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QUICKSILVER DEPOSITS IN SAN LUIS OBISPO COUNTY AND SOUTHWESTERN MONTEREY COUNTY CALIFORNIA

BY

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By E. B. Eckel, R. G. Yates, and A. E. Granger

ABSTRACT

Most of the deposits here described lie within an elongate area of about 75 square miles in northwestern San Luis Obispo County. Other deposits, most of them small, are scattered southeastward from southwestern Monterey County to the southern border of San Luis Obispo County. Quicksilver was first discovered in the region in 1862. Though mining since then has been intermittent, the output has been relatively large during or immediately after the periods of high quicksilver prices. Monterey County has produced very little quicksilver, but San Luis Obispo County, which ranks sixth among the quicksilver-producing counties of the State, produced 69,264 flasks between 1876 and the end of 1939, 70 percent of which came from the Oceanic and Klau mines.

All but one of the known quicksilver deposits are in or closely associated with the Franciscan formation, of Jurassic (?) age. This formation, embodying the oldest and most widely distributed group of rocks in the mapped areas, consists mainly of highly contorted and metamorphosed shale, sandstone, and con glomerate and is overlain by Cretaceous and Tertiary sediments. Extrusive and intrusive igneous rocks, most of them basic in composition, were formed at several periods after the Francisca formation was deposited. Many of the intrusive bodies are now represented by serpentine.

This part of the Coast Range province is characterized by numerous strong, complex, northwestward-trending fault zones, many of which have been intermittently active since late Jurassic time. Bodies of silica-carbonate rock ("quicksilver rock"), composed of dense quartz and mixed carbonates, were formed in many places by solutions that rose along the major faults and replaced the country rocks. Most of the igneous rocks also are closely associated with these faults.

The quicksilver deposits comprise not only irregular and discontinuous cinnabar-bearing veins but also rock masses that contain disseminated cinnabar. All are within or very near northwest-trending fault zones, and nearly all are intimately associated with silica-carbonate rock. Most of the ore shoots are small and irregular, though a few are several hundred feet in length and height and as much as 40 feet wide. The shoots are structurally controlled by local gouge zones or by changes in dip or strike of the enclosing vein matter. The quicksilver content of the ore has a wide range, but most of the ore mined in the past has probably contained 5 to 10 pounds of quicksilve to the ton.

Proved reserves of ore are very small at any given time, but some of the productive shoots in known mines have very likely not been exhausted, and further exploration will probably uncover new shoots in known mines or elsewhere. The geologic history and relations indicate that the total future production may equal if not exceed the past production of nearly 70,000 flasks and that, with stable and profitable prices, an annual production of 1,000 to 3,000 flasks may well be attained.

INTRODUCTION

The quicksilver deposits described herein occupy parts of the Santa Lucia Range, of the California Coast Ranges, about midway between San Francisco and Los Angeles (see fig. 74). Most of the deposits lie within an area 16 miles long by 4 to 8 miles wide in northwestern San Luis Obispo County (see pl. 78). Other deposits, all but one of which--the Rinconada--are relatively unproductive, extend southeastward from the extreme southwest corner of Monterey County nearly to the southern boundary of San Luis Obispo County (see fig. 74). The Parkfield district, in southeastern Monterey County, was not visited and is not described here.

The principal shipping points, Paso Robles and San Luis Obispo, on the Southern Pacific Railroad, are 15 to 40 miles from most of the mines; several smaller towns and many ranches are distributed throughout the two counties. Nearly all the mines are directly accessible to motor transportation by means of paved highways or good secondary roads, though a few are served only by trails. Roads can be built easily and cheaply in most places; in fact, many of the "trails" shown on the accompanying maps are overgrown wagon roads that could be reconditioned at little expense. The clayey nature of the soil and its general tendency to form landslides render travel on many of the secondary roads difficult if not impossible during the rainy winter months.

This part of the Coast Ranges consists of a chain of moderately rugged mountains 2,000 to 3,500 feet high, which

