NOTES ON THE GEOLOGY OF A PORTION OF THE CALICO MOUNTAINS, SAN BERNARDINO COUNTY, CALIFORNIA

By Homer D. Erwin * and Dion L. Gardner **

OUTLINE OF REPORT

ABSTRACT

The Calico Mining district, famous for its production of silver during the years 1883-1895, is located in the Calico Mountains. The rocks which compose these mountains are essentially middle Tertiary volcanics and lake-bed deposits (which may possibly be correlated with the Rosamond formation), a late Tertiary lava capping, and Quaternary gravels. Normal faulting outlines the mountains. A most interesting structural feature is a thrust fault of unknown displacement—readily traceable for about 5 miles along the lower front of the range. Veins, which occur in the central volcanic mass and lake beds, trend generally northwest. The dips are vertical to steeply southwest. Ore in the district consists of chlorides and chloro-bromides of silver in a gangue of barite and jaspery silica with coatings of cerargyrite and embolite. Galena and sphalerite also occur with minor amounts of chalcopyrite. Iron oxide, chrysocolla, and pyrolusite are essential supergene minerals. Part of the chlorides and chloro-bromides may be supergene, although the bulk of the ore is thought to have been deposited by ascending thermal (hypogene) waters near the surface.

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INTRODUCTION

Location and Accessibility

The Calico Mountains are situated north of the town of Yermo on Highway 91 in San Bernardino County, California. The range is readily accessible by auto over several roads maintained by the county. These parallel the mountain front and penetrate into Odessa, Mule, and Sunrise Canyons, the town of Calico, and mines to the west. The average elevation at the base of the range is about 2,000 ft., and Calico Peak, the highest point in the mountains, is over 5,000 ft. in elevation.

Purpose of the Work and Acknowledgments

Work was initiated to furnish a geologic reconnaissance of a region formerly important for mining. A detailed investigation was not attempted, for limited time and the lack of a good base map made this impossible. Despite the economic importance of the region—the Calico Mining district has produced over $20,000,000—there is no adequate topographic map of the Calico Mountains; so Public Land Survey Maps, supplemented by Mineral Land Survey Maps, were used. It is regrettable that no aerial mozaic was available, for the distinctive color differences in rock units and the excellent exposures make the area especially worthy of study.

Thanks are extended to Marsman and Company of California who aided the project; to Dr. Olaf P. Jenkins and Mr. W. B. Tucker of the California State Division of Mines for valuable assistance; to Mr. Granville Moore and Mr. C. D. Hill of the Burcham mine; to Mr. Jack Moore of the Union mine, and Mr. Jack Coke of Calico, who aided the project in various ways; and to Mr. Thomas Williams and Mr. McCormick of Yermo, who assisted in finding some of the necessary section corners. A geologic map of a portion of the Burcham mining property, prepared by Dr. C. D. Hulin, was very helpful; thanks are extended to the owners of the Burcham mine for permission to incorporate a few general features from this map.

The present field map and report are based on 15 days of field and office work by Mr. Erwin, and 10 days by Mr. Gardner.

Previous Investigations and Reports

To date little original work has been done in the Calico Mountain region in the way of accurate geologic mapping, apparently because no good base map is available. A few local and private investigations of the various mineral areas have been made. Papers of special interest are listed below:

MINING AND SCIENTIFIC PRESS
Calico district: M Sc Press 50:173, 180 (1885)

LINDGREN, WALDEMAR
The silver mines of Calico, California. Am I M Eng, Tr 15:717-734 (1887)

STORMS, W. H.
The mines of the Calico district (San Bernardino County, California). Eng M J 49:382-383 (1890)
The Calico mining district. Cal St M Bur, St Mineralogist's Rp 11:337-349 (1892)

PALMER, L. A.
The Calico district, California. M Sc Press 116:755-758 (1918)

FOSHAG, W. F.
Calico Hills (San Bernardino County, California). Am Mineralogist 7:208-209 (1922)

WEEKS, F. B.
Possibilities of the Calico district (San Bernardino, California). Eng M J 119:757-763 (1925)

UNDIFFERENTIATED TERTIARY VOLCANICS

Tuff Series

These rocks comprise the main portion of a prominent volcanic series in the southern and western Calico Mountains. They are massive, heavy to medium-bedded tuffs showing red, brown, and gray colors, and forming a step-like structure in the higher fronts of the range. Their strike ranges from northwest to north-northwest, their dip from 10° to 40° southwest.

