filled the interior basin, and even overflowed it.

But little material, however, is carried out of these basins unless it be in solution. The water from the gorges soon loses itself in the coarse waste of the fans and plains, and does not reappear again, except, perhaps, when there has been a very heavy or extensive downpour, in which case it issues as innumerable springs at the head of a "crossing," *i.e.*, a gorge that connects one waste-filled valley with another.

The mouth of a crossing is shown in Fig. 2. The little hills, composed of bright red and white sandstone, are local and are sedimentary, while the surrounding hills are igneous. The age of these sediments I could not determine. The crossing is about 3 miles long. Water can be obtained in these crossings, even in the driest seasons, by digging a short distance, sometimes only a few feet; and also, in many cases, by digging at some distance from the mouth of a gorge that comes from the hills, especially if it be a main gorge, having branches and a pretty large steep cone at its mouth.

The porosity of the waste-filled valleys does not allow the water to go far on the surface, so that its burden, as it comes from the hills, is entirely deposited on the alluvial fans. Subsequent rains move this deposit farther and farther out, until the line where two slope-plains meet is encountered, at which place the finer material is worked down towards the mouth of a crossing, so that the waste-filled valleys slope upward in every direction from the head of a crossing. The mouth of a crossing may or may not be one of the highest points in the waste valley into which it disgorges; but the general level of the valley from which it comes is higher than that of the valley into which it runs.

The local topography of the Mojave district shows a mass of eruptive rocks, whose highest and most northerly point, Sole-

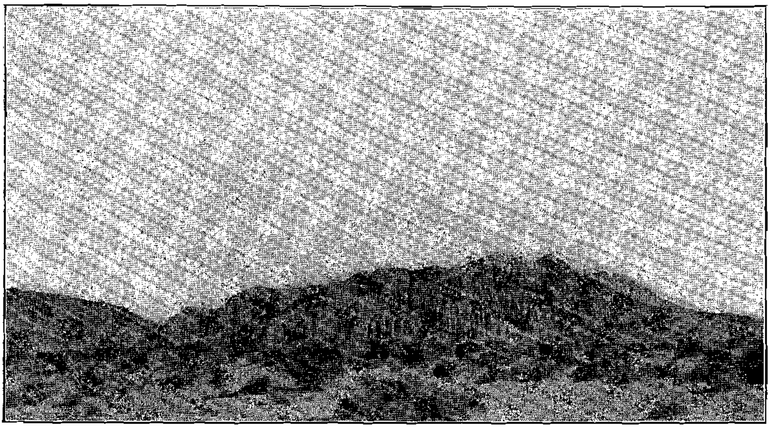

FIG. 2.—MOUTH OF A "CROSSING" IN THE MOJAVE DESERT.

dad peak, is about 4,000 ft. above sea-level and about 1,250 ft. above the general level of the surrounding desert. Mojave and Rosamond stations, on the desert, are 2,751 and 2,315 ft. above sea-level respectively.

A considerable number of much smaller hills are grouped south of Soledad peak, of which the miners consider them to be "spurs."

The map, Fig. 3, shows the generally circular to oval contours of all these hills.

Bowers hill, the only small one with a name, rises about 400 ft. above the desert, about a quarter of a mile northeasterly from Soledad peak, and is less than a mile long.

IV. Rocks.

Five varieties of igneous rock appear in the district.

