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Geology and Mineral Deposits of the Calico Mining District

By

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THESIS

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PART 1

INTRODUCTION

This study of the Calico Mining District was undertaken as a thesis requirement for the degree of Mining Engineer in the Division of Mineral Technology, College of Engineering, at the University of California. The report and map are based on two weeks field work in the summer months of 1948 and three months in 1949. The geological data was plotted on aerial mosaics and then transferred to a base map by the radial-line method of plotting. The elevations on the base map were calculated without the use of a parallax bar and should be regarded as form lines only.

Acknowledgements

The writer would like to thank Dr. C. Hulin, Consultant Mining Geologist, for suggesting the Calico Mining District as a possible thesis area, and for the use of his detailed mine maps of the Burcham Mine; and Messrs. Billingsley and Locke for the use of their maps and report on the Calico-Odessa and Zenda Mining properties. The use of this information is of especial value as the mines have been closed for twenty years or more. Thanks are also extended to Mrs. Lane, owner of the Calico-Odessa Mines for the use of her confidential reports; to Mr. Snyder, president of the Zenda Mining Company, for the use of mine maps of the company holdings; to Mr. Henry Britt, owner of the Bismark and Leviathan Mines, for detailed information regarding his mines; and to Mr. and Mrs. Larry Coke of Yermo who supplied the writer with much of the historic and detailed claim information of the area.

Figure 1

Sketch map of California showing the location of the Calico Mining District.

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Associated Students' Store, Publishers

The writer acknowledges his indebtedness to Professor Turner for discussions of some of the thin sections, and to Professor Wisser for his helpful suggestions and criticism.

LOCATION

The Calico Mining District is situated in San Bernardino County 150 miles northeast of Los Angeles (see figure 1). The area examined in the accompanying map is a rectangle which lies between 116° 45' 00" and 116° 55' 00" west longitude and 34° 54' 10" and 35° 00' 50" north latitude. It is roughly nine miles from west to east and seven miles from south to north covering an area of 63 square miles.

Two towns are near this district, Yermo and Daggett; the old town of Calico is now abandoned except for a museum. Barstow, the only sizable town in the district, is 13 miles west of the Calico townsite. The old townsite of Calico is situated two miles north of U.S. Highway 466 and 10 miles north of Highway 66. Two railroads service the district, the Santa Fe which passes through Daggett, and the Union Pacific which passes through Yermo.

Climate

The climate of the Calico District is that of the Mohave Desert. The summer months of July, August, and September are hot and dry and temperatures range as high as 115 degrees for long periods. The temperature during the rest of the season may range as low as 15 degrees. Rainfall is only a matter of a few inches per year, which falls during the violent desert storms.

On account of the aridity of the climate, there is little vegetation. Sage brush and Joshua Tree are common on the lower sandy parts of the Mohave Desert.

Water Supply

Abundant water, of an unusual degree purity, is obtained from shallow wells (not deeper than 300 feet). The heavy and continuous pumping during the past 50 years has not lowered the depth of the water table.

HISTORY OF MINING IN THE CALICO MINING DISTRICT

In 1881 John McBride, Larry Silvia, and Charlie Meacham discovered rich silver ore at the head of Wall Street Canyon. Active mining began in 1882 and the important mines of the district, Waterloo, Silver King, Oriental, Old Oriental, Bismarck, Garfield, Odessa, and Blackfoot, started in operation at this time. The first rich ores were hauled to Ore Grande, a distance of 40 miles. However, the installation of stamp mills at Calico and Daggett permitted profitable mining of the low grade ore, which had a total value of over 20,000,000 dollars (California State Bureau of Mines Report for July 1940).

The sudden slump of the price of silver from one dollar and thirteen cents to sixty-three cents per ounce in 1894, and to fifty-seven cents in 1896, and the lack of high grade ore close to the surface caused the cessation of mining activity in the Calico district.

When the mines closed down the miners stayed on and were kept in supply by the local storekeeper, J. R. Lane, who later accepted the mines as part payment for the materials owing. In this manner J. R. Lane acquired clear title to all of the land east of Wall Street Canyon.

The Zenda Company purchased the Silver King and Oriental properties in 1920 and started a deep exploration program. Lane and his associates organized the Calico-Odessa Mining Company, with the intention of exploring the lower portions of the Bismarck vein. However, the falling price of silver in 1932 discouraged further work in the silver mines in the Calico area. The Burcham mine, a gold mine, was actively explored until the fall of 1941.

The borate deposits three miles east of the Calico townsite are of equal commercial importance. These deposits, located in Mule Canyon, were mined prior to the discovery of the richer borate deposits in Death Valley in 1882. Records of the total value are not available; estimates of doubtful value range from 20,000,000 to 50,000,000 dollars; the former is probably a close approximation.

A comprehensive study of the area is lacking, despite the fact that the Calico Mining District has produced some 40,000,000 dollars in silver and borax. The following discussion reviews some of the reports covering the Calico District.

Literature

Lindgren visited the area in 1886 and the following year he published "The Silver Mines of Calico" in the Transactions of the American Institute of Mining Engineers. In 1892 Storms published a brief account "San Bernardino County" in the California State Division of Mines Bulletin. Since 1892 various reports have been published. Foshag published a description of the borax minerals in 1922 and 1923. Weeks (1925, 1926, 1927) wrote three articles, the first two in the "Engineering and Mining Journal Press" and the third in the "Mining and Metallurgy". These articles contain abundant detailed information on some of the mines. Erwin and Gardner published a reconnaissance map of the area in the 1940 issue of the California State Division of Mines.

The above reports, although excellent for their detailed information on some of the mines, fail to give the complete extent of the mineralization, the complete dependence of the mineralization on faulting and favorable structures, and the extent of the underground workings.

TOPOGRAPHY AND PHYSIOGRAPHIC DEVELOPMENT

The Calico Mountains, a typical member of the Basin and Range Province, start about a mile north of the town of Yermo and trend in a northwest direction. In West-Calico are a series of even crested ridges, which have an elevation to 2800 feet and are separated by high-level valleys and form a fault scarp with the desert basin (figure 5). North of the townsite of Calico the ridges trend north-south, have

FIGURE 2

Terrace remnant of the Older Cycle of erosion, east of Calico townsite. The small hills are sediments of the Barstow Formation. Calico Dry Lake is in the centre of the background.

FIGURE 3

Box canyon formed in dacite tuffs of the Calico Formation at the entrance to Odessa Canyon. The land-surface, near the top of the figure developed during the Older Cycle of erosion.

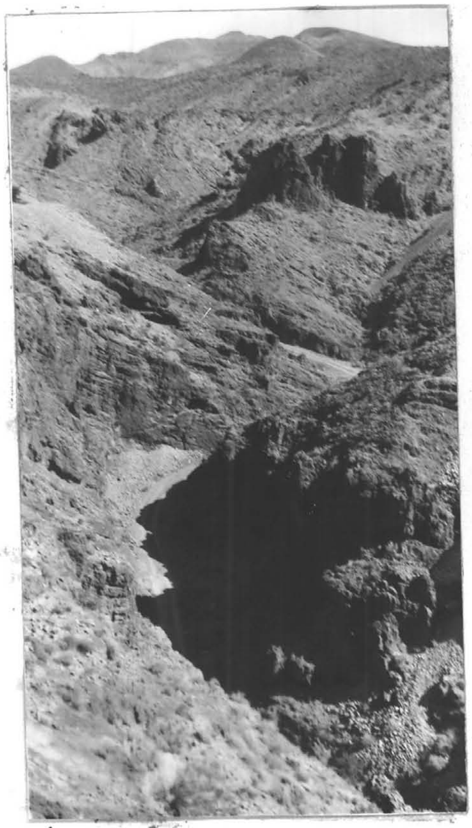


FIGURE 4

Odessa Canyon at the Odessa Mine.
Note the depth of the canyon here compared to that in figure 3. Calico Peak is in the distant background.

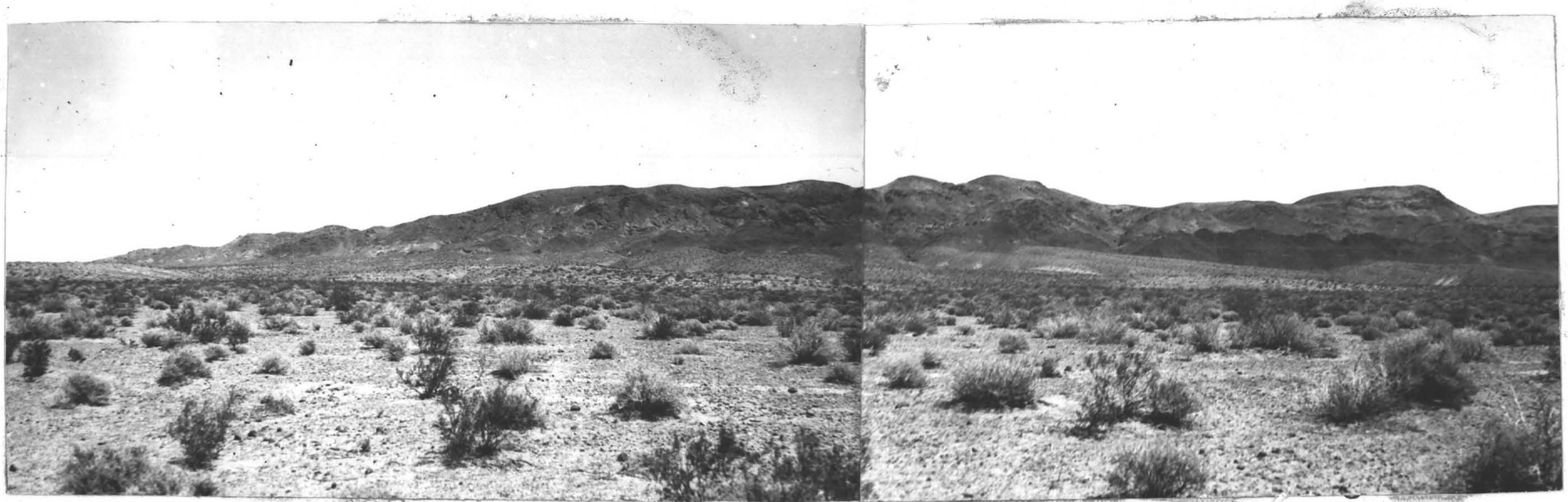


FIGURE 5

Fault scarp in West Calico. The Barstow sediments are in the foreground and at the base of the scarp. The The black bed is the andesite agglomerate of the Odessa Formation and the overlying light colored bed is the tuff member of the Calico Formation.

a maximum elevation of 4500 feet at Calico Peak, and are separated by a series of box canyons, such as Wall Street, Bismarck, and Odessa Canyons (figure 3). In East Calico the ridges again conform to the northwest trend of the range. North of the borate workings lies a high-level valley (figure 25) which has a maximum elevation of 3200 feet, and slopes eastward to join imperceptibly with the floor of the Mohave Desert.

Physiography

The physiographic development of the Calico District appears to be at a youthful stage of erosion, owing to a recent elevation of the area. Prior to the present cycle it appears that the Calico Area had reached a mature stage of geomorphic development. In the southwest border of the range are the features of youthful topography, box canyons, fault scarps, and alluvial fans which are in the process of formation. In the northeastern parts of the range are the features of mature topography, high level valleys with the alluvium extending to the divides (figure 25), the accordance of the summits, and the wide rounded canyons. The differential weathering and the behavior of the rock units during deformation are important features in the development of the present profile.

The Present Cycle

The dominant process in the area is mechanical weathering and down cutting by the intermittent streams. The large quantities of water of the desert storms in the form of "sheet-floods"

LONGITUDINAL PROFILES

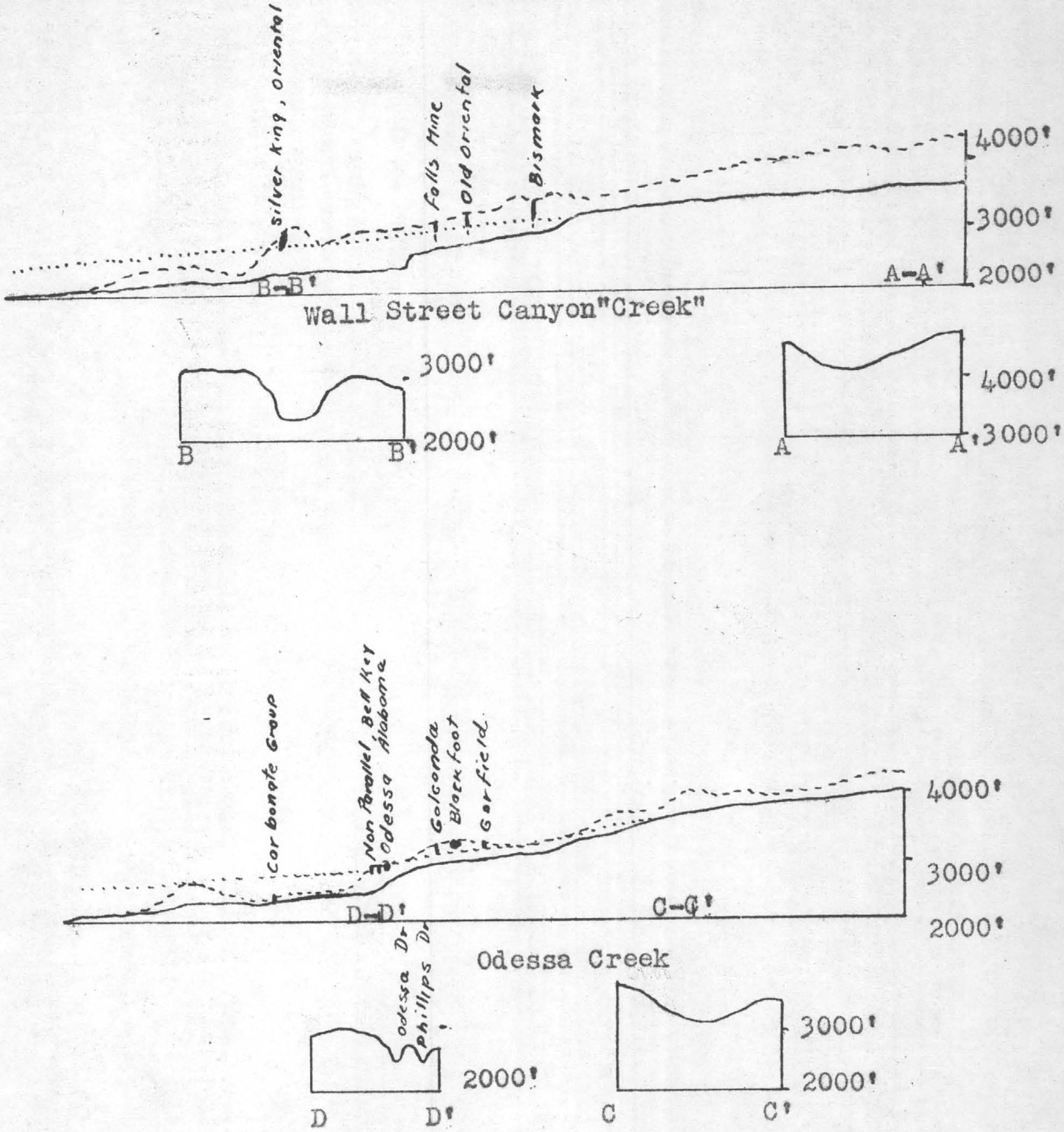


Figure 6

Profile of Wall Street Canyon and Odessa Creeks.

Dotted lines are canyon profiles of an earlier erosion cycle.

Diagram also shows the relation the ore deposits and this early profile.

Horizontal scale 1" = 5000'
Vertical scale 1" = 2500'

has removed the debris from the upland surfaces and rapidly scoured box canyons in the older channels. The debris is flushed well beyond the canyon entries to Calico Dry Lake, the base level of erosion. Wall Street and Odessa Canyons in their lower extremities have been deepened 300 to 500 feet and are about 200 feet above the base level. The intermittent streams, in the process of forming channels in the scarp face in West Calico, have cut shallow box canyons, not deeper than 50 feet. The gradients of these canyons is usually in tens of feet per hundred, and the channels following fault planes, tend to run diagonally across the front of the scarp.

The Older Cycle

Remnants of the Older Cycle are abundant in the area. In figure 6 it can be seen that an old erosion surface existed, and one can readily trace in the field this surface, which rises northward from King Mountain (3000 feet) through the Old Oriental Mine and culminates at Calico Peak (4500 feet). The streams south and west of Calico Peak occupy rounded valleys of gentle gradient until they join abruptly the box canyons in their lower reaches. Since the initiation of the new cycle the intermittent streams have incised channels in the alluvium to a depth of 20 feet.

Judging from the height of the fault scarp and the projection of the stream profiles of the Older Cycle, the magnitude of the vertical movement which initiated the present cycle is 800 to 1200 feet.

Physiographic History

The physiographic history of the Calico Mountains has a direct bearing on the ore deposits. In figure 6 one can see that the ore deposits are located near the surface of the Older Cycle of erosion. Downcutting by the present streams has exposed and partially eroded the silver deposits.

The rocks of the district are essentially Tertiary volcanics and sediments lying on a schistose and granitic basement. The hydrothermal alteration that accompanied this extrusion has masked any effects of cooling or erosion between the flows. A slight warping of the Calico District followed this early extrusion as an unconformity exists between the Odessa and the overlying Calico formation. These formations were subjected to erosion and the erosion products formed the Barstow sediments on the southwest front of the range. In late Miocene times the area was subject to normal faulting along the northwest trending faults (basin and range type). The doming movement north of the Calico townsite formed the series of antithetic faults and synthetic faults. During this period of deformation the competent lavas and tuffs acted as units and were deformed by faulting and differential movement of the different blocks, the incompetent sediments were sharply folded. The period of mineralization followed this movement. A period of erosion followed and the formations were beveled before the extrusion of the Pliocene andesites. Following the extrusion of the andesite the area was subjected to a long period of erosion, which developed the mature topography of the Older Cycle. It was during this period of erosion that the ores were oxidized and distributed to their present position. Movement of the blocks along these earlier faults initiated the Present Cycle of erosion.

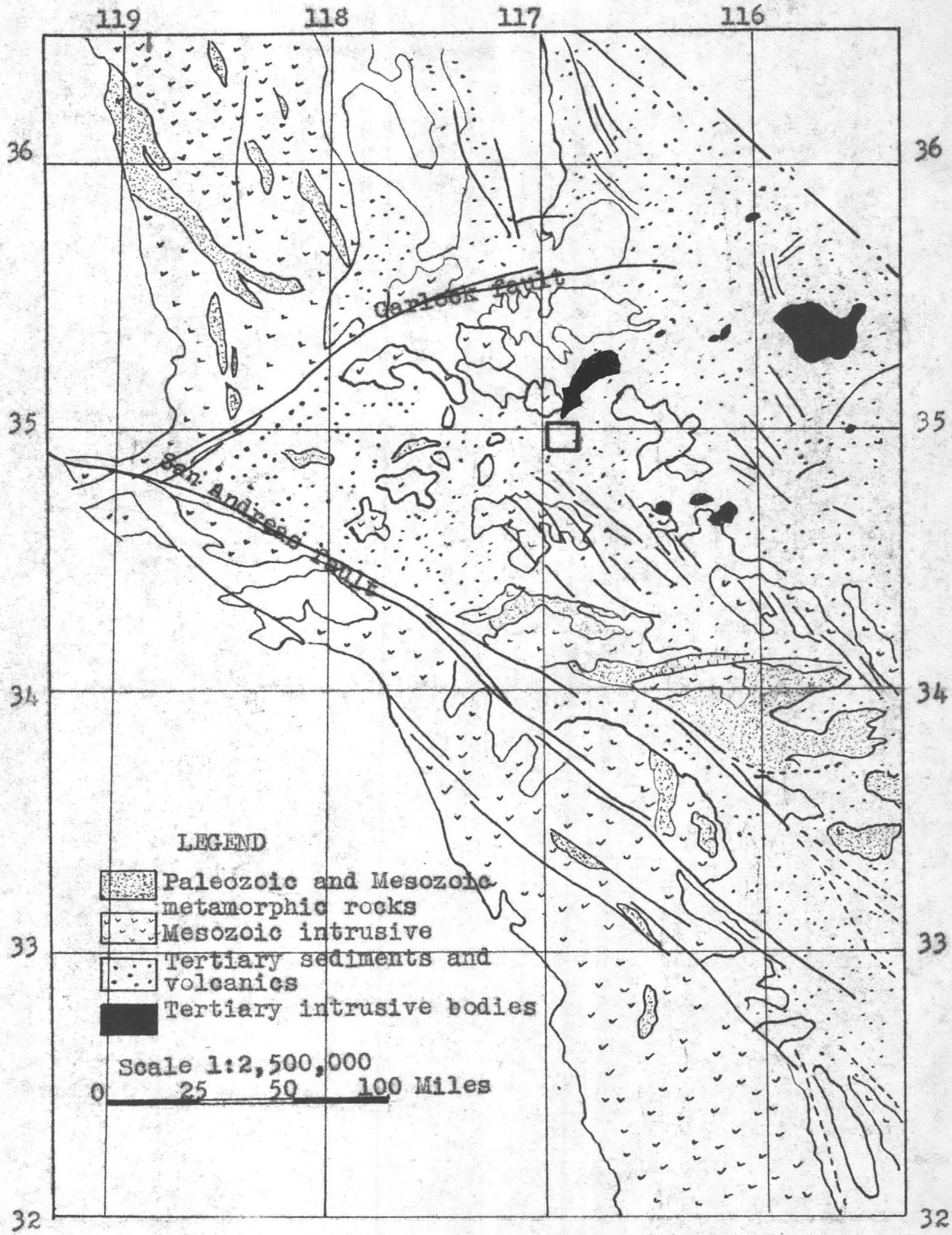


Fig. 7. Generalized geological map showing the geology of the area surrounding the Calico Mining District.

(Modified from A.A.P.G. Tectonic Map, 1944)

GENERALIZED GEOLOGIC COLUMN OF THE CALICO MINING DISTRICT

Age	Formation	Thickness	Column	Description
Quaternary			Qal	Recent alluvium.
Quaternary		100'	Qoal	Older alluvium terrace remnants.
Pliocene	Red Mountain Volcanics	400'	Trv	Andesite flows.
Upper Miocene	Barstow	300' 1500'	Tba Tba Tbs	Interbedded andesite flows. Thin beds of gray sandstone and shale, with areas of ferruginous sandstone, also beds of chert, borax and travertine.
Upper Miocene	Calico	600' 800'	Tcdt Tcd	Thick beds of dacite tuffs. Breccia dikes and dikes of andesite (vitrophyric) Volcanic pipes containing fragments of granite, schist and quartzite. Dacite flows
Upper Miocene	Odessa	400' 200' 400' 200' +500'	Torsa Tot Toaa Tort Tor	Altered rhyolite tuffs and interbedded red agglomerate. Gray rhyolite tuff. Red andesite agglomerate. Ferruginous rhyolite tuff and breccia. Red and green rhyolite tuffs. and flows
Jurassic			J	Red quartzdiorite.

Figure 8

GEOLOGY

The geological setting of the Calico Mining District is shown in figure 7. The rock types are those of igneous, volcanic, and sedimentary origin. The igneous rocks are intrusions of quartzdiorite; the volcanic rocks are composed of flows, pyroclasts and agglomerates; and the sediments are shales and sandstones of continental origin. The thickness and relationship of these types are shown in the generalized geological column, figure 8. The age of the quartzdiorite is Nevadan, and that of the volcanic and sedimentary rocks is Tertiary.

Bedrock Beneath the Calico Mining District

The pre-Tertiary rocks within the vicinity of Calico are covered, but an idea of their composition may be obtained from the granitic and metamorphic material that is present in the lavas and pyroclasts. Fragments of quartzite, chlorite-schist, and quartzdiorite or granodiorite, although altered by hydrothermal alteration, can be recognized. The metamorphic rocks are part of the Hinkley-Hodge Complex of the Barstow Quadrangle. Miller (1944) regards this complex as pre-Cambrian age, Bowen (personal communication) regards this complex as a series of highly metamorphosed Paleozoic rocks. These metamorphic rocks outcrop at and form the basement rocks of the Waterman Mine 13 miles west of Calico. The quartzdiorite outcrops four miles north of the Calico District and along the Camp Erwin Road.

It appears then that the Tertiary rocks of the Calico District are underlain by the chlorite-schists and rocks of a granitic nature.

Quartzdiorite

The quartzdiorite outcrops along the northern front of the Calico Mountains as a broad band of low rolling hills, a small area has been included on the northern edge of the map. Irregular masses of white quartzmonzonite, white felsite and highly altered dark lamprophyre dikes intrude the quartdiorite.

Age and Correlation

Intrusive rocks of diorite, quartzdiorite and quartz-monzonite are plentiful in the Mohave Desert, especially in the Lane Mountain and Barstow Quadrangles. McCollah (1949) reports an area of over 80 square miles of diorite and smaller areas of quartzdiorite and quartzmonzonite in the Lane Mountains. Miller (1944, p103) reports similar intrusions in the Barstow Quadrangle, as the Victorville quartzmonzonite and the Bell Mountain quartzdiorite. The above authors designate the intrusions to be of Jurassic age. The quartz-diorite of the Calico Mountains appears to be of the same age.

Petrology In hand specimens the quartzdiorite has a pink color and the grains are up to three millimeters in length. In thin section estimates of the volume percentages are: labradorite, 60; quartz, 10; hornblende, 12; epidote, 7; biotite, 5; orthoclase, 4; and sericite, zircon, apatite,

FIGURE 9

The photograph is taken in a westerly direction from King Mountain. In the foreground is the rim of Wall Street Canyon which is composed of tuffs and flows of the Odessa Formation. Tuffs of the Calico Formation form the rim of hills in the background.

magnetite, and chlorite, 2. The plagioclase feldspars occur as zoned and twinned euhedral crystals, the ferromagnesians and biotite as grains and flakes partially altered to chlorite.

Odessa Formation

The Odessa formation, the oldest of the volcanic formations exposed in the Calico area, is composed of more than 1700 feet of tuffs, flows and agglomerate. The rocks of this formation, which Lindgren (1887) originally termed "liparites", are highly fractured and altered, and quartz, carbonate, kaolinite and zeolites have largely replaced the phenocrysts and groundmass. The alkali feldspars of the rhyolite members are particularly interesting, as they are composed chiefly of high temperature twinned anorthoclase with minor amounts of sanidine. (Both feldspars have a small optic angle which is normal for feldspars of this origin - Spencer, 1937).

Rhyolite Tuffs and Flows

The lowest member of the Odessa formation is 500 feet of rhyolitic tuffs and flows (exposed in Wall Street Canyon), which strike northwest and dip southwest at a low angle (figure 9). The tuffs and flows have a characteristic red and green coloring owing to the development of oxides of iron and chlorite. The individual flow and tuff beds attain a thickness of 50 feet or more, as seen in the walls of Wall Street Canyon.

Petrology. In thin section these rocks are composed of a heterogeneous mixture of lithic fragments; crystals of quartz anorthoclase, and sanidine; and irregular masses of chlorite, koalinite, limonite, and primary hematite in an intensely altered groundmass. The alkali feldspars are partially replaced by kaolinite, and there is a notable lack of plagioclase and ferromagnesian minerals, the latter two minerals may be represented by the chlorite and kaolinite. The abundance of quartz and alkali feldspar suggests a rhyolitic composition. The presence of microspherulites has been used as a criteria to differentiate between tuffs and flows.

Ferruginous Rhyolite Tuffs and Breccia

The ferruginous rhyolite tuff member, which has a thickness of 200 feet and is composed of tuff and minor breccia beds varying in thickness from two to 50 feet, stands out with its characteristic red color, and was therefore mapped as a separate unit. This member is exposed in the western wall of Wall Street Canyon and appears to lie entirely west of Wall Street Canyon.

Petrology In thin section the tuffs are composed of a heterogeneous collection of altered lithic fragments, crystals of quartz, and highly altered phenocrysts of anorthoclase and sanidine. The ground mass is highly altered and has a reddish tinge owing to the presence of oxides of iron. Vesicles, vugs, and fractures are abundant and are lined with quartz and zeolites.

Andesite Agglomerate

The andesite has a thickness of 400 feet and is exposed north of the town of Calico and in the fault scarp in West

Calico. The agglomerate has a chocolate brown color and contains rounded and angular blocks to several feet in diameter. In the fault scarp (figure 5) the formation strikes northwest and dips at small angles to the east, in the rim of Wall Street Canyon the formation dips to the southwest.

Petrology In thin section the blocks and the interstitial material have the same composition. They are composed of hornblende crystals largely replaced by iron oxide, plagioclase (Ab40 An60) crystals which are kaolinized, and augite crystals which are altered to masses of chlorite. Sanidine appears to be the only unaltered mineral. The ground mass is a brown glass containing miarolitic cavities lined with zeolite crystals. The small percentage of alkali feldspar and the lack of quartz suggests that this rock has an andesitic composition.

Gray Rhyolite Tuff

The rhyolite tuff member was mapped as a separate unit readily distinguished by its gray color. The tuff, striking northwest and dipping to the east, is exposed in the east wall of Wall Street and Bismarck Canyons. The tuff is not present in West Calico; it either thins to the west or is removed by erosion. It is porous soft rock and weathers in a manner similar to a poorly consolidated sandstone, forming areas of gentle slope.

Petrology In thin section the tuff contains abundant (30 per cent) euhedral quartz crystals up to 3 millimeters in length. The plagioclase and alkali feldspar crystals have been largely

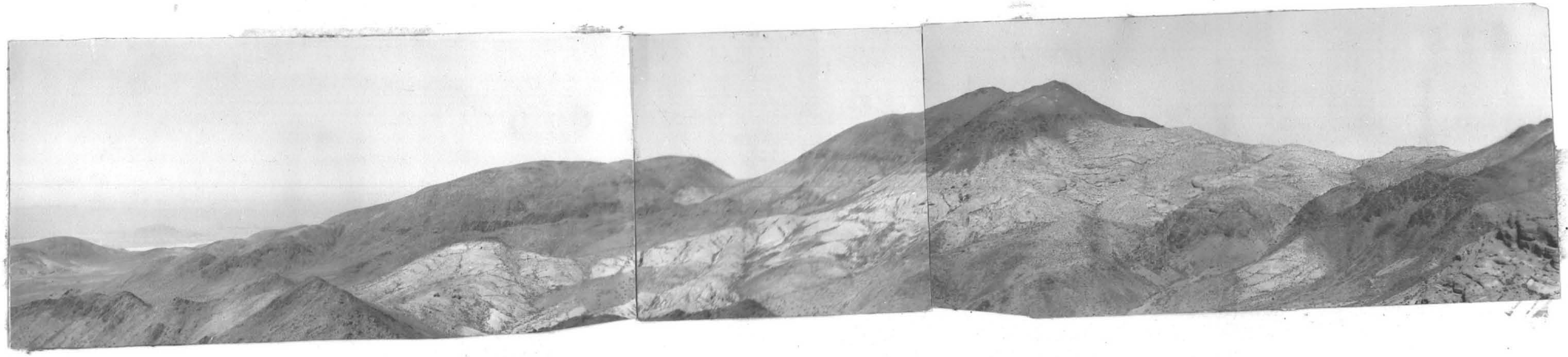


FIGURE 10

Calico Peak. The light colored beds are tuffs of the Calico Formation and the dark colored beds are flows of the Red Mountain andesite. In the lower-left corner is one of the feeder dikes of the Red Mountain andesite.

FIGURE 11

Bedded dacite tuffs of the Calico Formation in east Calico, just east of Calico Peak.

replaced by carbonate. The alkali feldspar forms about 20 per cent of the slide and is present in the form of euhedral anorthoclase crystals. The ferromagnesian minerals have been altered to chlorite and iron oxide. The ground mass is glassy and contains abundant lithic fragments of altered andesitic material.

Rhyolite Tuffs and Flows

Pink and green colored rhyolitic tuffs and flows, and thin intercalated beds of red agglomerate form the uppermost member of the Odessa formation. It has a thickness of 400 feet and is exposed east of Wall Street Canyon. The flows have characteristic bands of pink and green and show a notable parallelism of the feldspar laths. The rhyolite tuffs have a greenish tinge and occur chiefly in the upper part of this member east of Odessa Canyon. These green tuff beds are important as they are the loci of ore deposition in the Blackfoot mine.

Petrology In thin sections of the flows the feldspars are kaolinized, and the ferromagnesian minerals are chloritized. Estimates of volume per cents are: anorthoclase, 20; quartz, 15; oligioclase, 10; chloritized biotite, 10; magnetite, zircon, hematite, and chlorite, 5; and reddish colored ground mass, 40. The flows have a rhyolitic composition.

The Calico Formation

McCollah (1949) gave the name of "Calico Formation" to a series of dacite tuffs and flows that cover the greater portion of the Lane Mountain Quadrangle and the Calico Mining District. These tuffs and flows cover an area of 75 square miles and rest unconformably on the Odessa formation. The Calico formation, striking northwest and dipping at small angles to the east, forms a belt six to eight miles wide extending from East Calico in a northwesterly direction for 10 miles.

Dacite Flows

In East Calico directly north of the old borax workings is the principal area of the dacite flows, which has a total thickness of 800 feet. At the northern area and beyond the area included in this map, the dacite flows rest on the weathered surface of the quartzdiorite. The flows have a pinkish color and show an alignment of the feldspar laths.

Petrology In thin section the flows show an abundance of euhedral zoned and twinned plagioclase crystals. Estimates of volume percentages are: andesine, 20; sanidine or untwinned anorthoclase, 5; quartz, 5; red-brown biotite, 10; iron ore and apatite needles, 5; and the glassy ground mass 45. The flow is of a dacite composition. One slide from this series contained plagioclase of bytownite composition and only one fragment of quartz. This suggests that some of the flows may have a composition approaching that of an andesite.

Dacite Tuffs

The dacite tuffs have an approximate thickness of 600 feet and occur extensively in the Calico Mining District and the Lane Mountain Quadrangle. They have a characteristic

FIGURE 12

Volcanic pipe containing fragments of basement rock. Upper figure is from pipe by the Falls Mine: lower figure is from pipe by the Waterloo Mine.

yellow appearance, are highly vesiculated, and contain abundant lithic fragments. Large crustations and vug fillings of opal, to several inches in diameter, may be readily seen in the tuffs north of the borax workings in east Calico.

Petrology In the six sections examined there was considerable variation in the composition of the tuff. Quartz crystals and fragments were readily visible and formed about 5 per cent; oligioclase, which is largely replaced by kaolin, forms 25 per cent; biotite forms 10 per cent; and the pumaceous groundmass, intensely fractured and vesiculated, forms 40 per cent of the slide. Chlorite has replaced the ferromagnesian minerals and the groundmass is intensely altered by kaolin, hematite, and opal.

Age and Correlation of the Odessa and Calico Formations

The exact age of these volcanic formations is unknown, however a correlation with the surrounding areas suggests that these volcanics are of Miocene age. Baker (1911) considered these rhyolite flows and tuffs to be a part of the Rosamond (Miocene) Formation which contains 300 feet of rhyolitic flows and tuffs. Gardner (1940, p27) reports similar flows in the Newberry and Ord Mountains, which are similar to the Rosamond volcanics. Hulin (1925, p44) found definite evidence in the Randsburg Quadrangle that the Tertiary volcanics are of Miocene age.

Volcanic Pipes

Volcanic pipes containing fragments of basement rocks

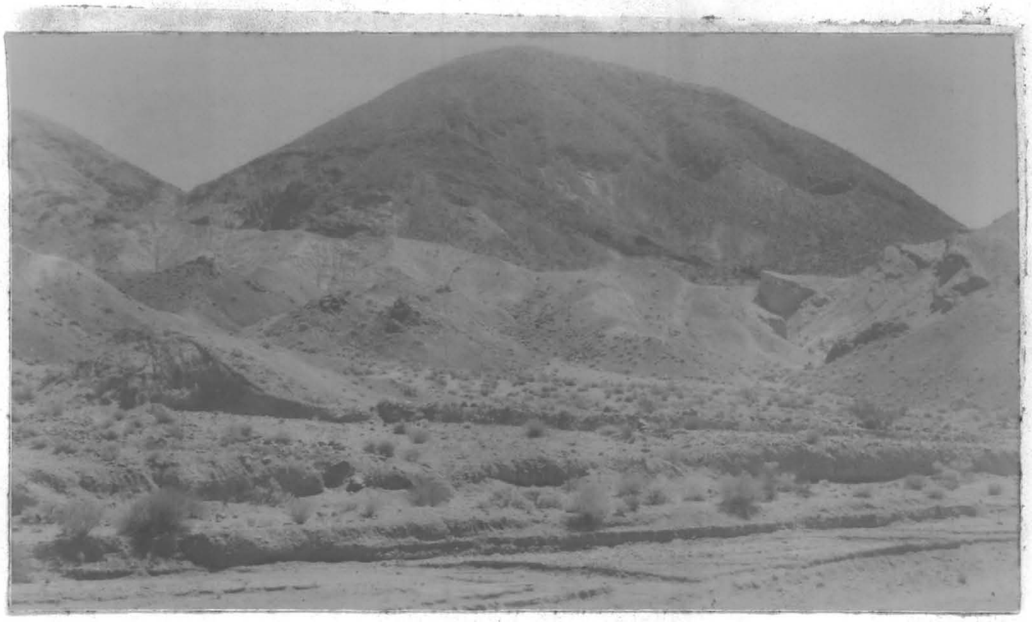


FIGURE 13

The Barstow sediments and Red Mountain volcanics at the entrance to Mule Canyon.

FIGURE 14

Fault contact between the tuffs of the Calico Formation on the left and the sediments of the Barstow Formation on the right. In the distance is Calico Dry Lake.

are found in the Calico area; one on the south slope of King Mountain immediately north of the townsite of Calico, two immediately north of the Waterloo mine workings, and one west of the Falls mine. These pipes are oval shaped, the long dimension is 2000 to 3000 feet and the short dimension is 200 to 300 feet. As seen in figure 12, the pipes are composed of rounded fragments of quartzdiorite, granodiorite, quartzite, and green chlorite-schist. The fragments are cemented by a dense red material which is principally hematite.

Breccia Dike

A breccia dike 2000 feet long and 100 feet wide occurs along a fault in the Burcham mine area. The dike is composed of angular fragments to several inches in diameter. These fragments have a dacitic composition, and suggest that this dike is one of the feeders of the Calico formation. The brecciation of the dike may be attributed to movement along the fault or to auto-brecciation by the release of gases. Durrell (1944, p225) explains the formation of the clastic dikes of Blairsden by auto-brecciation.

Vitrophyric Andesite

The vitrophyric andesite occurs as small dikes and sills north of the Bismarck mine and in the northern portion of the map area, as seen in plate 1. In hand specimen the andesite has a glassy appearance; the feldspar laths are less than two millimeters in length. In thin section zoned plagioclase with basic labradorite cores and rims of acid labradorite form 45 per cent; euhedral crystals of augite, hornblende, and flakes of biotite form 5 per cent; and orthoclase forms less than two per cent of the slide. The minor accessories are magnetite and apatite. In the glassy groundmass are abundant microlites of labradorite.

Barstow Formation

The Barstow formation, composed of approximately 1500 feet of sediments and intercalated andesitic flows, forms a belt along the southern flank of the Calico Mountains. The true sequence and thickness cannot be determined as the sediments are folded and faulted. McCollah used the name "Barstow Formation" in the Lane Mountains, where he was able to trace these sediments to the classic vertibrate fossil location of Merriam (1911, 1919) in the Barstow Trough. Baker (1911, p357) describes Merriam's fossil location as follows:

> "The presence of fossil remains of characteristic fresh-water gasteropods and abundant cursorial and plains-living mammals indicate that the strata containing these fossils are of terrestrial, fresh-water, and subaerial origin. The fossils are considerably checked and cracked as if they have been exposed for a considerable time to the action of sun, frost, and abrupt changes of temperature, on the surfaces of an open plains country."

The non-marine sediments and volcanics are of Miocene age and have an extensive distribution throughout the Mohave Desert and western Nevada. Buwalda (1914, p355) described a series of Miocene sediments in the northern Mohave desert that have a maximum thickness of 5000 feet. In the Death Valley region Noble (1934, p173) describes sedimentary beds

FIGURE 15

Shale and sandstone of the Barstow Formation which contains thin beds of colemanite. Figure taken at the entrance to Phillips Drive.

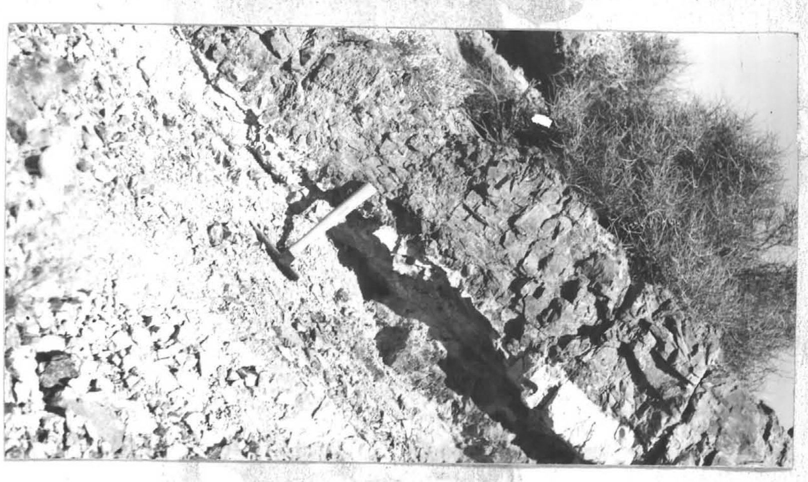


FIGURE 16

Chert bed of the Barstow Formation in Surprise Canyon.