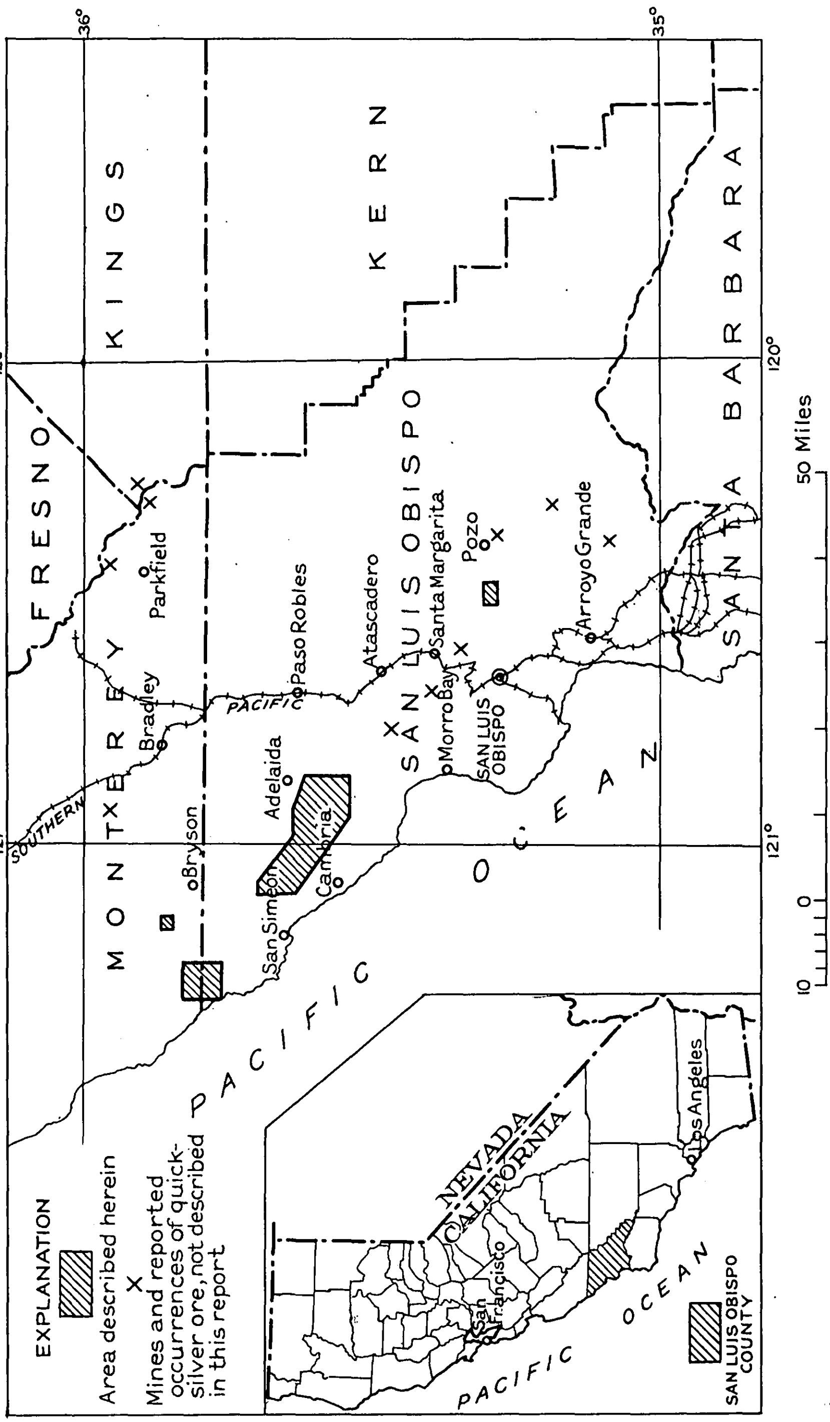

Figure 74.—Index map of San Luis Obispo and southern Monterey Counties, Calif.

closely parallel the northwest-trending coast line. The eastern part of the range is drained largely by the Salinas River and its tributaries, the western part by many streams of steep gradient that flow directly to the Pacific. The character of the rocks, together with the humid climate, has resulted in moderately deep weathering; the soil cover is therefore comparatively thick, and rock outcrops are scarce. Landsliding constitutes one of the major processes of erosion, and numerous landslide masses in various stages of development and of widely differing size occur throughout the mountains. A few comparatively large areas are grass-covered grazing land or tilled fields. The greater part of the mountainous area, however, is heavily timbered, principally with live oak and several species of pine, or is covered with brush. Much of this brush is virtually impenetrable, particularly that on north- or east-facing slopes. Manzanita, madroña, and several species of sage are the most abundant. Plentiful supplies of round mine timbers and of oak or pine for retort fuel are available locally, but all sawed lumber is now imported.

Field work was continued from mid-October 1939 through May 1940. Though E. B. Eckel was in nominal charge, responsibility for the field work and for the conclusions expressed in this report are shared equally by all three writers. Partly because of the urgent nature of the strategic-minerals program, with its limitations on time and expense, and partly because the general geology of the region had already been studied and mapped in considerable detail by another worker,[1/] field work was confined to the immediate objective of the project--study of the quicksilver deposits and of the rocks that contain them.

1/ Taliaferro, N. L., Geology of San Simeon, Adelaida, and Paso Robles quadrangles [abstract]: Pan-Am. Geologist, vol. 63, no. 4, p. 316, May 1935; Geol. Soc. America Proc., 1935, p. 338, 1936. Also unpublished maps and reports.

This report was hastily prepared in the field, without benefit of laboratory or library facilities, but its authors hope that the conclusions herein stated will not be materially altered by further office work.

All the areas studied are shown on topographic maps published by the Geological Survey on a scale of 1:62,500, or about 1 inch to 1 mile. Photographic enlargements of the maps of the San Simeon and Adelaida quadrangles, which include the principal productive area (pl. 78), and of part of the Pozo quadrangle near the Rinconada mine (pl. 85) were used for field mapping. Some of the mine maps were furnished by operators; others were made by the present party, as were several plane-table maps of small surface areas.

The mining men and other local residents with whom the writers came in contact were almost uniformly courteous and helpful. In particular, thanks are due to the following people: B. A. Gould and Fred Bachich, of the Klau mine; H. G. Tripp and O. E. Hanno, of La Libertad, Keystone, and Pine Mountain mines; Roy Wyatt, of the Mahoney; E. L. Bruce, of the Oceanic; O. G. McDonald, consulting geologist for the Hearst properties; Mrs. Theresa Bell, of the Rinconada; and C. C. Thompson, -- Swain, and Walter Warren. O. P. Jenkins, State geologist, was very helpful, as was Professor N. L. Taliaferro, of the University of California, who contributed materially from his intimate knowledge of the local geology.