A typical section through the series in the western Calico Mountains is as follows:

(1) Light yellow-gray mineral-fragment, medium to fine-bedded tuff of probable rhyolitic composition. This rock and material closely resembling it form the bulk of the tuff series. The type rock is composed of a yellow to gray-colored, fine matrix cementing material and small rock fragments. Distinct rounding of fragments suggests a water-laid origin.

(2) Red-brown fragmental tuff of probable andesitic composition. This rock is next in abundance to the lighter-colored tuffs of the series. It is generally of pronounced clastic character and is composed of rock fragments of pre-existent tuffs and lavas cemented by a matrix of fine reddish, clastic material. A portion of this series is also composed of basic lava flows.

(3) Purplish-red, medium-fine, water-laid sandstone, tuff, and associated lava. The latter two are probably andesitic in composition.

(4) Yellow-green, medium-coarse water-laid tuff, similar in composition and texture to (1).

(5) Light-pink to brown, medium-coarse tuff and agglomerate, both of probable andesitic composition.

(6) Dark-gray to light-colored fragmental tuff of probable rhyolitic to near-andesitic composition. This member varies considerably in appearance, but generally is made up of coarse clastic rock containing various lava and tuff fragments up to a foot or more in diameter imbedded in a fine to medium-fine tuffaceous matrix. A variable texture results in a pronounced cavernous appearance.

Yellow Tuff Breccia

Interbedded with the tuffaceous series on the southwest front of the Calico Mountains is a particularly interesting body of rock, worthy of special note. Along a portion of its southern contact with the lake-bed series, the megascopic 'porphyritic' and massive appearance of the rock suggested, at first inspection, an eruptive invading the sediments. However, as more of the contact was mapped, it became apparent that the rock was probably of noneruptive origin. Underground workings show that the texture is profoundly clastic. The mass consists of a medium to coarse breccia of tuff fragments in a matrix of finer material. The entire body is believed to be of rhyolitic or near rhyolitic composition, and has a yellowish to cream-gray field appearance. From a distance, rude heavy bedding is evident which further suggests a sedimentary origin.

Granite Breccia

Of special interest in the tuff series, also, is a unique granite breccia. It lies in the NW¼ Sec. 16, T. 10 N., R. 1 E., S. B., and forms an elongated body approximately one-half mile in length that trends N. 50° W. At first, this mass of rock appears to intrude the surrounding volcanic tuff. Though it is faulted along at least a part of the

contacts of the two longer dimensions, its intrusive nature is suggested by penetrating tongues and embayed contacts along the remainder of the contacts. There is no sign of alteration of invaded rocks. The outcrop has a massive appearance and shows no sign of stratification.

The mass is a pronounced breccia, the fragments of which possess a granitic texture. They are intimately included in a fine-grained, dense, red aphanitic igneous matrix of shallow intrusive origin. In a few instances resorption of granitic fragments was observed.

The included granitic fragments caught in the throat breccia of a central volcanic vent, consist of three types supposedly derived from the bedrock complex. The most striking, often found in masses five feet in diameter, is a coarse, equigranular granitic rock consisting of feldspar, quartz, and abundant biotite. The second type forms smaller blocks and is finer grained but similar to the first in texture and mineral constitutents. The third and most abundant rock fragment, usually less than four inches in diameter, is a fine- to medium-grained granitic type consisting of quartz and biotite with feldspar. In addition to the granitic fragments, a dark-green distinctly porphyritic rock also occurs as fragmentary material in the breccia.

In addition to the above variegated assemblage the tuff series includes a pure limestone member at one locality to the west.

Although the original thickness of the tuff series is not known, it was presumably between 1,500 ft. and 2,000 ft. Some of the material has been removed by erosion.