FIGURE 17

Chert bed of the Barstow Formation dislocated by the Burcham thrust fault at the entrance to Phillips Drive.

that he believes to be Miocene. In Nevada Turner (1900, p197) describes the Esmeralda formation as a thick series of volcanic rocks and non-marine fanglomerates which were deposited in closed basins similar to that of the Barstow formation.

Evidence of volcanic activity during the deposition of the Barstow can be seen in the yellow beds of tuff and the flows of andesite; the latter were mapped as a separate unit. In East Calico are beds of chert, travertine, and borax that are genebically related to the contemporaneous volcanism. The fine tuff bed near the top of the Barstow formation originated from volcanic outbursts related to the dying phases of the Miocene vulcanism.

The method of aggradation of the uplands and the deposition of the Barstow sediments is similar to that one can observe in the Mohave Desert today - sediments laid down as piedmont alluvial debris and as playa deposits. The sediments have a conspicuous lack of the products of decomposition-clays and mudstones, except in the Borate district of East Calico. Baker (1911, p358) suggests that the great thickness of the sediments of the Barstow formation can only be explained by an epoch of mountain making near the end of the Miocene.

Lithology The Barstow formation includes gray and brown weathering siltstones and shales, thin bedded sandstones, beds of chert, borax, and travertine, and intercalated flows of andesite. The sediments have been folded (see figures 17, 18, and 19), faulted, and crushed, and have (except in West

Calico) a fault contact with the older volcanics. The beds strike northwest and have a varying dip from 5 to 90 degrees, as seen in figure 14.

Petrology In thin section the sediments are composed of angular grains less than one millimeter in diameter. The composition of some typical sections is as follows:

Anorthoclase and sanidine	50 per cent
Quartz	20 " "
Altered lithic fragments	15 " "
Chlorite	4 " "
Carbonate	1 " "
Plagioclase	1 " "
Interstitial material	9 " "

The interstitial material is finely comminuted material of the above composition. Sandstone of this composition would be classified as a graywacke.

Andesite of the Barstow Formation

Andesites of varying colors, gray, green, and purple, are interbedded and in part intrude the Barstow formation. These andesites because of their varying colors have received such names as "purple porphyry, feldspar porphyry, and hornblende porphyry".

Petrology In thin section these flows and intrusives have a similar composition, the color difference is due to the oxidation of some of the ferromagnesian constituents. The plagioclase occurs as zoned euhedral crystals with a composition of intermediate labradorite, the alkali feldspar is clear and untwinned sanidine, and the ferromagnesian minerals are euhedral crystals of hypersthene, augite, and hornblende, which are partially altered to chlorite. The minor accessories are hematite, magnetite, and apatite.

Red Mountain Volcanics

The Red Mountain volcanics of Pliocene age are widespread and occur as cappings resting unconformably on the bevelled and eroded Miocene formations throughout the Barstow Trough. They are reported by Hulin (1924, p55) in the Randsburg Quadrangle, by Gardner (1941, p281) in the Newberry and Ord Mountains, and by McCollah (1949) in the Lane Mountains. In the Calico District these volcanics are 400 feet thick and rest on the folded and faulted sediments of the Barstow formation as seen in figure 13, and on the warped flows and tuffs of the Calico formation as seen in figure 10. The distribution of the Red Mountain volcanics can be seen in plate 1. A period of post Pleistocene deformation is indicated,as the Red Mountain volcanics are warped and faulted.

Petrology The plagioclase crystals are zoned and have a composition of labradorite. The largest pyroxene crystals are euhedral augite, while hypersthene is typically present as subhedral prisims in the red glassy groundmass. Estimates of the volume percentages are: labradorite, 50; augite, 20; hypersthene, 5; iron ore, 1; and the intersititial glass, 24. The Red Mountain volcanics are of andesitic composition.

Mode of Extrusion The conduits for the Red Mountain volcanics can be seen southeast of Calico Peak, where they appear as dikes of red andesite intruded along northwest trending fissures. The red andesite because of its freshness and resistence to erosion stands out as physiographic features above the surrounding area. When examined in detail the flow bands stand vertical and the intrusive relations are readily apparent.

Older Alluvium

Remnants of an earlier higher level stage of alluvium distribution can be seen in the form of terrace deposits, figure 2, that formed at a period when the land stood at a lower elevation than that seen today. Recent elevation of the Calico Mountains rejuvenated the drainage and the streams have incised the terrace remnants to a depth of 50 feet. The terraces are composed of stratified layers of coarse boulders, about 6 inches in diameter, and layers of sand and gravel, which are highly colored by oxides of iron.

Recent Alluvium

The Recent Alluvium deposits, composed of poorly sorted and unconsolidated sands, gravels, and boulders, surround the western, southern, and eastern borders of the Calico Mountains. The thickness of the alluvium as determined from a well north of Yermo, is greater than 200 feet.

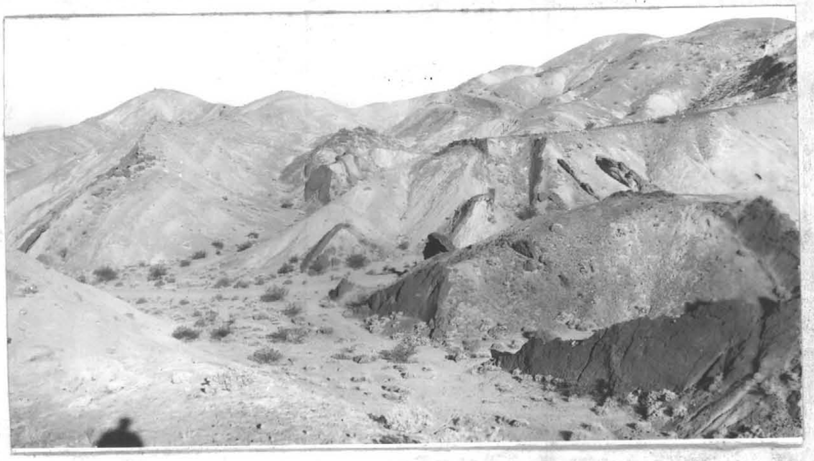


FIGURE 18

Eroded crest of an anticline in the Mule Canyon Area. The sediments are a part of the Barstow Formation.

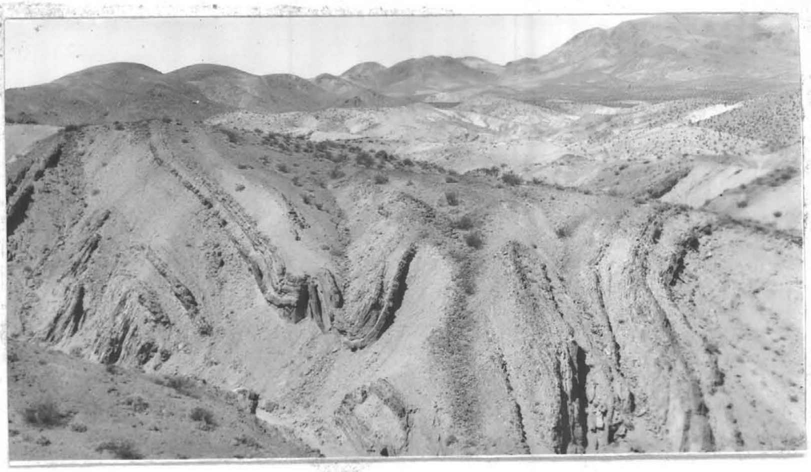


FIGURE 19

Sediments of the Barstow Formation showing "Appalachian type of folding" north of the old borax workings.

STRUCTURE OF THE CALICO MOUNTAINS

As shown in plate 1, the Calico area is intensely faulted. The dominant fault system strikes northwest with the trend of the range, and the southwest front of the range coincides with the masked zone of faulting. These faults are a minor part of the basin and range fault system. Superimposed on this system of faults are the faults related to a doming movement north of the town of Calico. Thrust faults form a minor part of the fault system along the front of the range. During the deformation that accompanied the orogeny at the end of the Miocene (?) the competent lavas were faulted, tilted, and slightly folded, the incompetent sediments were intensely folded, faulted, and overthrust, as is apparent from the accompanying illustrations, figures 17, 18 and 19.

Basin and Range Faults

The basin and range faults form a zone about a mile in width along the southwestern front of the range. The individual faults vary in length and attitude and tend to have an en echelon relation. The faults drawn in this zone are those partially visible and those required by stratigraphic evidence. Judging from the height of the fault scarp in West Calico (figure 5), the vertical component of movement is approximately 800 feet. The dips of the faults vary from 50 to 85 degrees to the south, and are steeper than the dips of the facets along the range fronts.

Evidence of recent movement along these faults can be seen in east Calico where the alluvium is displaced a few feet. Movement along this zone in 1940 destroyed several buildings in the old town of Calico.

Faults Related to Doming Movement

The area north of the townsite of Calico has suffered a doming movement which produced a series of antithetic and synthetic faults as seen in plate 1 and section E-F of plate 2. These types of faults and related movements have been illustrated by Wisser (1936, p11) and Balk (1948, p.31), and are therefore not repeated here. The antithetic faults traverse the crest of the dome, the synthetic faults form a series of parallel faults and bound the southern half of the dome. This type of half-dome bounded by a system of synthetic faults is a common structural feature of domed areas. Gilluly (1932) describes an identical half-dome structure at Ophir.

Cloos (1930) determined experimentally the mechanism of formation of the antithetic and synthetic faulting during a doming movement. Wisser (1936), in his analyses of the fault pattern at the Pachuca silver deposits, applied the Cloos school of "granite tectonics" even though the intrusive massif was not exposed. He was able to show a satisfactory analogy between the deformational experiments of Cloos and the fault pattern of Pachuca. In applying the above to the Calico area several factors are apparent. The antithetic faulting has affected an area east of Wall Street Canyon; the western side of the dome did not fault antithetically as the stresses were relieved along the northwest trending basin and range faults. The southern portion of the domed area is near the volcanic-sedimentary rock contact and has suffered a synthetic type of movement.

Antithetic Faults The antithetic faults form many of the physiographic features, such as Phillips, Odessa, Bismarck, and Wall Street Canyons. These faults strike north-northwest, are nearly parallel to the basin and range faults, and dip to the south at angles of 40 to 85 degrees. The dip of the individual faults tends to increase away from the crest of the dome, as seen in faults of King Mountain which have dips of 40 to 60 degrees and those of Thunderer Mountain which have dips of 50 to 85 degrees. The faults tend to flatten at depth as seen in the deep workings of the Silver King and Oriental Mines. The vertical movement along these faults has dropped the west side from 200 to 500 feet with a rotational movement. The antithetic faults of the Bismarck-Garfield Mine area have a horizontal displacement which may be related to the doming movement or may be of a later date. The horizontal displacement of the rhyolite tuffs north of the Old Oriental Mine is 400 feet. Billingsley and Locke in their confidential report on the Garfield Mine report that the horizontal movement of the Garfield fault is 800 feet, the east side has moved to the north.

Synthetic Faults The synthetic faults have an east-west trend and occur immediately north of the town of Calico. These faults have dips to the south of 30 to 45 degrees. Storms

(1892) called the principal fault of this system "The Great Fault", which has normal movement of 600 feet or greater, dropping the yellow tuffs of the Calico formation to the south. The antithetic faults tend to curve into and join the synthetic faults, suggesting that the two fault systems were formed during the same period of deformation.

Thrust Faults

The principal thrust fault, the Burcham thrust, dips 40 to 80 degrees to the north and is visible below the Burcham mine and in the low level tunnel of the Waterloo mine. The thrust is covered with terrace gravels in the vicinity of Calico, but is exposed in the east branch of Phillips Drive, where the chert beds are exposed and have been disrupted by low angle thrusting as seen in figure 17. This fault dips toward the domed area and may be in part related to the doming movement.

In the vicinity of the old townsite of Borate the sediments of the Barstow formation are thrust against the dacite flows as seen in section I-J of plate 2. This thrust has a dip to the south and may be related to a later period of compression.

Northeast Trending Normal Faults

At the northern edge and principally beyond the area mapped are a series of northeast trending normal faults which form a series of fault scarps. These faults have affected flows of the Red Mountain volcanics, and are therefore of

Pliocene or Recent age. The northern blocks have vertical displacement of about 200 feet.

Folding

The formations of the Calico area have been variously affected by folding. Apart from a small north-south trending fold north of Phillips Drive, the volcanic formations have suffered little deformation. The sediments of the Barstow formation (Bakers borate member, 1911) are intensely deformed, the beds for the most part dipping at angles of 50 to 90 degrees. The sediments form two east-west trending anticlines which are exposed at the entrances to the box canyons. These anticlines tend to merge at Bismarck Canyon and continue westward as a series of upturned beds. East of Phillips Drive the folds are partially covered by the Red Mountain volcanics. Mule Canyon has been eroded on the crest of one of these anticlines. In east Calico north of the borax workings the beds are intensely folded in an "Appalachian type" of folding as seen in figure 19.

The basin and range and the Burcham thrust faults have been superimposed on these folds and are therefore of younger age. The relation of the folds to the antithetic and synthetic faulting is unknown, however they likely formed during the same period of post-Miocene orogeny.

FIGURE 20

Typical vein of the Revier Mine, showing bands of barite, jasper, and haematite.

PART II

ECONOMIC GEOLOGY

Five diversified minerals and rocks, silver and gold, borate, barite, and building stone are mined and quarried in the Calico Mining District. The minerals and rocks will be discussed in the listed order of importance.

Silver and Gold

Silver mineralization is widespread, and the principal deposits are located within a mile of the Calico townsite. The principal deposits are halides of silver which occur as impregnations in porous rocks or as vein deposits with a barite gangue. The barite, which forms 95 per cent of the vein material, has taken the place of quartz and formed banded or ribboned structures as seen in figure 20. The gold occurs only in the fault zones in the Burcham Hill.

Significance of a Barite Gangue

From a perusal of the literature for information regarding barite one can see that barite occurs as a gangue with quartz in a few of the mesothermal silver-lead-zinc deposits of Germany and the United States, and as the principal gangue in a few of the silver-lead deposits of the United States. Barite occurs as the principal gangue in the following deposits:

Coeur d'Alene Ransome and Calkins (1908, p103) report barite associated with galena, sphalerite, and tetrahedrite in the gold ores of the Hunter mine of the Coeur d'Alene district.

Leadville (Loughin and Behre, 1933) At a distance from the Tuscan-Maid fault zone channel barite is one of the conspicuous gangue minerals, and zinc and galena are the principal sulfides. Barite deposits are scattered throughout a large area, where structural conditions favoured deposition, and evidently represented the lower temperature conditions of the mesothermal range.

Aspen Spurr (1898, p228) reports many large barite veins which are practically barren. Quartz and barite were deposited simultaneously and earlier than the sulfides.

Creed (Emmons and Larsen, p100) Barite forms 10 to 12 per cent of the gangue minerals and decreases rapidly with depth.

Ouray (Moehlman, 1936, p377) Barite is one of the earliest minerals and was replaced by quartz and the sulfides. Where the barite was intense as the early mineral the veins are not productive, as the quartz-sulfide surge was not strong enough to clear out the barite.

Summary The following points were notable in the literature:

1. The barite gangue is associated with deep epithermal or low temperature mesothermal deposits (leptothermal); the principal sulfides are those of silver, lead, and zinc.
2. The barite occurs in fissure vein deposits.
3. In the San Juan deposits the veins are fractures formed by uplift and tend to wedge out at depth.
4. Barite was one of the earliest of the minerals and was replaced by the sulfides.

In the Calico silver deposits the same relations are true. Barite is found in fissure veins related to uplift, and appears to wedge out at depth. This can be seen in the deep workings of the Silver King and Oriental Mines. Silver, lead, and zinc, were the ore minerals - the latter two are inconspicuous owing to the oxidational processes. The following points suggest that the deposits are of epithermal origin:

1. Occurrence in Miocene lavas
2. Delicate banding and many vugs
3. Low temperature mineral assemblages of the sulpho-salts of silver
4. Association of chalcedony and jasper in the veins as a common gangue mineral
5. Complete dependence on favorable structures as the loci of ore deposition
6. Shallow deposition - the present surface is not likely more than 1000 feet below the original surface.

Structural Control of Ore Deposition

In the Calico Mining District there is a definite structural control of the mineralization. The veins are located on faults or fissures that have provided the channels for the mineralizing solutions. Billingsley (confidential report) notes that in the Silver King and Oriental Mines some mineralization is found in the volcanic pipes, which also could have acted as channels for the solution. The ore occurs as ore shoots occupying a position of curvature on the faults where differential movement of the walls has provided the necessary openings for ore deposition.

FIGURE 21

Open pit workings of the Bismarck Mine. The bed in the foreground is a rhyolitic tuff member of the Odessa Formation and contains a large tonnage of low-grade cerargyrite ore.

FIGURE 22

The Bismarck vein. Note the workings are in the footwall of the vein.

FIGURE 23

Workings of the Odessa Mine in the footwall of the Odessa vein. Note how the workings follow the bedding.

FIGURE 24

Fault-breccia in the Garfield fault. The interstitial material is cerargyrite.

A second important control for the primary and secondary mineralization was the presence of a permeable horizon. In the Silver King and Oriental mines Billingsley (confidential report) reports that a "nigger head" member, a breccia, contains the ore. Four other permeable horizons in which large ore bodies occur are discussed fully under the oxidation heading.

A third important control was the presence of an impermeable hanging wall. This can be seen in workings of the Bismarck and Odessa Mines (figures 22, 23). In both cases the veins dip to the southwest and have large irregular ore bodies beneath the hanging wall. The mineralizing solutions, coming up the fissures beneath the Bismarck and Odessa faults, deposited their load below the impermeable hanging wall.

The fourth control was the presence of fault breccia as seen along the Garfield fault in figure 24. The breccia zone varies from 2 to 50 feet in width and was cemented by halides of silver. The breccia zone formed a large area of low grade silver mineralization.

Mineralogy

At the time of the writer's work in the Calico Mining District the mines were closed, so that few typical specimens of high grade ore were available. The following minerals have been determined in part from the writer's collections and in part by other workers. Bulletin 136 of the State of California Division of Mines was frequently used during the compilation of this list and the list of the borax minerals.

The following minerals have been found in the silver mines at Calico:

Anglesite ($PbSO_4$) (Weeks, 1925, p762) Occurs as a secondary mineral in the veins of the Leviathan, Silver Bow, and the Revier mines. Polished specimens show galena in the process of alteration to anglesite.

Azurite ($2CuCO_3 \cdot Cu(OH)_2$) Azurite stain is abundant with the other copper carbonate and silicates in the oxidized ores.

Argentite (Ag_2S) Occurs as a primary and secondary mineral at Calico (Weeks 1925). In two specimens of ore from the lower workings of the Silver King and Oriental workings the primary argentite occurred as irregular masses and blebs associated with tetrahedrite and galena.

Barite ($BaSO_4$) Barite is the principal gangue of the veins of the Calico District. In West Calico it occurs as great veins 50 feet or more in width and traceable for over a thousand feet. The barite occurs as crystals stained with hematite and limonite.

Bornite (Cu_5FeS_4) Occurs as small blebs in specimens taken from the lower workings of the Silver King and Oriental Mine. The association with chalcopyrite, tetrahedrite and galena suggests a primary origin.

Calcite and Siderite although not abundant, can be seen as crystalline aggregates in the veins.

Cerargyrite ($AgCl$) One of the chief ore minerals. Specimens have a waxy luster and the colour varies from grey to green. Museum specimens of cerargyrite appear to line vug-like cavaties, and when opened have a noticeable odour of chlorine. Fresh crystals are pure white, have a waxy luster, and tend to darken to gray on exposure to light. Cerargyrite has been found in the vein deposits with barite, as impregnations in tuff beds, and as a cementing material in a breccia along a fault zone.

Cerrusite ($PbCO_3$) Massive cerrusite is abundant in the oxidized ores. In one specimen it appears to be replacing anglesite.

Chalcocite (Cu_2S) Chalcocite occurred in the lower workings of the Silver King and Oriental mines. It appears to be of secondary origin, replacing chalcopyrite along fractures and crystal boundaries.

Chalcopyrite ($CuFeSO_4$) Occurs as irregular masses with tetrahedrite, galena, and argentite. It is of primary origin.

Chrysocolla ($CuSiO_3.\ 2H_2$) Occurs abundantly in the workings of the Garfield mine as coatings on breccia fragments.

Embolite (Ag(Br.Cl) Hanks (1884) reports embolite from the Alhambra mine. It is a green waxy material associated with cerargyrite in the Garfield mine.

Covellite (CuS) Occurs as filmy delicate layers replacing galena, and is of secondary origin.

Galena (PbS) Massive galena specimens were collected from the mines of West Calico and from the Carbonate Group in Calico. The specimens were partially altered to anglesite or cerrusite. In the Ballast and the Blackfoot properties east of Odessa Canyon crystals of galena occur in the tuffs.

Hematite (Fe_2O_3) Occurs as a minor constituent in all the veins in grains less than one millimeter in diameter. Massive hematite forms 90 per cent of west Burcham veins.

Hemimorphite ($Zn_4Si_2O_7(OH)_2 \cdot H_2O$) is reported in Dana's "System of Mineralogy" 6th Edition, 1903, p1097. This occurrence is doubtful.

Limonite ($Fe_2O_3 \cdot nH_2O$) Occurs with hematite, barite and horn silver in the zone of oxidation.

Malachite ($CaCO_3 \cdot (CuOH)_2$) One of the secondary copper minerals occurring as stains in the zone of oxidation.

Proustite (Ag_3ASS_3) Weeks (1925) reports that proustite was one of the primary silver minerals of the Silver King and Oriental Mines.

Polybasite (Ag_3SbS_3) Occurs with the above proustite.

Pyrite is common in all of the polished sections of unoxidized ore. It appears to be the earliest of the sulfides to be deposited in the veins.

Pyrolusite (MnO_2) Abundant in the oxidized zone with the chlorids and bromides of silver, and occurs as black sooty masses.

Quartz One of the early vein minerals. In polished sections the quartz crystals are corroded and replaced by the sulfides. Quartz crystals fill vugs and form crustifications on cracks and fissures.

Chalcedony, Chert and Opal form part of the crypto-crystalline vein matter - occurring abundantly in and near the veins.

Realgar (AsS) Reported by Weeks (1925) occurring as a secondary mineral in the oxidized zone, and indicating the presence of former arseno-sulpho salts.

Silver Lindgren (1887) and Storms (1892) report that masses of native silver occurred with the cerargyrite and the embolite. Specimens from the Silver King and the Oriental Mines have plates of silver occurring in the tuffaceous wall rocks.

Stibnite (Sb_2S_3) Noted by Weeks (1925) in the oxidation zone with realgar.

Stromeyerite ($(AgCu)_2S$) Melville and Lindgren (1890, p40) report stromeyerite from the Silver King Mine of the following composition:

Ag	Cu	Fe	S	Res = BaSO and SiO_2	
53.96	28.58	0.26	15.51	1.55 = 99.8 per cent	SpG-6.28

Tetrahedrite ($(CuFe)_{12}Sb_4S_{13}$) Where noted in specimens from the deep workings at Calico it has a primary association with galena, argentite, chalcopyrite and pyrite.

Wulfenite ($PbMnO_4$) A common mineral in the oxidized zone (Weeks 1925).

The above list is believed to be partially complete. Some of the sulpho-salts of silver which are common in the epithermal deposits are lacking owing to the incompleteness of the specimen collections.

Gold

Gold occurs as a minor constituent in the silver veins with a value of about one dollar per ton. The Burcham, Union and the Lone Star Mines are the only potential gold properties in Calico. In the Burcham Weeks (p762, 1925) reports 11,000 tons of ore with an average gold content of 11 dollars per ton. The ore of the Lone Star group, which is the eastern extension of the Burcham, has a value of 17 dollars per ton (J. Mulchay, personal communication). The gold in the Lone Star Group is not in quartz veins but in a shear zone which contains fragments of comminuted wall rock and red oxides of iron. These shear zones are narrow and may be seen in the face of the workings. Material panned from the shear zones yields flakes of gold.

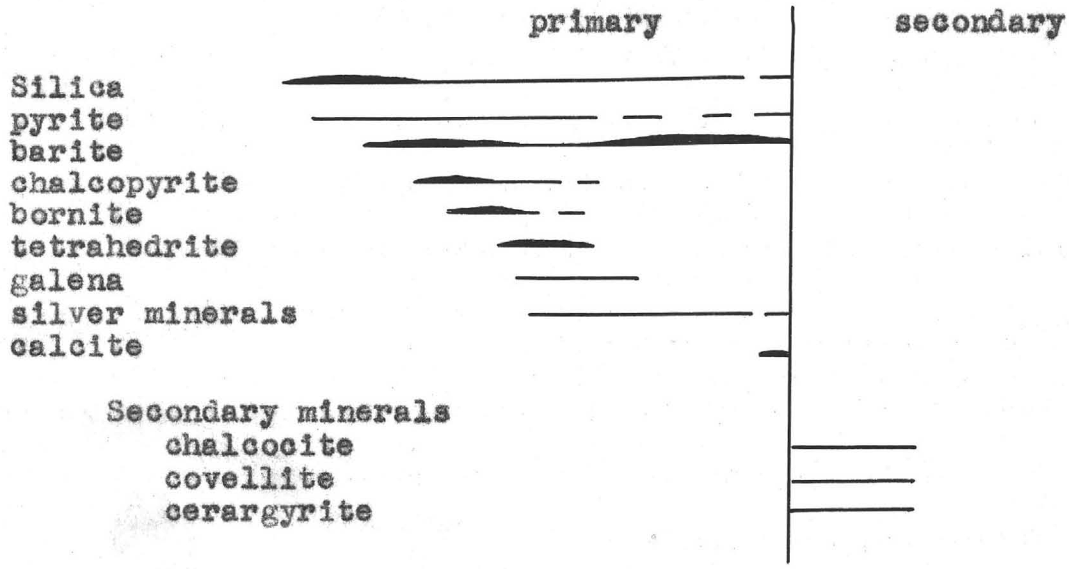
Textures and Paragenesis

Typical hand specimens taken from the barite veins as seen in figure 20 illustrate an interesting sequence of events; a sequence which may be found in many of the epithermal deposits. Barite, the principal gangue, occurs as crystals up to several centimeters in length with vugs and delicately banded structures of alternate layers of barite, red jasper, fine layers of quartz, and hematite. Evidence of continual movement during the formation of the vein is abundant; many of the bands show barite crystals that have been torn from the walls, crushed and recemented by quartz, jasper, hematite, and limonite. The movement along any one vein does not appear to be of a continuous nature. Specimens from one part of a vein will show a complicated history of crushing and recementation, while other specimens from the same vein will show only a minor amount of movement.

In polished section a siliceous material appears to be introduced in the early stages of vein formation, as the quartz crystals are corroded and partially replaced. Fine grained pyrite was introduced with the first wave of siliceous material. This was followed by the introduction of barite and the copper minerals, principally chalcopyrite and bornite. The barite and copper minerals corrode and replace the quartz and pyrite along crystal boundaries and fractures. Galena, tetrahedrite, and the silver minerals were introduced next in this order. Argentite appears to be the earliest and the principal silver mineral. Quartz and barite were introduced continuously during the deposition of the sulfides. The later quartz and barite have a dark color under reflected light. The late quartz appears as veinlets cutting the earlier sulfides, while the late barite occurs as irregular masses and pseudomorphs after galena. In the centers of the pseudomorphs can be seen rounded masses of galena. Along the borders of the late quartz veinlets are small blebs of a silver mineral, indicating the late introduction of silver. Calcite was one of the latest vein minerals.

The secondary minerals chalcocite and covellite have developed typical replacement textures along the boundaries and cleavage planes.

Order of Formation of the Minerals



Age and Genesis of the Silver Deposits

The exact age of the mineralization cannot be determined, however the time of mineralization can be fixed within certain limits. Silver mineralization occurs in the volcanic and sedimentary formations of the Odessa, Calico, and Barstow formations. These formations were folded and faulted before the silver mineralization, as the silver veins are only slightly deformed and faulted. The silver mineralization was introduced before the extrusion of the Pliocene Red Mountain volcanics. One can see in a canon in section 13, east of Phillips Drive, that the dacite tuffs contain barite-silver veins and are overlain unconformably by the Red Mountain volcanics. The silver deposits were formed in the latter phases of an orogenic period which occurred in late Miocene or early Pliocene. The occurrence of the veins along major faults and fissures suggests (but does not prove) that deep-seated magmatic reservoirs formed the mineralizing solutions.

Oxidation

All of the mines of the Calico District have oxidized silver ore. The history of the oxidation is similar to that in many of the silver camps of the Cordillera Region. The ores are halides of silver which have formed near their original place of deposition, the lead is now in the form of sulfates and carbonates, the copper minerals are concentrated at the present water table in the form of covellite and chalcocite, and any zinc minerals, if originally present, have been dissipated at the water table. The silver minerals have been deposited in veins, fissures, or adjoining porous zones.

The silver content in these porous zones has an expected gradient away from the veins, as the chloride solutions became more and more dilute. A large tonnage of low grade ore, varying from 2 to 15 ounces of silver per ton and containing varying amounts of lead still remains. The boundaries of the present stopes do not represent the boundaries of the mineralization. Porous beds in the form of tuffs, sandstones, and fault-breccia zones were available for the dilute chloride solutions, and as a consequence there exists four areas containing large quantities of low grade ore as seen in plate 1. The first area is the Lamar Mine, about a mile west of Calico, where the silver chloride solutions have saturated the sandstones of the Barstow formation. Mulchay (personal communication) reports 600,000 tons of ore with a silver content of 2 to 6 ounces of silver per ton. Weeks (1926, p484) notes three other areas. One is the belt of dacite tuffs that extends from the town of Calico eastward to Mule Canyon, this area is marked on plate 1 as "Tcdt". The principal mine in this area is the Carbonate Group. Judging from the scattered and irregular distribution of the workings, many pockets of ore have been mined from this area. The second zone of Weeks is the continuation of the rhyolite tuffs which form part of the workings of the Bismarck mine, and the third zone is a tuff member of the Odessa formation at the head of Phillips Drive, The latter area, known as the Blackfoot property, produced large quantities of ore. The rocks containing the low grade mineralization can only be recognized with difficulty in the field, as the sediments and tuffs are intensely colored owing to the alteration of their constituent minerals.

Grade of the Ore

Storms (1892) reports that the ore of the Calicos had an average value of 10 to 20 ounces in silver per ton, and that many of the high grade pockets contained cerargyrite or native silver with a value to 2000 dollars per ton. That large tonnages of mineable ore were available can be seen from the caved workings of the Waterloo Mine, and in the great open stopes of the King, Oriental, Bismarck, Odessa, Garfield, and Blackfoot mines.

Exploration for Silver

Despite the large amount of silver that has been produced in the Calico area there has been little deep exploration. The workings are generally within 400 feet of the surface, and only in the Silver King and Oriental mines have the veins been traced to the present water table.

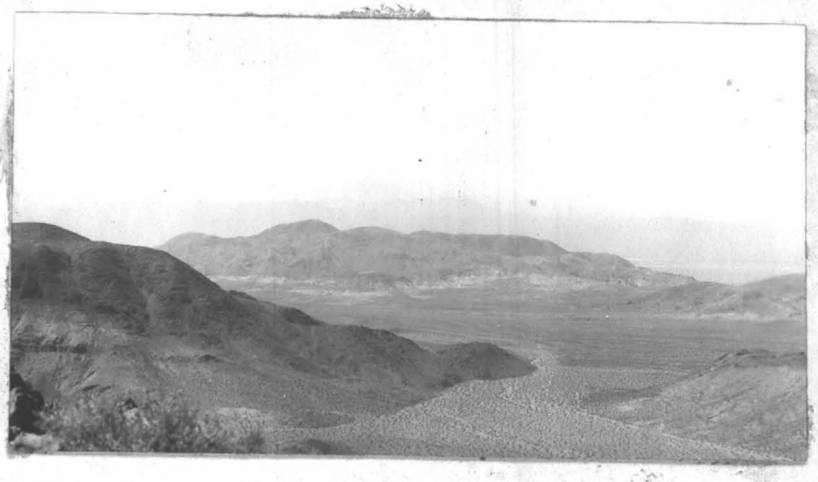


FIGURE 25

High level valley in East Calico.
The white beds in the distance are
the borate beds.
Note the cappings of the Red Mountain
andesite.

FIGURE 26

King Mountain as seen from the Calico townsite. The Silver King and Oriental veins are located on this slope.

The principal reason for the cessation of mining and deep exploration has been the fluctuation in the price of silver. The fall of the price of silver in 1887 and 1932 stopped the mining in both cases.

The deep exploration of the Zenda company in the Silver King and Oriental mines indicated the existence of an enriched sulfide zone at the water table; the principal enrichment is copper. Weeks (1929) reports that the ore in the enriched zone contained 5 to 25 per cent copper. Deep exploration was seriously hampered by the large flowage of water encountered at the water table, and swelling of the volcanic tuffs when saturated with water.

The Waterloo mine in section 18 has produced several million dollars in silver, from workings that extend from the surface to a depth of 400 feet. The caved workings, about 1000 feet long by 100 feet wide, are entirely in oxidized ore. Deep exploration for the downward extension of the ore shoots would be difficult in this locality since it would be necessary to consider the possibility of displacement on the underlying Burcham thrustfault.

The roots of the ore shoots of the Bismarck, Odessa, and the Garfield ore bodies still offer interesting possibilities for exploration. The box canyons provide a means for exploration 300 to 500 feet below the present workings. For example the Bismarck vein dips west and could be explored 800 feet below the outcrop by a tunnel from Wall Street Canyon.

Borax Deposits

The ore mined from the borax deposits in east Calico in the vicinity of the old townsite of Borate, has an estimated value of over 20,000,000 dollars. These mines were abandoned (not for the lack of ore) when deposits of a higher grade were discovered at Death Valley and later at Kramer.

The borax deposits form two horizons called the "Upper and Lower Colemanite". These beds, containing principally colemanite, vary in width from 10 to 30 feet and dip to the south at 25 degrees. The beds in the vicinity of the borax deposits are sandstones, shales, marles, and freshwater algae formations which are thrust against the dacite tuffs and flows of the Calico formation. Stratigraphically below the borate beds are some beds of sulfate bearing cherts, which Foshag (1931, p352) considers have no relation to the borate beds. The sulfate beds are lenticular masses not over 10 feet in thickness and contain the following minerals (Foshag), which in their order of abundance are alunite, coquimbite, roemerite, voltaite, jarosite, halotrichite, krausite, metavoltite, fiberroferrite, sulfur, gypsum, and anhydrite.

The minerals of the sulfate and borate beds are many and varied, and have received careful attention by many mineralogists. The following list of minerals although not complete is believed to be a good representation of the borate and sulfate minerals of the Calico District.

Minerals of the Borax Deposits

Compiled from Calif. Div. Mines Bull. 136

Mineral	Composition	Identified by
Alunite	$K_2Al_6(OH)_{12}(SO_4)_4$	Foshag, 1931, p.352
Anhydrite	$CaSO_4$	" " "
Aragonite	$CaCO_3$	Silliman, 1873, p.130
Bakerite	$8CaO.5B_2O_3.6SiO_2.6H_2O$	Giles, 1903, p.353
Borax	$Na_2B_4O7.10H_2O$	Bailey, 1902, p.56
Celestite	$SrSO_4$	Eakles, 1908, p.230
Colemanite	$Ca_2O_6B_{11}.5H_2O$	Bailey, 1902, p.358
Copiapite	$Fe_4(OH)_2(SO)_4.18H_2O$	Foshag, 1930, p.39
Coquimbite	$Fe_2(SO_4)_3.9H_2O$	Foshag, 1931, p.352
Datolite	$Ca_2B_2(SiO_4)_2(OH)_2$	Hanks, 1884, p.97
Fiberoferrite	$Fe_2O_3(SO_3)_2.10H_2O$	Foshag, 1931, p.352
Gypsum	$CaSO_4.2H_2O$	Bailey, 1902, p.58
Halotrichite	$FeSO_4.Al_2(SO_4)_3.22H_2O$	Foshag, 1931, p.352
Howlite	$H_5Ca_2B_5SiO_{14}$	Giles, 1903, p. 353
Jarosite	$K_2o.Fe_2O_3.4SO_3.6H_2O$	Foshag, 1931, p.352
Krausite	$K_2SO_4.Fe_2(SO_4)_3.2H_2O$	Foshag, 1931, p.352
Metavoltine	$(H,K)_4(FeOH)_2(SO_4)4.5H_2O$	" " "
Meyerhofferite	$Ca_2B_6O_{11}.7H_2O$	Foshag, 1921, p.200
Priceite	$Ca_5B_{12}O_{23}.9H_2O$	Hanks, 1884, p.313
Psilomelane	$BaR_9O_{18}.2H_2O$(R is Mn)	no reference, occurrence doubtful
Römerite	$FeO.Fe_2O_3.4SO_3.14H_2O$	Foshag, 1931, p.352
Soda Niter	$NaNO_3$	Williams, 1883, p.549
Strontianite	$SrCO_3$	Murdoch, 1945, p.719
Sulphur	S	Foshag, 1931, p.352
Ulexite	$NaCaB_5O_9.8H_2O$	Foshag, 1922, p.202
Voltaite	$3(K_2Fe)O.2(AlFe)_2O_3.6SO_3.9H_2O$	Foshag, 1931, p.352

Genesis of the Borate Beds

The borate beds are a part of the Barstow formation which is of continental origin. Interbedded in the Barstow are beds of travertine, chert, and andesite flows which are evidence of contemporaneous volcanism. It is believed the borax minerals were deposited in water by crystallization, the borates being supplied by the thermal springs associated with the volcanism. Hoyte Gale (1946, p327) explains the widespread borate deposits of the Kramer District in a similar manner as follows:

> "Volcanic waters probably flowed down through and over lava flow masses while these rocks were still hot. Thus these waters have concentrated rapidly by evaporation, as they passed on down towards the nearby basin areas, and may have accumulated in pools or lakes at the low part of the basin in a supersaturated condition with respect to borax. Spreading into a broad surface exposed to the air the waters in the lakes or pools may have undergone a relatively sharp drop in temperature, thereby throwing out borax....."

Exploration for Borate

Storms (1892, p348) shows a cross section of the borax workings of Mule canyon in which the deepest workings are 350 feet below the surface. The mines were closed shortly thereafter, and it is doubtful if the workings were advanced to a depth of more than 500 feet. In Mule Canyon the colemanite beds dip south under the capping of Red Mountain andesite. Borax beds have been mined on the southern side of this capping, however it is doubtful if they are the continuation of the Upper and Lower Colemanite beds. In Surprise canyon, an area intermediate between the workings, the sediments are folded and faulted and a black chert bed (figure 16) forms the southern wall of the canyon. In Mule Canyon this black chert bed is about a 1000 feet stratigraphically lower than the colemanite beds. If the formations form a synclinal structure as seen in section I-J, plate 11, then the southern outcrop of the colemanite beds is covered by the Red Mountain andesite.

At the entrance to Phillips Drive is an area where thin beds (about 1 inch in thickness) of colemanite are interbedded with the shales and sandstones as seen in figure 15. A similar material has been mined at the entrance to Odessa and Bismarck canyons. Here the thin beds of colemanite have a red color and dip north at 45 degrees. It is impossible to determine if these thin colemanite beds are the westward extension of the Upper and Lower Colemanite beds.

Borate beds may exist under the Calico Dry Lake. In the Kramer District such beds exist and Gale (1946) reports "that the borate deposits do not outcrop but lie beneath the surface of an area covered by an alluvial wash characteristic of desert areas". The Kramer deposits lie within an oval area four miles in length and one mile in width - an original basin of deposition. The principal borate deposits range in depth from 300 to 1000 feet below the surface of the ground. As far as the writer can determine deep tests have not been made under the Calico Dry Lake.

<u>Summary</u> The following facts may be used in the utilization of or the exploration for borate deposits:

1. The possibility that the southern exposures of the Upper and Lower colemanite beds are covered by the Red Mountain andesites north of Surprise Canyon.

FIGURE 27

Stone quarry in the dacite flows of the Calico Formation in East Calico.

2. The utilization of the thin beds of borax between Phillips Drive and Odessa Canyons.
3. Deep exploration under the Calico Dry Lake, for the possibility that extensive beds, such as found at Kramer, might exist.

Barite

The principal gangue mineral of the vein deposits is a potential source of barite. Large vertical barite veins, 2000 feet long and 50 feet wide, in West Calico could be cheaply mined by open pit methods. Samples of the barite vein have a specific gravity which varied from 3.66 to 4.10 and yielded a clean white product when panned. Barite can also be obtained from the dumps surrounding the old workings and the old mill sites.