HISTORY AND PRODUCTION

Quicksilver mining in this district began in 1862, when the Little Bonanza deposit was discovered. Prospectors were active during the next 15 years; within that period most of the now known deposits, including the two largest producers--the Oceanic and Klau--were discovered and opened, and many mines are reported to have been active and to have produced some quicksilver. There are no detailed records, however, for years prior to 1876. Since that time mining activity has been sporadic, with periods of relatively large output from 1876 to 1879, 1902 to 1907, 1913 to 1920, and 1929 to 1938. Most of the periods of large output doubtless in part reflect the discovery of new mines, but in far greater part they reflect periods of high quicksilver prices. In October 1939 only four mines were in operation, but, in response to the great increase in price occasioned by the war, interest quickened during the winter, and more than a dozen deposits were being mined or actively prospected by June 1940. This general history indicates clearly that most of the deposits are submarginal and can be profitably worked only when prices are high.

Since 1850 California has produced 2,400,000 flasks of quicksilver, worth $117,000,000. San Luis Obispo County, which ranks sixth among the quicksilver-producing counties of the State, produced 69,264 flasks between 1876 and the end of 1939, 70 percent of which came from the Oceanic and Klau mines. The production for each year is shown in the accompanying table. Production from the few mines in southwestern Monterey County has been negligible.

Recorded quicksilver production from San Luis Obispo County, 1876-1939 1/

Year	Flasks 2/	Value	Year	Flasks 2/	Value
1876.......	6,428	$282,832	1914.......	1,266	$62,097
1877.......	3,310	123,463	1915.......	1,473	125,542
1878.......	2,151	70,768	1916.......	1,227	114,724
1879.......	779	2,358	1917.......	1,565	151,034
1880.......	.....	....	1918.......	1,580	158,000
1894.......	.....	....	1919.......	1,286	110,596
1895.......	20	800	1920.......	1,224	89,186
1896.......	101	3,400	1924.......	20	1,860
1897.......	101	3,939	1925.......	2	173
1898.......	384	11,660	1927.......	470	53,600
1899.......	394	17,700	1928.......	435	48,254
1900.......	515	23,886	1929.......	1,076	120,995
1901.......	840	41,513	1930.......	1,306	157,440
1902.......	3,312	147,215	1931.......	2,574	202,870
1903.......	4,577	183,530	1932.......	2,035	106,508
1904.......	4,746	176,616	1933.......	285	15,759
1905.......	3,733	133,748	1934.......	1,302	91,677
1906.......	3,511	128,152	1935.......	2,474	167,613
1907.......	2,509	95,743	1936.......	2,588	196,786
1908.......	867	36,648	1937.......	2,133	179,731
1909.......	317	15,510	1938.......	1,114	77,938
1910.......	563	25,476	1939.......	276	26,587
1911.......	569	26,180			
1912.......	666	27,998		69,264	3,884,772
1913.......	1,160	46,667			

1/ From records of the California State Mining Bureau. Production for 1862-75 not known. No production for years not listed.
2/ A flask contained 76½ pounds previous to June 1904, 75 pounds thence through 1927, and 76 pounds since January 1928.

GEOLOGY

The parts of San Luis Obispo and Monterey Counties described in this report lie entirely within the Coast Range physiographic province. As shown on the geologic map of California, 2/ this part of the province is characterized by many strong and complex fault zones, nearly all of which trend northwestward. Many of them have been intermittently active since late Jurassic time. The faulting and other associated mountain-building forces have pushed enormous blocks of older rocks high above their original positions, thus forming the core of the Santa Lucia Range.

2/ Jenkins, O. P., Geologic map of California: California Div. Mines, 1938.

Younger rocks, which at one time may have covered the entire area, have been stripped from this core by erosion and now flank both sides of the range or appear as residual masses on its surface. Thus, in a general way, the Franciscan formation, probably of Jurassic age, forms an elevated basement complex, upon the sides of which Cretaceous and Tertiary rocks lap unconformably.

The sedimentary rocks comprise sandstones, shales, and siltstones, with some limestones and conglomerates. The older rocks, through many orogenic movements, have been strongly folded, broken, and altered, whereas the younger rocks show progressively less alteration.

Both extrusive and intrusive igneous rocks, most of them of basic composition, were formed at several times during the Jurassic and Cretaceous periods. These and the acidic and basic rocks that were formed during Tertiary time were all closely associated with movements along the major faults. Some of the more recent movements in the area produced fractures that allowed the access of hydrothermal solutions, which altered some of the rocks to silica-carbonate rock and formed quicksilver deposits in many places.

The geology of the part of the area within San Luis Obispo County is shown on plate 78.

Sedimentary rocks

Franciscan formation

The Franciscan formation, of probable Jurassic age, is the oldest and most widely distributed group of rocks in the mapped areas (pls. 78 and 85), and all but one of the known quicksilver deposits are within or closely associated with this formation. It consists mainly of shale, sandstone, and conglomerate, which are interbedded with basaltic lavas and associated lenses of chert. The series is 10,000 feet or more thick, but the absence of fossils, the highly complex structure, and poor exposures combine to render subdivision impracticable, if not impossible. The Franciscan is unconformably overlain by Cretaceous and Tertiary sedimentary rocks and is intruded by several kinds of igneous rocks. Depositional and intrusive contacts can be seen in some places, but many of the contacts between this series and the later rocks are faults.

Shale seems to be the dominant rock within the areas studied, though it can seldom be seen except in recent stream or road cuts or in mine workings. In general it is a dark brown to black rock, the bedding of which, insofar as it ever was apparent, has been largely obliterated by crumpling and metamorphism; much of the rock, moreover, was originally massive mudstone or siltstone, in which lamination was ill-defined or entirely lacking. Franciscan shales can generally be distinguished from the Cretaceous and Tertiary shales by their lack of fossils, by their darker color and lack of lamination, and by the fact that they are commonly sheared and contorted.