1. *Granite.*—This is the oldest formation exposed, and prob-

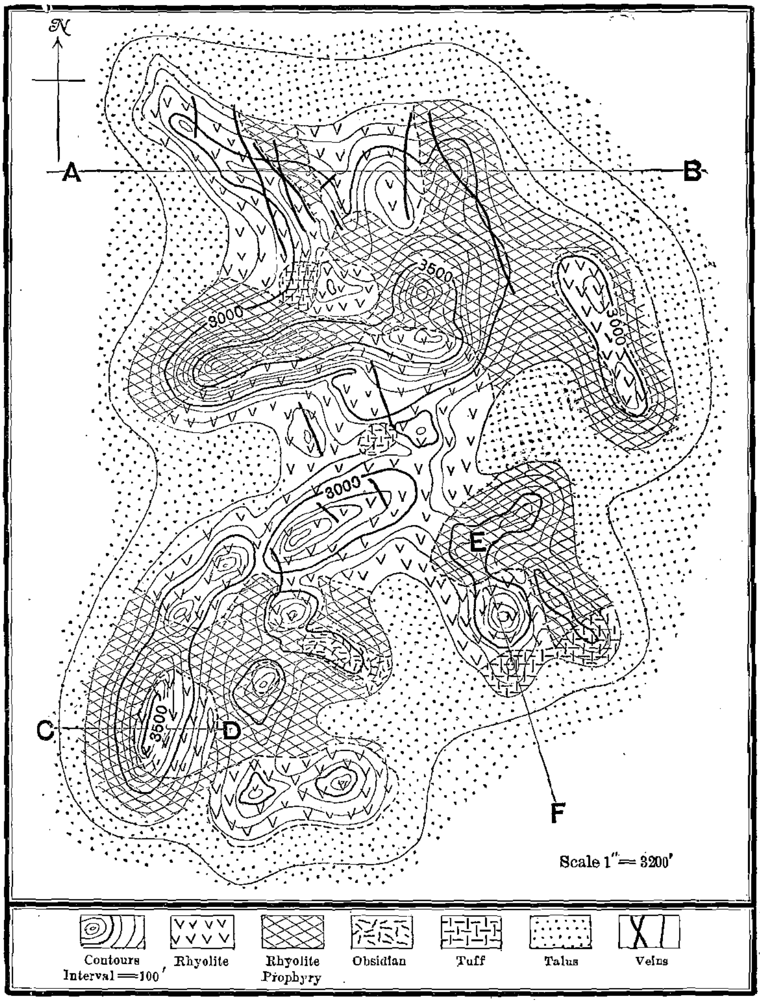

Fig. 3.—Topographical and Geological Map of the Mojave District, Kern County, Cal.

ably underlies the entire district. It shows at the surface along the northeast flank of Bowers hill. It extends to the southwest and does not re-appear in the mineralized zone. It is seen, however, about 5 miles SSW. of Soledad peak, where it underlies some low hills of tuff.

Hand-specimens of this granite show a coarse-grained quartz-orthoclase-albite rock, containing a very small quantity of biotite.

2. *Rhyolite-Porphyry.*—This rock, lying upon and in contact with the granite, has by far the greatest exposure of all the rocks of the district, as shown in Fig. 3, and is the most important by reason of its quantity, and because it is the country-rock of the veins.

Both in hand-specimens and under the microscope, it presents a much decomposed appearance. Quartz, often showing a decidedly hexagonal outline, is the only mineral distinguish-

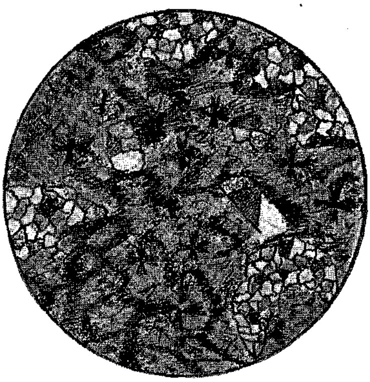

FIG. 4.—RHYOLITE-PORPHYRY GREATLY ALTERED.

able to the naked eye. In hand-specimens the rhyolite-porphyry is nearly or quite white. In thin sections under the microscope the rock is seen to be very extensively altered, as shown in Fig. 4. Because of the complete obliteration of all traces of structure, quartz is the only original mineral recognizable. Quartz occurs, also, in considerable amount as a secondary mineral. Kaolin, showing slightly developed spheroidal structure, is present in large quantity. Secondary calcite is probably present, but in no place is it developed sufficiently to be identified. Neither in hand-specimens nor in thin sections does the rhyolite-porphyry show lines of flow.

3. *Rhyolite.*—This rock, in sheets and patches, overlies the rhyolite-porphyry and forms the summits of many of the hills,

as shown in Fig. 3. A few veins outcrop in the rhyolite, but they have not been developed, even slightly.