Building Stone

Building stone is quarried (see figure 27) in East Calico two miles north of the borax workings. The rock quarried is a flat lying dacite flow, which has a desirable pink tinge. It is used for ornamental purposes and especially for the front pieces of a fireplace.

Mines and Prospects

The mines were idle at the time of the writer's work in the Calico Mining District. Information was therefore compiled principally from the California Division of Mines Bulletins, and from discussions with local mine owners and prospectors.

The mines and prospects are discussed in their order of occurrence from west to east, and only the principal silver mines are mentioned.

West Calico

Leviathan Mine (owner H. Britt, Daggett) is the largest mine in West Calico. The veins are explored by four tunnels, comprising 1500 feet of workings, and two winzes. The property consists of nine patented claims.

The veins are 50 feet in width and plainly traceable on the surface for over 2000 feet. At a depth of 200 feet below the surface the main vein is still 50 feet in width. The veins carry four to six ounces of silver in hematite-limonite-jasper-barite gangue. At the west end of the vein are several stringers of silver-lead ore.

Several large samples of barite material have been panned and produced a clean white product. A large tonnage of barite (over 1,000,000 tons) is visible on this property.

Silver Bow (owner J. R. Reber, San Bernardino) The Silver Bow consists of one patented claim that adjoins the Leviathan mine. Development on the property consists of an inclined shaft 230 feet deep and 500 feet of drifting. The ore is a silver-lead in a barite gangue. The shaft, sunk on an unoxidized ore shoot, contained several carloads of ore averaging 100 ounces of silver per ton according to Weeks (1925). The ore shoot, which is faulted off in the lower levels, has not been located by exploration. The property is a potential value as a producer of barite and possibly silver and lead.

Langtry (Owners H. Britt and A. Alf, of Daggett) The Langtry mine is a barite silver vein in the Barstow sediments. The property has been developed by 250 feet of workings and a 50-foot winze. The vein is vertical and varies from 3 to 10 feet in width. About 200 tons of silver ore averaging six to eight ounces of silver per ton has been stoped from the veins.

Revier (Owner, status unknown) Revier vein is located near the fault scarp in West Calico. The vein is 10 feet in width and stands vertical. The minerals are silver(?)-lead in a barite-hematite and jasper gangue.

Silver Contact (Owner and status unknown) Is located on the road to upper Wall Street Canyon. The vein is a small silver vein located on the hanging wall of a small dike. All the silver ore found to date was located in a small pocket at the surface. The property is explored by two winzes each 100 feet deep.

Possibility Group (Owner L. Coke, Yermo, and J. Mulchay, San Bernardino) Four staked claims in section 17 which are located along a mineralized fault zone in the Barstow sediments. Figure 13 is taken on the possibility claims and shows the fault contact between the sediments and the volcanic formations. The ore consists of silver chlorides which have saturated the sediments and contains four to six ounces of silver per ton.

Lamar Group (Owner J. Mulchay, San Bernardino) Consists of eight claims, patented and unpatented, located on the extension of the same mineralized zone of the Possibility group. The ore is in sediments of the Barstow formation which have been saturated with silver chlorides. Mulchay reports a large tonnage of ore which averages four to six ounces of silver per ton.

The Calico District (proper)

Waterloo (Part of the holdings of the defunct Silver King Consolidated Company) Owner of 22 patented claims in the Calico district, eight of the claims are located on the eastward extension of the Prosperity-Lamar mineralized zone in section 16. This was one of the principal mines of the Calico district. A large tonnage of ore averaging 11 to 20 ounces of silver per ton was treated in the company mill at Daggett from 1881 to 1896. The ore occurs on the "Waterloo fault" and has been developed to a depth of 300 to 400 feet.

The total amount of the underground workings is approximately 10,000 feet of drifting and an inclined shaft. The upper workings have caved and formed a large pit over 1000 feet in length and 80 to 100 feet in width. The shaft and the lower tunnel are still accessible. Tucker and Sampson (1943, p490) report that there is still ore on the third and the sixth levels.

Union (Owner Jack Moore, Yermo) The Union group consists of five patented claims north of and adjoining the Waterloo mine, located in section 16. The vein, which strikes northwest and dips 50 degrees to the south, is in the fault zone in the dacite tuffs of the Calico formation. The vein varies from two to 10 feet in width and carries gold, silver, lead-carbonate in hematite-barite gangue.

The property is developed by about 1000 feet of workings and two winzes each sunk on the vein to a depth of 100 feet.

Burcham Mine (Owner the Burcham Mines Inc., Los Angeles) (Total wreck) The Burcham Mine comprises 21 patented claims located in the northeast corner of section 21 and the southeast corner of section 16. The ore at the Burcham consists of gold, silver and lead, located along two veins, the Mulchay and the Burcham. The Mulchay vein is 300 to 500 feet north of the Burcham vein and is the eastward extension of the vein in the Union mine. Tucker and Sampson (1943, p476) report that "the Mulchay vein strikes north 45 degrees west and dips to the south 65 degrees; width 4 to 30 feet; with a high grade streak in the foot wall; width 26 inches; with the mineralization extending into the hanging wall for a width of 15 to 30 feet. The ore shoot in this vein is 600 feet long; average width of 20 feet; and has a value of $6.60 per ton".

The Burcham vein high grade streak has a width of 26 to 30 inches, with a value of 15 dollars per ton. The total amount of workings is 10,000 feet of tunnels and three or more winzes.

Lone Star Group (Owner J. Mulchay) The Lone Star group consists of an irregular area of about the size of two claims located between the Burcham mine and Wall Street Canyon. The ore occurs along a fault zone, and is gold in a finely comminuted wall rock material which is stained with hematite. Mulchay reports that the streaks have a value of 20 dollars in gold per ton, and that free gold can be panned from the ore.

Consolidated and the Consolidated Extension (former Consolidated and St. Louis claims) (Owner G. A. Hoffman) Located on the west rim of Wall Street Canyon, on the southwest corner of section 15. The ore is located along a series of six closely spaced veins which dip to the east at 80 degrees. The ore is silver chlorides in hematite-limonite-barite gangue. The property is developed by about 500 feet of workings. Ore of unknown value has been shipped from the property.

Wishing Well (Owner L. Coke, Calico) (former Governor Smith Claim)

Falls Mine (Owner Mrs. Osbourne, Daggett) (former Sioux Claim)

Elizabeth Group (Owner Mrs. Mulchay) The Wishing Well, Falls mine, and the Elizabeth group are located along the same northwest trending series of veins, located at the head of Wall Street Canyon. The claims adjoin each other and are named in their order of occurrence from south to north. They are located in the northwest corner of section 15. The veins are parallel to each other and dip to the east at 75 to 90 degrees. The ore is silver chlorides in a hematite-limonite-barite gangue. The Falls mine, the central claim, is developed by several hundred feet of workings. The stopes are 200 to 500 feet in length, have been developed to depth of 300 feet, and are two to five feet in width.

The road to the head of Wall Street Canyon terminates at the Falls mine.

Zenda Gold Mining Company (of Los Angeles) The Zenda Gold Mining Company owns 26 patented and staked claims immediately north of the townsite of Calico. This includes the former holdings of the Silver King and Oriental Mines, which are the largest mines in the district. The Oriental vein intersects the Silver King vein near the southwest corner of the Silver King claim. The veins strike northwest and dip 60 to 70 degrees to the south. There has been considerable movement along these veins, with the development of fault breccia in the veins. The ore is chlorides, bromides of silver in a barite, hematite, and jasper gangue. The ore shoots are irregular and plunge to the southeast. They vary in thickness from 20 to 50 feet, and carry 10 to 40 ounces of silver per ton, with many high grade lenses of solid cerargyrite having values in the thousands of dollars per ton.

Tucker and Sampson (1943, p492) report that the Silver King and Oriental veins are developed by two shafts. No. 1 is a vertical shaft 340 feet deep and 542 feet southeast of No. 2 shaft, which is a three-compartment shaft 550 feet deep. About 15,000 feet of development has been carried out from the No. 2 shaft. The two shafts are joined together by underground workings. The No. 1 shaft was located in Wall Street Canyon, and the No. 2 shaft on the high ground north of the townsite of Calico. Owing to the slumping of the water-saturated sediments, the shafts are caved and no longer accessible.

<u>Calico-Odessa Group of Mines</u> (Owner Mrs. J. R. Lane, San Julian) This group of mines consists of a number of the producing properties known as the Garfield, Odessa, Thunderer, and the Blackfoot. It covers the ground from Bismarck Canyon

to Phillips Drive. The holding comprises about 45 staked and patented claims located in sections 15 and 14.

The Garfield-Thunderer is located on the ridge between Odessa and Bismarck Canyons. The Garfield fault contains the principal ore bodies and dips to the southwest at 75 degrees. In the Garfield a fault breccia has been cemented by silver chlorides. This property has about 10,000 feet of workings. Judging from the stopes,which are up to 300 feet long and 40 feet in width, great quantities of ore have been mined.

The Odessa mine is situated west of Odessa Canyon and consists of a vein which strikes north 40 degrees west and dips to the west 70 degrees. The ore of the Odessa mine is silver chlorides and bromides which have saturated the sediments in the footwall of the vein (figure 21).

The Blackfoot Mine is located at the head of Phillips Drive. The ore occurs as impregnation in an rhyolitic tuff. The ore formed shallow irregular pockets in the tuff and is reported to carry one to 14 ounces of silver per ton (Weeks, 1925).

Bismarck (Owner H. Britt) In the Bismarck mine the principal workings are at the head of Bismarck Canyon. The Bismarck vein strikes north-south and dips to the west at 45 to 70 degrees. The ore occurs principally in the footwall of the vein and in the sediments below the footwall (see figures 19 and 20). The ore is entirely chlorides of silver. The Bismarck is one of the former large producing mines of the Calico area.

Carbonate Group (Owner J. Mulchay, San Bernardino) Consists of eight claims located in the yellow tuffs from Bismarck Canyon west to Phillips Drive. The ore occurs as impregnation in the tuffs, and picked shipments had values in silver to 25 ounces, gold to 0.89 ounces, lead 19 per cent, and zinc to 1.0 per cent. This forms part of Weeks (1927) "breccia ore".

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Western Slope of Wall Street Canyon,
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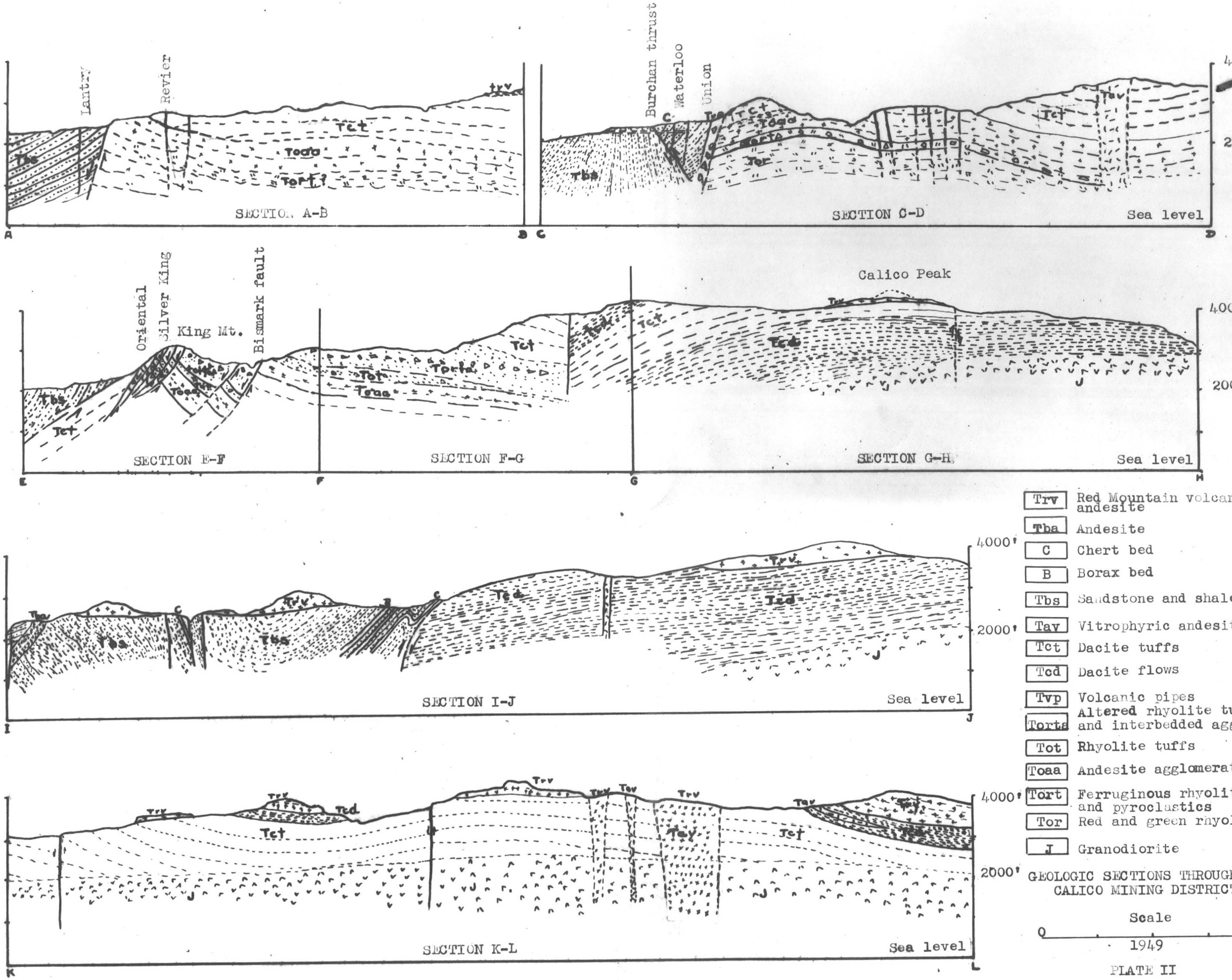

Trv	Red Mountain volcanics andesite
Tba	Andesite
C	Chert bed
B	Borax bed
Tbs	Sandstone and shale
Tav	Vitrophyric andesite
Tct	Dacite tuffs
Tcd	Dacite flows
Tvp	Volcanic pipes
Torta	Altered rhyolite tuffs and interbedded agglomerate
Tot	Rhyolite tuffs
Toaa	Andesite agglomerate
Tort	Ferruginous rhyolite tuffs and pyroclastics
Tor	Red and green rhyolite tuffs
J	Granodiorite

GEOLOGIC SECTIONS THROUGH THE CALICO MINING DISTRICT

Scale

0 — 1 mile

1949

PLATE II

Possibilities of the Calico Mining District

A Description of an Almost Forgotten Camp in California That Was Worked for Its High-grade Ores Forty Years Ago

By F. B. Weeks

[redacted]

...field mill treated 11,476 tons of

Diamond Drilling for Carnotite

...

addition to ...
ore deposits.

Location 10,000 ...

northwest, adapting themselves to a radial attitude with respect to a north-plunging anticlinal axis. Here again is a resemblance to Cre where the Amethyst vein, in its productive, far southern portion, starts to turn southeast along a similar radial fracture.

That the axis of the Jarbridge anticline does plunge to the north is suggested by the southerly dip of the Buster and other cross fractures, which are oriented as cross joints normal to the axis (Fig.4C).

Jarbridge shows points of resemblance to Terlingua also. It was shown that the main Chisos ore body was localized along a tension fissure east of and parallel to the Long Draw graben where fault movement had been impeded on the eastern graben fault, resulting in acute arching of the strata on the east side of the graben. At Jarbridge the entire west flank of the arch was fissured rather than faulted. The comparison to the Neuwied dome pictured in connection with the Chisos deformation is very close (Figs.26A,26B). Magma at Neuwied ascended the fissured part of the arch and avoided the more important antithetic faults. Ore-bearing solutions at Jarbridge appear to have done the same.

Calico, California

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W.H.Storms(1892), San Bernardine Co., Calif., in State Mineralogists Report No.11, p.337-349.

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__________(1929A), Possibilities of the Calico mining district, Engr.& Min.Jour.-Press, vol.   , p.757-763.

__________(1929B), Calico mining district, Min.& Met. vol.10, p.531-534.

J.L. Deleen(1949), Unpublished thesis for degree of Mining Engineer, University of California.

This epithermal silver district lies in the desert province of southeastern California (Plate 1). Miocene rhyolite and dacite tuffs and flows are overlain by sandstone and shale with interbedded andesite flows.

Structure.- A complexly folded and faulted uplift is bounded on the south by the Great South south-dipping normal fault. The major feature of the uplifted block is a west-northwest anticline. As at Ophir, Matehuala, Los Lamentos and elsewhere, maximum displacement on the Great South fault occurs where the fault cuts the crest of the anticline and displacement dies out either way from the crest. On the northeast upper flank of the anticline and just north of the fault is a sharp, highly-faulted parasitic dome.

A series of major longitudinal antithetic faults follows the northeast flank of the anticline, the faults having dip and downthrow toward the anticlinal axis in the manner of those shown in Figure 4A. Toward the south these faults curve around to subparallelism with the Great South fault, suggesting that the arching producing them accompanied the fault movement on the Great South fault.

Nearly all the faults and fractures, including the Great South fault, are mineralized. The area of important mineralization coincides roughly with that of maximum uplift: most ore deposits were found along the antithetic faults along the upper part of the northeast flank of the anticline, and in fractures in the parasitic dome.

Ore Deposits.- Metallic minerals included galena, tetrahedrite, chalcopyrite, bornite,argentite, proustite,polybasite and stibnite. The principal gangue mineral is delicately-banded barite,older than the sulphides;the barite shows druses and is accompanied by chalcedony and jasper.

Tectonic Analysis of Calico.- The ores shoots were completely dependent on favorable structure,those along the antithetic faults occupying permeable segments produced by fault curvature and differential movement of the walls (Hulin, 1929,p.38-40; Newhouse,1940,p.445-464; Emmons, 1948, p.58-81).

Vein formation was brought about by continual intramineral movements affecting the vein-fractures; barite was torn from its walls and recemented by quartz, jasper and sulphides. On a give vein crushing and recementation was visible in places, unborken symmetrical banding in others.

In discussing the crustified-banded veins of Terlingua (p.127) Berg (1932,1938) was quoted to the effect that symmetrical banding results where the walls of vein-fissures are drawing apart and where opening proceeds faster than filling. Berg in the same papers points out also that where filling was faster than opening any crack was at once filled by vein matter and that new vein matter had to await reopening, which was apt to be localized by surfaces of least resistance such as gougy slips,or bands of drusy cavities down the center of the vein.

Berg recognizes also intramineral minor fault movements in the plane of the vein,but thinks that nearly all veins which are results of open space filling formed in tension fissures,and that mineralization of thrusts and other planes of shear took place usually through metasomatic replacement. McKinstry (1949) also, dealing with mesothermal and hypothermal veins, rejects post-quartz shearing to explain the ribbon structure so commonly displayed by these veins, favoring an origin by replacement of sheeted zones.

Curvature of the walls of the Calico antithetic faults takes the form mainly of sudden changes in dip (Figs. 30A, 30B). The wall rocks for these faults consist of flows and tuffs of varying physical characteristics. The antithetic faults are roughly perpendicular in dip and parallel in strike to these heterogeneous layers, so that the latter abutt horizontally against the fault surface (Fig. 30A).

Knopf (1929, p. 24-25, Figs. 11, 12, cited and discussed by Newhouse, 1942, p. 11-13) and others have shown the deflection of fractures in passing from rock of one physical type to that of another. Tectonic refraction at Calico and elsewhere might explain the "zigzag" control which created, with differential movement of fault walls, permeable places for ore to deposit. Following Berg, those portions of the Calico veins which show symmetrical banding lie in segments of the antithetic faults where the walls were moving apart faster than the resulting opening was being filled. With normal faulting, such segments would correspond to the steeper parts of the faults, as shown in Figure 30A and Figure 30B.

Those parts of the veins showing older vein matter ripped open to permit entry of younger vein matter lie in areas where filling was faster than opening. Such places might have been steeper segments of veins lying close to solution channels which pumped into them abundant material, or they might have been flatter-dipping segments where during the fault movements one wall moved past the other (Figs. 30A, 30B); even in such segments mathematically plane fault surfaces cannot have existed and small openings would be continually formed by continued differential movement of the fault walls. Such conditions would seem to

explain especially well those portions of the Calico veins wher
the vein matter is very finely crushed and recemented.

Parral, Chihuahua, Mexico

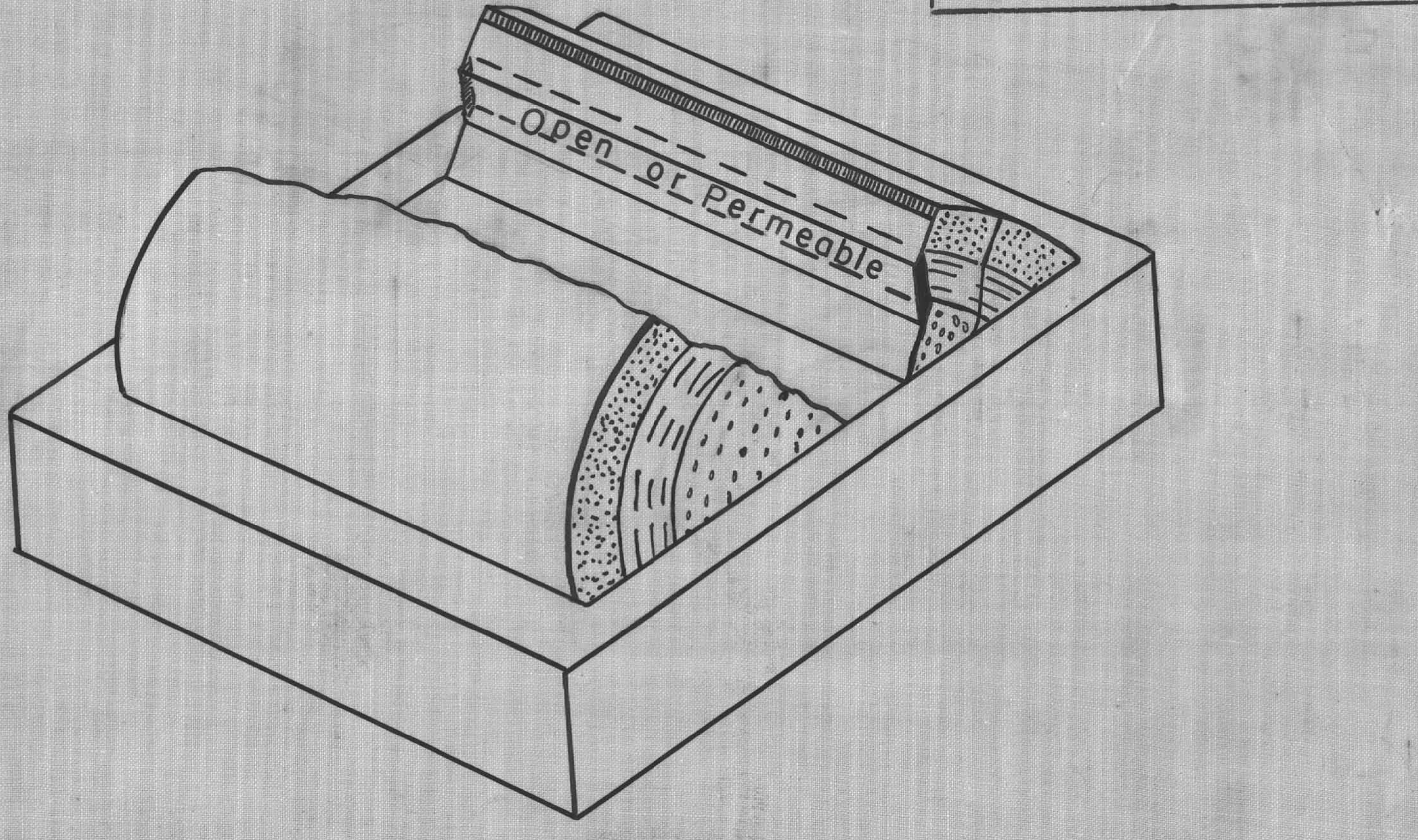
Sources.-

F.W.Smith (1910), Conditions at the Palmilla mine, Parral, Mexico, Engr.& Min.Jour. vol. p. .

Harrison Schmitt(1931), Geology of the Parral area of the Parral district, Chihuahua, Mexico, Am.Inst.Min.&.Met. Engrs., Trans., General Volume, p.268-289.

H.E.McKinstry(1931), Discussion of Schmitt paper, ibid., p.289-290.

Edward Wisser(1945A), Unpublished reports and field notes.



30 B

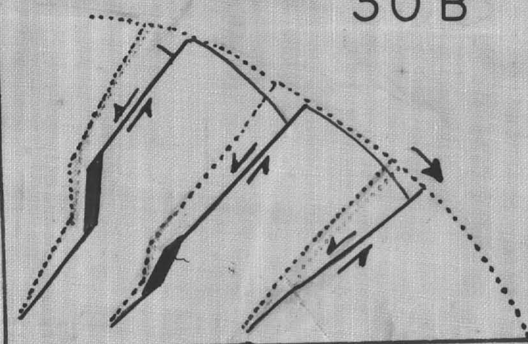


FIG 30A

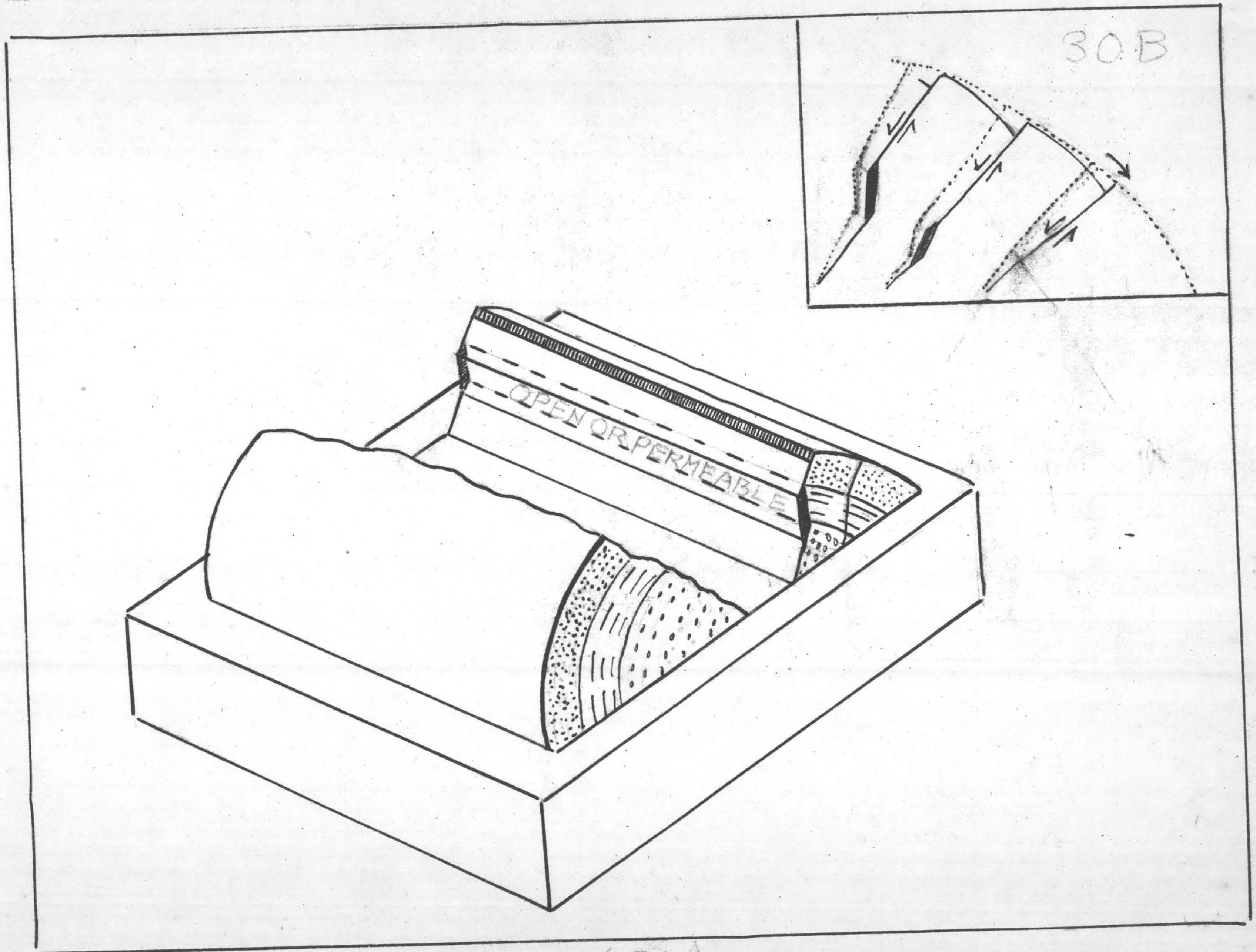


FIG 30A

BLOCK DIAGRAM AND SKETCH ILLUSTRATING TECTONICS OF CALICO

The Calico Mining District*

By F. B. Weeks

by solution from their upper and oxidized portions ciated with oxidized vein matter and ho[illegible]d,

Source - Thesis for degree of Mining Engineer, by J. L. De Leen, 1949

Put under Complex Anticline in Incomtent rocks, faulred margin,

Half Dome, probably not simple.

Calico Ag, Calif.

CR: Miocene rhyolite tuffs, dacite tuffs, rhy. dacite flows, overlain by ss, sh, IB andesite flows.

Structure: In immediate Calico, main mining area, half-dome like Ophir, bounded on S by relatively flat synthetic fault which xxxxxxx is concave toward the helf-dome. Traversing the irregular dome is a serie of step-faults.

Complex WNW uplift bounded on south by major S-dipping normal fault, Great South Fault. San Dimas type of free-block deformation, for in detail high of uplift is NNW anticline plunging to N. Great series of antithetic faults parallel in strike to this anticline. Toward S they curve around to subparallelism with Great S fault zone.

Displacement on Great S fault reaches maximum near centerline of the NNW uplift, and does out either way. Just E of pt of maximum displace- is very sharp, highly faulted local dome: locus of main mineralization.

Marginal thrust to W, where Great S fault dies out or joins another f.t May be of later age.

Practically all the fractures described are mineralized, with the

main area of mineralization in the area of maximum uplift, esp. the antithetic fault area on E flank of NNW anticline, and the focus of mineralization in the highly faulted superimposed dome.

Main gange barite, notably delicately banded. Pre-sulphide. In fissure veins related to uplift, wedge out in depth. Silver King, Oriental mines in the dome. Vugs; chalcedony, jasper.

Complete dependence on favorable structure. Epithermal.

OBs shoots of occurrence along the antithetic flts., positions of curvature. proovded openings by differential movement of walls.

Primary Minerals beside those mentioned: argentite, tetrahedrite, ta galena; bornite, ccpy; proustite, polybasite, stibnite

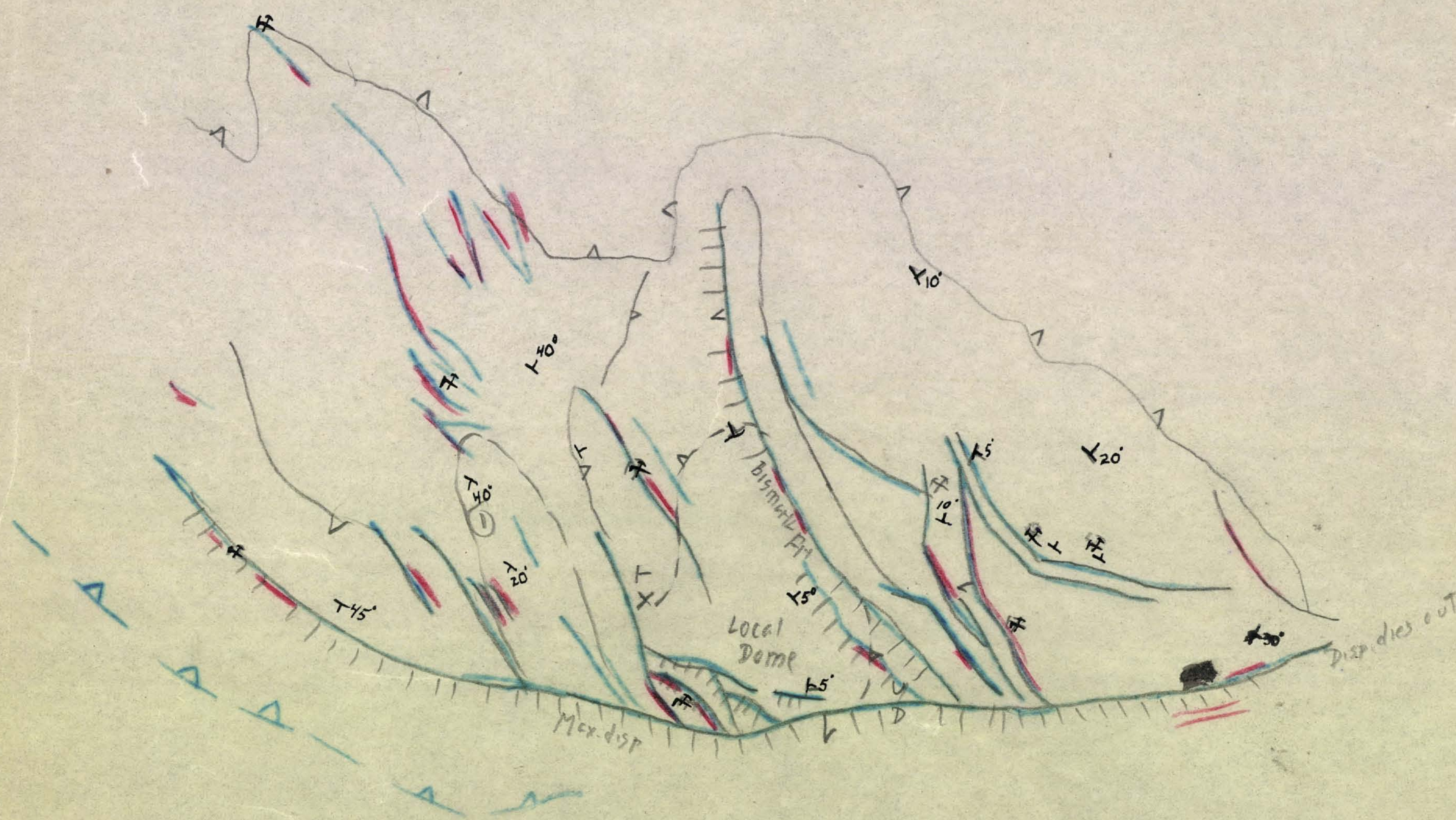
Continual IM movement: bands show barite xx torn from walls, recemnted by qtz., jasper, sulphides. On a given vein, much crushing, recementation at one place, simple banding, little obvious IM movement in another. According to Berg, in 1st place solutions came in faster than fissure could open; 2nd opening faster than solutions came in. Logical.

Relative age of mineralization: Silver veins only slightly deformed and faulted, so Ag after major folding and faulting. Veins are along major faults and fissures, possibly from deep-seated ore reservoirs.

Waterloo mine along Great S fault zone. One of main mines. Union on Great S fault itself; in dacite tuffs of Calico formation. 2*10'.

Burcham, same zone as Waterloo, to E; another vein in mine, E extension of Union vein.

Anticlines of this type give master fractures - ± important OBs


Bismuth Flt
Local Dome
Max. disp
Disp. dies out
10°
40°
40°
20°
45°
5°
10°
5°
20°
30°
5°

Calico
1" = 2 mi

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Geohydrochemistry of the San Gabriel Valley area, Los Angeles County, California. By Sanford L. Werner. Copyright, 1965. M. S. Thesis. On file at University of Southern California, Los Angeles. Abstract on file in Division of Mines and Geology Library, San Francisco. Emphasizes the use of chemical analyses of various types of water as a basic tool to show geohydrochemistry.

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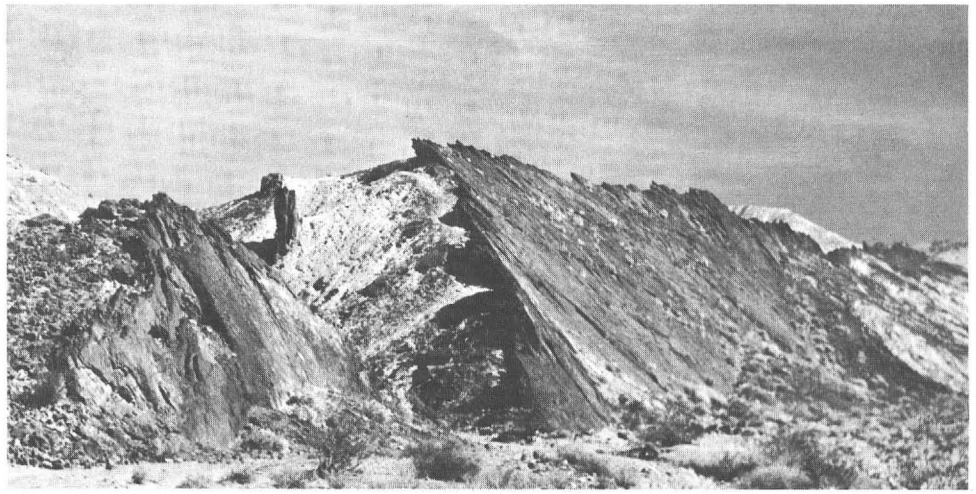
A PUBLICATION OF THE CALIFORNIA DIVISION OF MINES AND GEOLOGY

VOLUME 19 NUMBER 5
MAY 1966

IN THIS ISSUE



Calico Mountains

STATE OF CALIFORNIA ▪ THE RESOURCES AGENCY ▪ DEPARTMENT OF CONSERVATION ▪ DIVISION OF MINES AND GEOLOGY

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MINERAL INFORMATION SERVICE is designed to report on the progress of earth science in California, and to inform the public of discoveries in geology and allied earth sciences of interest and concern to their lives and livelihood. It also serves as a news release on mineral discoveries, mining operations, statistics of the minerals industry, and new publications. It is issued monthly by the California Division of Mines and Geology. Subscription price, January through December, is $1.00.

Other publications of the Division include the Annual Report of the State Geologist; the Bulletin, Special Report, Map Sheet, and County Report series; the Geologic Map of California; and other maps and publications. A list of the Division's available publications will be sent upon request. Communications to the Division of Mines and Geology, including orders for publications, should be addressed to the San Francisco office.

Mary R. Hill, *Editor*

THE HISTORY TRAIL

From Mr. Braeme E. Gigas comes good news concerning the name Mount Mary Austin. Writes he, "Happily, we need no longer put that phrase in quotes, because I have just received a letter from the Board of Geographic Names that the name has been approved." An enclosed letter from the Board adds, "This decision will be published in Decision List 6601 and the entry will read as follows:

> Mary Austin, Mount: mountain, elevation over 13,040 ft., 1 mi. NE of Black Mountain and 8.5 mi. W of Independence; named for Mrs. Mary Austin, a prominent writer, natural historian, and long-time resident of the area; Inyo Co., Calif.; 36° 48′ 57″ N., 118° 21′ 43″ W."

THE HISTORY BOOKSHELF

Mines of the High Desert, by Ronald Dean Miller. 63 pages, 20 photos, maps, index, references. Price $1.95.

History of the Dale mining district, in and about Joshua Tree-Twentynine Palms National Monument, is recounted by Mr. Miller, who was for years a naturalist at the Monument. The two dozen mines of the area—among them the Virginia Dale, Old Dale, New Dale, Supply, OK, Zulu Queen, Gold Coin, Snowcloud, Lost Horse, Hexie, Anaconda, and Desert Queen—were "small, almost do-it-yourself" turn-of-the-century ventures, but their story contributes an interesting and picturesque page to desert lore.

Mines of the High Desert is the fifth booklet in Walt Wheelock's La Siesta Press desert series . . . its predecessors *Freeman's, A Stage Stop on the Mojave*, by E. I. Edwards (price $1.95); *Exploring Joshua Tree*, by Roger Mitchell (price $1.00); *Baja California Overland*, by L. Burr Belden (price $1.95); and *Desert Peaks Guide, Part I*, by Walt Wheelock (price $1.00). They may be obtained from La Siesta Press, Box 406, Glendale, California, 91209.

❋

Dedicated to keeping the gold mining industry from becoming an irrevocable page from history is the monthly paper *American Gold News*, the official publication of the American Gold Association and the Mineral Association of Northern California. Those who wish to keep a finger on the pulse of the ailing industry can do so with a subscription, price $3.00 per year (foreign $4.00 per year) or $5.00 for two years. Address P.O. Box 427, San Andreas, CA 95249.

❋

The Rock Paintings of the Chumash, by Campbell Grant. 163 pp., 120 figs., 30 colored plates and frontis. University of California Press, Berkeley and Los Angeles. 1965. Price $10.00.