The sandstone layers in the Franciscan are medium- to coarse-grained, contain abundant fragmental feldspar and relatively little quartz, and are massive, rarely showing any evidence of bedding. They range in color from greenish gray to buff or brown. They are commonly much fractured, and many of the fractures are filled with characteristic veinlets of quartz or clear calcite, which commonly serve to distinguish the sandstone of the Franciscan from that of the younger formations. Conglomerate composed of pebbles and boulders of igneous and metamorphic rocks forms many small, discontinuous lenses, which apparently occur at several horizons in the formation. Many of the pebbles have been fractured and recemented with quartz or calcite. The Franciscan conglomerates are best distinguished from those in the Cretaceous rocks by their total lack of Franciscan chert and volcanic rocks, of which some of the younger rocks contain an abundance.

Discontinuous lenses of varicolored, thin-banded chert with thin partings of shaly material are characteristic of the Franciscan formation. None of the lenses within the mapped areas is more than 500 feet long, and few are more than 50 feet long. These chert lenses are not distinguished on the geologic maps in this report. Many of the chert bodies are intricately folded, others are rather strongly brecciated, and many are closely associated with altered pillow basalts.

Locally certain rocks of the Franciscan are highly silicified. Small bodies of glaucophane schist thinly scattered throughout the area represent metamorphosed Franciscan sedimentary rocks.

The Franciscan formation weathers to form moderately gentle slopes that are broken by comparatively small jagged outcrops of chert, conglomerate, volcanic rocks, and sandstone (pl. 79), and the softer rocks are rarely exposed. Few of the slopes are steep. Soils developed from the Franciscan rocks have a strong tendency to slide, and many areas underlain by this formation are characterized by hummocky surfaces that have resulted from incipient or well-marked landslides.

Cretaceous rocks

Sedimentary rocks of Cretaceous age overlie the Franciscan formation in many parts of the mapped areas. Their total thickness is several thousand feet. They could be divided into several distinct stratigraphic units, but it was deemed sufficient for present purposes to group all of them into two lithologically distinct parts that correspond roughly to the upper and lower parts of the Cretaceous system. These rocks are known

TYPICAL VIEW OF TOPOGRAPHY AND VEGETATION ON FRANCISCAN ROCKS.

Prominent outcrop in foreground is chert.

SERPENTINE SHEET, PARTLY ALTERED TO SILICA-CARBONATE ROCK, NEAR KLAU MINE.

The sheet dips toward the right, parallel to ground surface. The brush-covered areas above and below the white cliff are underlain by silica-carbonate rock, which grades into slightly altered serpentine that forms the white cliff. Grass-covered foreground is underlain by Franciscan sandstone and shale.

to contain only one small quicksilver deposit, which is near Bryson. They possibly acted as traps for the rising solutions that deposited ore in other places.

The lower part of the Cretaceous, which consists largely of thin-laminated brown to gray-black shale, contains thin concretionary lenses of limy siltstone and silty limestone in places and locally prominent thin layers of sandstone, interbedded with the shale. The shales resemble those of the Franciscan formation, but they are less contorted and sheared and some of them contain fossils.

The upper part of the Cretaceous is characterized by sandstone, much of it in thick, massive beds, though it also contains some shale resembling that in the lower part. Most of the sandstone is medium- to coarse-grained and contains numerous grains of feldspar interspersed with the predominant grains of quartz. It is commonly gray on fresh surfaces but weathers yellowish brown, being similar in color to the buff and brown sandstones of the Franciscan but much softer and with characteristically spheroidal surfaces. Fossils are present but rare. Lenses of conglomerate occur in both parts of the Cretaceous but are more abundant in the sandy upper part. They contain rounded pebbles of serpentine and of chert and volcanic rocks derived from the Franciscan formation as well as of granite, porphyry, and quartzite from still older rocks. Many of the pebbles are highly polished, and few of them are fractured or recemented except along fault zones.

Tertiary rocks

Sedimentary rocks, most if not all of which are Miocene, rest unconformably on the older Cretaceous and the Franciscan rocks at several places in the mapped areas, and they cover large parts of San Luis Obispo and southern Monterey Counties

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outside those areas. As with the Cretaceous rocks, no attempt was made to subdivide this series into its component formations. The Oceanic mine exploits the only known deposit of quicksilver ore in the Tertiary rocks.

The shale, limestone, and sandstone, with a few layers of conglomerate, are listed in the order of abundance. Most of the layers are thin-bedded and comparatively soft, and many of them contain fossils or volcanic ash. Largely because of their relatively high content of bituminous and carbonaceous matter, the shales range from gray to black in fresh exposures, but they are commonly light gray to white on weathered surfaces. Many of them are highly siliceous, but others contain calcite and grade into fine-grained white to light-gray limestone, some of which consists of rather pure calcium carbonate. The sandstones are light buff to cream-tinted and fine- to coarse-grained. Most of the sandstone beds consist principally of quartz sand, but some of the coarser ones contain much feldspar.

In general, the Tertiary rocks are thinner-bedded and softer than the Cretaceous rocks but can be distinguished from them with certainty only by means of their contained fossils. The Franciscan formation can be distinguished from both the Cretaceous and the Tertiary rocks by its lack of fossils and its relatively intense deformation.