In hand-specimens, the rhyolite is dirty brown in color, and greatly resembles devitrified obsidian, having strongly marked flow-lines. In thin sections under the microscope, as shown in

FIG. 5.—RHYOLITE GREATLY ALTERED, SHOWING ORTHOCLASE TWIN CRYSTAL REPLACED BY QUARTZ.

Fig. 5, it is seen to be very much decomposed and similar to the rhyolite-porphyry. Quartz, the only recognizable mineral, is both primary and secondary. In many cases the secondary quartz has replaced feldspar crystals, molecule by molecule;

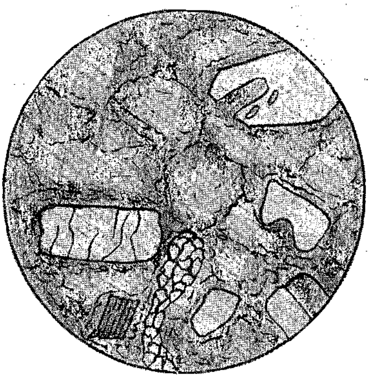

FIG. 6.—RHYOLITE, SHOWING LINES OF FLOW.

and in one case (the crystal near the center of Fig. 5) it has even preserved the orientation of an orthoclase twin crystal. No other mineral is recognizable.

Fig. 6 shows a thin section of a nearly fresh specimen of this rhyolite. In hand-specimens it is almost white, of fine texture, and shows faint flow-lines. In the thin sections it is seen to be a devitrified rhyolite, showing phenocrysts of orthoclase, biotite and quartz. The biotite and orthoclase have no unusual features, and the quartz occurs both primary and secondary. The primary quartz originally had well-marked crystal outlines that later became indistinct in most of the crystals through re-absorption of the silica; while, in others, it remained fairly well preserved. The secondary quartz is in minute, interlocking pieces of no crystal outline and of varying orientation.

4. *Obsidian.*—In hand-specimens, the obsidian is black in color and full of small holes, about an eighth of an inch in diameter. Thin sections are nearly opaque, and show nothing except that it is greatly devitrified. It is probably a more quickly-chilled part of the rhyolite, and not a distinct flow. It occurs only in one place, as a capping to one of the smaller hills, and is underlain by the rhyolite-porphyry described above, and shown in Fig. 3.

5. *Tuff.*—The tuff, composed of volcanic ash, is now so much decomposed that very little can be made of its mineralogical character except that quartz and, at rare intervals, a fragment of feldspar are recognizable. In hand-specimens it generally varies from a dirty white to a pale, greenish color, and appears rather fine-textured for a tuff. It occurs in three small patches, overlying the rhyolite in two cases, while in the the third it seems to overlie a contact between the rhyolite and the rhyolite-porphyry. Its actual contact was not seen on the rhyolite-porphyry, being covered by the talus, although it was seen on the rhyolite. The map, Fig. 3, shows it resting in part on the rhyolite-porphyry, because outcrops of the rhyolite-porphyry came very near it, and there was no intermediate talus of rhyolite. The detritus and waste of the hills are shown in Fig. 3 as surrounding them.

V. Origin of the Rocks.

There are two tenable hypotheses in regard to the relation between the rhyolite-porphyry and the rhyolite.

1. According to the first, the rhyolite is the outside quickly-chilled portion, and the rhyolite-porphyry is the more slowly-cooled portion, of a volcanic outburst.

2. According to the second, there have been several erup-

tions, at least two of which are observable. Of these, the first produced the rhyolite-porphyry (which may or may not have been finer-grained on its surface), and was followed by a period of quiescence, during which considerable erosion took place, and after which the second eruption produced the rhyolite, and, in its expiring stages, the volcanic tuffs.