Our thanks to reader "C.S.", Librarian at Santa Barbara Museum of Natural History, for his complaint that we had not reviewed *Rock Paintings of the Chumash*. We are much in his debt for calling to attention this unusually beautiful volume, typified by a clear, understandable text and some of the most finely reproduced Indian paintings it has been our pleasure to view. Campbell Grant, author and artist, has copied many of the original paintings, on the spot; his copies are printed in color, along with a few color photos of the originals for comparison.

The book explores the territory of the Chumash, their history, and their culture, and the text is supplemented by numerous black and white illustrations. The material presented is authentic, yet its rendition is not hampered—for the layman—by the language barrier common to many scientific works.

Mr. Grant has included a short section entitled "Erosion and Vandalism" in which he concludes that "Damage through vandalism is a far greater threat to the existence of these pictographs than erosion". Fortunately their locations are not too well known, nor are they too accessible (what a sad comment to have to make!); but even so, many of them have been seriously damaged by vandals.

Rock Paintings may be ordered from University of California Press, Berkeley, California 94720. It is not distributed by the Division of Mines and Geology.

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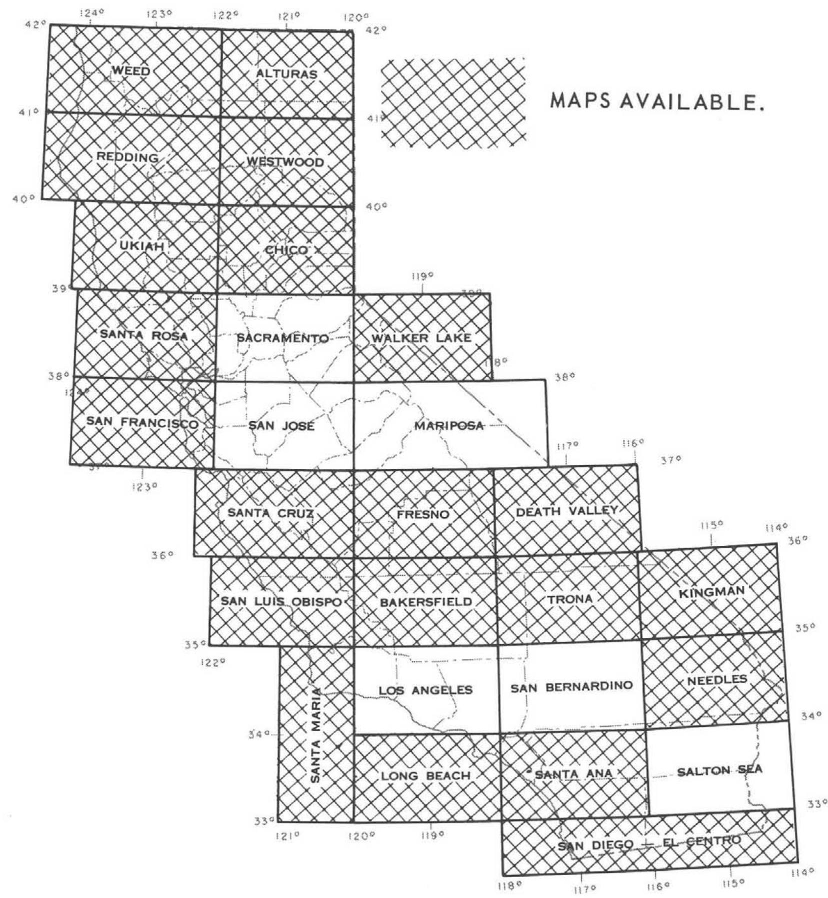


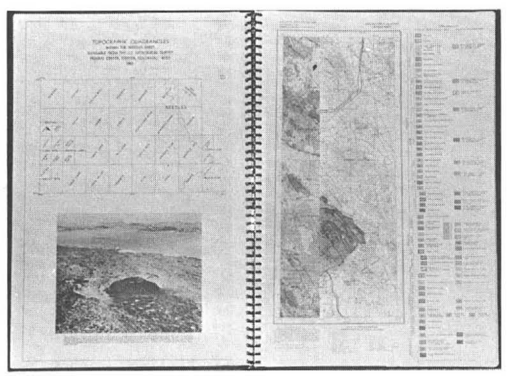
Individual sheets of the geologic map may be purchased from the Division of Mines and Geology, Ferry Building, San Francisco, California, 94111. Each sheet is accompanied by a data sheet which explains more fully the map units, and also lists the sources of information used in preparation of the map. The price of each map and data sheet set is $1.50, plus tax. Map sheets on which the geologic units are not colored are available for 50 cents.

NOW AVAILABLE....

GEOLOGIC ATLAS

The geologic atlas of the State of California was prepared by the California Division of Mines and Geology to present an integrated summary of current knowledge of California geology. Preparation of these maps began in 1952, after the popular 1938 edition of the 1:500,000 scale state geologic map went out of print. This atlas, the first sheet of which was published in 1958, has been designated the "Olaf P. Jenkins Edition" in recognition of the stimulus Dr. Jenkins provided to geologic mapping in California during the 29 years he served as Chief Geologist and later as Chief of the Division of Mines, and in recognition of his personal direction of the atlas program at its inception.

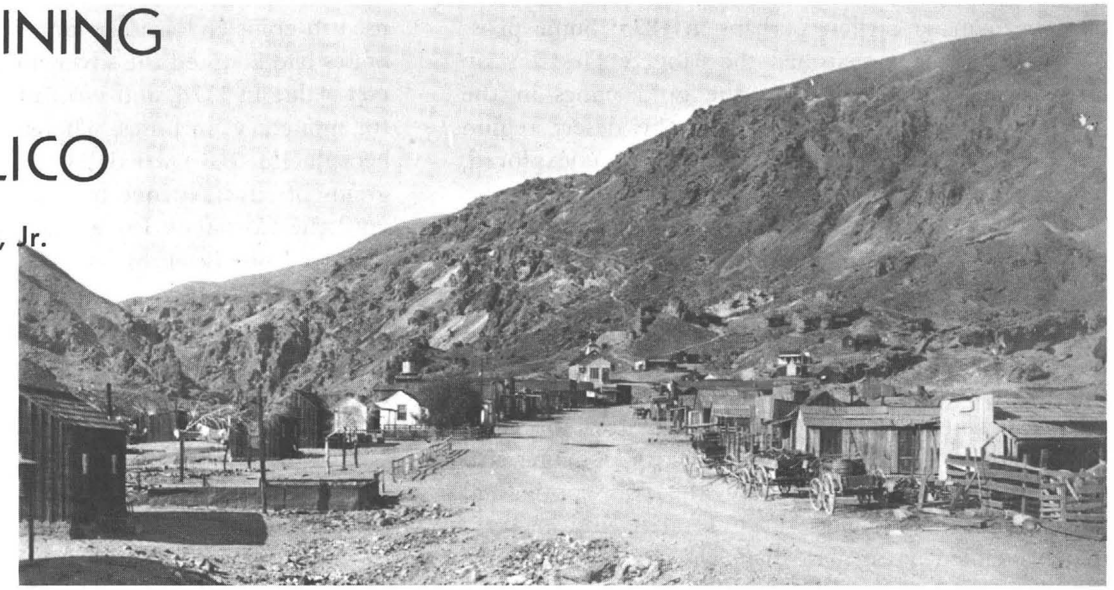
The atlas consists of 27 map sheets which show the regional distribution and interrelationships of the various rock units and the major geologic structures that are present in California. One hundred and twenty-four cartographic units representing plutonic, volcanic, marine sedimentary, and non-marine sedimentary rock types of different geologic ages are delineated in the atlas. The many hundreds of formational units recognized in California preclude the possibility of depicting each of these separately on the map sheets; therefore, the formational units have been grouped in "time-rock units" according to their generally accepted age assignments. Contact lines of two different weights are used on the maps, the lighter weight being used to represent depositional or intrusive contacts, and the heavier weight being used to represent faults.



ATLAS BINDER. A loose-leaf, library size binder (16-½ inches by 22-½ inches) in green cloth with gold lettering. Included with the binder are enough adhesive strips to accommodate all of the sheets of the geologic map and all of the data sheets, as well as a title page and instruction sheet. Price $7.00, plus 28¢ tax.

SILVER MINING IN OLD CALICO

By F. Harold Weber, Jr.



Early Calico, view north; in background are mine workings of Wall Street Canyon area to left and King Mountain area to right. Mine dumps on King Mountain are principally from Silver King and Oriental mines. Date of photograph not determined, perhaps about 1890. *Collection of The Huntington Library, San Marino.*

Seven miles north of Daggett is the much talked of city of Calico. One narrow and serpentine street is the only thoroughfare. The place is built on a narrow ridge; the back end of lots on each side of the street end on or over a bluff. Small, hastily-built houses are the order of buildings, only a few two-story houses gracing the camp. Saloons are more than numerous. Business generally is overdone, and the number of black-legs and tin-horn gamblers that infest the place is remarked by a newcomer. The only water supply is that hauled two miles from Evans' well, and costs from 3 to 5 cents per gallon. Wood is $10 per cord. Board, $7 to $8 a week. The Occidental and Whitfield House are the only hotels, and they are pushed to their utmost capacity to accommodate the travel that is arriving daily. The camp is a good one, but at present is overestimated and overcrowded by men out of money and work. Capital, development and a chance is all this camp needs to be a second edition to the Comstock at no great distant date.

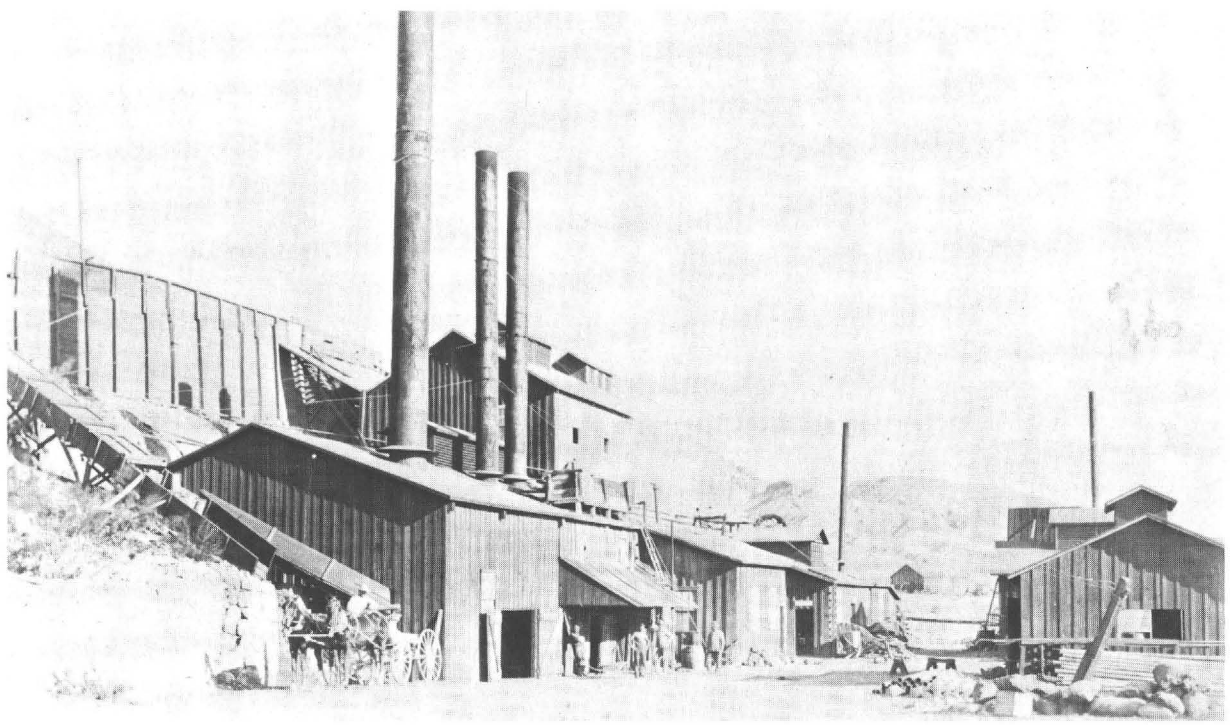
These words, written by a correspondent of the *Mining and Scientific Press*, were published in the issue of March 14, 1885. The "bonanza" Calico district then was in its fourth year of productivity, and near its zenith; within a few years it would begin to wane, becoming a near "ghost" by the very early 1900's. During this period of roughly 20 years, the 50-odd mines of the Calico district and surrounding region—the Silver King, Oriental, Waterloo, Bismarck, Garfield, Odessa, Occidental, Waterman, and others—yielded an estimated $13 to $20 million in silver. This production is small in comparison with $225 million taken from the great Comstock Lode at Virginia City, Nevada, but very significant in terms of metal mining in southern California. Since 1900, silver mining operations in the Calico district have been mostly small and intermittent; but great interest shown in the district by the mining industry since 1963 suggests that once again it may become the site of important silver mining operations.

The little "ghost" town of Calico lies at the southern edge of the Calico Mountains, about 10 miles northeast of Barstow in the central part of the Mojave Desert of southern California, and about 100 miles northeast of Los Angeles. It is commercialized now, and hardly a ghost: parking lots often are filled with modern automobiles, whose brash, shiny colors seem out of place in an old mining camp. Genteel tourists poke curiously along the town street, perusing relics of former mining days, and wander among the dusty graves of the cemetery. Loudspeakers blare inducements to concessions, and the whistle from a sightseeing train echos hauntingly back into the mountains, to the north, where lie the old mine workings of the district. These workings consist both of extensive, professionally engineered adits and shafts, and of widespread, crude gopher-like surface diggings. Altogether, the mine workings have yielded perhaps 15 to 20 million ounces of silver, plus small amounts of barite, gold, lead, and copper. In addition, the region has yielded $9 million worth of borax minerals, mined from 1884 to 1907.

Prospecting for silver in the Calico Mountains and surrounding region apparently was begun seriously during 1880–81, although the first discoveries may have been made earlier, perhaps in 1875. Some prospectors must have searched the Mojave Desert soon after development began of the gold mines in the Mother Lode region, but because the desert region was desolate, poorly accessible, and largely unexplored, mineral discoveries were few. The real spark to prospecting in the eastern mountain and desert region of California, and in Nevada, probably was ignited by discovery of the Comstock Lode at Virginia City in 1859, about 300 miles north-northwest of Calico, and its spectacular development during the 1860's. From this focal point, prospectors spread out widely over the west, and began to discover other great districts, including Eureka, Tintic, and Pioche. Prospecting also was sparked by completion of the transcontinental railroads, beginning with the Central Pacific in 1869, which enabled more men to come west to seek their wealth. In eastern California, during the 1860's and 1870's, Blind Spring Hill, Cerro Gordo, Panamint City, and Darwin were discovered; then Calico; following it, during the late 1890's and early 1900's, were developed the gold districts of Mojave and Randsburg, which eventually also yielded large amounts of silver.

The demand for silver that was the basis for prospecting was natural, as long through history silver had been considered a precious metal, and had been used in coins and as a backing for wealth. The United States had adopted the silver dollar as its unit of monetary value in 1776; and ultimately adopted bimetallism for monetary purposes, whereby the dollar eventually became (in 1837) worth 23.22 grains of gold or 371.24 grains of silver (hence the expression "16 to 1"). But until the Comstock Lode was discovered, the country imported nearly all of its silver. Since that discovery, the U.S. has been a major producer of silver, and during most years from 1871 to 1915 was the world's leading producer. In 1964 the United States ranked third in world output, following Mexico and Peru, and ahead of Canada and USSR. In that year, the United States produced about 36 million ounces of silver, worth about $47 million, principally as a by-product of base-metal mining operations, but partly from ore mined for gold or primarily for silver itself. About 52 million ounces of silver was imported during 1964.

One very important event that was gradually to blight the nation's young but growing silver mining industry occurred in 1873, when the United States went off bimetallism and onto the gold standard (though without basic change to the monetary policy). Soon afterward, the price of silver began to fall



Mill of the Silver King Mining Company (also called Garfield mill). Photo taken perhaps about 1890. At that time ore from Occidental (including Garfield mine), Odessa, and Oriental groups was being processed here. Site of mill is on south side of hill between mouths of Wall Street and Odessa Canyons. *Collection of The Huntington Library, San Marino.*

GEOLOGIC GUIDEBOOKS REPRINTED

GEOLOGIC GUIDEBOOK OF THE SAN FRANCISCO BAY COUNTIES

The book, issued as *Bulletin 154,* is now in its fourth printing in fifteen years. It deals with a region that has contributed greatly to the color and character of the West: not only to its tales and legends, its swashbuckling history, and its fabulous wealth, but also to its steady economic and cultural evolution to its present position as one of the nation's important centers.

The natural features and factors that helped the area attain its eminence are the subjects of the guidebook. Of the twelve counties treated, nine (Alameda, Contra Costa, Marin, Napa, San Francisco, San Mateo, Santa Clara, Solano and Sonoma) border on the shores of San Francisco Bay, and three (Sacramento, San Joaquin, Yolo) are in the delta region of the San Joaquin and Sacramento Rivers, yet all twelve unite to form one large unit, naturally, historically, and industrially. Although a diversity of scenic beauty is found in the twelve counties, from the rugged relief of mountain ranges to the wide expanse of ocean waters, or the flat monotony of fertile delta lands, the story of each is bound to the other, and the complete story of the landscape not only tells the story of the background against which the human history of the San Francisco Bay area took place but also shows the natural reasons for the course of that history.

The perceptive reader and the earnest student will derive much enjoyment from the 32 authoritative articles that comprise the book. Each was prepared by a technical expert, yet they are written in an easily understood manner, and are grouped into seven logical parts, including, "Historical background," "History of the landscape," "Geologic history," "Prehistoric life," "Mineral industry," "Water," and "Places to go and routes to travel." The casual reader, too, will find the 28 authors have prepared for him a tale in words and pictures – nearly 300 illustrate the text – that will stir his interest and enthusiasm. Because the 392 text pages cannot present an exhaustive study of the natural history and resources, nearly all of the articles append a bibliography that will serve as a useful beginning for further research. Those who like to roam will find Part VII, "Places to go and routes to travel," an invaluable collection of motorlogs for short trips in the San Francisco Bay area; this section, together with the seven colored strip maps of the 12 counties showing the geology and roads forms a handbook that will enhance their driving pleasure. Because it is necessary to introduce in the text some unfamiliar technical words, a convenient glossary has been included.

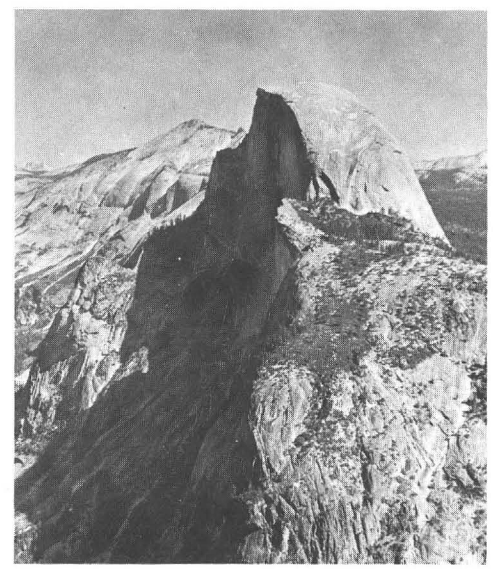
The book, containing 392 pages and more than 300 photographs, drawings, and maps, is bound in sturdy tan cloth. It may be purchased for $2.50 plus tax.

GEOLOGIC GUIDE TO YOSEMITE VALLEY

Originally prepared for the annual meeting of the American Association of Petroleum Geologists held in California in 1962, *Geologic guide to the Merced Canyon and Yosemite Valley, California,* has been out of print recently, but is again available.

Issued as Bulletin 182, the book contains "Summary of the pre-Tertiary geology of the western Sierra Nevada metamorphic belt, California," by Lorin D. Clark; "Granitic rocks of the Yosemite Valley area, California," by Frank C. Calkins and Dallas L. Peck; "The geology, geomorphology, and soils of the San Joaquin Valley in the vicinity of the Merced River, California," by Rodney J. Arkley; "Geomorphology of the Yosemite Valley region, California," by Clyde Wahrhaftig. Included also are road logs for "do-it-yourself" geologic guiding.

Price of the bulletin, bound in paper, is $1.50, plus 6¢ tax for California residents.



Half Dome from Glacier Point. *Photo by U. S. National Park Service.*

methods (such as open pit), taking advantage of modern techniques and equipment (such as giant earth-moving equipment); and the ores processed with the most modern of metallurgical techniques: with barite, lead, copper, or gold also recovered as byproducts.

Indeed, the Calico district still remains an "attraction" to the mining industry, as well as "campers, hikers, and rock hounds". If the district could speak out, it might use Mark Twain's famous words:

"The reports of my death are greatly exaggerated."

A list of references will accompany the last article on the subject of Calico, to be published in a future issue of this magazine.

CALICO
— Highlights of its history —

1881: April 6, claims are located for future Silver King mine.

1882: Spring; mining is underway; about 100 people live in Calico camp. Fall, mining gathers momentum, as smaller properties consolidated, and the part of Atlantic and Pacific Railroad nearby is completed. Price of silver, about $1.14 per ounce.

1883: At beginning of year, active mines include Silver King, Oriental, Burning Moscow, Garfield, Odessa, Bismarck, Blackfoot and others; also Waterman mine, to west.

1884–1885: Productivity is at peak, with perhaps 2,500 people living in district. Beginning of 1884, Silver King mine is developed to a depth of 500 feet; January 1884 to March 1885, Silver King yields $1 million in bullion. Price of silver about $1.09.

1886–1889: Productivity decreases, as price of silver drops to 93 cents by 1889. In addition, deeper, more expensive mining is mostly in leaner ore. Many mines are shut down.

1889–1892: Mining stimulated briefly by (1) short-lived Congressional Acts which briefly raise silver price to $1.05 in 1890, and (2) completion of narrow gauge railroad from Waterloo and Silver King mines to mill at Daggett.

1892–1896: In 1892, Waterloo mine is closed; by 1896 most other mines are inactive.

1915–1919: Activity in district is stimulated as price of silver rises from 48 cents in 1915 to $1.38 in 1919, before beginning to fall. But the activity is not accompanied by important production of silver.

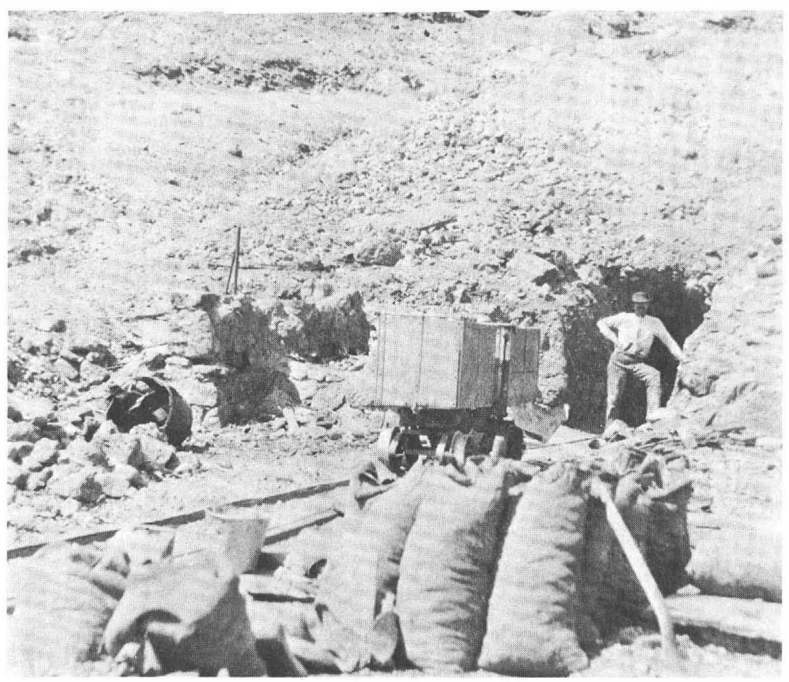
1926–1930: Zenda Company begins deep exploration program at Silver King mine in 1926 when price of silver is 62 cents an ounce. Program ceases in late 1930, as price falls to about 32 cents.

1930–1950: Small and intermittent mining operations for recovery of silver, as well as gold, lead and copper, take place. In addition, old mill tailings are processed for silver.

1957–1961: Oil Base, Inc. recovers barite from barite-jasper vein material.

1963–1966: As price of silver rises to $1.29 per ounce, interest in district is greatly accelerated. Ironically, as "ghost" town tourist operation grows, chances also grow for important future silver mining operations.

Total production of silver: Estimated roughly at between $13 and $20 million; mined mostly between 1882 and 1896.

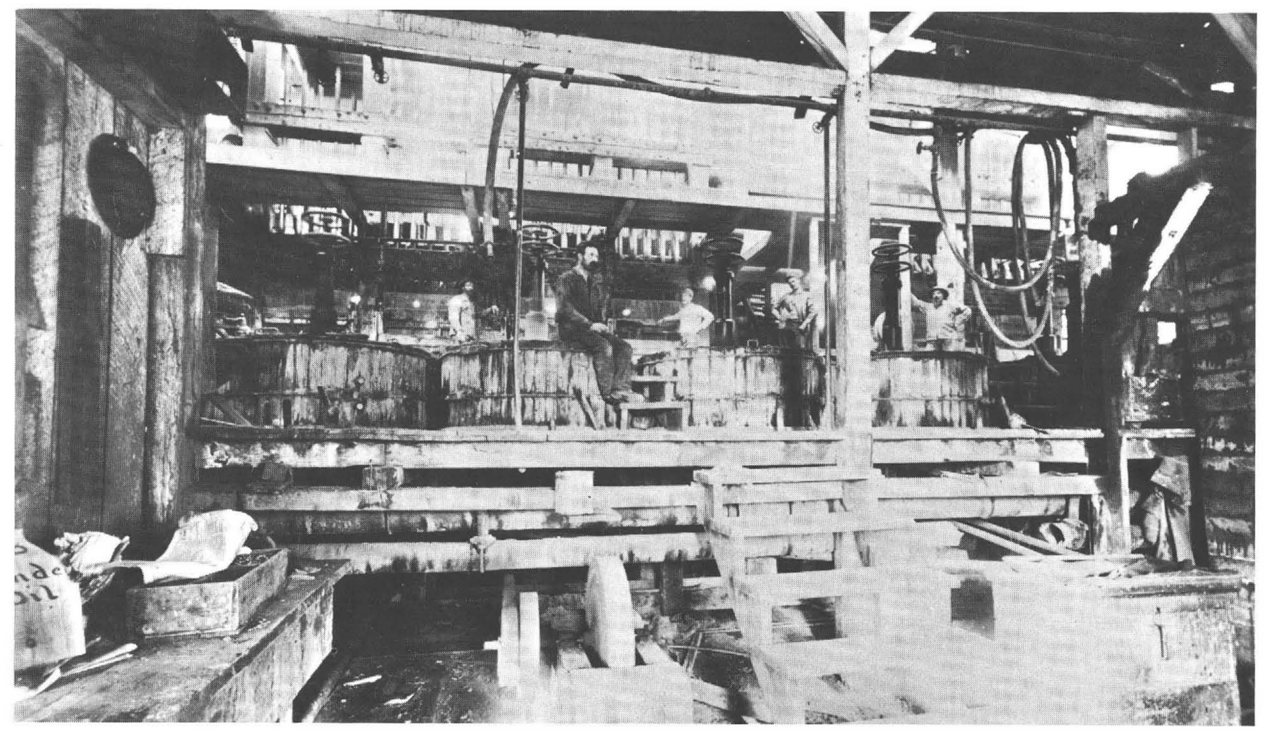


Portal of unidentified mine, showing sacks of handcobbed, presumably highgrade ore ready for shipment to mill. *O. A. Russell Collection.*

irregularly from an average high during 1865–73 of about $1.33 per troy ounce to roughly $1.13 in 1881, when Calico was discovered, and to about 64¢ by 1894, when most of the larger operations in the Calico district had ceased or nearly ceased. The price continued to fall, though with fluctuations, to 51 cents in 1915, and to its ultimate low, about 25 cents, in 1932; even during this last period, however, developers and promoters were actively attempting to reopen and redevelop the mines of Calico.

In some respects it is ironic that the Calico district should lie so close to the new freeway of Interstate Highway 15, which links Los Angeles and Las Vegas, Nevada. For Los Angeles epitomizes the unbridled growth in population of the nation, which is reflected in the growth of the Nevada gambling industry that has evolved from the early days of silver mining. This growth in population has led basically, if indirectly, to the renewed demand for silver, and to the increase in its price from about 91 cents in 1961 to $1.29 by 1963. This relatively high present price has stimulated hope in the mining industry for an even higher price, which, in effect, evokes a rebirth in interest in all inactive silver-bearing deposits and districts. Especially of interest are "bonanza" districts such as Calico, which have yielded relatively large amounts of silver from near-surface workings in rich, shallow deposits, mined almost wholly for precious metals, because many such deposits in California commonly have not been thoroughly explored or studied either at depth or on the surface.

Development of the Calico district might be said to have begun earnestly on April 6, 1881 when S. C. Warden, Hues Thomas and John C. King and others located claims which they began to develop as the Silver King mine. Calico did not then grow with a great "rush", but by the spring of 1882 about 100 people were reported to be living in the town, and mining was underway. Activity was slowed during the summer, partly because of illness in the camp, and perhaps also because of the intense desert heat. But in the fall of 1882 mining in the region seemed to gather momentum: consolidation of smaller properties into larger ones led to more efficient development and mining, and more professional miners had arrived. In July, for example, the Silver King mine had been sold for $300,000 to San Francisco interests. In addition, the Atlantic and Pacific Railroad was being constructed eastward from Mojave. By October 22, 1883 track had reached Waterman's, near present-day Barstow, and by the end of the year it had reached Ludlow, 130



Inside mill of Silver King Mining Company. Tanks shown were part of system of Boss (multiple pan) process which utilized chlorination and amalgamation to recover silver. *Collection of The Huntington Library, San Marino.*

miles to the east beyond Calico. The railroad, obviously, became a vital link for the district, essential to growth.

By the end of 1882, the district had taken shape geographically: immediately north of Calico camp, on the steep sides of Wall Street Canyon and on King Mountain were the Silver King, Oriental, Burning Moscow, Red Cloud, and other mines. To the northeast, in the vicinity of presentday-named Odessa Canyon, were the mines of "East Calico", including the Garfield (opened December 1882), Odessa, Bismarck, Blackfoot, and others; and to the west and northwest lay "West Calico," with ultimate development of the Waterloo, Langtry, and other mines. About 5 miles west of Calico, in low hills beyond a broad valley, was developed the Lead Mountain mine; and about 10 miles to the west the Waterman mine had been developed (perhaps even before the first mines at Calico).

Along with development of the mines, mills for processing the ore and recovering the silver were constructed near Calico and along the Mojave River, several miles to the south, where water was plentiful. The ore was hauled to the mills in horsedrawn wagons, and the earliest ore from the Silver King mine was hauled 40 miles to a mill along the Mojave River at Oro Grande. The general silver recovery process used in the region was the so-called "continuous pan" (or Boss) process, in which ore pulverized in stamp mills flowed as pulp through a series of pans in which it first was chlorinated, then amalgamated for recovery of the silver. Such a process apparently handled the free-milling oxide ores of the Calico mines relatively efficiently, for it recovered as much as 95 percent of the silver from the purest chloride ores, and about 75 to 80 percent of the silver from deeper, sulfide-bearing ores. Salt for the chlorination came from south of Danby (100 miles east of Calico) and coal for fuel came from New Mexico.

The Silver King was the most prominent mine in the district, according to a report of the Director of the Mint for 1882; by the end of the year it had been developed to a depth of 250 feet, with about 500 feet of drifts and crosscuts. These developments were reported to have exposed "a ledge 20 feet wide, between well-developed walls, with rich streaks of from 2 to 3 feet on each wall. . . . Many car loads of partially selected ore from the mine have been sold in San Francisco, averaging $300 per ton. . . ." The next in importance was the Oriental mine, under management of Judge James Walsh, a veteran miner, who said that Calico was "another Comstock". The 1882 mint report went on to say that "the Burning Moscow, Red Jacket, and Sue and Fay, and several others have been sufficiently developed to be called mines. In all these mines the ore contains scarcely anything but silver in spar, and in the shape of chloride, bromide, verda plate (green silver), and horn silver." The report also stated that "The Cuba mine is another valuable location in East Calico, and is being developed with promising results. On looking over the Cuba location, almost the entire surface of the claim appears covered with a conglomerated mass of calcareous tufa and porphyry carrying chlorides and horn silver. Wherever the surface has been broken, ore is visible to the eye. . . . All the first class ore from the mine will work $300 per ton, and the owners make it a point not to sack any that will not assay that much." (Silver was then worth about $1.14 per ounce). No minable gold had been found.

MINES OF THE CALICO DISTRICT

1. Alabama
2. Argentum
3. Backdoor No. 1 prospect
4. Baltic
5. Bismarck
6. Blackfoot
7. Burcham (Total Wreck) (Gold-lead)
8. Burning Moscow
9. Carbonate group
10. Cisco
11. Cuba (location undetermined)
12. Dietzman
13. Gale Group
14. Galena King
15. Garfield
16. Grandview
17. Grant
18. Humbug
19. Falls
20. Le Montain (Sliver-lead-barite)
21. Lamar
22. Langtry
23. Lead Mt. (Silver-barite)
24. Leviathan
25. Lone Star group
26. Mulcahy group
27. Occidental
28. Odessa
29. Old Oriental
30. Oriental
31. Possibility group
32. Red Cloud
33. Revier
34. Runover
35. St. Louis Consolidated
36. Silver Bow (Silver-lead-barite)
37. Silver Tip (Silver-lead-barite)
38. Silver King
39. Silverado
40. Sioux
41. Snowbird
42. Thunderer
43. Union (Gold)
44. Voca (Washington)
45. Waterloo
46. Waterman
47. Zenda

ing the early mining years (cyanidation was developed in the late 1880's, and not used in California until 1891). Through the 1930's and 1940's small mining operations continued at such mines as the Sioux (by J. B. Osborne), the Waterloo (by Morris Mulcahy), the Burcham (Gold-Lead, also by Mulcahy), and the Zenda (by Lawrence Coke).

During the 1950's ore mined from several properties was processed for recovery of silver, lead and barite: such operations took place at the Le Montain and Silverado mines (by R. C. Buch and associates) and at the Silver Bow mine (by W. S. Hubbard). From 1957 to 1961, Oil Base, Inc. mined and processed relatively large tonnages of low grade barite ore at the Leviathan silver mine. Barite recovered in the district has been used as a weighting material in oil well drilling fluids. During 1964–65, the Alexander-Wattell mill was constructed near Barstow for recovery principally of silver and gold.

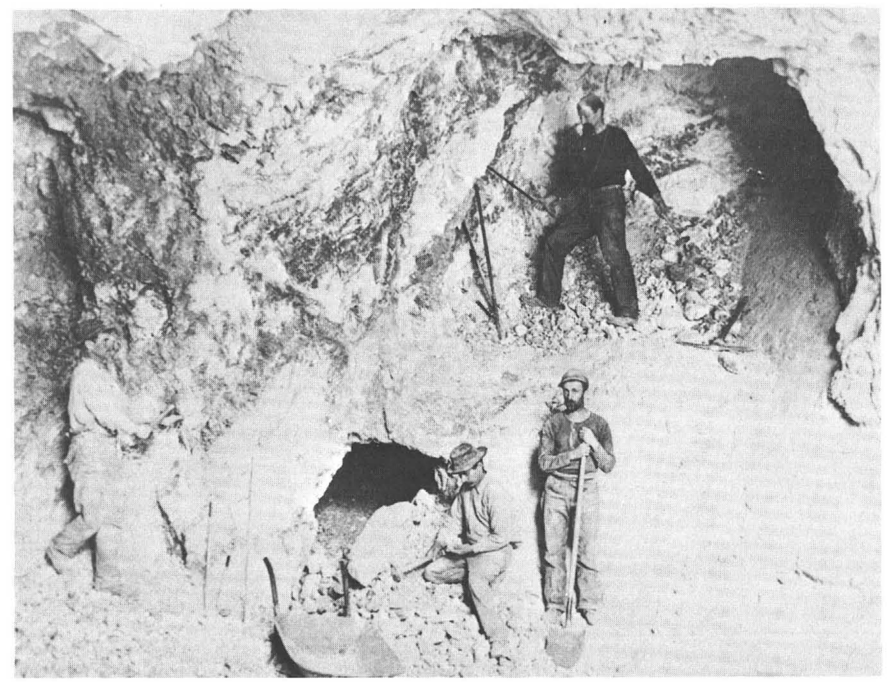
Perhaps because there have been no large, significant silver mining operations in the Calico district since the 1890's, and no mining operations at all from 1962 to 1965, the Calico district might be considered to have very little or no potential as a future source of silver. A pamphlet, issued in August 1965 by the United States Bureau of Land Management, which describes the recently established "Calico resource conservation area," states that

> "The Calico Mountain area, once rich in silver, which spawned the brawling, lusty mining town of Calico, now a County recreation facility, is still an attraction to campers, hikers, and rock hounds."

Such a statement sounds almost like an epitaph for mining.

Actually, as the year of 1966 began, chances for renewed and significant silver mining in the Calico district seemed better than at any time since the 1890's, when the larger early day operations were closed down. These chances were in the form of very significant interest shown in the district by the mining industry since about 1963. This interest stemmed from an increase in the price of silver from about 91 cents an ounce in November 1961 to $1.293 per ounce in June 1963. (In November 1961 the U.S. Treasury stopped sales of its silver at the price of 91 cents, and the free market price gradually rose to $1.293 per ounce, the United States monetary value of silver). Because of the higher price, and the possibility for an even higher price accompanying anticipated increased United States and world industrial and monetary demand, interest in older districts with significant silver production, such as Calico, became very logical.

Especially of interest to large mining companies in the Calico and other districts are very large, very low grade deposits, measured in tens and possibly many scores of millions of tons of potential ore, and scores and possibly a hundred million ounces or more of silver. Such deposits can be mined by simple, low cost



Red Cloud mine, part of Oriental group. Early day work in west end of Mammoth stope, which was reported to be 60 feet wide. Highest of four miners seems to be carefully working part of steeply dipping vein that consists of highgrade ore. Middle of three lower miners may have handcobbed and sorted ore before carrying it from stope in wheelbarrow. *O. A. Russell Collection.*

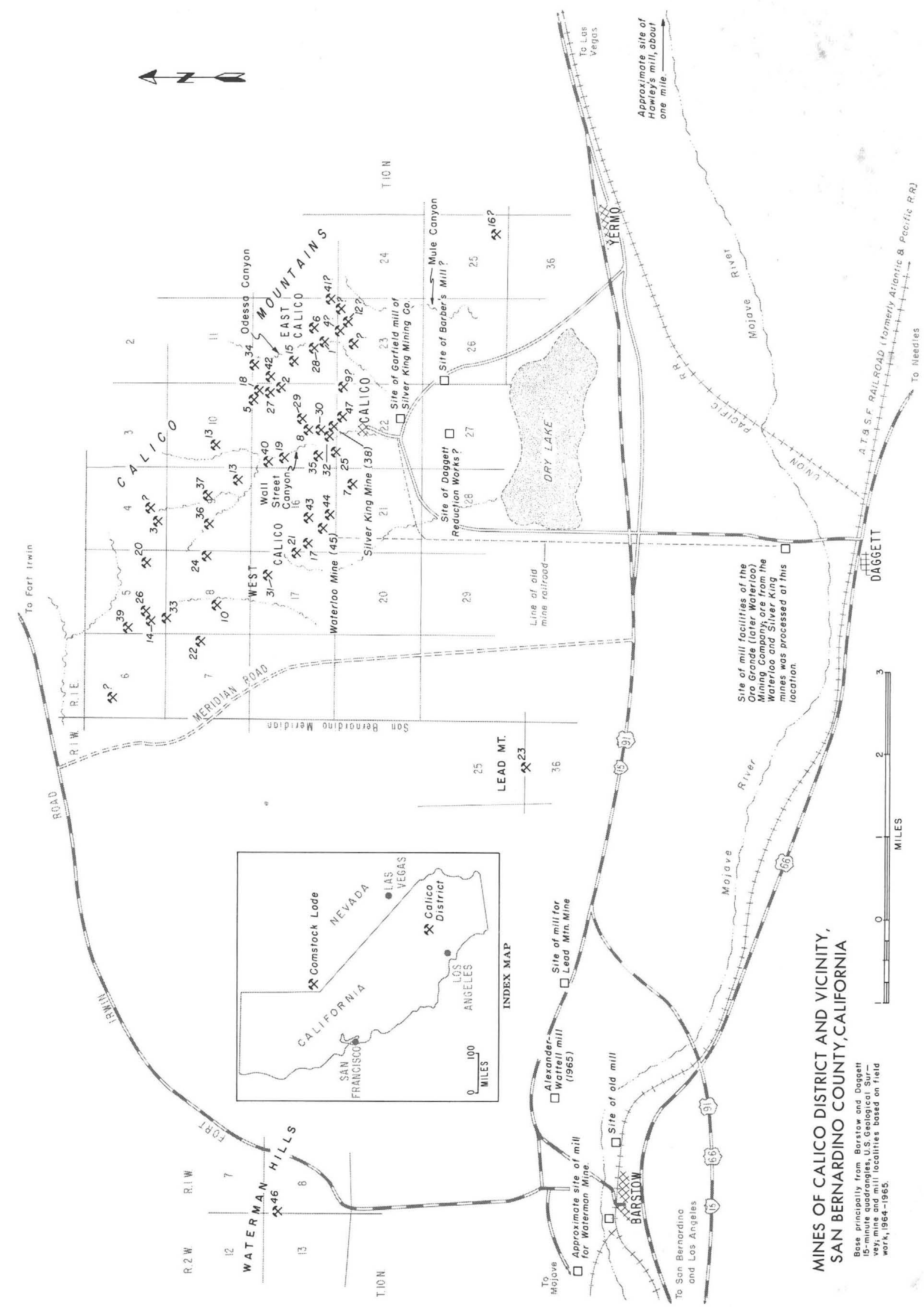
sulting in the Pittman Act) caused by World War I. With this rise in price, the district became very active again, but the activity was not reflected in significant production of silver.