Igneous and metamorphic rocks

Volcanic rocks in the Franciscan formation

Numerous bodies of basaltic lava and related volcanic rocks are interlayered with the sedimentary rocks of the Franciscan formation. They are commonly dark green to dark brown, and all are so strongly altered that in places it is only with difficulty that they are distinguished from the more massive sandstones. Close examination, however, usually reveals an interlocking crystal texture that contrasts with the granular texture of the sandstone beds. Most of the bodies are roughly tabular in form and range in thickness from 5 feet to several hundred feet. None of those seen are more than 2,000 feet in greatest dimension, and most of them are much smaller. Only the largest ones are shown on plate 78. Many of these bodies are shown by their tabular shapes, by the occasional presence of amygdaloidal and pillow structures, and by other evidence to have been formed as flows on the land surface or on the sea floor; but others represent intrusive dikes or sheets. These rocks vary greatly in their resistance to erosion. The less altered and fractured bodies form some of the boldest outcrops in the area, whereas the more altered or fractured ones are rarely seen in place, being largely reduced to crumbly rubble.

Serpentine

Many bodies of igneous rock, several of which are closely associated with quicksilver deposits, were intruded into the Franciscan formation and the lowermost Cretaceous rocks during the Cretaceous period. These bodies originally consisted in large part of the ultrabasic rocks pyroxenite and peridotite, but these have been altered in varying degrees to minerals of the serpentine group--hydrous magnesian silicates--and the rocks themselves are commonly called serpentine. They are all mapped as such on plates 78 and 85. The least altered of the ultrabasic rocks are dark blue green on fresh surfaces but weather to dark red-brown hues. In general, they are porphyritic, with large crystals of pyroxene or silky-lustered pseudomorphs after pyroxene, set in a dull, fine-grained groundmass. Locally, particularly along fault zones, the original granular texture has been completely destroyed, and the rocks are light green, soapy in feel and appearance, and strongly sheared. Narrow veinlets and networks of asbestos characterize some of the serpentine, and pods and lenses of chromite are occasionally present. Dark-gray fine-grained dioritic rock is apparently associated with some bodies of serpentine, but none was found in place. The serpentine is moderately resistant to erosion and forms the tops of many hills (see pl. 80).

The two serpentine bodies differ greatly in size. The largest, that on Red Mountain, in the western part of the area shown on plate 78, is a mile wide and more than 3 miles long. Several of the others shown on plates 78 and 85 are nearly as large, but many cover areas of only a few square rods; few of these small ones are shown on the geologic maps. In general, the bodies are relatively long in one direction and short in the other two. It seems probable that most of them were intruded as sills or sheets between the beds of the sedimentary rock, but they doubtless cut across the beds, like dikes, in many places.

Rhyolite

Several irregular bodies of rhyolite crop out within the area shown on plate 78, where they are rather close to many of the quicksilver deposits. Many other bodies of rhyolite or closely related rocks are known elsewhere in San Luis Obispo County, but none are known to occur near any of the other mining districts. The rhyolite ranges in color from chalk white to brownish gray and in texture from dense to porphyritic. The porphyritic varieties display large well-formed crystals of unaltered feldspar and rounded crystals in a dense matrix. The rock is resistant to erosion and forms very rugged topographic features. Individual bodies vary greatly in size and shape. The largest one, which forms the backbone of Pine Mountain, is almost continuously exposed for a distance of more than 5 miles and is locally more than a mile wide. Most of the others are comparatively small. Irregular, branching dikes, which swell out locally to form irregular plugs or small stocks, predominate, but a few bodies are sill-like. Nearly all the rhyolite is clearly of intrusive origin, but large gas cavities seen in a few places on Pine Mountain suggest that some of the rhyolite magma reached the surface or at least approached it closely. The small mass of rhyolite southeast of Cypress Mountain (pl. 78, section B-B') shows well-defined lamellar structure that parallels the present surface, which, with other evidence, suggests that this body, as well as some of the bodies on the southwestern slopes of Pine Mountain, is a surface flow in part, though it may be an intrusive sill. The rhyolite intrudes the Tertiary rocks as well as the older formations, and all the evidence indicates that it is relatively young, though there are no means of dating it exactly within the areas examined. Most of the bodies lie within or close to major fault zones, which they fill completely in some places. Since the few visible contacts between rhyolite and older rocks or fault breccia are nearly all intrusive, it follows that the rhyolite was emplaced after deposition of the Miocene Tertiary rocks and after the major movements along the faults.

Diabase

Several comparatively small bodies of dark-gray fine- to medium-grained diabase, most of them having the form of irregular sills, intrude the Tertiary sedimentary rocks in the southwestern part of the area shown on plate 78, particularly along the fault zone that separates the Tertiary from the Franciscan rocks. One body is said to be present in the Oceanic mine. All are small and poorly exposed, and as they have no apparent relation to the ore deposits they are not shown separately on plate 78.

Glaucophane schist

Small discontinuous masses of blue-gray glaucophane schist are present in some localities. Few of those seen were in place, but they are closely associated with bodies of serpentine and appear to represent Franciscan sedimentary rocks that were metamorphosed by the intrusive ultrabasic rocks. They have no known bearing on the ore deposits.

Silica-carbonate rock

Bodies of rock made up essentially of quartz and carbonate are widely distributed throughout the Franciscan formation. (Pls. 78 and 85.) This rock is known locally as "quicksilver rock" because it is closely associated with most of the quicksilver deposits. Its recognition is of the utmost importance in further search for ore.

The rock will here be called silica-carbonate rock, for it consists mainly of chalcedony, quartz, and granular carbonate in intimate intergrowth, but it locally contains residual specks, crystals, and irregular masses of chromite. The carbonate has not been examined in the laboratory, but it is probably an isomorphous mixture of carbonates in which calcium, magnesium, and iron predominate, and it may tentatively be called ankerite. The proportion of carbonate to quartz ranges between wide limits, but the rock is generally more siliceous near ore deposits than elsewhere. There is evidence that the carbonate was deposited before most of the quartz, which replaced the carbonate in varying degree.