The members of this series are lake and continental (fluviatile) deposits resulting from a violent and prolonged period of volcanic explosive activity near large inland bodies of water. These, as well as the lava-agglomerate series described below, are pre-lake-bed sediments which are tentatively classified as Rosamond (?) or upper Miocene. The volcanics are possibly lower Miocene in age.

Lava Agglomerate Series

The lava agglomerate series of undifferentiated Tertiary volcanic rocks forms a large part of the total assemblage, and lies largely in the south-central portion of the Calico Mountains with the later tuff and sedimentary series areally surrounding it in all the areas observed. This series has been referred to variously as 'liparite' or 'rhyolite' and forms the dominant core of older rocks in the vicinity of the richest mines of past years.

This series consists of red-brown to chocolate-brown lava flows and agglomeratic beds with included areas of greenish rock which have resulted from hydrothermal alteration of the lavas. The members dip at moderate angles in various directions of the compass, as a result of faulting in the originally moderately dipping formations.

A typical and abundant rock of the series is a dominantly red and red-brown, with grayish phases, medium-porphyritic andesite. Phenocrysts of feldspar (chiefly plagioclase), round, partially resorbed quartz, and sparse biotite can be seen in the hand specimen. The groundmass is dense, fine-grained aphanitic, and exhibits no particular megascopic structure. Alteration phases are typically propylitic with prominent development of green-colored rocks showing distinct

relic porphyritic appearance. This alteration is due principally to mineral decomposition by the vein and early metalizing solutions which rose along pre-existent fractures in the rocks, but antedated most of the ore mineralization. Flow banding is occasionally prominent in the unaltered rock areas, but flow lines are sparsely developed. In cross-joints in the lavas, calcite, jasper, and barite mineralization carries some metallic minerals in narrow veins, but these are of little economic value.

Another rock of the red series is light purple in color and distinctly vesicular. It exhibits a sparsely, medium-fine porphyritic texture with phenocrysts of plagioclase, biotite, and quartz in a groundmass of aphanitic material containing fine feldspar microlites and glass. This rock is probably a dacite. One flow is from 50 to 100 ft. thick, and is immediately overlain by the tuff-breccia on the southwest slope of Wall Street Canyon.

Besides the predominant lava flows, the series consists in its upper portion of 500 ft., more or less, of largely sedimentary beds—fine to medium-grained reddish sandstones, dark-red to brown fragmental tuffs, coarse red agglomeratic and conglomeratic members and reworked detrital gravels which were originally derived from the higher portions of the earlier lava series. These gravels are the youngest of the lava series and lie conformably under the lake-bed series. In Wall Street Canyon, immediately west of Calico, the following rock types are found in the upper lava agglomerate series between the lower tuff member of the lake beds to the south, and the green alterations of lava to the north.

(1) 160 ft. of yellowish-gray, well indurated, fine-textured tuff containing scattered fragments of rock up to several inches in diameter.

(2) 50 ft. of dark-gray, coarse fragmental tuff.

(3) 75 ft. of light greenish-yellow medium-coarse fragmental tuff.

(4) 70 ft. of chocolate-brown medium to medium-heavy-bedded fragmental tuff and agglomerates. These are probably andesitic in composition and include the red gravels above mentioned as derived from the higher masses of pre-existent lava and agglomerates.

The total thickness of the lava series is between 1,500 and 2,000 ft. which, no doubt, is something less than the original accumulation.

The lava series was thought to have been deposited more or less contemporaneously with the tuff series, but in some localities, as on the southwest wall of Wall Street Canyon, the tuff (breccia) seems to overlie the red lavas. In the Newberry and Ord Mountains to the south of Calico Mountains Gardner * found a series of undifferentiated Tertiary tuff, lava, and agglomerate which he regarded as lower Miocene. The Calico Mountains assemblage of lava and tuff seems to correlate with this series.

POST-VOLCANIC SEDIMENTARY SERIES

Lying more or less conformably on top of the volcanic mass of rock are sedimentary lake beds and associated tuffs and flows, which form a most important unit of the stratigraphic column. These beds extend continuously along the lower front of the range to the west, south, and east in the areas mapped.

* *See* accompanying report by D. L. Gardner, Geology of the Newberry and Ord Mountains, San Bernardino County, California.