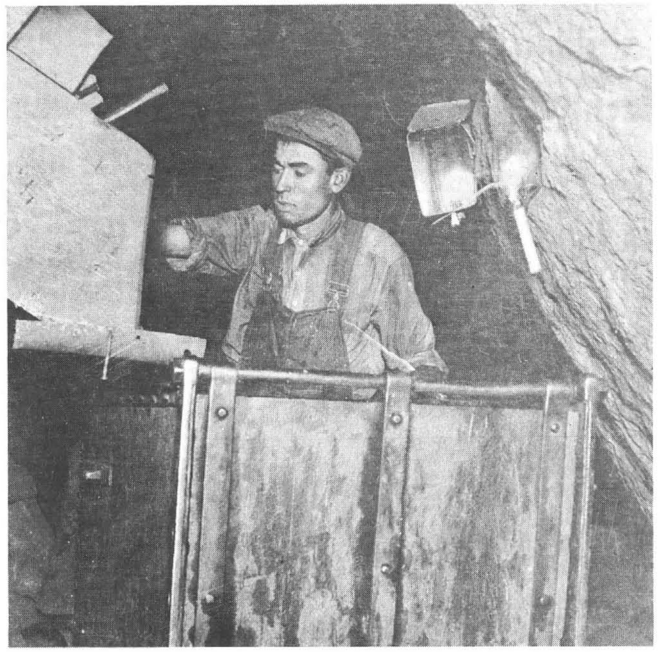
The period from 1915 to the mid-1920's did contain several relatively important events though: The Calico-Odessa Company was organized in 1915 by J. R. Lane, and subsequently explored and mined on a small scale in a wide area east of Wall Street Canyon; the Daggett Reduction Company and others treated some of the old mill tailings by cyanidation; and some ore mined in the district was sent to smelters.

In 1926 the total output of the district was reported as 157 tons of ore, which yielded 35 ounces of gold, 582 ounces of silver, 115 pounds of copper, and 190 pounds of lead. Also in 1926, the Zenda Company acquired the assets of the Waterloo Mining Company, and began an exploration and development program on the Silver King property, though the price of silver had dropped to about 62 cents. The company core-drilled 2 holes, and subsequently sank 2 shafts, of 550 and 350 feet, to explore deeper parts of veins whose upper parts formerly had been so productive. A 50-ton shipment of ore from these workings to a smelter in 1930 is said to have averaged 67 ounces of silver and no gold per ton. But the price of silver continued to fall (to about 32 cents by late 1930), and operations ceased in November 1930, when 47 men were laid off.

From that time until the present (early 1966) the only metal mining operations in any of the Calico mines have been very small and intermittent. Mill tailings, discarded after treatment of earlier mined Calico ores, continued to be processed by cyanidation through the 1930's, even though recovery apparently averaged only about 1 ounce to 2 ounces of silver per ton (with the range of recovery about 1 ounce to 9 ounces per ton). These tailings could be processed economically by cyanidation mainly because less efficient processing methods had been used at Calico dur-

View west-northwest in 1951 shows old workings of Odessa silver mine, on west side of Odessa Canyon, East Calico, mined principally from 1882 to 1896. Rugged topography is cut in andesite. Ubiquitous, gopher-like workings resulted from expedient mining of near-surface, "bonanza" deposits. *Photo by O. A. Russell, Yermo.*





By the light of a candle and metal reflector, a Calico miner fills an ore car from a chute. Unidentified mine and date. *O. A. Russell Collection.*

As an example of how mining developed, the Garfield mine is reported to have been worked from December 1882 until April 1883 by only 2 men, who shipped 11 tons of selected, high grade ore which yielded $5,885 in silver; but from November 1883 to January 1, 1885, 2,400 tons of ore was shipped from the mine, which yielded $290,400 in silver (and a "large amount" of "unassorted" ore was worked locally at Barber's mill). By January 1883, the Waterman mine had yielded 9,000 tons of ore which yielded $39.30 per ton, with the resultant tailings yielding about $10 per ton (making a total of about $440,000); and during 1883, the Silver King mine was reported to have yielded about $426,000 in silver.

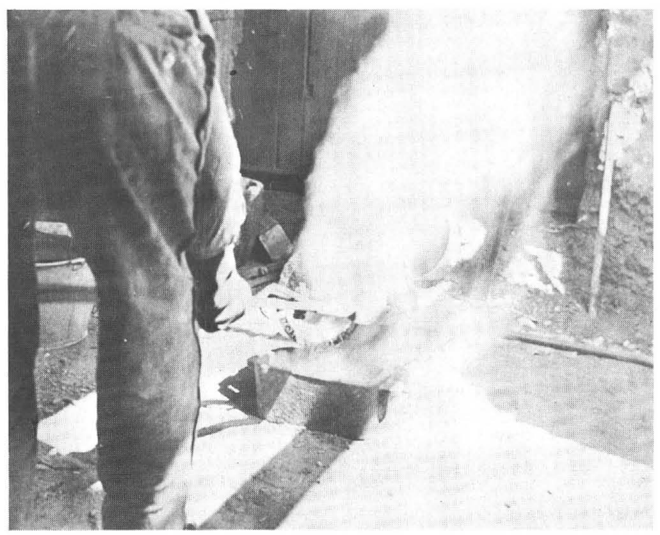
Smaller properties often were worked by so-called "chloriding" methods, whereby lessees operated mines individually or in small groups, paying one-quarter to one-fifth of the mill proceeds to the owners. This procedure was very inefficient, and hindered or prevented maximum possible development of the mines. For most such lessees cared only to mine expediently the richest possible ore, which was commonly composed of thin stringers and veinlets of silver chloride and associated minerals. Compounding the problem were the expensive charges to miners for hauling and milling: the charge for hauling from Calico mines to mills along the Mojave River was $2.50 per ton; and the charge for custom-milling was $11 to $14 per ton, even though the actual milling cost was only $3 to $5.

Productivity in the district reached its peak during 1884–1885, when perhaps as many as 2,500 people lived in the district. By this time, the Silver King mine had been purchased by the Oro Grande Mining Company, owned principally by C. M. Sanger of Milwaukee. (Ultimately the Oro Grande Mining Company also was to gain control of the Waterloo mine, after settlement of a law suit.)

At the beginning of 1884 the Silver King mine had been worked to a depth of 500 feet, and was reported to "still show well at the bottom." From January 1884 to March 1885, the mine yielded about $1 million worth of silver bullion, with the company mill at Daggett reportedly averaging $40,000 to $50,000 per month. Each ton of ore was reported to yield about $30 to $45 in silver (at about $1.11 to $1.06 per ounce), and to cost about $18 total to mine, haul, and mill. Miners were paid about $3.50 per day.

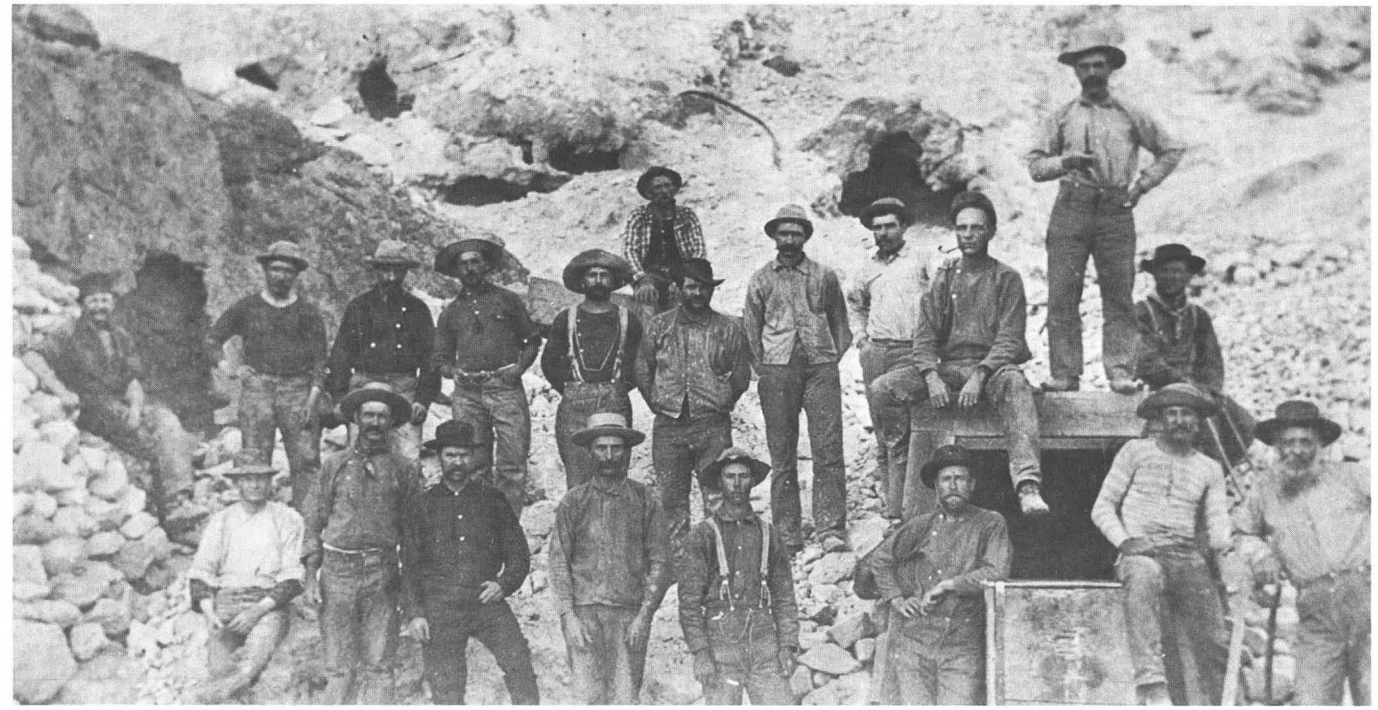
The Sue mine,* northwest of the Silver King, also was prominent; and Barber's mill, just south of Calico, was operating. In East Calico, 10 tons of ore mined daily at the Bismarck mine yielded $100 per ton; and ore from the Cuba mine was processed at Hawley's mill. The Snowbird mine also was active, and the main adit of the Garfield mine had reached a length of 1,000 feet. In West Calico, the Waterloo mine was worked extensively underground, though it is said mostly for rich pockets.

Activity in the district began to decrease after 1884–1885, as the price of silver began to fluctuate downward more sharply from about $1.10 in 1884 to 93



Molten silver is being poured from a melting pot into a bullion mold by J. Bert Osborne, 1924. Silver probably was recovered from ore taken from the Sioux mine, which was worked by Osborne at that time. *O. A. Russell Collection.*

* Probably same as mine later spelled "Sioux".



Early day miners at Occidental mine. Gopher-like workings, typical of most of East Calico, are in background. *O. A. Russell Collection.*

cents by 1889; in addition, once the richer deposits near the surface had been mined, operators were forced to mine deeper, leaner ore, which cost more to mine, as well as providing less revenue. Thus the Waterman mine ceased operations in 1886; and activity in the region probably became very light by the end of 1888, although the Oro Grande Company accelerated its operations (constructing a new 60-stamp mill in 1888). An event of note was the visit to the district in December 1886 of Waldemar Lindgren, a young mining engineer and geologist, later to become perhaps the most eminent in his field.

Two events then served to stimulate mining in the Calico district briefly: the first, late in 1888, was construction by the Waterloo Mining Company (successor to the Oro Grande Company) of a small railroad which extended from the Silver King and Waterloo mines to the company milling facilities at Daggett. This railroad reduced the cost of ore haul from about $2.50 to 12 cents per ton. The second event was passage of two Congressional Acts: the Bland-Allison Act and the Sherman Purchase Act of 1890, which enabled the Government to purchase silver for monetary use. The consequent administration of these laws drove the price of silver upward significantly, even though the Acts were soon defeated by their opponents (as was William Jennings Bryan, the famous proponent of "16 to 1" bimetallism.) Thus, during the period from 1889 to 1892, mining was revived: in September 1889 about 100 tons of ore from the Silver King mine and 50 tons from the Waterloo mine were reported being mined daily; in addition, it was reported that in December 1891 the Garfield mill was taking ore from the Odessa, Oriental, and Occidental groups. At one point during the period, it was reported that 700 men were employed in the district, 150 stamps were operating in mills, and about $200,000 per month in bullion was being produced.

Soon, though, the price of silver dropped again, from about $1.05 in 1890 to about 64 cents by 1894. The Waterloo was forced to close down in March 1892, with 130 men losing their jobs. In 1896 the Silver King Company apparently ceased hoping that the price would somehow rise again, for it shut down operations at its Occidental and Oriental groups. The Odessa mine also was closed.

The district remained nearly dormant from about 1900 to 1915, when the price of silver again began to rise. From a low of about 48 cents in 1915, the price rose briefly to about $1.38 late in 1919, before it began to decrease. The rise was caused principally by industrial demand and international monetary needs (re-

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SILVER DEPOSITS OF THE CALICO DISTRICT

Part II, page 3

FILM REVIEWS

page 2

MINERAL INFORMATION SERVICE
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Other publications of the Division include the Annual Report of the State Geologist; the Bulletin, Special Report, Map Sheet, and County Report series; the Geologic Map of California; and other maps and publications. A list of the Division's available publications will be sent upon request. Communications to the Division of Mines and Geology, including orders for publications, should be addressed to the San Francisco office.

MARY R. HILL, *Editor*

FILMS

In this column, which will appear from time to time, we hope to list films concerning the earth sciences. We would like to borrow a review print from film makers or distributors who have films for use by schools, mineral societies, technical organizations, or other groups. Please indicate the audience for which the film was prepared (i.e., primary, secondary, college, general, professional groups), how and where prints may be obtained, and the price of purchase or rental. The title, maker, and date of copyright would also be helpful. Please send film to:

Mary R. Hill, Editor
Mineral Information Service
California Division of Mines and Geology
Ferry Building
San Francisco, California 94111

The Beach: A river of sand. 1965. Encyclopaedia Britannica Films, Earth Science Series, produced in collaboration with the American Geological Institute. 17 min. 16mm. color, or b-w. Science Advisors: Douglas Inman and John S. Shelton. (Dr. Inman is a specialist in beaches at Scripps Institute of Oceanography; Dr. Shelton is Chief Science Advisor for the AGI-EBF Earth Science Program.) Producer: Stanley Croner; Director-Editor: Warren Brown; Cameramen: I. Mankofsky, Frederic Goodich. Available by purchase from Encyclopaedia Britannica Films, 1150 Wilmette Avenue, Wilmette, Illinois 60091. Price: color, $240; black-and-white, $120.

By means of time-lapse, animation, and fast-motion techniques, *The Beach* explores the environment of the shore, with special attention to the sand that makes up the beach. The film shows where sand along the California coast comes from (rivers on shore), how it is moved (by the waves and longshore currents), and where it goes (into submarine canyons).

By concentrating on the sand and its movement, and by using numerous methods of illustrating the behavior of the sand and the waves that move it, including underwater, aerial, and wave-tank sequences, the film maintains a high pace and achieves a unity, both uncommon in earlier educational films. It has been the unfortunate fate of many films in the earth science field to have contained errors that made earth scientists squirm. This reviewer detected none in *The Beach*. Other films, although technically correct, have been cinematographically bad or exceedingly dull, or both. *The Beach* is neither.

The EBF-AGI Earth Science Series was especially designed for junior high school students. They, or anyone interested in beaches (including the many mineral societies), should find it interesting and informative. . . . M.R.H.

Wilderness quest. Promotional Films, Inc., sponsored by The Red Wing Shoe Company. 29 min. Color. Consultants and actors: Montana Department of Fish and Game; Charles L. Sommers Wilderness Canoe Base, Region 10, Boy Scouts of America; U.S. Park and Forest Services; University of Minnesota Museum of Natural History. Producer: Alfred Peterson; Written by: Cliff Sakry; Production: George Daugherty. Available from: Boyd Film Company, 1569 Shelby Avenue, Saint Paul, Minnesota. 16mm.

The out-of-doors is colorfully displayed in this film, with an emphasis on "scenery." There is not much coherence—the film is rather like a slide show—but the mountains, valleys, and water are of sufficient interest in themselves to make this a good film for the general audience. Clubs and organizations should find it excellent program material.

The Red Wing Shoe Company, sponsors of the film, are to be congratulated on their desire to present the wilderness as a conservation topic. There is no advertising.

It is to be wished that the film makers had as much knowledge of the subject as the sponsor had good will. At no point is the fabric of the out-of-doors seen closely; almost all the shots are "postcard views" with obtrusive people and a never-ceasing narration that drowns out even the sounds of the nature it intends to portray. Moreover, several scenes showing doubtful outdoor manners will not gladden the heart of conservationists (including this one): a woman picks a wild flower (a merciful cut almost saves the scene); a man carries a pistol in a side holster; and, worst of all, while the narration talks about "water pure enough to drink," man, woman, and child wash in a running stream. . . . M.R.H.

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Bonanza in the lonely desert

SILVER DEPOSITS OF THE CALICO DISTRICT

By F. Harold Weber, Jr.

Second of three parts *

Silver was first discovered in the east-central Mojave Desert of southern California during the mid- or late-1870's, when the desert still was very remote. In the region near the discoveries a small community grew and was named Calico, probably by prospectors. The bright, splotchy patterns of parts of the nearby terrane probably made these men away from home think of Calico cloth, so popular in those days for ladies' dresses. They probably realized too that the Calico-like areas were the best to prospect, for they comprised the Tertiary sequences of continentally deposited sedimentary rocks, intruded by volcanic rocks, which even then were known to be the hosts for "bonanza" deposits of silver and gold. The "small community" shortly was renamed Daggett, in favor of a Lieutenant Governor of the state, and the name "Calico" moved 6 miles north to a mining camp and mountain range, where the major silver discoveries were made in 1881, and where the rock patterns of the region are the brightest and the splotchiest.

Important mining operations began in the Calico district in 1882, and continued until 1896. Since that time, little silver has been mined, because of the generally lower price of the metal, and because ore rock that remains is generally deeper and lower in grade. The total value of silver produced is estimated at between $13 and $20 million. Also obtained from the deposits in more recent years have been much smaller-valued amounts of barite, lead, copper, and gold. Borax also was once mined in the region, and crushed and broken stone for a variety of roofing granules is produced today from the multi-colored rocks. But most significant to the region in early 1966 was the fact that the price of silver had risen during the past few years from about 92 cents to $1.29 per troy ounce, and, with other factors, had created renewed interest by the mining industry in the Calico district.

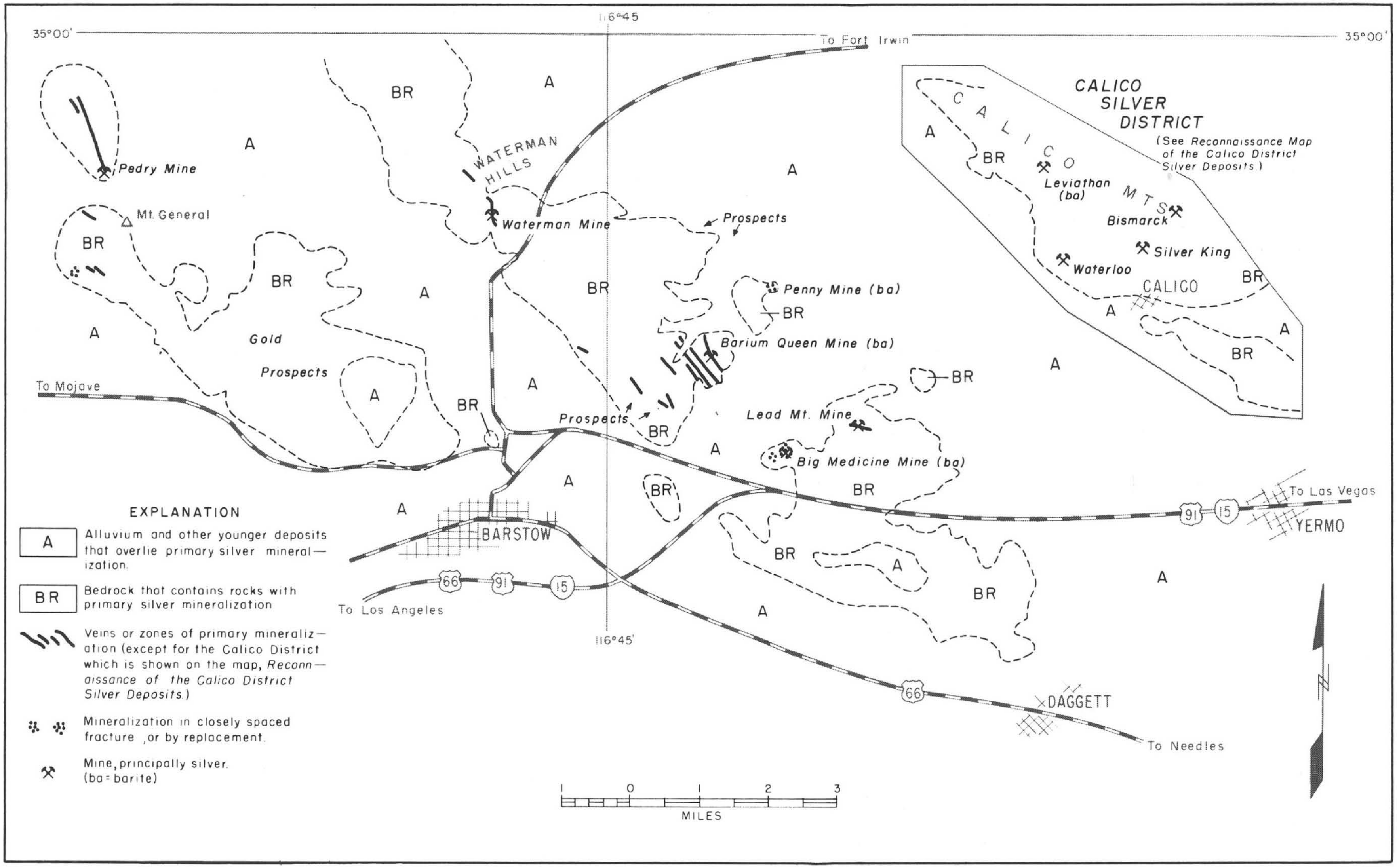
The central Mojave Desert comprises small to moderate ranges and groups of hills separated by small to broad valleys which commonly contain playa lake beds. The ranges and hills generally are blocks of rock that have been faulted relatively upward, and the valleys blocks that have been faulted relatively downward. Most of the blocks have been faulted along lines that trend northwest, generally parallel to the San Andreas fault, whose nearest point lies about 50 miles southwest of Calico. This fault, which dominates the structural geology of southern California, is believed by most geologists to have moderate to very large right lateral movement, whereby the rocks on the northeast side of the fault have moved southeastward relative to the rocks on the southwest side. Similar movement along faults of the central Mojave Desert has been shown by Dibblee (1963) and others.

The Calico Mountains themselves constitute a range which trends generally northwest but is irregular in plan. Silver deposits are mainly in the southwest portion, known as the Calico mining district, which has peak elevations of about 3,000 to 4,000 feet. The range is bounded mostly by nearly flat alluvial areas, as low as 1,900 feet, and is separated from the lowlands to the west and south by a steep northwest-trending front, along the base of which is the Calico fault zone —the predominant structural feature of the region.

To many people, the most spectacular sights in the Calico Mountains are steep-sloped hills, commonly capped with resistant volcanic rocks (which are dark shades of gray, red, or green) and underlain by much softer sedimentary rocks (such as sandstone or tuff, which are pale green, pale yellow, or buff). The resistant volcanic caps have shed trains of bouldery fragments down the steep slopes, giving the overall appearance perhaps of chocolate syrup dribbling down scoops of ice-cream. Such sights can be seen at the steep southwest edge of the mountains, even from a car, while travelling along Interstate Highway 15 near Yermo. At other localities, colorful sedimentary strata are steeply tilted or spectacularly folded, and penetrated by deep canyons, especially Wall Street Canyon, which extends northward from the reconstructed "ghost" of Calico town, at the southwest edge of the mountains.

Geologic terrain somewhat similar to that of Calico also underlies other mining districts in the Mojave Desert, including Mojave, Randsburg, Stedman, and Lava Beds. But the classic illustration of a "bonanza" deposit is the Comstock lode, at Virginia City, Nevada.

* The first part of Mr. Weber's series on Calico appeared in the May, 1966 issue of this magazine.



CALICO SILVER DISTRICT AND VICINITY

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The veins and zones range in length from less than 50 feet to about 4,500 feet. The veins range in width from less than a quarter of an inch to perhaps 50 feet (at the Leviathan mine, where barite has been recovered), and most commonly from about half a foot to several feet. Most of the veins dip steeply, commonly 75 to 85 degrees west. Parts of some veins that are very thin (less than 2 or 3 inches) can be traced remarkably continuously for many hundreds of feet along the surface. One vein, for example, which is as much as 7 to 8 feet thick, where exposed in the Silver Bow mine shaft, can be traced southeast along the surface from the shaft, though less than one inch wide, for nearly 500 feet. This continuity helps to suggest that the vein may widen at some point beneath the surface, southeast of the shaft, below possible constrictions, which may have acted as traps to the mineralizing solutions. Possibly the constrictions were caused by a change in lithology. In other areas, a rock unit that seems to have a constrictive cap-like effect on vein deposits is pale-yellow weathering lithic tuff of the Pickhandle Formation. An example of this effect is at the St. Louis Consolidated deposit.

The richest vein deposits, near the southeast end of the belt, consist of zones that once contained rich bodies of so-called secondary silver minerals in their upper parts. Examples were the ore bodies for the Silver King, Oriental, and nearby mines (see accompanying illustration). Deeper parts of these veins are composed nearly wholly of primary minerals; and primary ore minerals are common near the surface in the north-central part of the vein system, at the Silver Bow, Le Montain, and other deposits. The primary deposits generally have been lower in grade than the secondary ones.

The most economically important variation apparently in the character of the principal veins, in the southeast part of the belt, is that with depth they decrease in grade. The best example of this economically unfortunate phenomenon is exposed by the Silver King mine, where ore yielded less silver as mining proceeded—mostly downward. Another variation is that the veins of the central and northwest part of the belt contain principally primary sulfide minerals in their upper parts, and no rich secondary deposits, as do the veins to the southeast. Thus these deposits have been infinitely less important economically than the ones to the southeast. For example, the thick Leviathan deposit is reported to be very low in silver.

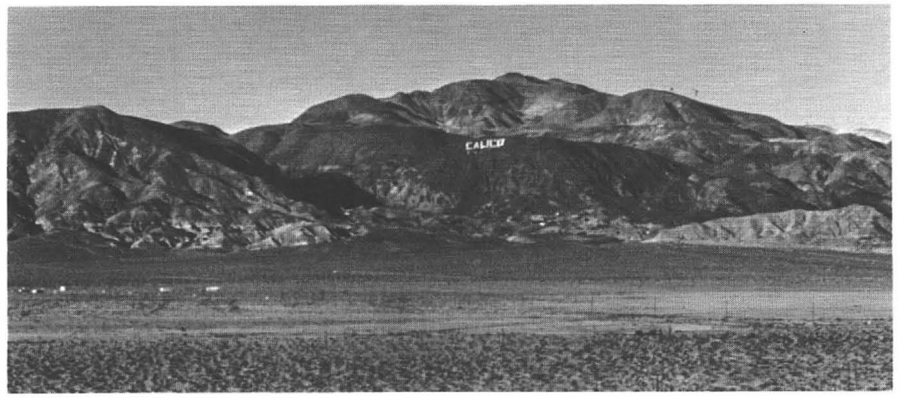
Southeast of the belt of veins lie the areas of stockworks, where veins or zones also occur, some in conjunction with the stockworks. The Bismarck and Garfield deposits comprise a combination of veins and stockworks. The stockworks consist of shallow networks of multitudinous fractures in tuff, sandstone, and other rocks which are filled with silver minerals. The Blackfoot mine is characteristic (as shown in the accompanying diagram). At least some of these deposits are restricted to a single layer, or to adjacent layers (such as perhaps the Occidental mine).

The third type of deposit includes those that are associated with the Calico fault zone, which extends along the southwest edge of the range. Silver minerals occur in vein-like deposits in faults of the zone, and as deposits of stockworks in sandstone and shale of the Burcham and Barstow Formations, which are adjacent to the zone. Potentially important, very low grade deposits, explored during 1965–66, constitute disseminated silver minerals in bodies of a landslide breccia, which is associated with the Calico fault zone. In addition, the only gold deposits of the district (the Burcham mine, particularly) occur in the zone.

West of the Calico Mountains, in the hills beyond the broad lowlands, lie additional deposits, including the rich Waterman mine, the Lead Mountain mine, and the Penny, Big Medicine, and Barium Queen barite deposits (as shown on the accompanying map). Most of these deposits seem to be primary veins, with the Waterman mine having contained rich secondary deposits.

A bibliography on the Calico district will accompany the third part of this series.

Order form on page 2



View north-northeast shows portion of southwest Calico mountains. The word "Calico" lies at the crest of King Mountain, with the Silver King and Oriental mines just below, and the town of Calico at the base of the mountain. Wall Street Canyon lies to the left of King Mountain, and Odessa Canyon lies to the right. The Burcham mine is shown near the left edge of the photo, which was taken in 1959.

The ore deposits of the Calico region have been studied briefly by many geologists and engineers. The most eminent is Waldemar Lindgren (1887), who formulated the "hydrothermal" classification for the origin of certain ore deposits. The areal geology of the mountains has been mapped in detail by T. H. McCulloh (1965), as part of a regional study.

The oldest rocks in the Calico Mountains region consist principally of the Waterman Gneiss, which may be as old as Precambrian. Next younger are metasedimentary rocks of Paleozoic age, and granitic intrusive rocks of probable Jurassic or Cretaceous age. Together, these older rocks compose the "basement," rocks formerly at great depth but uplifted irregularly along faults during late Cretaceous or early Tertiary times, creating mountain ranges and valleys. Material eroding from the ranges into the valleys during the Tertiary period created the sedimentary rocks, into which the volcanic rocks were intruded. Such a cycle of sedimentation and subsequent volcanism, stimulated by faulting and uplift, has been repeated at least several times since the beginning of the Miocene epoch of the Tertiary period, about 25 million years ago.

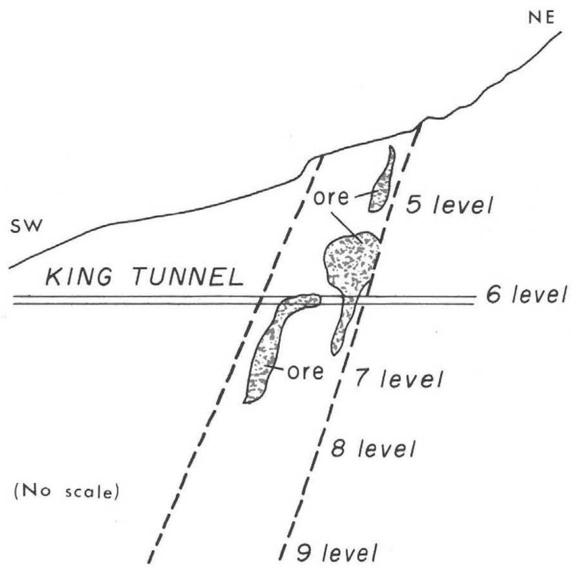
In the Calico district, the principal sequence of rocks consists of faulted and gently tilted tuff, tuff breccia, granite breccia, and sandstone, which was named the Pickhandle Formation by McCulloh (1965). It is probably middle Miocene in age. This sequence has been faulted, gently tilted, and intruded by volcanic rocks which range in composition from rhyolite to andesite. The earliest silver-bearing deposits occur within veins that cut the Pickhandle Formation and intrusive volcanic rocks (as shown on the accompanying map of the district). Related to the veins in the Pickhandle Formation are silicification, baritization, and other forms of alteration.

Composing the remainder of the bedrock, but apparently not containing veins, are the younger Barstow Formation and the Burcham Formation of McCulloh (1965), both probably of late Miocene age. These rocks mainly border the Calico fault zone on the southwest, and also lie within an embayment into the Calico Mountains, where they are mostly surrounded by the older, middle Miocene rocks. The Barstow and Burcham Formations consist mostly of sandstone, mudstone, and conglomerate, along with limestone and other rocks. These rocks appear fresh and unaltered, except in the Waterloo mine area, where probably they were altered as mineralization of the Calico fault zone occurred. They appear to be younger than the primary veins, but do not seem to contain clasts of the vein matter.

Lying above the Tertiary rocks are deposits of uplifted, unconsolidated terrace gravels, probably as old as early Pleistocene or possibly even Pliocene. The youngest deposits consist of Recent alluvium.

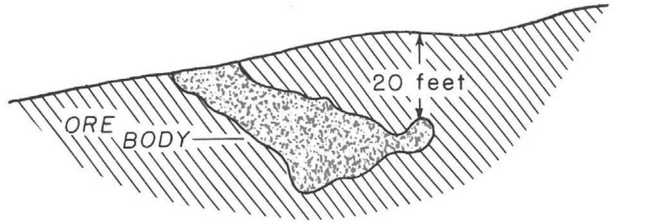
Silver has been sought in the Calico district from three closely related types of deposits: most obvious are veins or vein-like zones which lie north and northwest of Calico and include the Silver King mine ; less obvious, and southeast of the principal veins ("East Calico"), are areas of near-surface stockworks; and west and northwest of Calico lie deposits (including the Waterloo mine) that are associated with the Calico fault zone.

The vein and zone deposits are the basic (primary), oldest, and most widespread silver-bearing occurrences of the district. Veins consist of elongate, tabular bodies which generally consist principally of red jasper and white barite, commonly thinly interlayered parallel to the sides of the veins, with much smaller proportions of manganese, iron, silver, and other minerals. Zones consist of closely spaced thin veins or vein-like features which contain principally stains of iron oxide minerals. The veins trend mostly northwest to north-northwest, and make up a northwest-trending belt roughly 4 miles long and a quarter of a mile to a mile wide. This belt extends from the northwest corner of the Calico Mountains, with a bend near its middle, to points north and east of the town of Calico, where it seems to evolve into the area of stockworks.

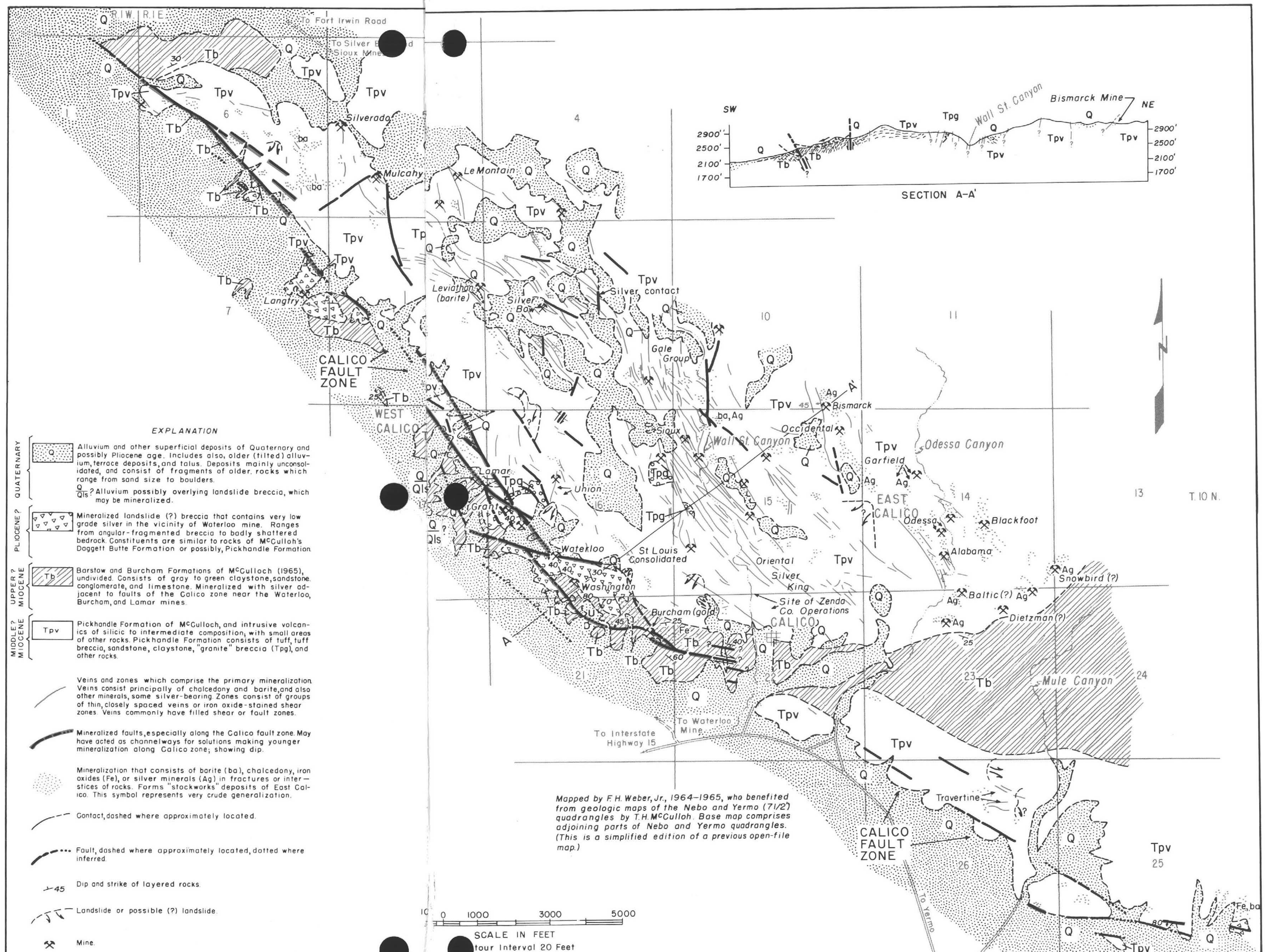


Silver King mine; cross section showing ore bodies of secondary minerals in upper part of steeply dipping zone, which cuts layered and intrusive volcanic rock. Sketch was drawn in the late 1880s for court trial (Storms, 1893).

RECONNAISSANCE MAP OF THE CALICO DISTRICT SILVER DEPOSITS



Blackfoot mine showing in cross section one of the shallow ore bodies as seen in active mine by W. Lindgren (1887). Silver minerals fill fractures in tuff (called "tufa" by Lindgren) with body of minerals following layering of tuff.



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WORLD CLIMATE CHANGES RESULTED FROM CONTINENTAL DRIFT

Much of the variation in climate during the geologic past has been caused primarily by the movement of continents across the face of the earth, rather than by worldwide changes in climatic zones, reports Warren Hamilton of the Department of the Interior's Geological Survey.

Dr. Hamilton, who recently completed a study of the earth's ancient climates, supports the theory that continents "drift" about the surface of the earth.

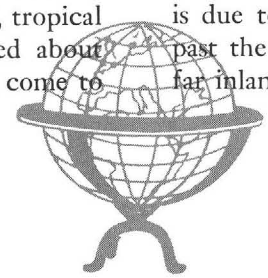
"Each continent," Dr. Hamilton notes, "has its own pattern of climatic variations, rather than a pattern shared with all other continents. Thus, it is likely that climatic zones remain relatively unchanged in width and position, and that the continents have drifted through these zones throughout geologic time."

Past climates are recorded in rock strata by fossils of land plants and marine shells, and by such rocks as the deposits of ancient glaciers and of tropical coral reefs. Tropical climates today are limited to a belt centered on the equator, and the tropical deposits of the past 15 million years show a similar distribution. Farther back in the geologic record, however, tropical deposits become progressively more scattered about the earth, indicating that the continents have come to their present positions gradually and irregularly.

Two hundred and seventy million years ago, tropical coral reefs grew in a warm shallow sea in what are now arctic Canada, Greenland, and Spitzbergen, and at the same time great glacial ice caps covered now-tropical parts of India, Australia, and Africa. Neither reefs nor glaciers could possibly have formed where these lands are now, so the continents must have moved to their present positions.

Dr. Hamilton regards the data now available as proving that continental drift has occurred throughout at least the past half-billion years.