Weathered silica-carbonate rock forms prominent and distinctive outcrops (pl. 80), buff to brown or tan in color and highly porous to cellular in texture. It closely resembles some spring deposits but has a very different origin. The porous texture is due to solution and removal of the carbonate, which has left residual boxworks of quartz. Most of the brown color is caused by oxidation of iron in the carbonate to ocherous limonite, though some of that near the mines is probably derived from disseminated pyrite.

As can be seen on plates 78 and 85, nearly all of the silica-carbonate bodies are within or close to major fault zones; others are associated with outcrops of serpentine. This rock constitutes the chief gangue or country rock of nearly all the quicksilver deposits. Even where, as in the Klau and Mahoney mines, it is not directly associated with the ores, extensive bodies of it are commonly present. The bodies exhibit a wide range in size and shape, but most of them are elongate and all are small as compared with any of the other rock units shown on the maps.

There is much evidence that silica-carbonate rock has been derived from serpentine, from various types of Franciscan rocks and from fault breccia by hydrothermal alteration. Serpentine is by far the most susceptible to replacement, and most of the large silica-carbonate bodies are clearly derived from that rock. All the rocks that make up the Franciscan--sandstone, volcanic lava, and shale--have been converted to silica-carbonate rock in places. Shale was definitely the least replaceable; many bodies of silica-carbonate rock are bounded by masses of shale, or of shaly gouge, and some locally enclose abundant unreplaced shale fragments.

The evidence gathered in this study indicates that all the silica-carbonate rock was formed during a single wave of mineralization, probably not long before the introduction of the quicksilver ores. Variations in composition and texture reflect variations in character and extent of replacement of the original rocks. In part too, they depend on the extent to which the earlier-formed carbonate was replaced by later silica.

It is possible, however, that the silica-carbonate rock is the result of two distinct stages of alteration, similar to those in Lake County, Calif., described by Ross;[3] that is, the ultrabasic rocks may have been altered to silica-carbonate rock as a closing phase of serpentinization. After the silica-carbonate rock was formed, but before the mercury-bearing solutions came in, it may have been further altered and silicified by other solutions, which may also have formed other similar bodies in the fault zones.

Structure

General character

The geologic structure of the area is exceedingly complex; but because of poor exposures, lack of marker beds within the Franciscan, and other factors only the larger structural features could be delineated. Detailed mapping of a larger area, with differentiation of the stratigraphic units in the later rocks, would doubtless have yielded a more complete and accurate picture of the structure within the area that was mapped.

The Franciscan rocks are everywhere intricately folded and faulted. The structure of the Cretaceous rocks is considerably less complex, and that of the Tertiary rocks even less so; northeasterly dips prevail in both. Most of the structural features are alined in a northwesterly direction. A northwest-trending series of strong fault zones dominates the structural pattern in the mapped areas. The faults are more numerous, more strongly developed, and far more important economically within the Franciscan formation than elsewhere. Many faults affect only the Franciscan rocks and pass beneath essentially unbroken

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3/ Ross, C. P., Quicksilver deposits of the Mount Diablo district, Contra Costa County, Calif.: U. S. Geol. Survey Bull. 922-B, pp. 37-38, 1940; Quicksilver deposits of the Mayacmas and Sulphur Bank districts, Calif.: U. S. Geol. Survey Bull. 922-L, pp. 332-333, 1940.

Cretaceous and Tertiary beds. Others continue through part or all of the Cretaceous but not into the Tertiary, and still others affect all the sedimentary rocks in the area. It seems probable that the fault pattern was developed shortly after the end of the Jurassic period and that all the faults affecting younger rocks have been intermittently active ever since.

Faults

The following description is confined essentially to faults within the Franciscan rocks, because only two of the faults that affect later rocks are known to be associated with ore deposits. One of these exceptions is at the Rinconada mine, where the ore deposits occur in Franciscan rocks and serpentine that have been thrust over late Cretaceous and Tertiary rocks by a low-angle thrust fault (see pl. 85). The second exception is the fault that marks the contact between Franciscan and Tertiary rocks along the southwestern edge of the area shown on plate 78. Along this fault, on which the Oceanic and Cambria mines are located, the Tertiary beds are but slightly brecciated except locally, whereas the Franciscan rocks are strongly sheared and brecciated.

Fault zones within the Franciscan formation are marked by zones of sheared and brecciated rock that range from a few feet to several hundred feet in width. The stronger zones are many miles long, although most individual faults split or die out within shorter distances (pl. 78). The courses of the faults across the hills and valleys and the attitudes of shear planes within the fault zones show that most of the faults are steep, with dips ranging from 60° to vertical. The dips of some of them swing through the vertical, being in one direction at some places and in the opposite direction elsewhere. The major fault at the Rinconada mine is the only low-angle fault seen during this study, but several others are said to be present in the region.

In a broad way, the lineation of individual shear planes and of breccia fragments is northwesterly, or parallel to the strike of the enclosing zones. In detail, however, there is no definite orientation, for shale and gouge are invariably contorted and wrapped around blocks and fragments of harder rock. (See pl. 84.) All the Franciscan rock types, as well as the somewhat younger serpentine, have been involved in the faulting, and all have reacted differently to deforming forces. The stronger rocks, such as chert, massive sandstone, and basaltic lava, are strongly fractured, but in general they form subangular to lenticular blocks of greatly variable size. Most of the main fault splits shown on plate 78 are caused by large blocks of hard rock, around which the faults have bent. Serpentine, as well as much of the silica-carbonate rock derived from it, commonly takes the form of long curved and twisted fingers that wrap around other rocks in the breccia. The brittle silica-carbonate rock must obviously have been formed after the major deformation; otherwise such long narrow bodies could not have survived. Shale, the most plastic of all the rocks, acted as a sort of mortar in the fault zones. It was sufficiently plastic to flow around the harder blocks, preventing their being ground up but permitting their orientation within the faults.