The evidences to support the first view (that of a single flow) are:—

In several places the rhyolite grades from a rock which resembles the obsidian, shown in Fig. 5, having the same dirty brown color, into a nearly porphyritic rock almost white in color, shown in Fig. 3. Then, after an interval of from 150 to 200 ft. covered by talus, the typical rhyolite-porphyry appears. At no place was I able to find exposed a continuous gradation of one into the other. The mineralogical characters of the rock serve in a way to support this view. Both the typical rhyolite, shown in Fig. 5, and the typical rhyolite-porphyry, shown in Fig. 4, are too greatly decomposed to give clear evidence; and the only satisfactory thin sections, shown in Fig. 6, came from a rock that is almost porphyritic in texture, and is clearly a part of the rhyolite.

In favor of the second hypothesis, namely, that there were two separate and distinct flows, the following facts may be regarded as evidence:—

In one spot, on the Echo claim, a direct contact was found where the rhyolite-porphyry is typically developed, as is also the rhyolite. The rhyolite-porphyry occurs as a small circular outcrop, about 2 ft. in diameter, which is entirely surrounded by a breccia, from 1.5 to 3 in. thick, colored brown and containing a great deal of quartz, followed by the rhyolite. I think that the presence of the breccia precludes the view that this outcrop is a boulder that had become imbedded in the rhyolite. But whether it is a boulder or rock in place is unimportant, since in either case its occurrence shows that the rhyolite-porphyry is older than the rhyolite.

One of the smaller hills was capped with rhyolite in the form of black obsidian, below which all outcrops were concealed by talus until near the base, where rhyolite-porphyry was exposed. These two rocks, the rhyolite and the rhyolite-porphyry, were sharply contrasted and could easily be distinguished. The talus, however, contained only the typical examples of each, there being no transition-forms. From this occurrence the inference was reached that they represented distinct and separate outbreaks.

The dome-like shape of the hills, with the rhyolite as a cap, shown in Fig. 3, seem to indicate that a cone of this harder, more-resistant rock came up through the rhyolite-porphyry in necks and overflowed on the surface, and that these necks have resisted weathering better than the more easily disintegrable rhyolite-porphyry. The mineralogical characteristics of the rocks, however, do not strongly support this hypothesis. Practically all that can be said is that the primary quartz in the rhyolite generally shows considerable re-absorption, while that of the rhyolite-porphyry does not; moreover, the rhyolite shows flow-lines, which are not observed in the rhyolite-porphyry. The mineralogical characters of the rocks would, on either hypothesis, be very similar, since the magmas were in all probability identical, being doubtless derived from the underlying granite. Hence, the relationships in the field are the strongest and most trustworthy evidence, and they indicate, with a high degree of probability, two flows. These relationships are illustrated by Fig. 7.

That the Mojave district is an isolated one, and that the origin of all the desert hills is not the same, or even due to similar causes, is shown by contrasts presented in the Randsburg-Johannesburg area. That district, as already observed, occupies the northern end of a long, low ridge rising from 1,000 to 1,500 ft. above the general level of the surrounding desert. The back-bone of the ridge is diorite, which is flanked on both sides by heavy beds of metamorphosed hornblende schist, dipping in places as much as 45° away from the center or axis of folding.[1]

VI. Veins.

Almost all the veins now known are on the northern flank of Soledad peak, and their strike is generally a little south of west, as is illustrated in Fig. 3. The principal and largest veins are operated by four companies. Beginning at the west, the Echo Mining Co. works the Echo, Grey Eagle and Star-

[1] *13th Report of the State Geologist of California:* Gold—Kern Co. (1895–96).

light veins; about 0.5 mile farther east the Queen Esther Mining Co. works the Queen Esther vein; and next to the Queen Esther is the Karma Mining Co., working the Karma vein.

The Exposed Treasure vein on Bowers hill is worked by the Treasure Mining Co., a New York concern.