"Early concepts of continental drift such as the development of the Atlantic Ocean by the separation of the Americas from Europe and Africa, and the northward migration of the island continent of India until it collided with Asia, are substantiated by abundant new data," he stated. "In addition, however, we can now define complex bending, breaking, and sliding within continents. The San Andreas fault, whose movement caused the 1906 San Francisco earthquake, is due to the northward sliding of coastal California past the interior, and related motion is distributed as far inland as the Rocky Mountains."



Please note: Orders for all books and maps to be sent to a California address must include 4% sales tax. There is no tax on subscriptions to *Mineral Information Service*.

Please send me:

. . . .copies, Special Report 87 (Expansible shale resources of the San Jose-Gilroy area), at $1.50 each, plus tax.

. . . .copies, Bulletin 170 (Geology of southern California), in two cloth-bound volumes, at $13.00 per set.

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MINERAL INFORMATION SERVICE

A PUBLICATION OF THE CALIFORNIA DIVISION OF MINES AND GEOLOGY

VOLUME 20 NUMBER 2
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NEWS NOTES

REVIEWS

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MINERAL INFORMATION SERVICE is designed to report on the progress of earth science in California, and to inform the public of discoveries in geology and allied earth sciences of interest and concern to their lives and livelihood. It also serves as a news release on mineral discoveries, mining operations, statistics of the minerals industry, and new publications. It is issued monthly by the California Division of Mines and Geology. Subscription price, January through December, is $1.00.

Other publications of the Division include the Annual Report of the State Geologist; the Bulletin, Special Report, Map Sheet, and County Report series; the Geologic Map of California; and other maps and publications. A list of the Division's available publications will be sent upon request. Communications to the Division of Mines and Geology, including orders for publications, should be addressed to the San Francisco office.

MARY R. HILL, *Editor*

MAP PRICES GO UP

The U.S. Geological Survey has announced that, as the result of a recent analysis of costs, map prices will be increased. The new prices and discounts became effective October 1, 1966, and they have been announced by the Survey as follows:

The list price of topographic quadrangle maps at scales 1:24,000, 1:31,680, 1:62,500, 1:63,360, and 1:125,000 is 50 cents each. The list price of topographic maps at scale 1:250,000 is 75 cents each. National Park and other special topographic maps are individually priced. A price list is available from the U.S. Geological Survey, Washington, D.C., upon request.

AWARD TO LYDON

Philip A. Lydon of the Division of Mines and Geology staff has been made the recipient of a Sigma Xi grant-in-aid. The grant, presented by Dr. Harlow Shapley, Chairman of the Sigma Xi Grants-in-Aid of Research Committee, was made in order to assist Mr. Lydon in his study of the geology of the Butt Mountain area, a source of the Tuscan Formation in northern California. Mr. Lydon has been on educational leave for two years, and began study of this area at the University of Oregon in Eugene, Oregon, where he is a candidate for the Ph.D. degree.

FIRST LADY TO RECEIVE MINERAL BROOCH

The American Federation of Mineralogical Societies is directing the preparation of a special jeweled brooch for the First Lady, Mrs. Lyndon B. Johnson. The brooch will contain at least one gem or mineral from each of the fifty states. California will be well represented by three contributions: several ounces of gold were contributed by the San Francisco Gem and Mineral Society; pink tourmaline was donated by Mrs. Goldie E. Wood, of the Los Angeles Lapidary Society, and by Captain John Sinkankas; and rare benitoite was contributed by Glen A. Frost. Among other interesting gems and minerals in the brooch are Arkansas diamonds, a North Carolina ruby, Hawaiian black coral, and petrified wood from West Virginia.

After receiving this unusual piece of jewelry at the National Gem and Mineral Show in Washington (June 29-July 2, 1967), Mrs. Johnson will present it to the Smithsonian Institution for the use of all First Ladies.

FILMS

In this column, which will appear from time to time, we hope to list films concerning the earth sciences. We would like to borrow a review print from film makers or distributors who have films for use by schools, mineral societies, technical organizations, or other groups.

Erosion: leveling the land. Copyright 1964. Encyclopaedia Britannica Films, Earth Science Series, produced in collaboration with the American Geological Institute. 14 min. 16mm. color or b-w. Chief Science Advisor: John S. Shelton. Producer: Stanley Croner; Director: H. William Varney; Photographers: I. Mankofsky, Paul Leimbach. Available by purchase from Encyclopaedia Britannica Films, 1150 Wilmette Avenue, Wilmette, Illinois 60091. Price: color, $150; black-and-white, $75. Suitable for Junior High, High School.

Purpose of the film is to show how erosion, acting through wind and weather, wears the mountains down to dust. As is true of others in the EBF-AGI Series, it succeeds admirably. It is a good film to introduce geology to a naive audience.

Particularly effective are shots of Cleopatra's Needle, taken a century apart; a nail rusting, a milk bottle freezing, artificial rain wearing away limestone—all while one watches, thanks to time-lapse techniques.

Teachers who have attempted to encourage students to see in three dimensions will be very interested in a clay model that is used to reveal structure by means of a table knife. The clay strata are artificial, but a natural sand dune in another shot is just as neatly sliced by a shovel (in the hands of the science advisor), and shows just as tidy banding.

The Airborne magnetometer. n.d. Produced by the U. S. Geological Survey. 34 min. 16 mm., black-and-white. Available on loan from Information Offices, U. S. Geological Survey, 300 North Los Angeles Street, Los Angeles; or 468 Custom House, Denver, Colorado; or Room 2647, Interior Building, Washington, D.C. 20242.

The longer version is detailed presentation of the methods of aerial magnetic surveying. For those wishing to know how to make such a survey (university classes, for example), this is a thorough introduction. It is not suitable for younger or nonprofessional groups. . . . M.R.H.

TWO NEW EXPANDED SHALE PLANTS

Stimulation provided by geologists of the Division of Mines and Geology has resulted in the enlargement of the expansible shale industry in the San Francisco Bay Area. Following a comprehensive study of expansible shale deposits in the southern San Francisco Bay area, private prospectors and scientists intensified their search for suitable raw materials to sustain the lightweight aggregate industry in the area.

The result is the establishment of two new expanded shale plants, one to be operated by Kaiser Industries, the other by Port Costa Clay Products Company.

The Kaiser plant is located on a 170-acre site north of State Highway 84 between Fremont and Sunol. A deposit of shale will be quarried on the site and processed through a 4.5 million dollar facility centered around a rotary kiln 11 feet in diameter and 170 feet long. The crude shale is crushed and heated to 2100°F. where it expands to form lightweight aggregate. The Sand and Gravel Division of Kaiser Industries hopes to produce 230,000 yards of aggregate per year which will be marketed under the trade name KI-LITE.

The other new plant has been opened near Port Costa on Carquinez Strait by Port Costa Clay Products Co., a subsidiary of the Homestake Mining Co. The raw material is quarried at the plant site from a thick section of marine shale and sandstone of Cretaceous age which lies between Crockett and Martinez. The plant is fully integrated to produce brick as well as lightweight aggregate for concrete.

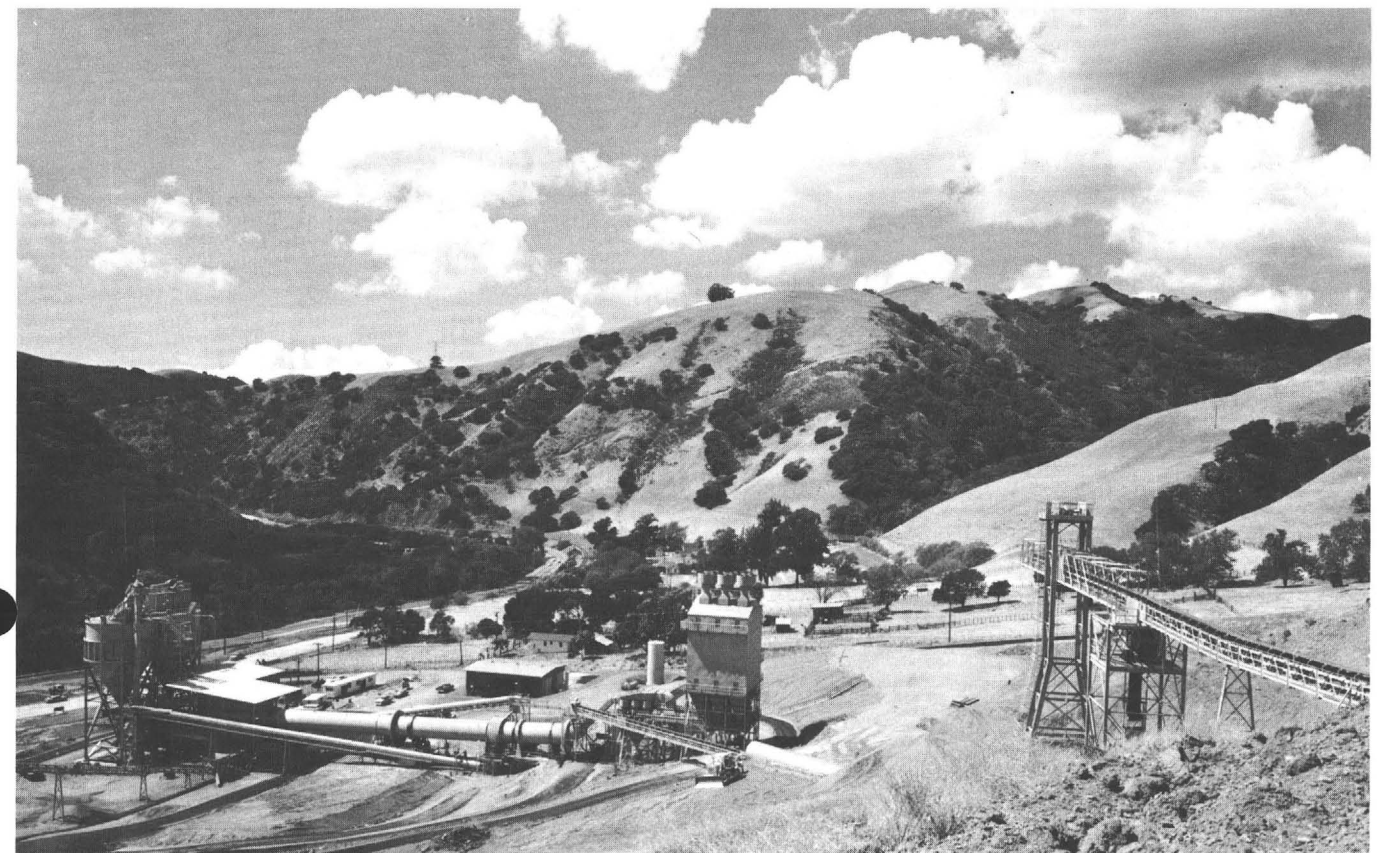
Two other plants have been producing expanded shale aggregate for the Northern California market for many years—the Basalt Rock Company near Napa and the McNear Company at San Rafael.

The results of the intensive study of expansible shale deposits of the area were published in late 1965 by the California Division of Mines and Geology as Special Report 87, written by the principal investigator, staff geologist John L. Burnett.

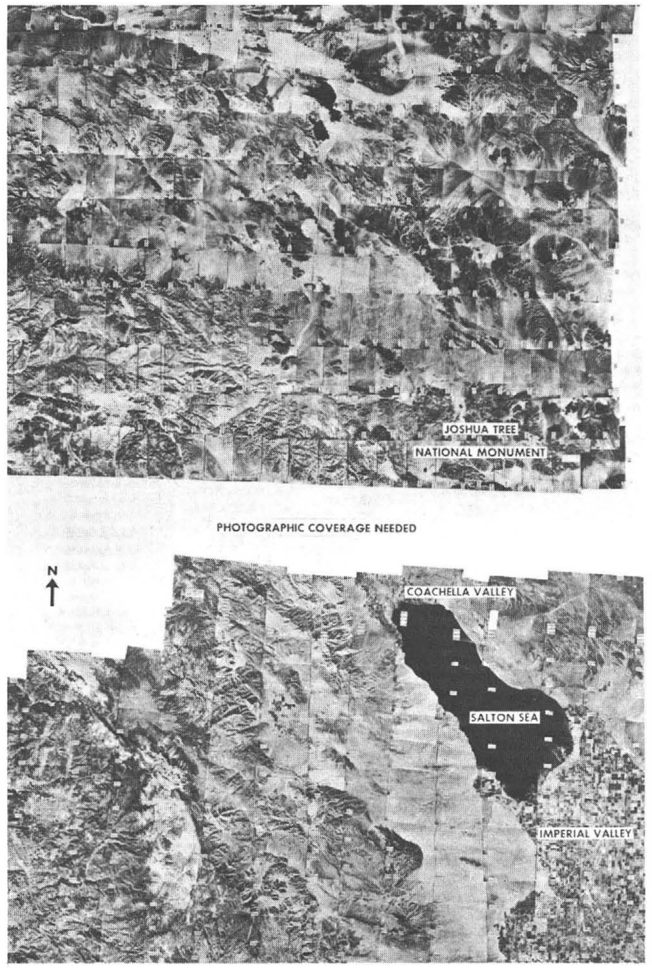
Special report 87, entitled *Expansible shale resources of the San Jose-Gilroy area, California*, presents an analysis of the marketing economics and raw materials available for the manufacture of lightweight concrete aggregate as well as the field and laboratory methods developed by the Division for appraising deposits of expansible shale.

Copies of the report are still available, and may be ordered by mail from the Division's main office in the Ferry Building, San Francisco 94111, or over-the-counter from any of the branch offices in Sacramento, Redding, or Los Angeles. Its price is $1.50, plus tax.

Kaiser Industries expanded shale plant, Sunol. *Photo courtesy Ki-lite Division, by Kaiser Graphic Arts.*



MAPPING BY U. S. SPACECRAFT



Photos courtesy U. S. Geological Survey.

Some of the practical results of the Gemini mission are shown in the two photographs above. To the left is a mosaic of the more than 500 aerial photographs needed to show the area around the Salton Sea and Joshua Tree National Monument. Some of the photographs are missing; the area has not yet been covered by conventional aerial mapping methods.

To the right is the same area, shown in one photograph taken by Gemini. It is not necessary to spend many laborious hours to compile a mosaic; in addition, there are no missing areas.

REVIEWS

VISIBLE GEOLOGY

Geology illustrated. By John S. Shelton. Drawings by Hal Shelton. Published by W. H. Freeman and Company, available at bookstores. 1966. 434 pp. Price $10.00.

An interestingly organized book on "visible" geology. The Shelton brothers, here in concert, have together produced a book that is a new look at old subjects; in addition, it will serve many an author as a good source book for illustrative material, particularly for Dr. John Shelton's air photos.

SOUTHERN CALIFORNIA STUDIED

Engineering geology in southern California was released in October 1966 by the Association of Engineering Geologists. This publication, edited by R. Lung and R. Proctor from 39 contributors, contains a wealth of information pertaining to geologic hazards and problems of interest to engineering geologists working in southern California, including landslides, flood control, earthquakes, faults, nuclear reactor sites, and many more. Numerous case histories of failures due to geologic hazards are detailed in the 389-page volume. Extensive bibliographies are presented at the end of each chapter. Chapter titles are:

1. Earthquakes and faults; 2. Aqueducts, dams and tunnels; 3. Highways and freeways; 4. Landslides and urban development; 5. Legal aspects of engineering geology; 6. Grading Codes; 7. Ground water; 8. Subsidence; 9. Flood control; 10. Marine geology and beach erosion; 11. Foundations, soil mechanics and rock mechanics; 12. Nuclear reactor siting.

Three maps have been prepared to show the major geologic and engineering features, landslides, and soil and bedrock distribution.

Engineering geology in southern California may be purchased from the Association of Engineering Geologists, P.O. Box 21-4164, Sacramento, California 95821. The price is $12.00 plus tax.

The Division of Mines and Geology has copies for reference, but none for sale.

Genesis of riches

SILVER DEPOSITS OF THE CALICO DISTRICT

By F. Harold Weber, Jr.

Third of three parts *

The principal silver mineral of the Calico district and vicinity has been cerargyrite (naturally occurring silver chloride, colloquially called "horn silver"). It is a soft, waxy-looking mineral, which at Calico has ranged in color from pale gray to pale green. A similar mineral found in the district, but much less commonly, is embolite. These two minerals are called "secondary" minerals, because they have formed near the surface of the earth, generally by dissolution of the original primary silver-bearing minerals of veins, and subsequent redeposition. The primary minerals include tetrahedrite, tennanite, stromeyerite, proustite, argentite, galena, and chalcopyrite. Gangue minerals—in addition to chalcedony (mainly variety jasper) and barite—include hematite, pyrite, and secondary manganese oxides.

Precise data for grade and character of the ore mined at early Calico are not available, as engineering records for those operations apparently no longer exist. The best general idea of grade can be gained from reports of mill returns, keeping in mind two factors: that roughly 75 to 90 percent of the silver generally was recovered from the ore, and that some of the rich ore shipped was carefully hand mined or hand selected from rock mined, thus yielding a higher grade than the rock in place. Generally the earliest reports showed the highest grade not uncommonly to have been 50 to 100 ounces of silver per ton. But a better idea of true grade probably is shown in a report of Goodyear (1888) for the important Silver King mine. This report shows that the mine apparently yielded about 36 ounces per ton from 1883 to 1886, with a maximum of 64 ounces in 1883, diminishing to 20 ounces in 1886. The range of yield for 1885 may have been about 28 to 43 ounces per ton of ore. Another idea can be gained from a report by Lindgren (1887), who said that the grade was "seldom below $20, and often in the hundreds" (price then about $1.00 per ounce). Another old report suggests that the very productive Waterloo mine may have averaged about 25 ounces per ton, though lower grade ore and rich pockets yielding 2,000 ounces per ton also were mined. Additional examples are the Garfield mine: about 36 ounces per ton, during 1886–1887; and the Waterman mine: about 45 ounces during 1883.

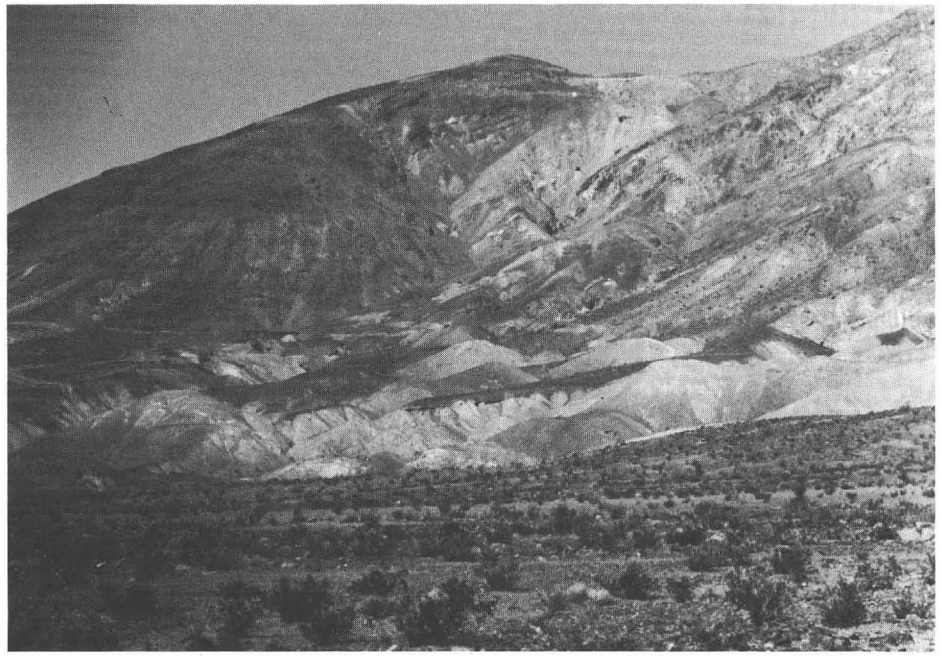
More recent data regarding grade are from the activities of the Zenda Company, which in 1930 shipped ore to a smelter from its deep shaft in the Wall Street Canyon area, just before it ceased operations, as the price of silver dropped to less than 35 cents an ounce. Reports indicate that the rock shipped apparently yielded about 50 ounces of silver per ton, though it might have been at least partially hand selected. Another source of data is a consulting report on the Burcham gold mine which shows that the two principal veins, with assay widths of 2 inches to 4 feet, average 0.03 to 0.31 ounces of gold, and 0.1 to 3 ounces of silver. One of the veins also averages 1 to 3 pounds of lead per ton. The average ratio of silver to gold, both veins, is about 5 or 7 to 1.

Unfortunately, not nearly enough is known of the relationship of the areal geology to the mineralization to be able to understand well the genesis of the deposits, and hence, to predict additional occurrences. What follows, therefore, is only a very general guess as to "how the silver got there" and where there might be more.

The earliest mineralization—which formed the belt of primary veins of the Calico district—perhaps took place during early late Miocene time. The belt of northwest-trending fractures that the vein matter filled may have represented an ancestor of the present Calico fault zone, in the same area as even prior ancestral faults, which had been avenues for the upward intrusion of lavas (the probable instigator, if not the basic source, of the silver and barite mineralization). The volcanic rocks had intruded the middle Miocene Pickhandle Formation—sandstone, conglomerate, tuff, and other strata—during perhaps late middle Miocene time. These events, including emplacement of the veins, took place at unknown depths, but deep enough so that the temperatures must have been relatively high and the chemical systems involved at least partially confined.

The primary, silver-bearing deposits must have formed specifically as the result of the interaction of

*The first part of Mr. Weber's series on Calico appeared in the May, 1966 issue of this magazine; the second part in January, 1967.



View north shows part of southwest edge of Calico mountains, at area of Burcham mine. Large, dark-colored mass of rocks in upper left part of photograph constitutes landslide mass, which contains lower-grade silver mineralization. Calico fault zone skirts base of steepest slopes shown, with Barstow Formation in gully areas to left and Pickhandle Formation to right.

certain fluids (including waters), or the reaction of fluids with certain rocks. These fluids may have been hydrothermal (which rose along faults from deep-seated igneous activity); or they may have been derived from, or associated with, shallow igneous (volcanic) activity; or they may have included connate waters (indigenous waters within the sedimentary rocks) or meteoric (rain) waters circulating through the ground (beneath playa lakes, and within faults, alluvium, and other rocks). Any of these fluids may contain at least minute quantities of practically any element, which may be indigenous or gained by absorption from rocks through which the liquids passed, and with which they may have reacted.

The thin interlayering of chalcedony and barite (along with formation of silver minerals) within many of the primary veins must have been the result of a cyclical change in the character of the fluids entering the fractures, and at least partly precipitating. The change may need not have been extreme, but was distinct. It may have been caused by changes in tectonic conditions (renewed fault movement, for example), changes in deep volcanic activity, or changes in climate (changing the volume of downward circulating waters). But the exact process by which silver and other metals are gained by solutions, then phenomenally concentrated by precipitation into rich deposits, is not understood completely.

After essentially vertical emplacement of the veins, perhaps also during early late Miocene time, the rocks that make up the present day Calico Mountains were uplifted along the present Calico fault zone. With this uplift, the rocks in the west and northwest parts of the mountains seemingly were raised higher than rocks to the east and southeast. Thus, lower parts of the veins in the west and northwest parts apparently were raised higher than veins to the east and southeast, as shown in the accompanying diagram. Consequently, with this uplift, tilting, and subsequent bevelling by erosion, deeper parts of veins were exposed at the surface to the northwest than to the south and southeast.

During this period also, as the faulting and uplift continued during early late Miocene, the upper parts of the veins or zones were being removed by intense erosion. Consequently, the rich secondary silver deposits were being formed by downward and lateral drainage just beneath the surface of the eroding terrain. These deposits formed within zones (the Silver King mine for example) and as areas of stockworks away from veins (as at the Bismarck mine, for example). This process involved the dissolution of the primary silver minerals, as weathering and erosion continued, with the solutions then being carried directly downward into fractures in the zones and redeposited, or out into the surrounding rocks and redeposited (especially in easily mineralized tuff and tuff breccia). These deposits were formed, dissolved, and reformed in a continuing process as the rocks were eroded, with the presentday deposits finally formed perhaps as the period of uplift ended.

Slightly later, during late Miocene time, the lake and other beds of the Barstow and Burcham Formations were deposited against and onto the rising block of the Calico Mountains. As faulting and uplift con-

Railroad loading station at Seca Valley, Nimba, Liberia.

Liberia Mining Company and the Liberian Iron and Steel Corporation, respectively, to determine their economic potential.

Gold and diamonds occur in stream and river beds in various parts of the country. Individual miners are engaged in placer mining by hand methods. Several diamond concessions are engaged in more systematic and productive methods of alluvial mining by mechanical means. Kimberlite, an ultrabasic rock which is believed to be the source rock of most diamonds, has been found in three different areas in Western Liberia. One of these areas is at Weasua, near the Lofa River, where there is much activity in prospecting and mining for diamonds.

Joint mapping project

Under the terms of a project agreement between the Government of Liberia and the United States Agency for International Development, a geologic mapping and mineral appraisal program was initiated in 1964. This program is being implemented jointly by geologists of the Liberian Geological Survey and the U.S. Geological Survey.

The primary objectives of the program are twofold:

(1) To prepare a geological map of Liberia at a scale of 1:250,000 and establish a systematic geological mapping program at larger scales to support detailed mineral exploration.

(2) To evaluate the mineral resources of Liberia and prepare recommendations for future mineral exploration and development.

Aerial photographs and mosaics are utilized in the field as base maps for accomplishing reconnaissance geologic mapping along rivers, foot trails, and motor roads. Traverse lines are cut in areas not accessible by trails and roads. Heavy mineral concentrates, stream sediments, and soil samples are collected systematically for laboratory studies.

Field methods employed for mineral exploration include conventional prospecting and detailed geologic mapping, as well as geochemical and geophysical exploration. The appropriate techniques are applied if areas of economic mineral interest are found as a result of geologic reconnaissance mapping.

In equatorial rainforest regions such as Liberia, relatively few bedrock exposures are visible due to the dense, luxuriant vegetation and the thick overburden caused by lateritic weathering. The application of geochemical exploration methods under these conditions could result in new mineral discoveries through systematic sampling and analyses of soils, rocks, sediments, and stream water. Geophysical surveys are also applicable, since they serve to detect discontinuities or changes in character of concealed geological formations, and to outline certain mineral bodies which differ in physical properties from their surrounding country rock.

It is anticipated that the implementation of this geological exploration and resources appraisal program will ultimately result in significant new mineral production and mineral industries in Liberia.

Monrovia, Liberia
November 10, 1966

scale. Some structural features in these rocks are uniform over relatively large areas. Gneissic structure and schistosity dip at high angles in most places and are often vertical. The predominant strike is NE-SW.

More knowledge about the geology of Liberia will be obtained during the course of the joint mapping activities of the Liberian Geological Survey and the United States Geological Survey which are now in progress. It is anticipated that, after 1966, geological maps of sections of the country will be published, and, by 1972, a complete geological map of Liberia will be available.

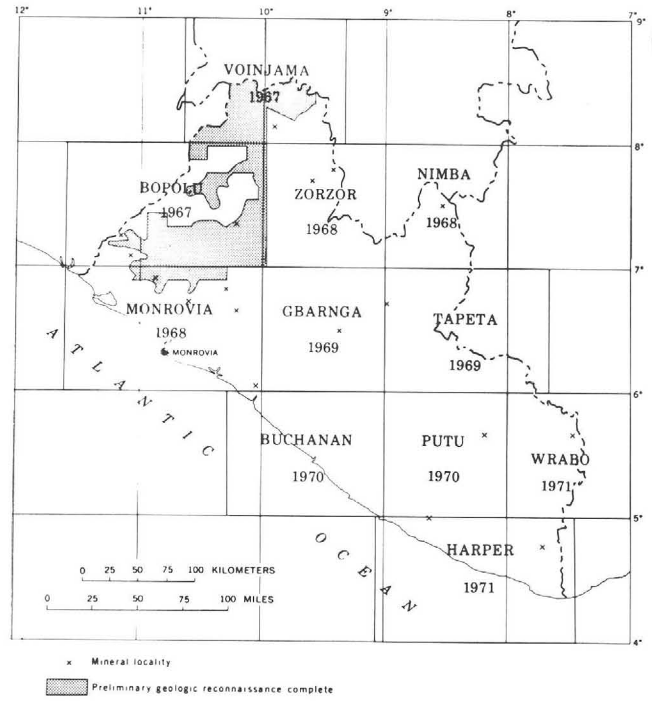
Mineral resources

Liberia is now the largest producer of iron ore on the continent of Africa, and the third largest exporter of iron ore in the world. Gold and diamonds are other minerals which are found in economic quantities and are being extracted for local use and for export. In addition, many other minerals are known to occur in Liberia, but their economic potentials have not yet been determined. These minerals are presently being investigated by geologists of the Liberian Geological Survey and the United States Geological Survey, under a joint geologic mapping and mineral appraisal program.

The following are known mineral occurrences in Liberia:

Asbestos	Kyanite
Barite	Lead
Bauxite	Manganese
Chromite	Mica
Clay	Monazite
Columbite-tantalite	Platinum
Copper	Quartz
Corundum	Rutile
Diamond	Talc
Gold	Tin
Graphite	Tungsten
Ilmenite	Uranium
Iron	Zircon

The Liberian iron ores consist mainly of hematite, magnetite, and itabirite. The Bomi Hills deposit, located about 50 miles northwest of Monrovia, was the first iron ore deposit to be discovered and developed. It contains proven reserves of 50 million tons of high grade magnetite ore yielding 68 to 70 percent pure iron, and 150 million tons yielding 35 to 50 percent. This deposit is being developed by the Liberia Mining Company, which is the pioneer mining company in Liberia. Total exports in 1965 reached two and half million tons.



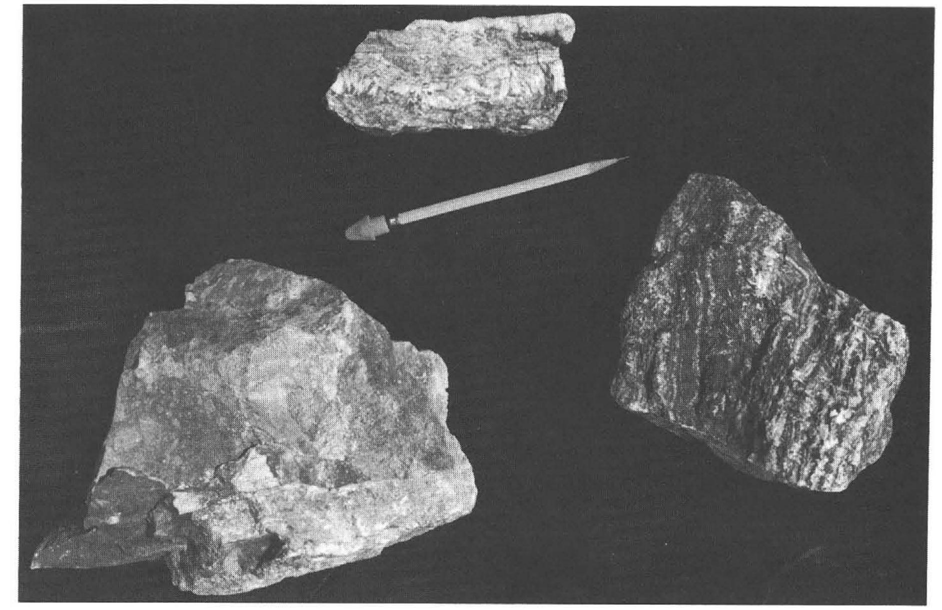
Index map showing areas of coverage of scale 1:250,000 geologic map series and scheduled completion dates of reconnaissance mapping

The largest iron ore deposit in Liberia is located at Mount Nimba near the Guinea and Ivory Coast border. Total reserves are estimated to be 250 million tons of high grade hematite ore yielding 65 to 69 percent pure iron. In addition, there is a considerable amount of low grade ore. The Nimba deposit is being mined by LAMCO (Liberian American-Swedish Minerals Company). The first iron ore shipment by LAMCO was made in April, 1963. In the year 1964 this company exported six and half million tons of iron ore, and eight million tons in 1965.

Other iron ore deposits of lower grade occur in the Mano River area near the Sierra Leone border, and in the Bong Range, 50 miles northeast of Monrovia. The estimated reserves of iron ore are 50 million tons in the Mano River Mine, and about 250 million tons in the Bong Mine yielding 35 to 45 percent pure iron. The National Iron Ore Company is developing the Mano River deposit. Two and half million tons of iron ore were exported in 1964, and three and half million tons in 1965. The Bong Range deposit, which went into production in April 1965, is being developed by DELIMCO (German Liberian Mining Company). Its export of iron reached three million tons in 1965.

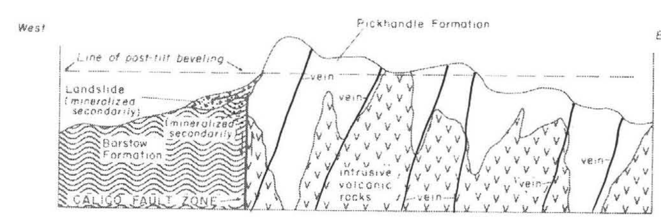
Extensive iron deposits are also known to occur in the Bie Mountains of Grand Cape Mount County and the Wologisi Range in Lofa County. Detailed appraisal of these deposits has been undertaken by the

Specimens of vein material from Calico district. *Lower left:* Pale gray vein barite at bottom is in contact with grayish red andesite wallrock. Barite is broken away at lower left, to show smooth surface of vein wall. *Upper center:* Specimen of cross section of thin vein, with coarse-grained barite in middle, and banded barite-jasper rock in outer portions. Specimen is liberally sprinkled with very fine-grained silver-bearing sulfide minerals. *Right:* Specimen across thin vein; similar to upper specimen, but jasper more abundant, and more concentrated toward middle.



tinued into the Pliocene, the appearance of the terrain was much different than today, though the general position of ranges and valleys probably was similar. But the climate was much more humid than now, with vegetation relatively abundant, hot springs along the active Calico fault zone, and perhaps small lakes. Silver minerals were being deposited by hot waters circulating in the Calico fault zone and adjacent rocks, with the silver gained perhaps from primary or secondary deposits being eroded nearby. Weathering and erosion were intense, cutting the present gorge-like canyons into the range as it was being uplifted; and great masses of broken-up material were being carried out from the range and deposited as alluvium. Mass wasting was common, with the occurrence of the landslide * that led to the mineralized breccia. This slide, which headed down the steep southwest slope of the range, over the Calico fault zone, probably was derived from bedrock now mostly eroded away. After

* Also interpreted by others as being of tectonic origin.



Hypothetical and exaggerated cross section across ancestral Calico Mountains, showing possible tilting of rocks along Calico fault zone, which raised deeper parts of veins to west and northwest higher. Subsequent bevelling by erosion exposed deeper parts in the west and northwest than in the east and southeast.

sliding it was mineralized by the previously noted silver-bearing solutions percolating upward in the Calico fault zone.

Barely enough is known of the mineral deposits and geology of the Calico district and vicinity to guess as to the possible location of additional ore deposits. Especially unknown are the rocks which lie beneath the broad stretch of alluvium west and south of the Calico Mountains, beyond the Calico fault zone. For example, the northwest end of the primary belt of veins and zones extends to the Calico fault zone, west of which lies alluvium. Presumably the mineralization is dying out to the northwest, but possibly it might increase in intensity at some point beyond where the belt renews on the other side of the fault, probably to the northwest, beneath alluvium.

Also offset by the Calico fault zone is the mineralized landslide breccia; portions of this faulted mass may be buried nearby, beneath alluvium.

Additional silver deposits may lie somewhere beneath the broad stretch of alluvium that extends westward from the Calico Mountains to the hills which contain the Waterman and Lead Mountain mines. Even the Calico Mountains themselves contain alluvium, with unknown rocks beneath. Silver mineralization also may have enriched rocks that lie below the Barstow-Burcham Formations, provided that these formations are younger than the belt of primary veins and zones and the deposits of stockworks. Especially, such mineralization might occur beneath the lobe of the Barstow Formation which lies just south of East Calico.

Silver-bearing deposits may also be associated with the volcanic rocks which are nearly surrounded by alluvium or younger rocks west of Calico, in the vicinity of the Waterman and Lead Mountain mines. In these areas, prospecting might be aided by an understanding of why silver and barite occur together at the Waterman and Lead Mountain mines and barite occurs alone at the Barium Queen and Penny deposits.

Within the Calico Mountains themselves, very low silver enrichment with economic potential may exist in rocks other than the landslide breccia.* For example, certain tuffs within the Pickhandle Formation of East Calico, which were mined for rich pockets at the surface, might contain additional deposits of voluminous though extremely low grade mineralization (tuff is known as an absorber of minerals from solution). Fractured volcanic rocks, filled partly with barite, occur especially at several localities in the northwest part of the range, but a possible link with silver is not known.

Another factor concerning exploration for silver at Calico is the relationship of known deposits to depth. Though the grade of the deposits is known to diminish downward in mines, nothing is known about these deposits at much greater depths (thousands of feet).

In conclusion, though California never has been a great silver producing state, the metal has been mined at many localities, which suggests a variety of possibilities for renewed exploration and mining if the price continues to rise. Perhaps presently uneconomic deposits can be developed whereby silver and other metals or minerals are recovered together from very large tonnages of low grade rock considered previously to be noneconomic. In this respect, the Mojave desert, and the region to its north and east, contain many districts in many types of terranes, along with complex regional geology and great stretches of alluvium which cover possible deposits. Unfortunately, very few geological workers in the region today are studying the academic geology of metal deposits. However, more and more regional geologic data are being accumulated and perhaps such data will be utilized by economic geologists of the future to uncover additional deposits. Who knows, there may be another Comstock Lode somewhere out on the desert in some least suspected locality, buried beneath just a few hundred feet of alluvium—possibly even near the Calico Mountains.

* This subject was discussed in several papers by F. B. Weeks.

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Index map of Liberia.

highest elevations almost 5000 feet above sea level. The highest mountains are the Wologisi, Nimba, and Bong.

The country is drained by six principal rivers and several smaller rivers which flow from north to south into the Atlantic Ocean. The largest lakes are the Fisherman's Lake in Grand Cape Mount County, and the Shepherd Lake in Maryland County.

Geologic structure

Liberia forms a part of the West African Shield, which is a large Precambrian region consisting predominantly of ancient crystalline rocks. The rocks forming this crystalline shield are a series of granite, gneiss, and schist beds which have been subjected to intense folding and faulting.

With the exception of sandstone beds along the Liberian coast, the rocks comprising the basement complex are of Precambrian age. Iron-bearing formations (itabirites) are interspersed in this basement complex and appear to be a part of the Precambrian formation. The original sediments of the iron-bearing formation have undergone great physical and chemical changes resulting in metamorphosed and migmatized rocks.

Volcanic rocks occur along the coast, forming promontories at Cape Mount, Cape Mesurado, and Cape Palmas. The capital city, Monrovia, is built on a ridge of diabase about four to six miles long by a mile or two wide. Diabase and gabbro occur as basic rock intrusions in the interior of Liberia, forming numerous dikes. Bands of amphibolite which follow the trend of foliation in the gneisses are also common.

The igneous and metamorphic rocks of Liberia have been intensely deformed and metamorphosed by tectonic and metamorphic forces acting on a regional

MINERAL RESOURCES OF LIBERIA

By A. E. NYEMA JONES

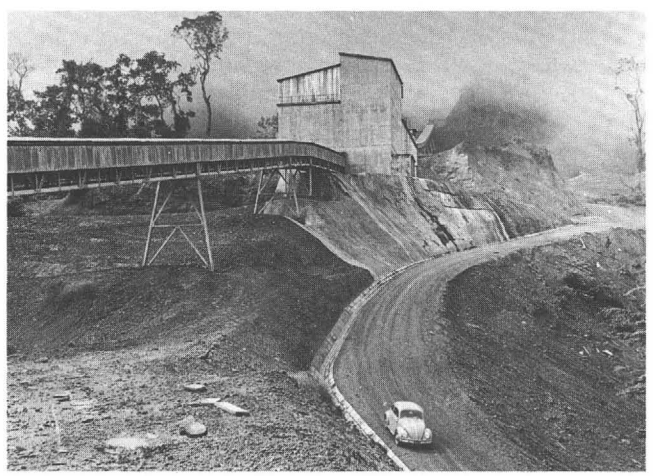
The following article was written especially for this magazine by one of its readers, Dr. Nyema Jones, now Chief of the Liberian Geological Survey, a branch of the Bureau of Natural Resources and Surveys. We thought our other readers would enjoy a brief view of the geology and resources of another country half a globe away.

. . . M. R. H.

Liberia is Africa's first and oldest republic. It lies in the western bulge of the continent, four to eight degrees north of the equator, with an area of 43,000 square miles and a continuous coastline of 350 miles along the Atlantic Ocean.

The Republic of Liberia had its origin in the efforts of several American philanthropic societies to provide an asylum on the west coast of Africa for freed American Negroes. In 1822 a settlement was established at the site where the city of Monrovia now stands, and on July 26, 1847, Liberia was declared an independent state. Its capital city, Monrovia, was named after James Monroe, fifth president of the United States of America.