At some time later than the period of major movement, minor tensional fractures were formed along parts of most of the faults. These allowed access of hydrothermal solutions that altered the components of the breccia. Locally, as in the vicinity of the Klau and Mahoney mines, large quantities of one or more clay minerals were formed. More commonly, however, the process resulted in the formation of networks of dense quartz and carbonate veinlets, which in their extreme development formed silica-carbonate rock.

The following criteria were found useful in distinguishing fault zones within the Franciscan rocks, but they are not all equally useful, and no one of them is sufficient in itself to prove a fault.

1. Topographic expression.--Major fault zones rarely crop out along the crests of ridges; they tend, rather, to extend along slopes or valleys or to form saddles where they cross ridges or spurs. This line of evidence is of little value when unsupported, but it is useful in projecting faults that are known from other evidence.

2. Drag folds.--Tertiary and Cretaceous rocks occasionally show drag folds near major faults, but such folds are rather rare even in these rocks and are not discernible in the Franciscan formation.

3. Breccia zones.--Zones of fault breccia, such as have been described above, constitute the most important and reliable evidence of major faulting. The Franciscan rocks, indeed, are almost everywhere broken and contorted, but in exposures that are not in fault zones they are likely to be comparatively homogeneous and to show some signs of original bedding.

4. Hydrothermal alteration.--So far as known, all hydrothermal alteration of the rocks is confined to major fault zones or at least closely related to them. The presence of kaolinized rock, of quartz or carbonate veinlets, of silica-carbonate rock, or of quicksilver deposits can therefore be considered as evidence of the proximity of a fault.

5. Displacement of rock bodies.--Visible displacements or offsets are scarce within the Franciscan, but they afford evidence of faults that involve the later rocks. In a few places, large continuous outcrops of Franciscan rocks are useful in delimiting adjacent fault zones or in showing places through which faults cannot possibly be projected.

6. Character of soil.--The soil on a fault breccia differs somewhat in appearance, and even in its feel underfoot, from that on other rocks, but the distinction is vague and can be applied only after considerable experience in the field.

7. Rhyolite dikes.--So far as has been observed, dikes of rhyolite occur only within or very close to fault zones. Their presence can thus be accepted as direct evidence of faulting, even where the entire fault zone is now filled with rhyolite.

There is little evidence within the areas examined to indicate the direction, amount, or character of the movement along the major fault zones, other than that they were certainly formed by compressive forces.

The orientation of the fragments in the breccia zones with the general attitude of the zones, the steep dips of most of the zones, and the presence in them of low-angle grooves and slickensides all strongly suggest that the major movement along faults within the Franciscan rocks was nearly horizontal. On the other hand, the Rinconada fault is clearly a low-angle thrust fault, and many others that involve Cretaceous or Tertiary rocks are probably of the same character.

ORE DEPOSITS

The quicksilver deposits of San Luis Obispo and southwestern Monterey Counties consist of irregular and discontinuous cinnabar-bearing veins and of rock masses containing disseminated cinnabar. All are within or very near northwest-trending fault zones, all but two are wholly within the Franciscan formation (one of these is partly so), and nearly all are intimately associated with silica-carbonate rock. Most of the ore shoots are irregular and of little vertical or horizontal extent. They are controlled by local gouge zones or by changes in dip or strike of the enclosing vein matter. Grade of ore ranges between wide limits, but most of that mined in the past has probably contained 5 to 10 pounds of quicksilver to the ton. Reserves of possible ore seem fairly large, but the cost of finding and exploiting new deposits will doubtless be relatively high.

Minerals of the ore deposits

Name 1/	Composition	Remarks
Metallic minerals:		
Gold	Au; native gold	Reported in very small noncommercial quantities from Rinconada and Libertad mine.
Mercury (quicksilver)	Hg; native quicksilver	Small globules disseminated in Oceanic and Libertad ores; reported from Madrone.
Stibnite	Sb_2S_3; antimony sulfide	Known only at Marquart antimony prospect; may be present in some quicksilver ores.
Metacinnabar	HgS; black mercuric sulfide	Widespread ore of quicksilver but probably nowhere as abundant as cinnabar.
CINNABAR	HgS; red mercuric sulfide	Most important ore of quicksilver in all mines described.
Millerite	NiS; nickel sulfide	Tiny needles in Libertad ore may be millerite; not seen elsewhere.
Pyrite	FeS_2; ferric sulfide	Widespread in small quantities in nearly all ores; relatively abundant in Klau and Mahoney ores.
Marcasite	FeS_2; ferric sulfide	
Nonmetallic minerals:		
QUARTZ	SiO_2; silica	Commonly dense and fine-grained. Intimately associated with most cinnabar and an essential constituent of silica-carbonate rock.
Opal	$SiO_2 \cdot nH_2O$; hydrous silica	Widespread but seldom abundant associate of quicksilver ores.
Cervantite	$Sb_2O_3 \cdot Sb_2O_5$; antimony oxide	Known only as yellow crusts and stains on ore from Marquart antimony prospect.
Stibiconite	$H_2Sb_2O_5$; hydrous antimony oxide.	
Chromite	$FeO.Cr_2O_3$; chromium iron oxide.	Forms residual crystals and blebs in silica-carbonate rock.
"LIMONITE"	Hydrous ferric oxide	Most prominent oxidation product of pyrite and mixed carbonate.
Calcite	$CaCO_3$; Calcium carbonate	Small clear crystals line vugs in many deposits.
Dolomite	$CaCO_3 \cdot MgCO_3$; calcium magnesium.	Small clear crystals line vugs in many deposits.