The Echo vein has the normal strike and dips to the northeast, as shown by Fig. 7. Its outcrop can be traced for 1,800 ft., and

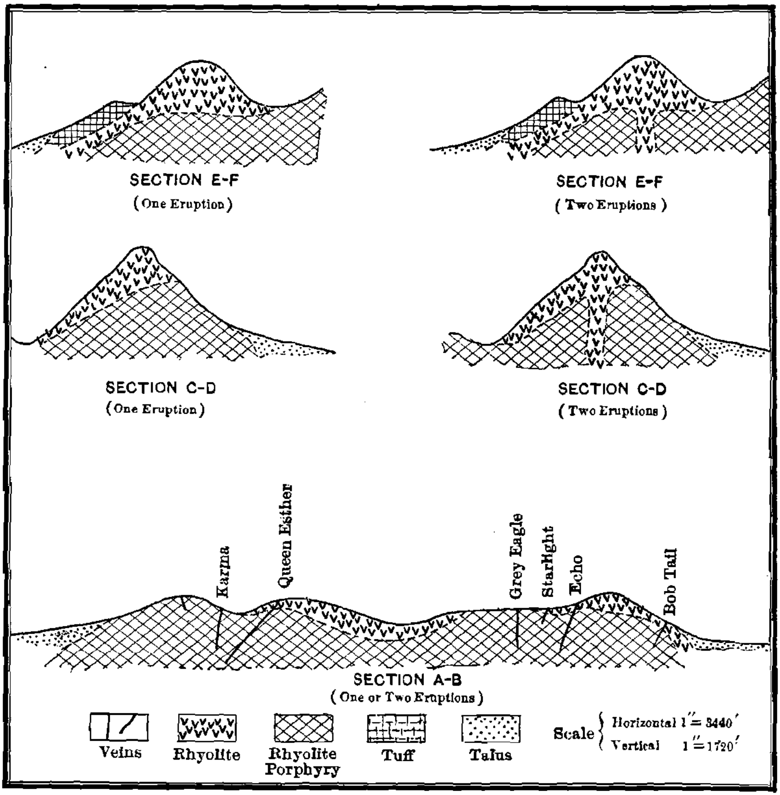

FIG. 7.—SECTIONS OF PORTIONS OF THE MOJAVE DISTRICT, SHOWN IN FIG. 3, ILLUSTRATING THE PROBABLE RELATIONSHIPS.

throughout its entire length a rather constant width of about 3 ft. is preserved. This general width also persists in depth as far as the vein is known—something over 200 feet. The gangue, or vein-filling, is quartz of the variety generally known as "sugary." In general, the line of demarcation between the quartz-filling and the country-rock is sharp, although in places the walls seem to be much shattered for a few feet on each side of the vein, the quartz having filled any spaces and cracks that were formed. No gouge-seams, slickensides or other evidences of extensive movement after the quartz-filling had been introduced were observed. In places next to the country-rock, and even in the quartz itself, patches of kaolin are found. The wall-rock is silicified rhyolite-porphyry, which is very hard, and difficult to mine. The values are in gold and silver. The gold occurs free in very minute scales associated with pyrite. Along the outcrop and near the surface the gold is almost all free. The silver occurs as horn silver (cerargyrite) in small specks along and near the outcrop, changing to argentite in depth. The entire vein is mineralized to some extent. The workable portions, however, occur in irregular bunches, which may have considerable dimensions, both in length and depth; that is, from 100 to 200 feet.

The Starlight vein, distant about 300 ft. east of the Echo, is parallel to it in strike, and dips to the northeast. Its outcrop cannot be traced for the entire distance. Its average width is about 3 feet. The vein-filling, the relationship between the vein and the wall-rock and the mineralization, are the same as in the Echo. The major part of the value is in silver.

The Grey Eagle vein commences near the northern end of the Starlight and diverges from it in a southerly direction, until about 100 ft. or more from it, and then turns parallel to it. In general the dip is 90°, from which, however, it varies, sometimes to one side and sometimes to the other. The vein connects with the Starlight at increasing depths towards the south. Its average width is a little less than 3 feet. The vein-filling, and the relationship of vein to the wall-rock and the mineralization, are the same as the Echo and Starlight, except that the gold-value is greater than that of the silver. At the one place developed, where the two veins join, shown in Fig. 8, considerable kaolin occurs, and the values are not so high as on either side of the connection. The quartz-filling, however, shows no discontinuity in passing from above the connection to below it.