The Constitution of Liberia provides for a democratic republican form of Government, and is modelled after that of the United States of America. The Government consists of three separate coordinate branches —Legislative, Executive, and Judicial. The country is divided into nine counties and five territories, each administered by a Superintendent appointed by the President of the Nation.



Conveyor belt from mine to railroad loading station at Seca Valley, Nimba, Liberia.

Liberia has a population of approximately one and a half million people. These people are descendants of the early settlers, and of indigenes who lived in that area several centuries ago, some of whom migrated from the north and east. Although relatively small in area, Liberia is occupied by 28 tribes of hospitable and friendly people. Each tribe has its own language, customs, and traditions, but English is the official language and is widely spoken and taught throughout the country.

Geography

Since Liberia is situated in the equatorial rain forest belt of West Africa, its climate is tropical and humid, with alternating dry and rainy seasons of almost equal duration—the former from November to April and the latter from May to October, approximately. The duration of the dry season increases northward with distance from the equator. The average yearly rainfall varies from 80 inches in some parts of the interior to as much as 200 inches at elevated areas on the Atlantic Coast, such as Cape Mount. In the coastal areas there are two weeks of steady sunshine in the middle of the rainy season, known as the "middle dries".

Although Liberia is close to the equator, it does not have the extremely hot and unhealthy climate usually associated with the tropics. On the coast, the climate is tempered by the almost constant seabreeze, while most parts of the interior are cool and comfortable because of the higher altitudes, particularly in the mountainous regions. The relative humidity varies from 60 to 100 percent. Average daily temperatures are 75 to 80 degrees Fahrenheit, with extremes of about 50 degrees and 95 degrees Fahrenheit. The lower temperatures occur during the night. Because the constancy of temperature and the accompanying humidity is favorable to luxuriant plant growth, there is an abundance of evergreen vegetation.

The physiography of Liberia is characterized by coastal plains, rolling hills, dissected plateaus and mountain ranges. Three promontories are in the coastal region, forming capes on the Atlantic Coast. Cape Mount near the Sierra Leone border is 1068 feet above sea level; Cape Mesurado at Monrovia rises to approximately 300 feet, and Cape Palmas near the Ivory Coast border is about 100 feet above sea level. There are several mountain ranges in the country, with the

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A limited supply of a more extensive bibliography on the Calico district has been prepared by Mr. Weber and is available at no charge upon request.

THE HISTORY BOOKSHELF

Walker's R.R. Routes—1853, by Pat Adler and Walt Wheelock. La Siesta Press. 61 pages, maps, photos, drawings. 1965. Price $4.50.

Orders should be addressed to La Siesta Press, Box 406, Glendale, CA 91209.

The role played by Joseph R. Walker in the history of California is significant as he was, perhaps, one of the first guides who led mapping and exploratory companies through the territory. His discovery of the pass at the southern tip of the Sierra Nevada which now bears his name became the topic for heated debate when the choice of routes was being discussed. The pass was easily accessible, and was travelled by many coming into California in search of gold or land. The practicality of this route having been demonstrated, it is difficult to comprehend why it was not selected. One reason may be found in the conditions that existed in Congress. As the authors summarize, "It would not be exaggerating to say that this [the] Benton-Fremont alliance was the most powerful single force in the development of the western routes. . . ." Their influence, exerted against a southern route, was too great and expediency was substituted for practicality.

—Albert D. Ortiz.

The Songs of the Gold Rush. Edited with Introduction by Richard A. Dwyer and Richard E. Lingenfelter; music edited with guitar arrangements by David Cohen. University of California Press, Berkeley and Los Angeles, 2d printing, 1965. 200 pages, illustrated. Price $3.50.

A collection of 88 gold-rush songs, drawn chiefly from such contemporary song-books as *Put's Original California Songster* (1855), *California Songster* (1855), *The Gold Diggers' Song Book* (1856), and *Johnson's Original Comic Songs* (1858). The songs are grouped by subject under various headings— "Ho! for California!", "Seeing the Elephant", "An Honest Miner", "Life in California", etc.—and each group is introduced by a short commentary on the sundry gems that it contains.

The songs, say the authors in their introduction, "exhibit . . . every facet and mood of the great rush—the voyage around the Horn or by the Panamanian isthmus, the trek across the plains, the humor and drudgery of mining, the hopes and the disillusionment of the miners, the hardships and humbugs of life in California, and the last reminiscences of the days of '49": this for the "buff" of gold rush history or romance. He who would like actually to *sing* the songs will find this collection has an advantage over many others: he is not left—in most instances, at least—to scour his memory for some tune a hundred years dead ("Air: I Get in a Weaving Way"; "Air: Lucy Long"; "Air: Rosin the Bow"). Words, guitar chording, *and music* appear together on the page.

To order, address University of California Press, Berkeley, CA 94720; the book is not distributed by the Division of Mines and Geology.

E.L.E.

Inyo 1866–1966. Sponsored by Inyo County Board of Supervisors. 95 pages, many illus. 1966. Price $3.27, paperback; $6.39, hardback; price includes tax and handling charges. Address orders to Miss Mary Cavitt, County Librarian, Courthouse, Independence, CA 93526.

Marking the centennial of the formation of Inyo County in 1866, this book, with its beautifully reproduced illustrations and interesting text, recounts the history of Inyo, from the first attempts at settlement to the County's current productions and activities. The many short articles that make up the book cover a multitude of subjects—pioneer resident Samuel Bishop, who drove cattle from Fort Tejon to Owens Valley in 1861; Camp Independence, the Civil War fort of adobe, which stood until the earthquake of 1872; mining; agriculture; forestry; the interdependence of Inyo and that old water pirate, Los Angeles; tourism and recreation; and many others.

E. L. E.

THE GEORGE A. GROTEFEND MINERAL COLLECTION

By Irene Kitchell

During his lifetime, George A. Grotefend acquired an extensive mineral collection, including many excellent specimens from the mines in Shasta and Trinity counties. In 1950 he loaned this collection to the California Division of Mines for display at the Redding office. When the provisions of his will were revealed after his death in 1951, it was learned that he had bequeathed his mineral collection to the Division of Mines with the stipulation that it be kept on exhibit and displayed at the local office. Visitors are welcome to see the display at our Redding office, which is located at 2135 Akard Avenue, Room 10. Office hours are 8:00 to 12:00 and 1:00 to 5:00 daily, Monday through Friday.

Dr. Grotefend came from pioneer stock in Shasta County. His father, August Grotefend, was born in Germany in 1824 and came to St. Louis with his family in the same year. Lured by the stories of gold discoveries, he came to California to seek his fortune, settling in Shasta County in 1849. After several unsuccessful mining attempts he discovered a rich pocket of gold ore in Schaeffer Gulch, from which he removed about $18,000. In 1853 or 1854 he married Emilie Zumdahl and engaged in the mercantile business in the town of Shasta, where he was very successful. The remains of his store are still preserved as a part of the Shasta State Historical Monument.

George Adolph Grotefend was born in 1869, the next to the youngest son of August and Emilie Grotefend. He was educated in the local schools and the Methodist College in Napa. He then attended the University of Pennsylvania, graduating in dentistry in 1889. He returned to Redding where he opened an office in 1890, which he maintained for 20 years, in the Odd Fellows Building. He was considered Redding's leading dentist, keeping abreast of all modern techniques and equipping his office with the finest fixtures available.

About 1909, together with Bill Foster, Dr. Grotefend organized the Trinity Farm and Cattle Company. The firm had headquarters near Trinity Center and grazing land in the Bald Hills. Actually the doctor made his money in his mining ventures and invested the proceeds in the land and cattle company. He held the controlling interest in this company at the time of his death.

George Grotefend had considerable mining interests throughout his lifetime. Probably his most outstanding mining venture was the purchase, about 1930, of the Washington mine in the French Gulch mining district. Lode gold was first mined in Shasta County in 1852 at the Washington mine; thus it ranks among the earliest lode locations in California. By 1890, total production was estimated at $500,000 to $600,000. The mine was continuously active until 1865, after which it was operated only intermittently by lessees. He bought all the stock of the mine "for a song" and put several men to work driving what is known as the H level, sometimes called the 350 level. The level was driven ahead about 150 feet, where it encountered a nice showing of ore. About 100 tons of ore was mined and stockpiled on the dump, as the old Washington mill had deteriorated to a point where it would have to be rebuilt before the ore could be milled. About that time J. H. Scott came to the French Gulch district, having so far been unsuccessfully engaged in mining ventures. Dr. Grotefend agreed to sell him the Washington mine for $10,000 down and 25 percent royalty to apply on the purchase price of $70,000 for the mine. Scott paid the $10,000 down. He shipped the ore on the dump to the smelter and recovered over $13,000 from the 100 tons. Another $800,000 worth was mined from the shoot of ore before he was forced to shut down the mine during World War II.

George A. Grotefend. Photo courtesy *Redding Record-Searchlight.*

Dr. Grotefend had once married, but the marriage ended in divorce, and there were no children. From the seven children born to his mother and father, only one grandchild grew to adulthood. This niece, Bessie Prehn, was never married and died in 1957, leaving the Grotefend family with no descendants. Dr. Grotefend retired from active practice in the early 1940's and spent the last twenty-five years of his life living at the Golden Eagle Hotel. [This old landmark, built in 1888, burned to the ground in 1962.] He died there in 1951 at the age of eighty-two. His will, made only two months before he died, contained some unusual and surprising provisions. After bequests to several friends, he bequeathed his extensive mineral collection to the California Division of Mines and set up three trust funds.

The third fund, an amount of about $261,000 was set up as a scholarship fund for students who spend four years in Shasta County high schools and who desire to go to college. There are very few restrictions and the students are able to choose their own schools. They must be worthy and in need of help other than can be afforded by their parents but it is not necessary that they be of the current graduating class, so that students already in college are eligible.

The scholarship fund is administered by three trustees: the principal of Shasta Union High School, the county superintendent of schools, and a third member to be selected by them. This third member currently is Superior Court Judge Richard B. Eaton. As much as $20,000 has been given in a single year. Beneficiaries of this program who have graduated include doctors, nurses, dentists, ministers, and teachers.

The Grotefend story is in a sense the story of America—thrift, energy, wise investment, and charity. The Division's Grotefend Mineral Collection symbolizes the physical aspect of that story and the George A. Grotefend Scholarship Fund symbolizes its more human aspects. It is hardly possible that the doctor could have left his fortune for a more worthy cause, or a more fitting memorial to perpetuate the name of Grotefend.

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Amesbury, H. Clyde, 1958, Dr. George A. Grotefend *in* The Covered Wagon: Shasta County Historical Society.

Redding Searchlight, February 22, 1898, page 48.

Henry Carter, personal communication, 1956.

Judge Richard B. Eaton, personal communication, 1965.

Wanda Grooms, personal communication, 1965.

Raymond V. Darby, personal communication, 1966.

The mean velocity of a sound wave in a crystal of quartz is 9,811 miles per hour.

GOWER LEGAL SERVICE ADDED TO LIBRARY

Through the generosity of Mr. Philip R. Bradley, Chairman of the Mining and Geology Board, the Division of Mines and Geology Library in San Francisco is proud to announce that we now have a subscription to the Gower Federal Service in Mining. This publication is specifically devoted to legal decisions concerning mining, and it appears in three sections. Selected decisions of the Bureau of Land Management and Hearing Examiners are printed on white sheets. All opinions of the Solicitor on mining are printed on green sheets. And, from time to time, significant judicial decisions are reported or abstracted; they appear on yellow sheets. A full year's index appears at the end of each year.

A binder containing the 1966 issues will be placed on the DMG Library shelves for public use and study. As new decisions appear, they will be added to those already shelved.

Another set of the decisions, which are published by the Rocky Mountain Mineral Law Foundation at the University of Colorado, will be placed in the Division's Library in Los Angeles. This set is being provided by courtesy of the California Mine Operators Association.

NEW INVENTIONS USE AUTO SCRAP TO OPEN NEW SOURCES OF IRON, ZINC

Two processes that promise increased use of the metal in millions of old autos discarded each year are among new U.S. Bureau of Mines inventions patented by the Department of the Interior.

A less costly method for reclaiming zinc from die-cast zinc-aluminum alloys used for carburetors, trim, and other parts of automobiles is the objective of one invention. Bureau researchers found that an iron compound can be used to convert the aluminum in such alloys to easily separated forms at lower temperatures than are required by the distillation method used conventionally.

Besides reducing the amount of fuel required to reclaim the zinc in relatively pure form, the process yields aluminum chloride as a marketable byproduct.

Also aimed at wider use of scrap automobiles is the process invented by the Bureau for using the metal in them to beneficiate off-grade iron ores which, though abundant domestically, have so far remained unused. These ores, a form of taconite, lack the magnetic property possessed by other taconites now being developed commercially.

In the Bureau's process, scheduled for demonstration-scale tests in the near future, auto scrap conveys magnetic properties to the off-grade ores when mixed with them and roasted in a rotary kiln.

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The veins and zones range in length from less than 50 feet to about 4,500 feet. The veins range in width from less than a quarter of an inch to perhaps 50 feet (at the Leviathan mine, where barite has been recovered), and most commonly from about half a foot to several feet. Most of the veins dip steeply, commonly 75 to 85 degrees west. Parts of some veins that are very thin (less than 2 or 3 inches) can be traced remarkably continuously for many hundreds of feet along the surface. One vein, for example, which is as much as 7 to 8 feet thick, where exposed in the Silver Bow mine shaft, can be traced southeast along the surface from the shaft, though less than one inch wide, for nearly 500 feet. This continuity helps to suggest that the vein may widen at some point beneath the surface, southeast of the shaft, below possible constrictions, which may have acted as traps to the mineralizing solutions. Possibly the constrictions were caused by a change in lithology. In other areas, a rock unit that seems to have a constrictive cap-like effect on vein deposits is pale-yellow weathering lithic tuff of the Pickhandle Formation. An example of this effect is at the St. Louis Consolidated deposit.

The richest vein deposits, near the southeast end of the belt, consist of zones that once contained rich bodies of so-called secondary silver minerals in their upper parts. Examples were the ore bodies for the Silver King, Oriental, and nearby mines (see accompanying illustration). Deeper parts of these veins are composed nearly wholly of primary minerals; and primary ore minerals are common near the surface in the north-central part of the vein system, at the Silver Bow, Le Montain, and other deposits. The primary deposits generally have been lower in grade than the secondary ones.

The most economically important variation apparently in the character of the principal veins, in the southeast part of the belt, is that with depth they decrease in grade. The best example of this economically unfortunate phenomenon is exposed by the Silver King mine, where ore yielded less silver as mining proceeded—mostly downward. Another variation is that the veins of the central and northwest part of the belt contain principally primary sulfide minerals in their upper parts, and no rich secondary deposits, as do the veins to the southeast. Thus these deposits have been infinitely less important economically than the ones to the southeast. For example, the thick Leviathan deposit is reported to be very low in silver.

Southeast of the belt of veins lie the areas of stockworks, where veins or zones also occur, some in conjunction with the stockworks. The Bismarck and Garfield deposits comprise a combination of veins and stockworks. The stockworks consist of shallow networks of multitudinous fractures in tuff, sandstone, and other rocks which are filled with silver minerals. The Blackfoot mine is characteristic (as shown in the accompanying diagram). At least some of these deposits are restricted to a single layer, or to adjacent layers (such as perhaps the Occidental mine).

The third type of deposit includes those that are associated with the Calico fault zone, which extends along the southwest edge of the range. Silver minerals occur in vein-like deposits in faults of the zone, and as deposits of stockworks in sandstone and shale of the Burcham and Barstow Formations, which are adjacent to the zone. Potentially important, very low grade deposits, explored during 1965–66, constitute disseminated silver minerals in bodies of a landslide breccia, which is associated with the Calico fault zone. In addition, the only gold deposits of the district (the Burcham mine, particularly) occur in the zone.

West of the Calico Mountains, in the hills beyond the broad lowlands, lie additional deposits, including the rich Waterman mine, the Lead Mountain mine, and the Penny, Big Medicine, and Barium Queen barite deposits (as shown on the accompanying map). Most of these deposits seem to be primary veins, with the Waterman mine having contained rich secondary deposits.

A bibliography on the Calico district will accompany the third part of this series.

Order form on page 2

V

Bonanza in the lonely desert

SILVER DEPOSITS OF THE CALICO DISTRICT

By F. Harold Weber, Jr.

Second of three parts *

Silver was first discovered in the east-central Mojave Desert of southern California during the mid- or late-1870's, when the desert still was very remote. In the region near the discoveries a small community grew and was named Calico, probably by prospectors. The bright, splotchy patterns of parts of the nearby terrane probably made these men away from home think of Calico cloth, so popular in those days for ladies' dresses. They probably realized too that the Calico-like areas were the best to prospect, for they comprised the Tertiary sequences of continentally deposited sedimentary rocks, intruded by volcanic rocks, which even then were known to be the hosts for "bonanza" deposits of silver and gold. The "small community" shortly was renamed Daggett, in favor of a Lieutenant Governor of the state, and the name "Calico" moved 6 miles north to a mining camp and mountain range, where the major silver discoveries were made in 1881, and where the rock patterns of the region are the brightest and the splotchiest.

Important mining operations began in the Calico district in 1882, and continued until 1896. Since that time, little silver has been mined, because of the generally lower price of the metal, and because ore rock that remains is generally deeper and lower in grade. The total value of silver produced is estimated at between $13 and $20 million. Also obtained from the deposits in more recent years have been much smaller-valued amounts of barite, lead, copper, and gold. Borax also was once mined in the region, and crushed and broken stone for a variety of roofing granules is produced today from the multi-colored rocks. But most significant to the region in early 1966 was the fact that the price of silver had risen during the past few years from about 92 cents to $1.29 per troy ounce, and, with other factors, had created renewed interest by the mining industry in the Calico district.

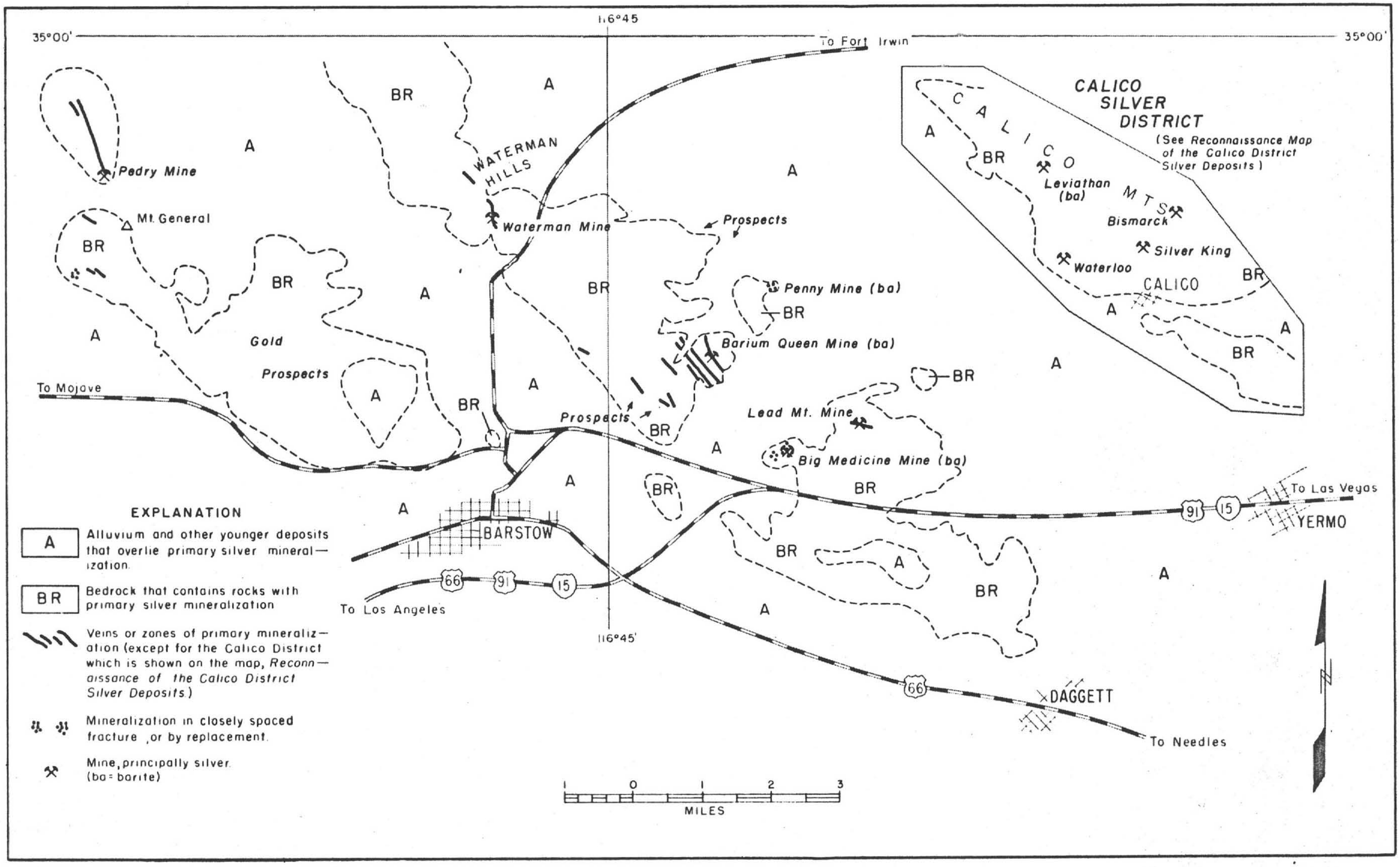
The central Mojave Desert comprises small to moderate ranges and groups of hills separated by small to broad valleys which commonly contain playa lake beds. The ranges and hills generally are blocks of rock that have been faulted relatively upward, and the valleys blocks that have been faulted relatively downward. Most of the blocks have been faulted along lines that trend northwest, generally parallel to the San Andreas fault, whose nearest point lies about 50 miles southwest of Calico. This fault, which dominates the structural geology of southern California, is believed by most geologists to have moderate to very large right lateral movement, whereby the rocks on the northeast side of the fault have moved southeastward relative to the rocks on the southwest side. Similar movement along faults of the central Mojave Desert has been shown by Dibblee (1963) and others.

The Calico Mountains themselves constitute a range which trends generally northwest but is irregular in plan. Silver deposits are mainly in the southwest portion, known as the Calico mining district, which has peak elevations of about 3,000 to 4,000 feet. The range is bounded mostly by nearly flat alluvial areas, as low as 1,900 feet, and is separated from the lowlands to the west and south by a steep northwest-trending front, along the base of which is the Calico fault zone —the predominant structural feature of the region.

To many people, the most spectacular sights in the Calico Mountains are steep-sloped hills, commonly capped with resistant volcanic rocks (which are dark shades of gray, red, or green) and underlain by much softer sedimentary rocks (such as sandstone or tuff, which are pale green, pale yellow, or buff). The resistant volcanic caps have shed trains of bouldery fragments down the steep slopes, giving the overall appearance perhaps of chocolate syrup dribbling down scoops of ice-cream. Such sights can be seen at the steep southwest edge of the mountains, even from a car, while travelling along Interstate Highway 15 near Yermo. At other localities, colorful sedimentary strata are steeply tilted or spectacularly folded, and penetrated by deep canyons, especially Wall Street Canyon, which extends northward from the reconstructed "ghost" of Calico town, at the southwest edge of the mountains.

Geologic terrain somewhat similar to that of Calico also underlies other mining districts in the Mojave Desert, including Mojave, Randsburg, Stedman, and Lava Beds. But the classic illustration of a "bonanza" deposit is the Comstock lode, at Virginia City, Nevada.

* The first part of Mr. Weber's series on Calico appeared in the May, 1966 issue of this magazine.



CALICO SILVER DISTRICT AND VICINITY

View north-northeast shows portion of southwest Calico mountains. The word "Calico" lies at the crest of King Mountain, with the Silver King and Oriental mines just below, and the town of Calico at the base of the mountain. Wall Street Canyon lies to the left of King Mountain, and Odessa Canyon lies to the right. The Burcham mine is shown near the left edge of the photo, which was taken in 1959.

The ore deposits of the Calico region have been studied briefly by many geologists and engineers. The most eminent is Waldemar Lindgren (1887), who formulated the "hydrothermal" classification for the origin of certain ore deposits. The areal geology of the mountains has been mapped in detail by T. H. McCulloh (1965), as part of a regional study.

The oldest rocks in the Calico Mountains region consist principally of the Waterman Gneiss, which may be as old as Precambrian. Next younger are metasedimentary rocks of Paleozoic age, and granitic intrusive rocks of probable Jurassic or Cretaceous age. Together, these older rocks compose the "basement," rocks formerly at great depth but uplifted irregularly along faults during late Cretaceous or early Tertiary times, creating mountain ranges and valleys. Material eroding from the ranges into the valleys during the Tertiary period created the sedimentary rocks, into which the volcanic rocks were intruded. Such a cycle of sedimentation and subsequent volcanism, stimulated by faulting and uplift, has been repeated at least several times since the beginning of the Miocene epoch of the Tertiary period, about 25 million years ago.

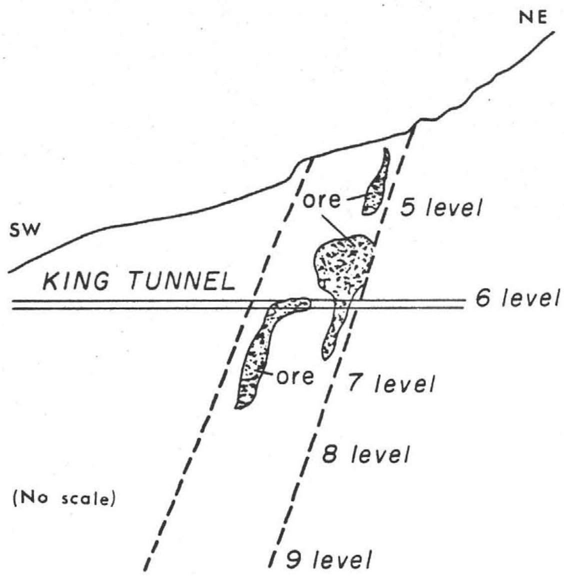
In the Calico district, the principal sequence of rocks consists of faulted and gently tilted tuff, tuff breccia, granite breccia, and sandstone, which was named the Pickhandle Formation by McCulloh (1965). It is probably middle Miocene in age. This sequence has been faulted, gently tilted, and intruded by volcanic rocks which range in composition from rhyolite to andesite. The earliest silver-bearing deposits occur within veins that cut the Pickhandle Formation and intrusive volcanic rocks (as shown on the accompanying map of the district). Related to the veins in the Pickhandle Formation are silicification, baritization, and other forms of alteration.

Composing the remainder of the bedrock, but apparently not containing veins, are the younger Barstow Formation and the Burcham Formation of McCulloh (1965), both probably of late Miocene age. These rocks mainly border the Calico fault zone on the southwest, and also lie within an embayment into the Calico Mountains, where they are mostly surrounded by the older, middle Miocene rocks. The Barstow and Burcham Formations consist mostly of sandstone, mudstone, and conglomerate, along with limestone and other rocks. These rocks appear fresh and unaltered, except in the Waterloo mine area, where probably they were altered as mineralization of the Calico fault zone occurred. They appear to be younger than the primary veins, but do not seem to contain clasts of the vein matter.

Lying above the Tertiary rocks are deposits of uplifted, unconsolidated terrace gravels, probably as old as early Pleistocene or possibly even Pliocene. The youngest deposits consist of Recent alluvium.

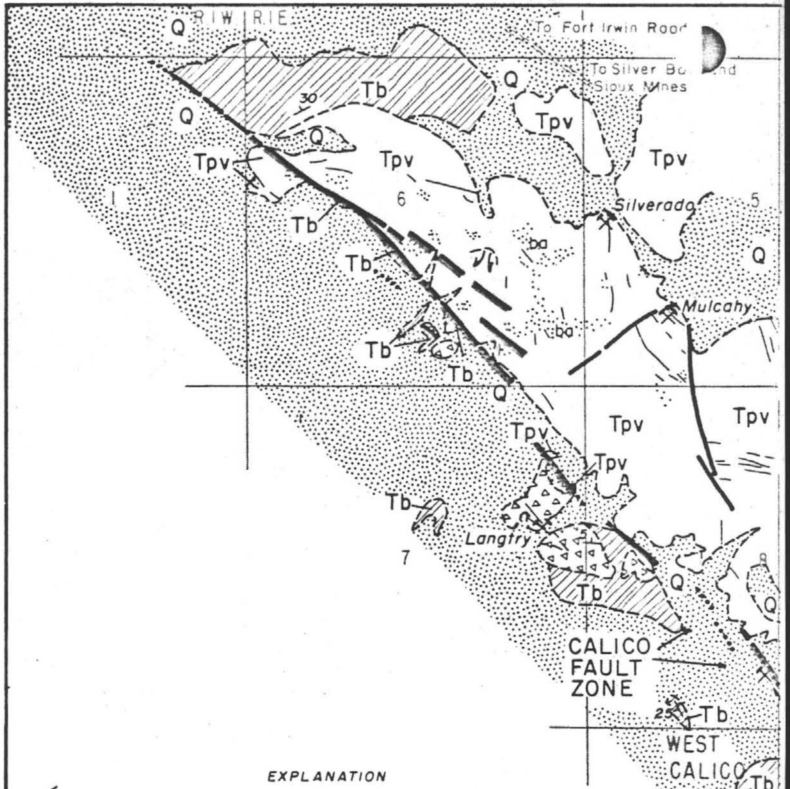
Silver has been sought in the Calico district from three closely related types of deposits: most obvious are veins or vein-like zones which lie north and northwest of Calico and include the Silver King mine ; less obvious, and southeast of the principal veins ("East Calico"), are areas of near-surface stockworks; and west and northwest of Calico lie deposits (including the Waterloo mine) that are associated with the Calico fault zone.

The vein and zone deposits are the basic (primary), oldest, and most widespread silver-bearing occurrences of the district. Veins consist of elongate, tabular bodies which generally consist principally of red jasper and white barite, commonly thinly interlayered parallel to the sides of the veins, with much smaller proportions of manganese, iron, silver, and other minerals. Zones consist of closely spaced thin veins or vein-like features which contain principally stains of iron oxide minerals. The veins trend mostly northwest to north-northwest, and make up a northwest-trending belt roughly 4 miles long and a quarter of a mile to a mile wide. This belt extends from the northwest corner of the Calico Mountains, with a bend near its middle, to points north and east of the town of Calico, where it seems to evolve into the area of stockworks.



Silver King mine; cross section showing ore bodies of secondary minerals in upper part of steeply dipping zone, which cuts layered and intrusive volcanic rock. Sketch was drawn in the late 1880s for court trial (Storms, 1893).

RECONNAISSANCE MAP OF THE CALICO DISTRICT SILVER DEPOSITS



EXPLANATION

QUATERNARY — Q: Alluvium and other superficial deposits of Quaternary and possibly Pliocene age. Includes also, older (tilted) alluvium, terrace deposits, and talus. Deposits mainly unconsolidated, and consist of fragments of older rocks which range from sand size to boulders.

Q/Qls ? Alluvium possibly overlying landslide breccia, which may be mineralized.

PLIOCENE ? — Mineralized landslide (?) breccia that contains very low grade silver in the vicinity of Waterloo mine. Ranges from angular-fragmented breccia to badly shattered bedrock. Constituents are similar to rocks of McCulloh's Daggett Butte Formation or possibly, Pickhandle Formation.

UPPER ? MIOCENE — Tb: Barstow and Burcham Formations of McCulloch (1965), undivided. Consists of gray to green claystone, sandstone, conglomerate, and limestone. Mineralized with silver adjacent to faults of the Calico zone near the Waterloo, Burcham, and Lamar mines.

MIDDLE ? MIOCENE — Tpv: Pickhandle Formation of McCulloch, and intrusive volcanics of silicic to intermediate composition, with small areas of other rocks. Pickhandle Formation consists of tuff, tuff breccia, sandstone, claystone, "granite" breccia (Tpg), and other rocks.

Veins and zones which comprise the primary mineralization. Veins consist principally of chalcedony and barite, and also other minerals, some silver-bearing. Zones consist of groups of thin, closely spaced veins or iron oxide-stained shear zones. Veins commonly have filled shear or fault zones.

Mineralized faults, especially along the Calico fault zone. May have acted as channelways for solutions making younger mineralization along Calico zone; showing dip.

Mineralization that consists of barite (ba), chalcedony, iron oxides (Fe), or silver minerals (Ag) in fractures or interstices of rocks. Forms "stockworks" deposits of East Calico. This symbol represents very crude generalization.

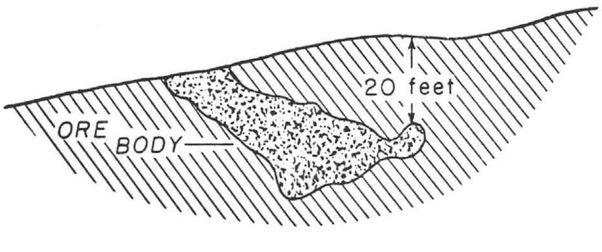
Contact, dashed where approximately located.

Fault, dashed where approximately located, dotted where inferred.

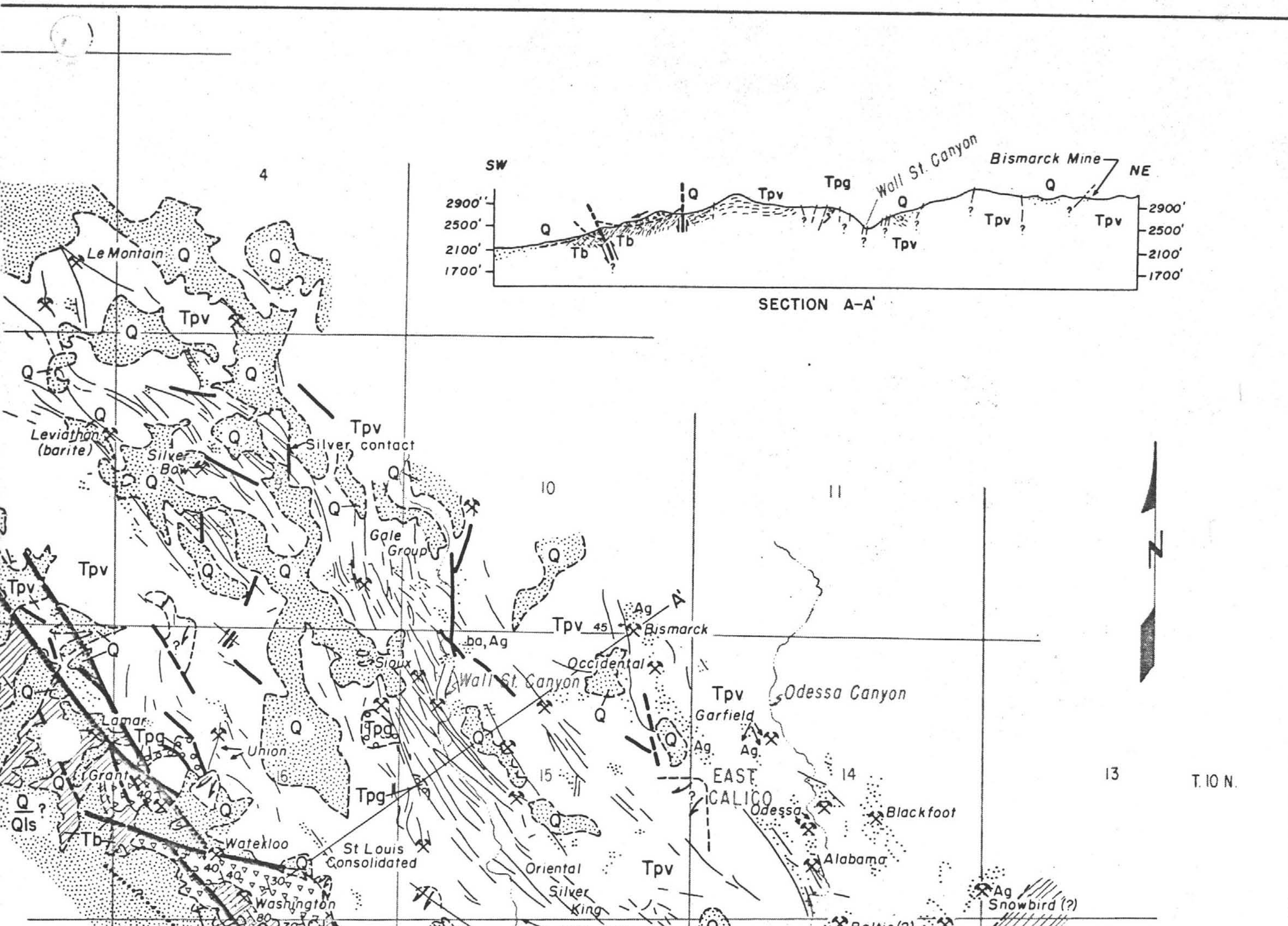
45 Dip and strike of layered rocks

Landslide or possible (?) landslide

Mine



Blackfoot mine showing in cross section one of the shallow ore bodies as seen in active mine by W. Lindgren (1887). Silver minerals fill fractures in tuff (called "tufa" by Lindgren) with body of minerals following layering of tuff.


SECTION A-A'
SW
NE
2900'
2500'
2100'
1700'
Wall St. Canyon
Bismarck Mine
Q
Tb
Tpv
Tpg
Le Montain
Leviathan (barite)
Silver Bow
Silver contact
Gale Group
Bismarck
ba, Ag
Sioux
Wall St. Canyon
Occidental
Odessa Canyon
Garfield
EAST CALICO
Odessa
Blackfoot
Alabama
Snowbird (?)
Baltic (?)
Dietzman (?)
Lamar
Grant
Union
Waterloo
St Louis Consolidated
Washington
Oriental
Silver King
Site of Zenda Co. Operations
Burcham (gold)
CALICO
Mule Canyon
To Interstate Highway 15
To Waterloo Mine
Travertine
CALICO FAULT ZONE
To Yermo
T. 10 N.
Q/Qls ?
0 1000 3000 5000
SCALE IN FEET
Contour Interval 20 Feet
Mapped by F.H. Weber, Jr., 1964–1965, who benefited from geologic maps of the Nebo and Yermo (7 1/2') quadrangles by T.H. McCulloh. Base map comprises adjoining parts of Nebo and Yermo quadrangles. (This is a simplified edition of a previous open-file map.)

SILVER MINING IN OLD CALICO

By F. Harold Weber, Jr.

Early Calico, view north; in background are mine workings of Wall Street Canyon area to left and King Mountain area to right. Mine dumps on King Mountain are principally from Silver King and Oriental mines. Date of photograph not determined, perhaps about 1890. *Collection of The Huntington Library, San Marino.*

Seven miles north of Daggett is the much talked of city of Calico. One narrow and serpentine street is the only thoroughfare. The place is built on a narrow ridge; the back end of lots on each side of the street end on or over a bluff. Small, hastily-built houses are the order of buildings, only a few two-story houses gracing the camp. Saloons are more than numerous. Business generally is overdone, and the number of black-legs and tin-horn gamblers that infest the place is remarked by a newcomer. The only water supply is that hauled two miles from Evans' well, and costs from 3 to 5 cents per gallon. Wood is $10 per cord. Board, $7 to $8 a week. The Occidental and Whitfield House are the only hotels, and they are pushed to their utmost capacity to accommodate the travel that is arriving daily. The camp is a good one, but at present is overestimated and overcrowded by men out of money and work. Capital, development and a chance is all this camp needs to be a second edition to the Comstock at no great distant date.