In appearance the sedimentary beds are light gray to green and brown in color, fine to medium heavy-bedded, water-laid arkosic sandstones, thin-parted argillaceous rocks and tuffs. Thin to medium-bedded limy shales and calcareous sandstones are not uncommon, being more prominent near the base of the series. The attitudes of these rocks are quite variable due to crumpling, folding and faulting. Folding in the beds seems sharpest near the valley fill in the vicinity of the thrust, becoming more moderate (25° to 40° to the south) northward. Synclinal and anticlinal structures were locally observed.

Near the base, and apparently interbedded with the sedimentary series, are two igneous rocks. One is dark-green in color on fresh fracture and yellow-green on altered surfaces. This rock is distinctly porphyritic, containing plagioclase phenocrysts, dark-green hornblende, and scattered biotite set in a dense aphanitic matrix—probably a hornblende andesite.

The second igneous rock is reddish-purple in color and shows definite phenocrysts of plagioclase and needles of brown hornblende in a fine-grained pink aphanitic groundmass. Minor flow banding is present. East of Mule Canyon, this rock occurs in association with the green porphyry. An intrusive relation is believed to exist between the two, the pink porphyry being the invading rock. This is further substantiated by alteration due to pneumatolysis along contacts, which gives pink, orange, and yellow alteration patches in the rocks, which are evident when the range is observed from the valley.

In close association with the sediments of the lower volcanic part of the sedimentary series are several members of hard, banded, gray, green, blue, and brown cherts. These occupy the lower frontal slopes and ridges of the hills to the west and northwest in the regions observed. They possibly were derived from the action of siliceous volcanic springs that fed inland bodies of water for a long period of time. Stratigraphically, they appear low in the lake-bed series. However, only fault contacts were observed, and determination of their true relationship to the rest of the series requires a more detailed study.

The total thickness of the lake beds is not known, for they dip or are faulted under the valley fill, and where they are exposed, are often repeated, at least in part. The thickness probably ranges upward from a minimum of 1,000 ft.

At the top of the sedimentary series, immediately below the overlying volcanics, a yellow-gray, water-laid, medium- to fine-bedded, soft tuff occurs. This varies in thickness from 500 ft. towards the west to 300 ft. to the south. The thickness to the southeast and east is not known, but is believed to be greater than elsewhere.

The various beds appear to have been deposited in a large inland body of water which received a continuous supply of tuffaceous and terrigenous material.

The sedimentary series is younger than the tuff-lava agglomerate series, and may be roughly comparable to the Rosamond series, which it lithologically resembles in many respects. Pending further study and possible discovery of fossil remains in the beds, no further discussion on this point can be made.

RED MOUNTAIN ANDESITE (?)

This rock occurs as a distinct capping above all pre-existent volcanic and sedimentary formations, in the southeastern portion of the Calico Mountains in the area surveyed.

It is a dark-brown rock which lies more or less horizontally or at low dips on the eroded surface of sediments and associated lavas. A fresh surface of this rock reveals a dark-brown to reddish-brown distinctly porphyritic texture of apparently andesitic composition. Feldspar phenocrysts up to a quarter of an inch in length occur in a dense, reddish, aphanitic groundmass.

Although this rock is largely a capping, at one locality in the extreme southeast part of the mountains, steeply dipping contacts suggest an intrusive mass. It is possible that this locality may represent the site of the volcanic throat and source of part of the cap rock. Associated agglomerate masses tend to confirm this interpretation. Elsewhere the flows lie on top of the eroded surface of the volcanic and sedimentary series, and upon the gravels derived from erosion of these formations.

The total exposed thickness of this unit is between 500 ft. and 700 ft., though this is, no doubt, only a part of the original accumulation.

In age, this lava is post-sedimentary, and on the basis of correlation with other areas is tentatively classified as lower Pliocene.*

QUATERNARY GRAVELS

Following the uplift of the range, the various units were attacked by the forces of desert erosion with consequent development of gravels in canyons and alluvial fan deposits extending out from all mountain fronts. Considering the amount of dissection, there is not a great deal of detrital material visible, indicating fairly recent movement along the frontal fault zones.