The mine-management believes that the Grey Eagle crosses the Starlight vein, basing the belief on a small length of outcrop found to the west of the Starlight vein, having a strike nearly the same as that of the Starlight vein, and being in a general line with that part of the Grey Eagle vein which joins

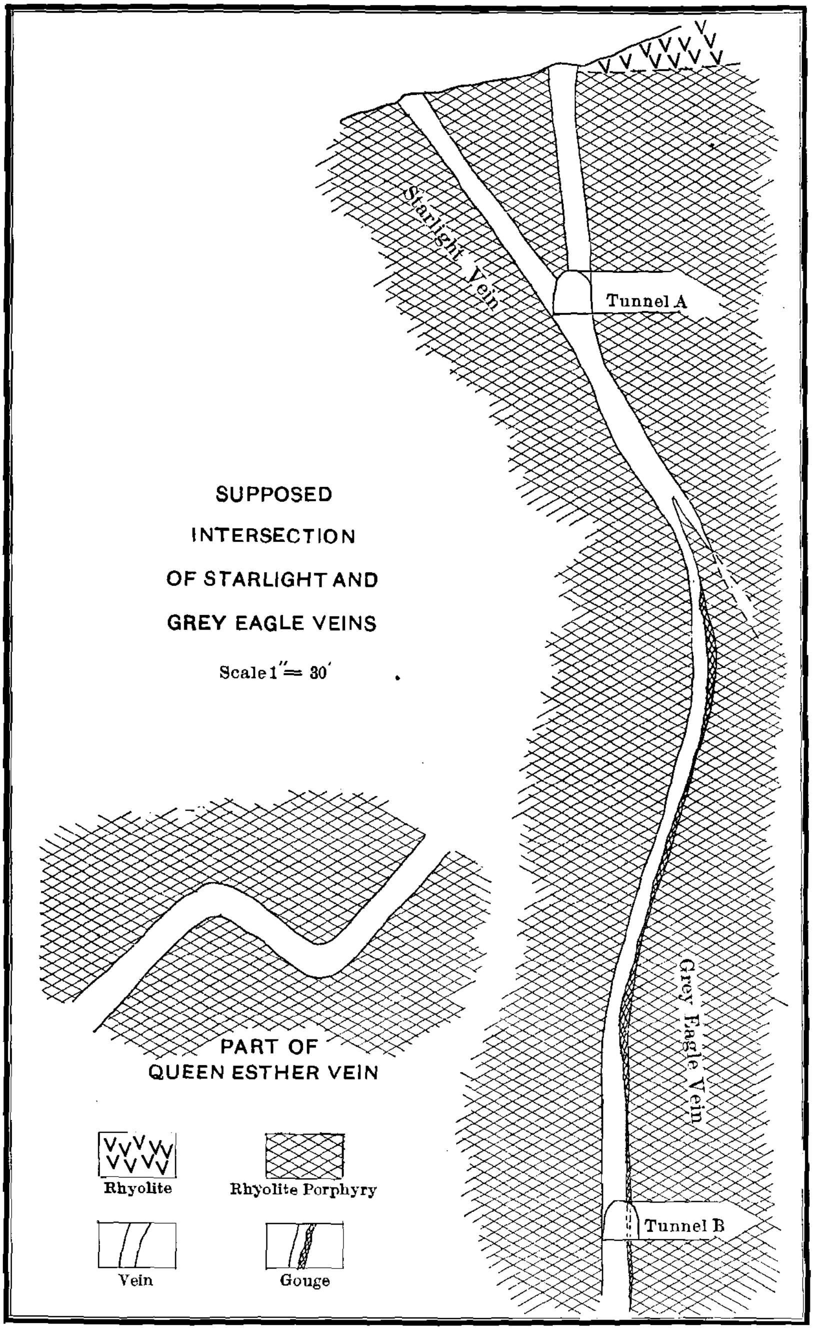

FIG. 8.—SECTIONS OF STARLIGHT, GREY EAGLE AND QUEEN ESTHER VEINS.

on the outcrop. It is believed that the Starlight has faulted the Grey Eagle.