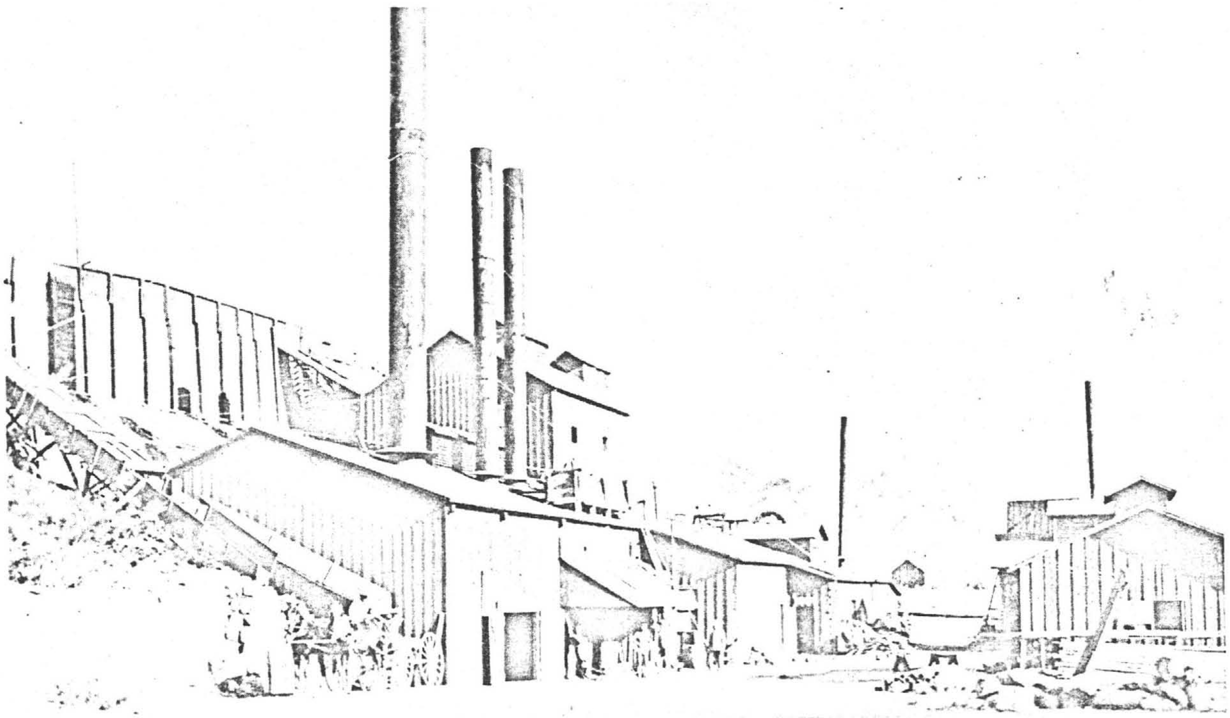
These words, written by a correspondent of the *Mining and Scientific Press,* were published in the issue of March 14, 1885. The "bonanza" Calico district then was in its fourth year of productivity, and near its zenith; within a few years it would begin to wane, becoming a near "ghost" by the very early 1900's. During this period of roughly 20 years, the 50-odd mines of the Calico district and surrounding region—the Silver King, Oriental, Waterloo, Bismarck, Garfield, Odessa, Occidental, Waterman, and others—yielded an estimated $13 to $20 million in silver. This production is small in comparison with $225 million taken from the great Comstock Lode at Virginia City, Nevada, but very significant in terms of metal mining in southern California. Since 1900, silver mining operations in the Calico district have been mostly small and intermittent; but great interest shown in the district by the mining industry since 1963 suggests that once again it may become the site of important silver mining operations.

The little "ghost" town of Calico lies at the southern edge of the Calico Mountains, about 10 miles northeast of Barstow in the central part of the Mojave Desert of southern California, and about 100 miles northeast of Los Angeles. It is commercialized now, and hardly a ghost: parking lots often are filled with modern automobiles, whose brash, shiny colors seem out of place in an old mining camp. Genteel tourists poke curiously along the town street, perusing relics of former mining days, and wander among the dusty graves of the cemetery. Loudspeakers blare inducements to concessions, and the whistle from a sightseeing train echos hauntingly back into the mountains, to the north, where lie the old mine workings of the district. These workings consist both of extensive, professionally engineered adits and shafts, and of widespread, crude gopher-like surface diggings. Altogether, the mine workings have yielded perhaps 15 to 20 million ounces of silver, plus small amounts of barite, gold, lead, and copper. In addition, the region has yielded $9 million worth of borax minerals, mined from 1884 to 1907.

Prospecting for silver in the Calico Mountains and surrounding region apparently was begun seriously during 1880–81, although the first discoveries may have been made earlier, perhaps in 1875. Some prospectors must have searched the Mojave Desert soon after development began of the gold mines in the Mother Lode region, but because the desert region was desolate, poorly accessible, and largely unexplored, mineral discoveries were few. The real spark to prospecting in the eastern mountain and desert region of California, and in Nevada, probably was ignited by discovery of the Comstock Lode at Virginia City in 1859, about 300 miles north-northwest of Calico, and its spectacular development during the 1860's. From this focal point, prospectors spread out widely over the west, and began to discover other great districts, including Eureka, Tintic, and Pioche. Prospecting also was sparked by completion of the transcontinental railroads, beginning with the Central Pacific in 1869, which enabled more men to come west to seek their wealth. In eastern California, during the 1860's and 1870's, Blind Spring Hill, Cerro Gordo, Panamint City, and Darwin were discovered; then Calico; following it, during the late 1890's and early 1900's, were developed the gold districts of Mojave and Randsburg, which eventually also yielded large amounts of silver.

The demand for silver that was the basis for prospecting was natural, as long through history silver had been considered a precious metal, and had been used in coins and as a backing for wealth. The United States had adopted the silver dollar as its unit of monetary value in 1776; and ultimately adopted bimetallism for monetary purposes, whereby the dollar eventually became (in 1837) worth 23.22 grains of gold or 371.24 grains of silver (hence the expression "16 to 1"). But until the Comstock Lode was discovered, the country imported nearly all of its silver. Since that discovery, the U.S. has been a major producer of silver, and during most years from 1871 to 1915 was the world's leading producer. In 1964 the United States ranked third in world output, following Mexico and Peru, and ahead of Canada and USSR. In that year, the United States produced about 36 million ounces of silver, worth about $47 million, principally as a by-product of base-metal mining operations, but partly from ore mined for gold or primarily for silver itself. About 52 million ounces of silver was imported during 1964.

One very important event that was gradually to blight the nation's young but growing silver mining industry occurred in 1873, when the United States went off bimetallism and onto the gold standard (though without basic change to the monetary policy). Soon afterward, the price of silver began to fall

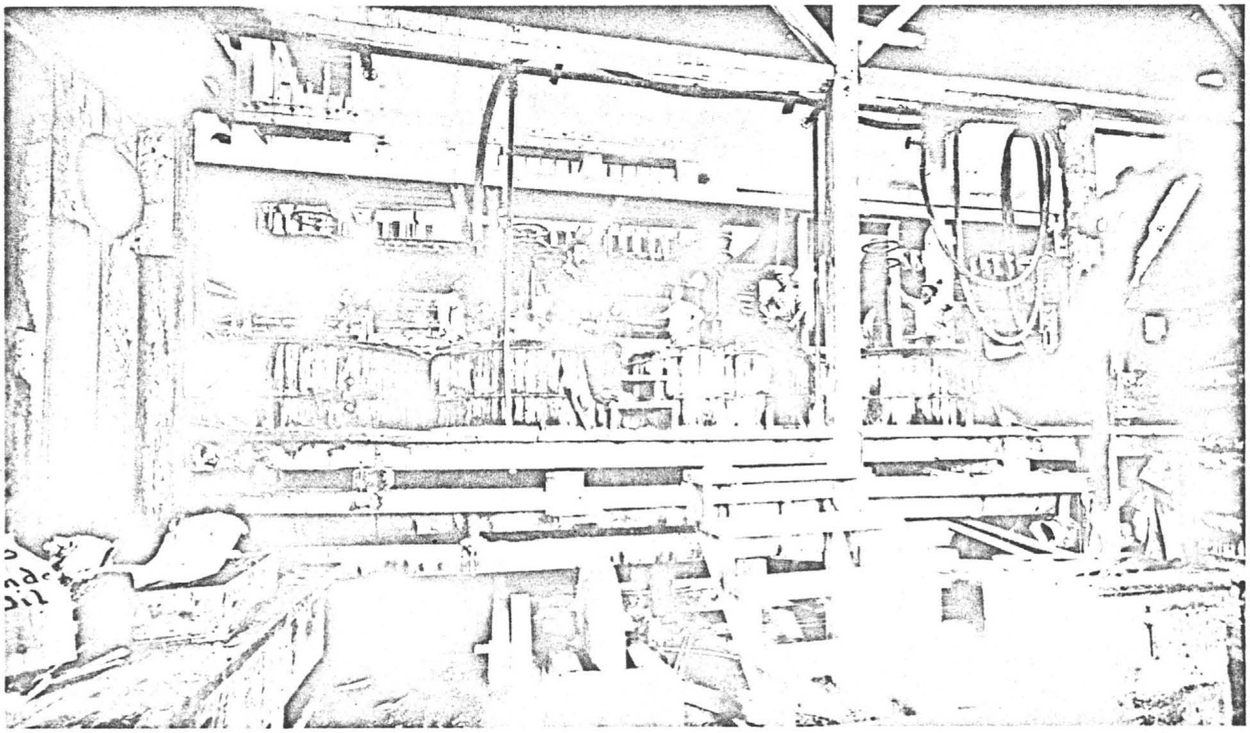


Mill of the Silver King Mining Company (also called Garfield mill). Photo taken perhaps about 1890. At that time ore from Occidental (including Garfield mine), Odessa, and Oriental groups was being processed here. Site of mill is on south side of hill between mouths of Wall Street and Odessa Canyons. *Collection of The Huntington Library, San Marino.*

irregularly from an average high during 1865–73 of about $1.33 per troy ounce to roughly $1.13 in 1881, when Calico was discovered, and to about 64¢ by 1894, when most of the larger operations in the Calico district had ceased or nearly ceased. The price continued to fall, though with fluctuations, to 51 cents in 1915, and to its ultimate low, about 25 cents, in 1932; even during this last period, however, developers and promoters were actively attempting to reopen and redevelop the mines of Calico.

In some respects it is ironic that the Calico district should lie so close to the new freeway of Interstate Highway 15, which links Los Angeles and Las Vegas, Nevada. For Los Angeles epitomizes the unbridled growth in population of the nation, which is reflected in the growth of the Nevada gambling industry that has evolved from the early days of silver mining. This growth in population has led basically, if indirectly, to the renewed demand for silver, and to the increase in its price from about 91 cents in 1961 to $1.29 by 1963. This relatively high present price has stimulated hope in the mining industry for an even higher price, which, in effect, evokes a rebirth in interest in all inactive silver-bearing deposits and districts. Especially of interest are "bonanza" districts such as Calico, which have yielded relatively large amounts of silver from near-surface workings in rich, shallow deposits, mined almost wholly for precious metals, because many such deposits in California commonly have not been thoroughly explored or studied either at depth or on the surface.

Development of the Calico district might be said to have begun earnestly on April 6, 1881 when S. C. Warden, Hues Thomas and John C. King and others located claims which they began to develop as the Silver King mine. Calico did not then grow with a great "rush", but by the spring of 1882 about 100 people were reported to be living in the town, and mining was underway. Activity was slowed during the summer, partly because of illness in the camp, and perhaps also because of the intense desert heat. But in the fall of 1882 mining in the region seemed to gather momentum: consolidation of smaller properties into larger ones led to more efficient development and mining, and more professional miners had arrived. In July, for example, the Silver King mine had been sold for $300,000 to San Francisco interests. In addition, the Atlantic and Pacific Railroad was being constructed eastward from Mojave. By October 22, 1883 track had reached Waterman's, near present-day Barstow, and by the end of the year it had reached Ludlow, 130



Inside mill of Silver King Mining Company. Tanks shown were part of system of Boss (multiple pan) process which utilized chlorination and amalgamation to recover silver. *Collection of The Huntington Library, San Marino.*

miles to the east beyond Calico. The railroad, obviously, became a vital link for the district, essential to growth.

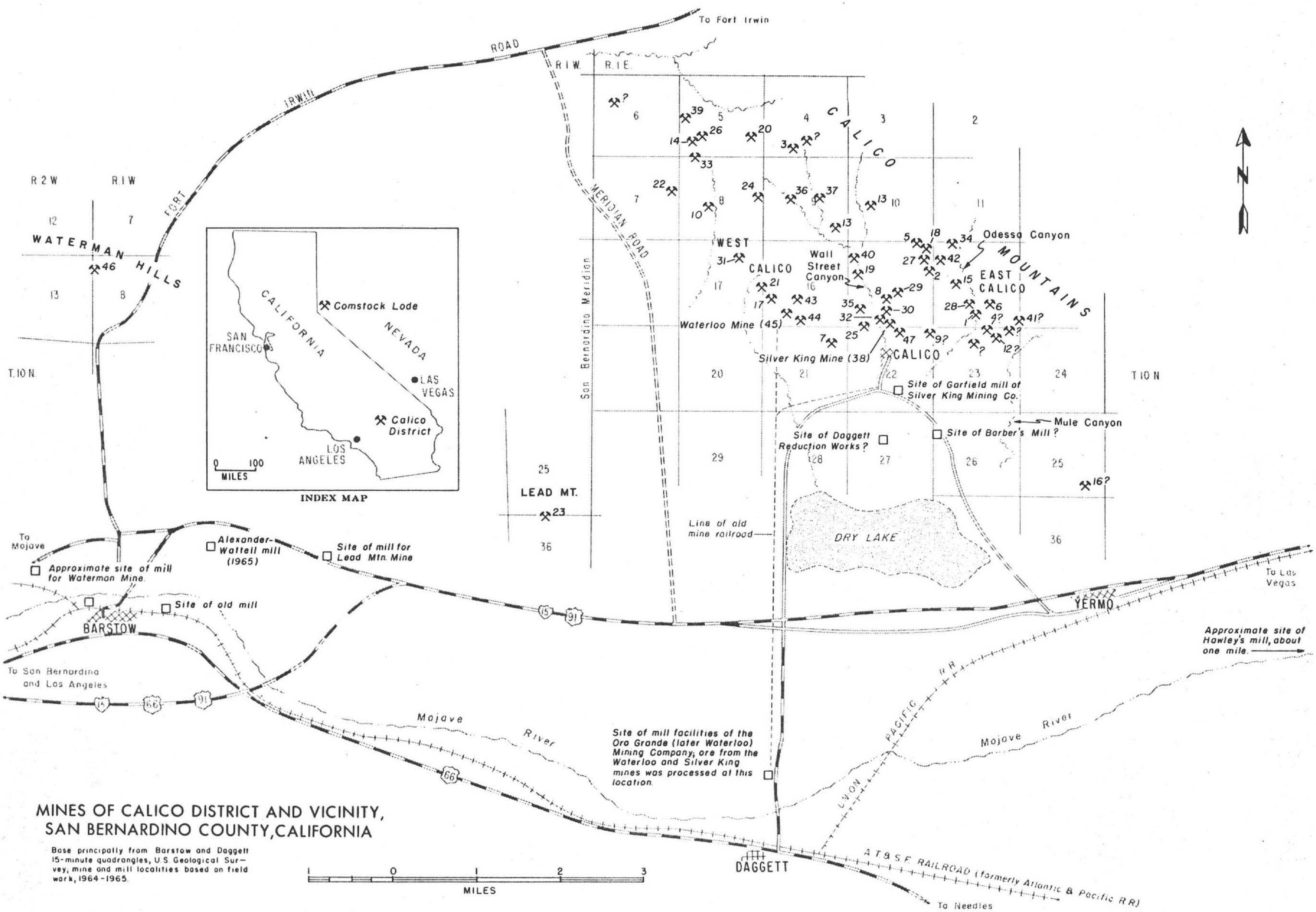
By the end of 1882, the district had taken shape geographically: immediately north of Calico camp, on the steep sides of Wall Street Canyon and on King Mountain were the Silver King, Oriental, Burning Moscow, Red Cloud, and other mines. To the northeast, in the vicinity of presentday-named Odessa Canyon, were the mines of "East Calico", including the Garfield (opened December 1882), Odessa, Bismarck, Blackfoot, and others; and to the west and northwest lay "West Calico," with ultimate development of the Waterloo, Langtry, and other mines. About 5 miles west of Calico, in low hills beyond a broad valley, was developed the Lead Mountain mine; and about 10 miles to the west the Waterman mine had been developed (perhaps even before the first mines at Calico).

Along with development of the mines, mills for processing the ore and recovering the silver were constructed near Calico and along the Mojave River, several miles to the south, where water was plentiful. The ore was hauled to the mills in horsedrawn wagons, and the earliest ore from the Silver King mine was hauled 40 miles to a mill along the Mojave River at Oro Grande. The general silver recovery process used in the region was the so-called "continuous pan" (or Boss) process, in which ore pulverized in stamp mills flowed as pulp through a series of pans in which it first was chlorinated, then amalgamated for recovery of the silver. Such a process apparently handled the free-milling oxide ores of the Calico mines relatively efficiently, for it recovered as much as 95 percent of the silver from the purest chloride ores, and about 75 to 80 percent of the silver from deeper, sulfide-bearing ores. Salt for the chlorination came from south of Danby (100 miles east of Calico) and coal for fuel came from New Mexico.

The Silver King was the most prominent mine in the district, according to a report of the Director of the Mint for 1882; by the end of the year it had been developed to a depth of 250 feet, with about 500 feet of drifts and crosscuts. These developments were reported to have exposed "a ledge 20 feet wide, between well-developed walls, with rich streaks of from 2 to 3 feet on each wall. . . . Many car loads of partially selected ore from the mine have been sold in San Francisco, averaging $300 per ton. . . ." The next in importance was the Oriental mine, under management of Judge James Walsh, a veteran miner, who said that Calico was "another Comstock". The 1882 mint report went on to say that "the Burning Moscow, Red Jacket, and Sue and Fay, and several others have been sufficiently developed to be called mines. In all these mines the ore contains scarcely anything but silver in spar, and in the shape of chloride, bromide, verda plate (green silver), and horn silver." The report also stated that "The Cuba mine is another valuable location in East Calico, and is being developed with promising results. On looking over the Cuba location, almost the entire surface of the claim appears covered with a conglomerated mass of calcareous tufa and porphyry carrying chlorides and horn silver. Wherever the surface has been broken, ore is visible to the eye. . . . All the first class ore from the mine will work $300 per ton, and the owners make it a point not to sack any that will not assay that much." (Silver was then worth about $1.14 per ounce). No minable gold had been found.

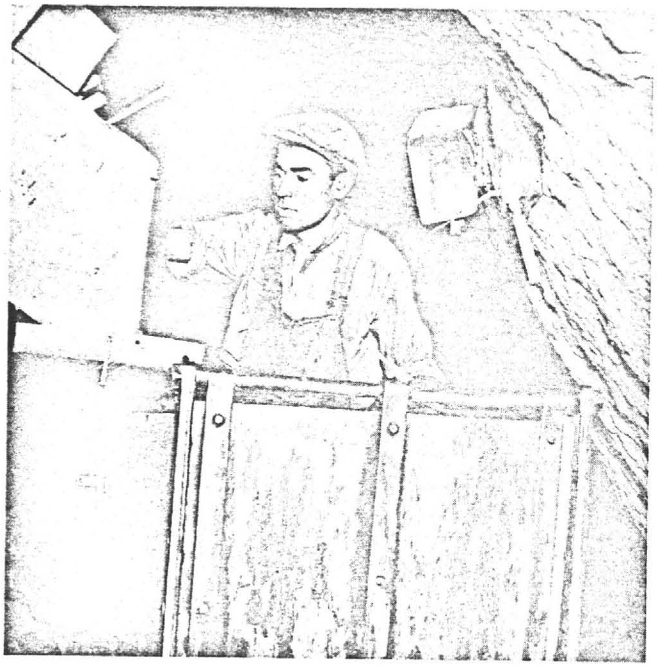
MINES OF THE CALICO DISTRICT

1. Alabama
2. Argentum
3. Backdoor No. 1 prospect
4. Baltic
5. Bismarck
6. Blackfoot
7. Burcham (Total Wreck) (Gold-lead)
8. Burning Moscow
9. Carbonate group
10. Cisco
11. Cuba (location undetermined)
12. Dietzman
13. Gale Group
14. Galena King
15. Garfield
16. Grandview
17. Grant
18. Humbug
19. Falls
20. Le Montain (Sliver-lead-barite)
21. Lamar
22. Langtry
23. Lead Mt. (Silver-barite)
24. Leviathan
25. Lone Star group
26. Mulcahy group
27. Occidental
28. Odessa
29. Old Oriental
30. Oriental
31. Possibility group
32. Red Cloud
33. Revier
34. Runover
35. St. Louis Consolidated
36. Silver Bow (Silver-lead-barite)
37. Silver Tip (Silver-lead-barite)
38. Silver King
39. Silverado
40. Sioux
41. Snowbird
42. Thunderer
43. Union (Gold)
44. Voca (Washington)
45. Waterloo
46. Waterman
47. Zenda



MINES OF CALICO DISTRICT AND VICINITY, SAN BERNARDINO COUNTY, CALIFORNIA

Base principally from Barstow and Daggett 15-minute quadrangles, U.S. Geological Survey; mine and mill localities based on field work, 1964-1965.



By the light of a candle and metal reflector, a Calico miner fills an ore car from a chute. Unidentified mine and date. O. A. *Russell Collection.*

As an example of how mining developed, the Garfield mine is reported to have been worked from December 1882 until April 1883 by only 2 men, who shipped 11 tons of selected, high grade ore which yielded $5,885 in silver; but from November 1883 to January 1, 1885, 2,400 tons of ore was shipped from the mine, which yielded $290,400 in silver (and a "large amount" of "unassorted" ore was worked locally at Barber's mill). By January 1883, the Waterman mine had yielded 9,000 tons of ore which yielded $39.30 per ton, with the resultant tailings yielding about $10 per ton (making a total of about $440,000); and during 1883, the Silver King mine was reported to have yielded about $426,000 in silver.

Smaller properties often were worked by so-called "chloriding" methods, whereby lessees operated mines individually or in small groups, paying one-quarter to one-fifth of the mill proceeds to the owners. This procedure was very inefficient, and hindered or prevented maximum possible development of the mines. For most such lessees cared only to mine expediently the richest possible ore, which was commonly composed of thin stringers and veinlets of silver chloride and associated minerals. Compounding the problem were the expensive charges to miners for hauling and milling: the charge for hauling from Calico mines to mills along the Mojave River was $2.50 per ton; and the charge for custom-milling was $11 to $14 per ton, even though the actual milling cost was only $3 to $5.

Productivity in the district reached its peak during 1884–1885, when perhaps as many as 2,500 people lived in the district. By this time, the Silver King mine had been purchased by the Oro Grande Mining Company, owned principally by C. M. Sanger of Milwaukee. (Ultimately the Oro Grande Mining Company also was to gain control of the Waterloo mine, after settlement of a law suit.)

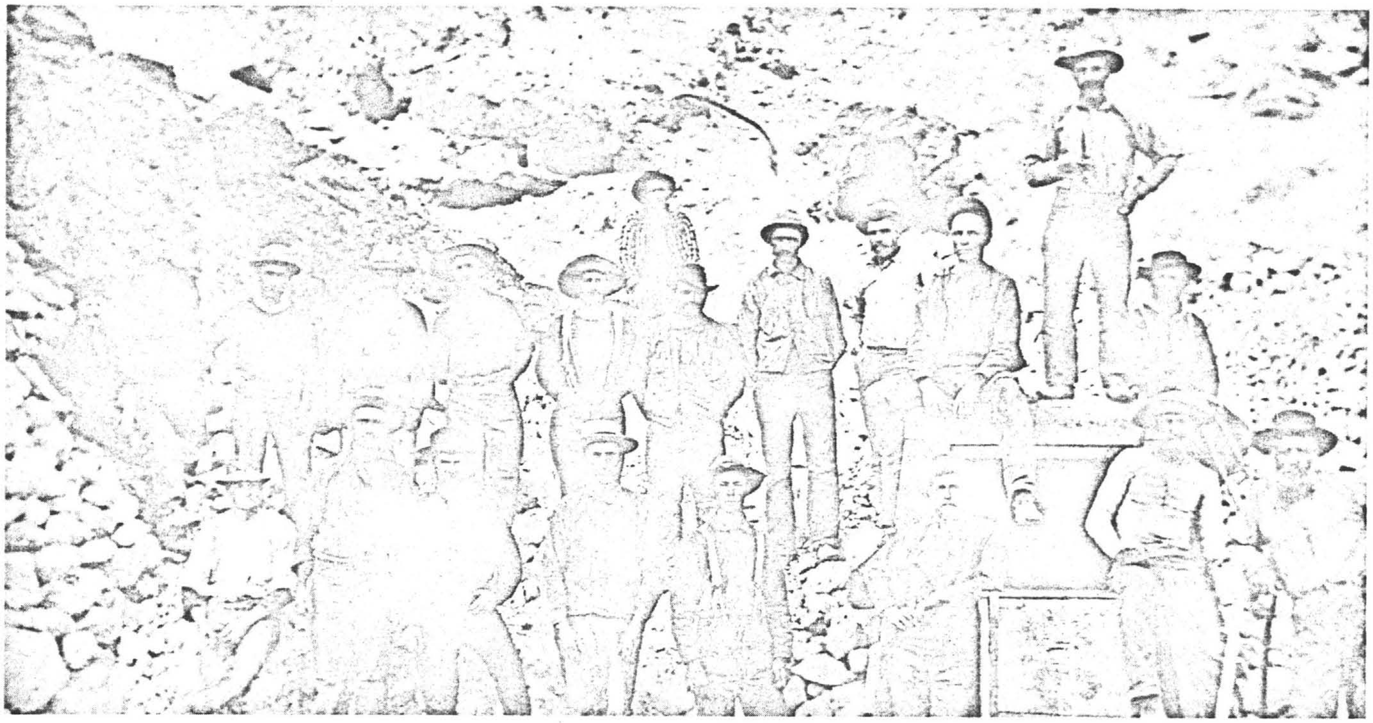
At the beginning of 1884 the Silver King mine had been worked to a depth of 500 feet, and was reported to "still show well at the bottom." From January 1884 to March 1885, the mine yielded about $1 million worth of silver bullion, with the company mill at Daggett reportedly averaging $40,000 to $50,000 per month. Each ton of ore was reported to yield about $30 to $45 in silver (at about $1.11 to $1.06 per ounce), and to cost about $18 total to mine, haul, and mill. Miners were paid about $3.50 per day.

The Sue mine,* northwest of the Silver King, also was prominent; and Barber's mill, just south of Calico, was operating. In East Calico, 10 tons of ore mined daily at the Bismarck mine yielded $100 per ton; and ore from the Cuba mine was processed at Hawley's mill. The Snowbird mine also was active, and the main adit of the Garfield mine had reached a length of 1,000 feet. In West Calico, the Waterloo mine was worked extensively underground, though it is said mostly for rich pockets.

Activity in the district began to decrease after 1884–1885, as the price of silver began to fluctuate downward more sharply from about $1.10 in 1884 to 93

Molten silver is being poured from a melting pot into a bullion mold by J. Bert Osborne, 1924. Silver probably was recovered from ore taken from the Sioux mine, which was worked by Osborne at that time. O. A. *Russell Collection.*

* Probably same as mine later spelled "Sioux".



Early day miners at Occidental mine. Gopher-like workings, typical of most of East Calico, are in background. O. A. Russell Collection.

cents by 1889; in addition, once the richer deposits near the surface had been mined, operators were forced to mine deeper, leaner ore, which cost more to mine, as well as providing less revenue. Thus the Waterman mine ceased operations in 1886; and activity in the region probably became very light by the end of 1888, although the Oro Grande Company accelerated its operations (constructing a new 60-stamp mill in 1888). An event of note was the visit to the district in December 1886 of Waldemar Lindgren, a young mining engineer and geologist, later to become perhaps the most eminent in his field.

Two events then served to stimulate mining in the Calico district briefly: the first, late in 1888, was construction by the Waterloo Mining Company (successor to the Oro Grande Company) of a small railroad which extended from the Silver King and Waterloo mines to the company milling facilities at Daggett. This railroad reduced the cost of ore haul from about $2.50 to 12 cents per ton. The second event was passage of two Congressional Acts: the Bland-Allison Act and the Sherman Purchase Act of 1890, which enabled the Government to purchase silver for monetary use. The consequent administration of these laws drove the price of silver upward significantly, even though the Acts were soon defeated by their opponents (as was William Jennings Bryan, the famous proponent of "16 to 1" bimetallism.) Thus, during the period from 1889 to 1892, mining was revived: in September 1889 about 100 tons of ore from the Silver King mine and 50 tons from the Waterloo mine were reported being mined daily; in addition, it was reported that in December 1891 the Garfield mill was taking ore from the Odessa, Oriental, and Occidental groups. At one point during the period, it was reported that 700 men were employed in the district, 150 stamps were operating in mills, and about $200,000 per month in bullion was being produced.

Soon, though, the price of silver dropped again, from about $1.05 in 1890 to about 64 cents by 1894. The Waterloo was forced to close down in March 1892, with 130 men losing their jobs. In 1896 the Silver King Company apparently ceased hoping that the price would somehow rise again, for it shut down operations at its Occidental and Oriental groups. The Odessa mine also was closed.

The district remained nearly dormant from about 1900 to 1915, when the price of silver again began to rise. From a low of about 48 cents in 1915, the price rose briefly to about $1.38 late in 1919, before it began to decrease. The rise was caused principally by industrial demand and international monetary needs (resulting in the Pittman Act) caused by World War I. With this rise in price, the district became very active again, but the activity was not reflected in significant production of silver.

The period from 1915 to the mid-1920's did contain several relatively important events though: The Calico-Odessa Company was organized in 1915 by J. R. Lane, and subsequently explored and mined on a small scale in a wide area east of Wall Street Canyon; the Daggett Reduction Company and others treated some of the old mill tailings by cyanidation; and some ore mined in the district was sent to smelters.

In 1926 the total output of the district was reported as 157 tons of ore, which yielded 35 ounces of gold, 582 ounces of silver, 115 pounds of copper, and 190 pounds of lead. Also in 1926, the Zenda Company acquired the assets of the Waterloo Mining Company, and began an exploration and development program on the Silver King property, though the price of silver had dropped to about 62 cents. The company core-drilled 2 holes, and subsequently sank 2 shafts, of 550 and 350 feet, to explore deeper parts of veins whose upper parts formerly had been so productive. A 50-ton shipment of ore from these workings to a smelter in 1930 is said to have averaged 67 ounces of silver and no gold per ton. But the price of silver continued to fall (to about 32 cents by late 1930), and operations ceased in November 1930, when 47 men were laid off.

From that time until the present (early 1966) the only metal mining operations in any of the Calico mines have been very small and intermittent. Mill tailings, discarded after treatment of earlier mined Calico ores, continued to be processed by cyanidation through the 1930's, even though recovery apparently averaged only about 1 ounce to 2 ounces of silver per ton (with the range of recovery about 1 ounce to 9 ounces per ton). These tailings could be processed economically by cyanidation mainly because less efficient processing methods had been used at Calico dur-

View west-northwest in 1951 shows old workings of Odessa silver mine, on west side of Odessa Canyon, East Calico, mined principally from 1882 to 1896. Rugged topography is cut in andesite. Ubiquitous, gopher-like workings resulted from expedient mining of near-surface, "bonanza" deposits. *Photo by O. A. Russell, Yermo.*

ing the early mining years (cyanidation was developed in the late 1880's, and not used in California until 1891). Through the 1930's and 1940's small mining operations continued at such mines as the Sioux (by J. B. Osborne), the Waterloo (by Morris Mulcahy), the Burcham (Gold-Lead, also by Mulcahy), and the Zenda (by Lawrence Coke).

During the 1950's ore mined from several properties was processed for recovery of silver, lead and barite: such operations took place at the Le Montain and Silverado mines (by R. C. Buch and associates) and at the Silver Bow mine (by W. S. Hubbard). From 1957 to 1961, Oil Base, Inc. mined and processed relatively large tonnages of low grade barite ore at the Leviathan silver mine. Barite recovered in the district has been used as a weighting material in oil well drilling fluids. During 1964–65, the Alexander-Wattell mill was constructed near Barstow for recovery principally of silver and gold.

Perhaps because there have been no large, significant silver mining operations in the Calico district since the 1890's, and no mining operations at all from 1962 to 1965, the Calico district might be considered to have very little or no potential as a future source of silver. A pamphlet, issued in August 1965 by the United States Bureau of Land Management, which describes the recently established "Calico resource conservation area," states that

> "The Calico Mountain area, once rich in silver, which spawned the brawling, lusty mining town of Calico, now a County recreation facility, is still an attraction to campers, hikers, and rock hounds."

Such a statement sounds almost like an epitaph for mining.

Actually, as the year of 1966 began, chances for renewed and significant silver mining in the Calico district seemed better than at any time since the 1890's, when the larger early day operations were closed down. These chances were in the form of very significant interest shown in the district by the mining industry since about 1963. This interest stemmed from an increase in the price of silver from about 91 cents an ounce in November 1961 to $1.293 per ounce in June 1963. (In November 1961 the U.S. Treasury stopped sales of its silver at the price of 91 cents, and the free market price gradually rose to $1.293 per ounce, the United States monetary value of silver). Because of the higher price, and the possibility for an even higher price accompanying anticipated increased United States and world industrial and monetary demand, interest in older districts with significant silver production, such as Calico, became very logical.

Especially of interest to large mining companies in the Calico and other districts are very large, very low grade deposits, measured in tens and possibly many scores of millions of tons of potential ore, and scores and possibly a hundred million ounces or more of silver. Such deposits can be mined by simple, low cost

Red Cloud mine, part of Oriental group. Early day work in west end of Mammoth stope, which was reported to be 60 feet wide. Highest of four miners seems to be carefully working part of steeply dipping vein that consists of highgrade ore. Middle of three lower miners may have handcobbed and sorted ore before carrying it from stope in wheelbarrow. O. A. *Russell Collection.*

methods (such as open pit), taking advantage of modern techniques and equipment (such as giant earth-moving equipment); and the ores processed with the most modern of metallurgical techniques: with barite, lead, copper, or gold also recovered as byproducts.

Indeed, the Calico district still remains an "attraction" to the mining industry, as well as "campers, hikers, and rock hounds". If the district could speak out, it might use Mark Twain's famous words:

"The reports of my death are greatly exaggerated."

A list of references will accompany the last article on the subject of Calico, to be published in a future issue of this magazine.

CALICO

— Highlights of its history —

1881: April 6, claims are located for future Silver King mine.

1882: Spring; mining is underway; about 100 people live in Calico camp. Fall, mining gathers momentum, as smaller properties consolidated, and the part of Atlantic and Pacific Railroad nearby is completed. Price of silver, about $1.14 per ounce.

1883: At beginning of year, active mines include Silver King, Oriental, Burning Moscow, Garfield, Odessa, Bismarck, Blackfoot and others; also Waterman mine, to west.

1884–1885: Productivity is at peak, with perhaps 2,500 people living in district. Beginning of 1884, Silver King mine is developed to a depth of 500 feet; January 1884 to March 1885, Silver King yields $1 million in bullion. Price of silver about $1.09.

1886–1889: Productivity decreases, as price of silver drops to 93 cents by 1889. In addition, deeper, more expensive mining is mostly in leaner ore. Many mines are shut down.

1889–1892: Mining stimulated briefly by (1) short-lived Congressional Acts which briefly raise silver price to $1.05 in 1890, and (2) completion of narrow gauge railroad from Waterloo and Silver King mines to mill at Daggett.

1892–1896: In 1892, Waterloo mine is closed; by 1896 most other mines are inactive.

1915–1919: Activity in district is stimulated as price of silver rises from 48 cents in 1915 to $1.38 in 1919, before beginning to fall. But the activity is not accompanied by important production of silver.

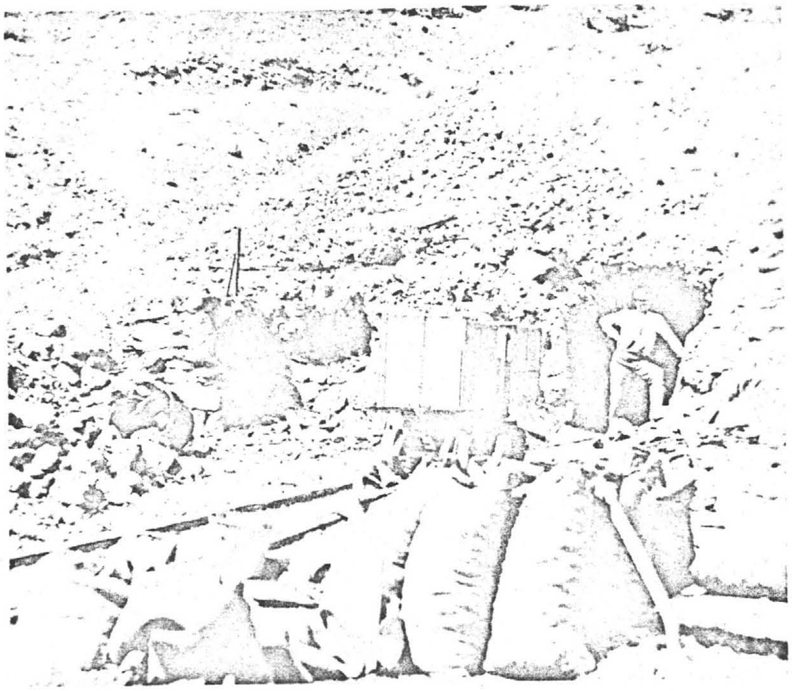
1926–1930: Zenda Company begins deep exploration program at Silver King mine in 1926 when price of silver is 62 cents an ounce. Program ceases in late 1930, as price falls to about 32 cents.

1930–1950: Small and intermittent mining operations for recovery of silver, as well as gold, lead and copper, take place. In addition, old mill tailings are processed for silver.

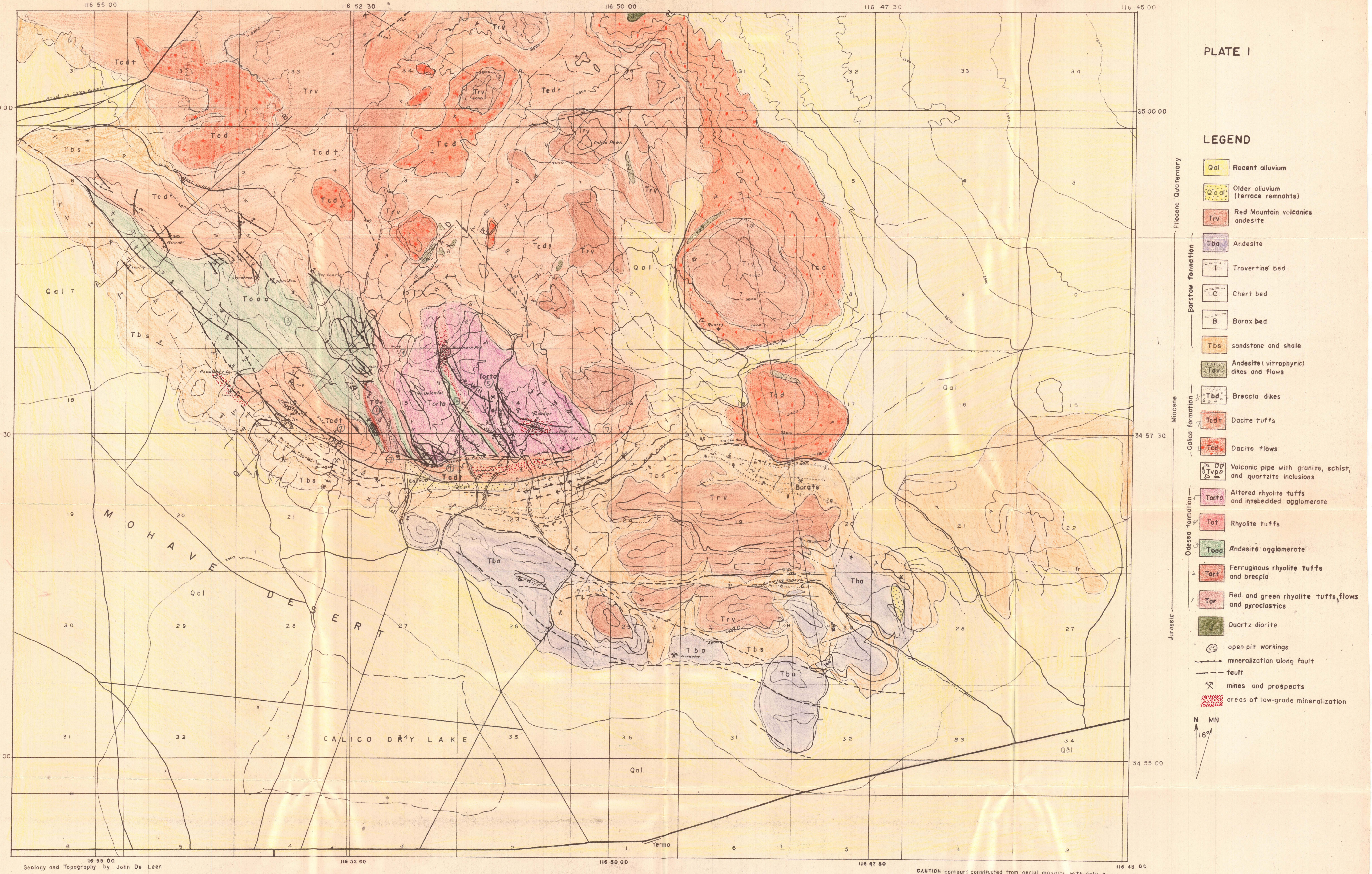
1957–1961: Oil Base, Inc. recovers barite from barite-jasper vein material.

1963–1966: As price of silver rises to $1.29 per ounce, interest in district is greatly accelerated. Ironically, as "ghost" town tourist operation grows, chances also grow for important future silver mining operations.

Total production of silver: Estimated roughly at between $13 and $20 million; mined mostly between 1882 and 1896.



Portal of unidentified mine, showing sacks of handcobbed, presumably highgrade ore ready for shipment to mill. O. A. *Russell Collection.*



GEOLOGIC MAP OF THE
CALICO MINING DISTRICT
SAN BERNARDINO CO., CALIFORNIA

Scale $\frac{1}{24000}$

0 — 2 Miles

Contour Interval 200 Feet

CAUTION contours constructed from aerial mosaics with only a minimum amount of vertical control—contours should be regarded as form lines