In common with adjoining mountain ranges, high dissected gravels with banks ranging from 10 ft. to 30 ft. in height are found in the canyons. These are indicative of a slightly older period of erosion and deposition.

GEOLOGIC STRUCTURE

As indicated on the diagrammatic cross section, a granitic basement complex is believed to underlie the range, buried beneath the massive red andesite flows, agglomerates, tuffs, and lake-bed series. Both volcanics and lake beds are broken by faults of two distinct types—normal frontal faults, and a thrust—which trend in a general northwest direction, paralleling each other. Tear faults with a northerly trend occur in close relation to the thrust along the lower front of the range, breaking it into several units. Vein fissures and faults of lesser displacement, parallel the thrust with reverse dip, and seem to be due to relaxation adjustments in the upper thrust block. These appear to die out at shallow depth and probably do not continue below the thrust, although this is problematical, as no extensive mine development has been done below the thrust plane. It is evident that the

* Hulin, C. D. Geology and ore deposits of the Randsburg quadrangle, California. Cal St M Bur, B 95, pp. 55-58 (1925)
Gardner, D. L., *op. cit.*

mountains were subjected to compressive stresses acting nearly horizontally. The fact that the lake beds are intensely folded, crumpled, and overturned, while the volcanic series to the north is not folded but broken, might suggest that the active forces of folding and thrusting were from the southwest. In this case, the movement would be underthrusting, with the southern block shoved under the northern. However, the fractured nature of the north block, considered in conjunction with the massive character of the andesite flows and the localization of intensely crumpled lake beds immediately along the thrust, suggests that the northern block was the active unit. Prior to thrusting, the lake bed series were folded and locally intensely crumpled and overturned. At one locality, a syncline developed along the southwestern front was broken by an axial thrust. Tear and relaxation faults developed in the thrust block, and were followed by mineralization. It appears that the mineralized fractures were stronger in the massive lava series and were dissipated in the overlying lake beds.

Long after the period of thrusting and mineralization, the present mountain range was outlined by normal and relatively recent faults. These strike more or less northwest in the areas observed, dip from vertical to 70° southwest, and drop all formations found in the mountains below the valley fill. None of the front faults are simple planes of rupture, but are separating, diverging, and rejoining splits and branches with differing amounts of displacement, evident principally because of topographic changes in the landscape. The frontal faults are paralleled, within the range, by other normal faults which further break the mountain mass into separate topographic units.

ECONOMIC GEOLOGY

Little published information on the Calico district is available, and all unpublished material is of confidential character. Consequently, it is difficult in a reconnaissance survey to form an adequate opinion regarding the ore, its origin and mode of occurrence. However, an attempt will be made to summarize pre-existing data and to present a brief but concise outline of the ore deposits.

As stated before, the general geology in the vicinity of the Calico mines is relatively simple. Basal andesite flows (?) variously termed 'rhyolite' and 'liparite' and recognized as both intrusive and extrusive by earlier workers, are overlain by 500± ft. of tuff, breccia, and sedimentary material. The lake-bed series rests on the earlier volcanic series, generally conformably, but with some local unconformity. Complex faulting, involving thrusting, and later normal faulting are in evidence along the southern front of the range. Veins are assumed to have originated as a result of continued normal tensional movements. Ore-shoots, locally rich in silver with very minor base metal and gold, are distributed in the upper portion of the veins. These were richest, so far as known, in fractures in the overriding thrust block in the vicinity of Calico. Sporadic mineralization is evident throughout the central mass of the Calico Mountains, decreasing in intensity and value farther to the northwest and southeast.

The mineral deposits of the Calico Mountains mining districts * can be classified roughly into two groups:

(1) The deposits lying in or closely associated with prominent fault fissures and wall fractures in the red lava-agglomerate, tuff, and lake bed series.

(2) Irregular and pockety shallow deposits in the tuff and lava series throughout the region.