The Queen Esther vein runs more nearly north and south than any of the others. It dips about 60° to the east. The vein-filling is sugary quartz. The country-rock is greatly decomposed rhyolite-porphyry. The mineralization is similar to the Echo. The width of this vein is generally from 5 to 6 ft., but it varies a great deal, in some places being nearly 12 ft., while in others it is only about 3 feet. A remarkable feature of this vein is the rolls that it takes as it gains in depth. This is shown in Fig. 8. At the present stage of development three of these rolls or folds are known. The first one encountered in depth is the smallest, and the third the largest. They dip along the vein about 10° to the north. The largest one displaces the vein 30 ft. horizontally and 10 ft. vertically.

The Karma vein, dipping about 85° to the east, has the prevailing strike of a little south of west. Its outcrop can be traced continuously for about 1,000 feet. It varies in width from 2 to 5 ft., although, in places, the mineralized zone reaches considerable width. In the case of the "glory hole," it is about 40 ft. to the vein-stuff, which fills cracks and fissures extending into the country-rock on both sides of the vein proper. At one place on the outcrop, about 200 ft. in length, this vein, together with the numerous small branches it there possesses, reaches a width of between 60 and 80 ft., but it is reported not to be well-mineralized at this point.

The gangue is sugary quartz, and the mineralization is the same as that described above. Bromyrite was reported to have been abundant in one of the stopes, now worked out. A small piece of quartz, still adhering to one of the walls, was obtained, showing small specks of the reported bromyrite. On careful investigation (the specimen was so small that entirely satisfactory results were impossible) the green specks were found to be in all probability copper stains, and not bromyrite at all. The character of this mineral as determined are:—color, dark green; luster, dull; hardness, from 4 to 5; opaque, even under the microscope. Very rich ore was obtained from this stope. The country-rock of this vein is rhyolite-porphyry.

The Exposed Treasure vein is on Bowers hill. I did not examine this vein, but from hearsay I present the following:—

The vein maintains the usual strike of all the veins of the district, but departs from the rule by dipping to the west. The wall-rock for a distance is rhyolite-porphyry, and then the vein follows the contact between the granite and the rhyolite-porphyry. The mineralization follows the general rule, and the pay ore is very rich but extremely irregular.

A small vein on the southwestern flank of Soledad peak, thought in all probability to be an extension of the Starlight (see Fig. 3), is interesting, because its wall-rock (see Fig. 9) shows a double brecciation. It also shows pyrite in the cementing material of the second brecciation. The first cementing material was mainly kaolin, with some secondary quartz. The

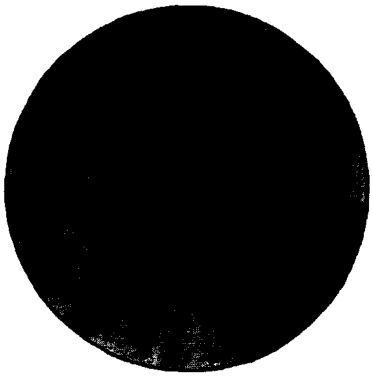

FIG. 9.—SECTION OF WALL-ROCK OF VEIN ON SOLEDAD PEAK, THOUGHT TO BE A CONTINUATION OF THE STARLIGHT VEIN.

second cement comprised secondary quartz and considerable kaolin, in places with pyrite, which carries considerable gold.

Whatever the history of the volcanic action may have been, it is quite evident that the veins were not formed until all volcanic action was over.

Almost all the known veins are on the northern flank of the group of hills, and these are easily divisible into two main groups:—one, the Echo group, to the west; and the other, the Queen Esther-Karma group, to the east. The Exposed Treasure and others, perhaps not yet found, make a third but less important group on Bowers hill. The general course of all these veins is a little west of north.

Both of the first two groups seem to have a focus where all of the veins in each group will meet, provided they preserve their present dip. In the Echo group, this focus is about 700 ft. below the general level of the desert, and in the Queen Esther-Karma group it is from 400 to 500 feet..

All these veins are typical quartz-veins, containing quartz and minerals derived from the decomposition or alteration of the country-rock, and deposited in fissures, caused by contraction on cooling; in this case the cooling has been from fusion. In some of the veins the brecciation of the wall-rock is clearly observable, and in one case a double breccia—a brecciated breccia—is shown.

In the Queen Esther vein rather remarkable rolls are found, which were not caused by any cross-fissures or faults, so far as could be observed, but were probably due to the original fissuring of the rock-mass by cooling, which has since remained undisturbed; that is, no vertical movement of the walls has taken place.

From the above description it appears that the fissures were originally formed by cooling, followed, in some cases, by slight movements of the rocks which caused the production of breccia by the attrition of the walls over each other. This result has happened, in one observed case, at least twice. In other cases there was no movement whatever, and in no case observed did the movement amount to more than a few inches. Accurate observation concerning the amount of movement in volcanic rocks, especially if they have been badly altered by decomposition, is extremely difficult, if not impossible.

A movement of only a few inches, or at most a few feet, is inferred here because there has clearly been no movement in some of the veins; and while there is brecciation of the walls in other veins, there is not enough variation in the width of any one of them to indicate extensive movement.

The quartz-filling of the veins and the silicification of the walls certainly did not take place until all movement had ceased, and since then there has been little or no movement, so far as has yet been observed.

In one or two veins there is a little gouge occuring irregularly on one or the other of the walls, which indicate some slight movement of that wall. This gouge is nearly pure kaolin, and in no observed locality did it cross the vein of quartz to the other wall; moreover, it was not great in amount; hence, at best, the movement was only a slight one. The Starlight-Grey Eagle junction may or may not be a cross-fissure. If it is, the fissuring was previous to the filling of the vein. The values are gold and silver. The gold occurs native in minute specks, and to a small extent in pyrite. The silver occurs mainly as a black sulphide, argentite, with cerargyrite in small grains sparingly disseminated in places near the outcrops. The values are not at all regularly distributed, but occur in irregular patches of no definite outline, and which vary in size up to a few hundred feet along the vein to a hundred or more in depth. The width of the veins varies from a few feet up to 12 feet. Mineralized zones occur, however, of much greater width.

VII. Summary.

The Mojave district is of volcanic origin, and has been formed by two eruptions, the first of quartz-porphyry and the second of rhyolite. The underlying country-rock is granite. After all volcanic action had ceased, fissuring took place, followed by deposition, from a rising solution, of the quartz with the gold- and silver-minerals, thus forming the veins.

The eruptives are very greatly altered, so much so that, with few exceptions, their original minerals are changed beyond recognition. The general form of alteration—the original minerals being quartz, orthoclase, some other feldspar, probably albite and biotite, with pyrite and perhaps some other minerals as accessories—is that which is typical of the belt of weathering in arid regions; namely:—

1. The feldspar was altered to kaolin and quartz, with the loss of potassium, calcium or sodium, as the case may be.

2. The original quartz remained as such.

3. The biotite was altered to kaolin with the probable formation of serpentine and gibbsite, although no gibbsite was observed.

4. The pyrite, gold- and silver-minerals went through the orthodox cycle of changes. The values in the early history of the veins probably were very evenly distributed.

Since the formation of the veins, however, considerable erosion has taken place, with the consequent lowering of the outcrop and also of the water-level. Secondary enrichment has taken place in portions of the vein by the well-known phenomena of downward concentration, caused by the leaching of the values from the upper portion of the vein, and their deposition at a lower level, at or near the ground-water level.

No mine, with the possible exception of the one on Bowers hill, has reached the ground-water level; hence, nothing can be said of the veins below that level, or of the further distance necessary to sink in order to reach it.

There is no reason why the mineralization of the veins should not continue into the granite, since in this district the wall-rocks, being of a like, if not identical, chemical composition, and varying only in the degree of their crystallization, possession or non-possession of flow-lines, etc., can have had no differential effects on the deposition of the ores in different parts of the vein. The portions enriched by downward concentration, which, at present, form the pay-portions of the veins, can certainly be expected to end when the ground-water level is reached. Whether it will pay to work the veins below that level—at present unknown—is a problem which can be solved only by actual trial.