Calico Mining Area

Silver King and Oriental Vein System. This system includes the past most important productive mines of the region. It consists of a series of prominent veins branching to the north and converging in a mass of crushed and mineralized rock towards the southeast. The veins are traceable for over two miles on the surface. The strike is northwest, and the dip vertical to 50° to the southwest (average about 70° southwest). Ores of silver chloride and chloro-bromides occur more or less regularly as fracture filling in a gangue of barite and jaspery silica. Manganese (pyrolusite) is common; finely distributed rich sulfides are sparingly present. Cerargyrite and embolite occur as thin coatings in joints and other fractures. The wall rock is a dark-brown to red lava of the lava agglomerate series. The fissures are a result of normal fault movements; the footwalls are to the north. Width varies from 2 in. to 2 ft., the average being about 8 in. Ore was exceedingly rich near the surface, but grew poorer with depth.

Intensive faulting and crushing occurs at the site of the old Red Cloud and Red Jacket mines. Here, barite and jaspery silica form a stockwork of small random veins in a zone up to 30 ft. wide. Ore is impregnated through the brecciated rock. All workings in this vein system are abandoned at present except for leasing on a small scale.

Calico-Odessa Mining Area

Bismark and Humbug Mines (Idle). The Bismark mine is on the divide between Bismark and Wall Street Canyons. Ore occurs in a prominent fissure of large throw, traceable for about a mile. Strike is N. 17° W., and dip 30° southwest. The ore is cerargyrite with a little chrysocolla in a gangue dominantly barite. The productive vein was 8 in. (maximum) and very rich near the surface. In depth it continues, but economic mineralization does not.

At the old Humbug mine east of the Bismark mine, there is strong mineralization in the lake-bed series, with impregnations of rich silver minerals. Ore-filled cross-joints and cracks are present in soft sediments, with secondary silver hydroxide and iron oxide. Mining was by the open-pit method.

Garfield Mining Group (Idle). This group lies on the divide between Garfield and Bismark Canyons, in a dense red volcanic rock.

At the old Garfield mine about 1½ miles northeast of Calico, the vein strikes west-northwest and dips about 80° west-southwest. Ore occurs in the fault fissure and forms a stockwork in the brecciated south or hanging wall. Silver ores occur in cracks in the breccia, cemented by gangue of barite and argentiferous minerals. Orebodies of cerargyrite and embolite were irregular and ranged up to 40 ft. in width. Cop-

* The description of ore deposits in the Calico and immediately adjoining areas is taken largely from Waldemar Lindgren's report, 'The silver mines of Calico, California', Am I M Eng, Tr 15: 725-734 (1887).

per is present in this area and chrysocolla is a common secondary mineral in the ore. There is some hydrothermal alteration of the wall rock.

Black-Foot Mines (Idle). This property is located about half a mile southeast of the Garfield property and lies in a decomposed and altered mass of greenish andesite. The vein strikes west-northwest, and dips around 75° to the south-southwest; its width varies from 6 in. to 10 in. and it can be traced on the surface about 400 ft. The vein fissure is prominent and ore occurs in fractured gangue. Little barite is present and silver chloride occurs in seams and streaks in the decomposed lava, tuff, and breccia. The original deposits were confined almost exclusively to the upper 30 ft. of ground.

Empire Silver-Lead Mining Property. No information is at hand regarding this property, which is shown on the mineral map of the Calico district.

Burcham-Waterloo Mining Area

Burcham Gold Mine (Formerly the Total Wreck Mine). These mine claims, located about one mile west of Calico, are at present developing low-grade gold ore in two roughly parallel veins above the frontal thrust. In addition, some ore is found along a fault zone about half a mile west of the present main workings.

The veins, termed North and South, are dissimilar in character. The South vein consists of a wide fractured zone trending N. 80° W. and dipping steeply to the southwest. It is reported to carry gold, silver, and lead, and at one time was known as the Lead vein. In oxidized ore there is a prevalence of iron-stained brecciated quartz. Small iron-oxide seams carry spotty mineralization. Development to slight depth reveals the occurrence of minor sphalerite and galena. The South vein is confined to the lake-bed series of sandstones, cherts, and shales. To the northwest it dies out rather abruptly, possibly due to structural conditions relative to the strike of the vein and strike of enclosing sediments. Roughly parallel or echelon fractures continue here but soon disappear. It seems probable that no further vein continuation exists.

The North vein, known at one time as the Gold vein, lies along the contact of the lake beds with the tuff breccia previously described. This vein trends N. 40° W. and is discontinuous in strike. It appears to die out to the east without intersecting with the South vein, and to continue in echelon structures to the north. Where observed in the main adit level, most of the gold is in narrow short shoots in the plane of the vein. Vein matter consists of iron-stained brecciated quartz with no visible sulfides or gold. It is probable that most of the gold is free in near-surface workings. The close association of the North vein with the tuff-breccia and lake-bed contact is noteworthy and suggests that vein fracture was the result of emplacement of the breccia! However, the tuffaceous nature, the bedded appearance and lack of alteration of the lake beds by the tuff breccia suggests the sedimentary origin of the tuff breccia, and localization along the contact is believed to be due to structural weakness of the contact of sediments with the massive, buttress-like tuff breccia.

It is evident that both North and South veins are localized in the thrust block, and probably do not persist below it.

Development in the west part of the Burcham property has shown the existence of a broad crushed zone showing low grade mineral values. Ore consists of mineralized, brecciated, iron-stained lake-bed material. Some quartz has been introduced. Iron oxide is present but wall rock alteration is not intense.

Waterloo Mining Property (Idle). This mine, located northwest of the Burcham mine, was formerly a large silver producer. Orebodies occur along the Waterloo fault zone which trends northwest, and dips approximately 40° southwest. The orebodies mined were large, irregular masses and bunches that extended over an area approximately 1,100 ft. in plan and 500 ft. in section, all above the plane of the thrust. Stope widths ranged up to 200 ft. in length, and a very large tonnage was mined from them.

No development has passed below the thrust intersection with the most productive veins, although the thrust is well exposed in the lower main cross-cut (level 17). The Waterloo fissures and ore seem to have been localized only in the upper thrust block and are not known to persist below it. Near the thrust in the lower level, the veins appear to play out, becoming lower in grade and somewhat divergent. This is substantiated by the fact that there are no stopes immediately above the lower level (long cross-cut).

Union Mining Property. This property, located north of the Waterloo, is similar in many respects to the Burcham North vein which it closely resembles in appearance and mineralization. The main vein trends N. 50° W. and dips 52° southwest, flattening 50 ft. below the main cross-cut level. The vein consists of a shear zone along the contact of the tuff-breccia and lake-bed series, ranging up to 30 ft. in width. Ore is spotty in brecciated iron-stained wall rock, with minor quartz.

Ore Genesis and Zoning

At the height of production the district was examined by several prominent geologists and mining engineers, and their views were summarized by Lindgren* and later by Storms.** The consensus at that time—that the ore deposits were formed by hot ascending thermal waters depositing the ore minerals in veins and fractured country rock —is still valid. The veins are reported to continue strongly in depth but mineralization does not. This points to a primary deposit of shallow or epithermal type.

Without detailed underground mapping, and knowledge of gold-silver ratios (lateral as well as vertical extent) in the veins, little can be said definitely regarding ore zones. However, it seems doubtful that lower ore zones exist, for, although the veins persist downward with decreasing metal content, the underlying thrust plane would seem to limit the occurrence of deeper ore. Solution damming, and telescoping of deposits above the thrust to the higher fractured wall-rock, might explain the exceedingly rich ore in the higher levels. It is pos-

* Lindgren, Waldemar, *op. cit.*

** Storms, W. H. The Calico mining district. Cal St M Bur, St Mineralogist's Rp 11:337-349 (1892)

sible that supergene processes aided in ore concentration to a limited extent, but a primary origin is accepted, on the whole. The presence of minor chalcopyrite in the deeper workings at the Calico mines, and of galena and sphalerite in the deeper workings at the Burcham mine, indicates that these sulfides may increase with depth. Gold, so far as known, shows no definite relationship to silver in vertical distribution. It is believed, however, that certain amounts of gold are associated with all silver mineralization throughout the area observed. Gold definitely occurs with minor amounts of silver minerals in the Burcham-Waterloo area, west of Calico.

RECONNAISSANCE GEOLOGY OF THE SOUTHERN CALICO MOUNTAINS, SAN BERNARDINO CO., CALIF.

BY H.D. ERWIN AND D.L. GARDNER