1/ Capitals denote mineral is abundant or widespread, or both; light type denotes mineral is moderately abundant or widespread; underscore denotes mineral is rare.

Minerals of the ore deposits--Continued

Name	Composition	Remarks
Nonmetallic minerals--Continued.		
MIXED CARBONATE (NEAR ANKERITE)	$CaCO_3\cdot(Mg,Fe,Mn)CO_3$; calcium, magnesium, iron, manganese carbonate.	Most abundant constituent of silica-carbonate rock.
Siderite	$FeCO_3$; iron carbonate	Known only as concretions in certain fault zones.
Serpentine	$3MgO\cdot2SiO_2\cdot2H_2O$; hydrous magnesium silicate.	Most prominent gangue mineral in Cambria and several smaller deposits.
Garnierite	$H_2(Ni,Mg)SiO_4$+aq.; hydrous nickel magnesium silicate.	Not identified but possibly responsible for green color in some clays and gouges.
Clay minerals:		
Dickite	$Al_2O_3\cdot2SiO_2\cdot2H_2O$; hydrous aluminum silicate.	These clay minerals, and possibly others, are widespread as alteration products of fault breccia material; by far most abundant in Klau-Mahoney district; bright-green clay in many mines probably due to volonskoite but possibly to garnierite in part.
Volonskoite	$Cr_2O_3\cdot4SiO_2\cdot H_2O$ aq.; hydrous chromium silicate.	
Montmorillonite	$Al_2O_3\cdot4SiO_2\cdot H_2O$ aq.; hydrous aluminum silicate.	
"Hector clay"	$3MgO\cdot4SiO_2\cdot H_2O$ aq.; hydrous magnesium silicate.	
Gypsum	$CaSO_4\cdot2H_2O$; hydrous calcium sulphate.	These and probably other secondary sulfates form post-mining crusts and efflorescences in many mines.
Epsonite	$MgSO_4\cdot7H_2O$; hydrous magnesium sulphate.	
Melanterite	$FeSO_4\cdot7H_2O$; hydrous iron sulfate.	
Copiapite	$Fe_4(OH)_2(SO_4)_5\cdot18H_2O$; hydrous iron sulfate.	
Hydrocarbons	C_nH_{2n} 2	Widespread as vug fillings but nowhere abundant.

Minerals

The accompanying table and figure 75 are believed to summarize with essential correctness the necessary information regarding the occurrence and history of all the minerals that are known to be associated with the ore deposits, though microscopic studies, had they been possible in the available time, might have revealed the presence of other minerals or have led to a

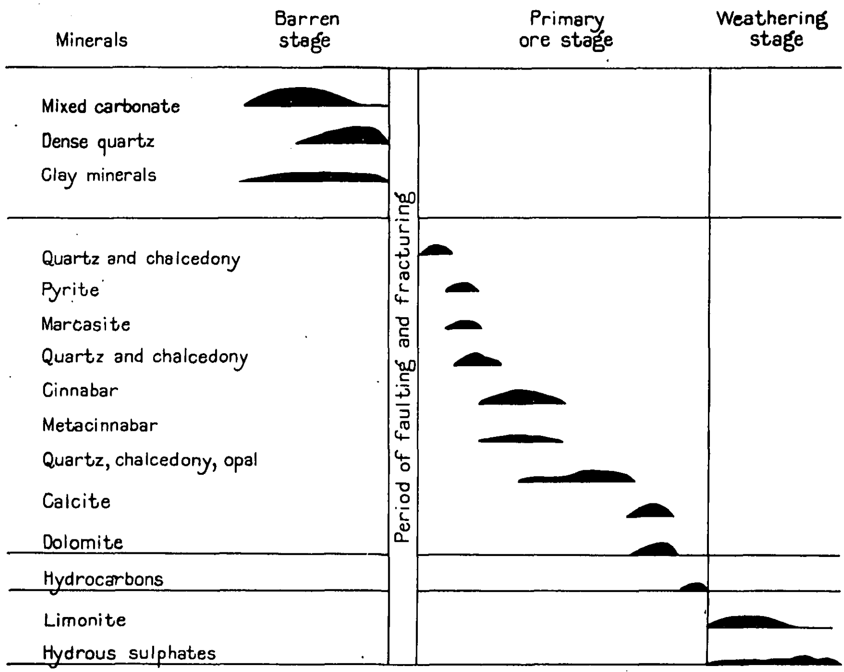

Figure 75.—Diagram showing mineralogic history of the ore deposits. Based on study of hand specimens.

slightly different interpretation of the history of mineral deposition.

Cinnabar is by far the most important ore mineral. It occurs as crusts or fillings along fractures in the gangue, as disseminated grains, and as irregular masses and lenses. Most of it filled open spaces, but some unquestionably was formed by replacement of older minerals. It is more closely associated with dense quartz than with any other mineral. The range in color exhibited by the cinnabar depends partly on the size of individual crystal grains but mainly on the relative proportion of admixed silica. The character of the most abundant and widespread gangue material, silica-carbonate rock, is described above. Variations in mode of occurrence of cinnabar and its associated minerals are briefly discussed in the descriptions of individual mines.

Distribution

Most of the ore deposits of San Luis Obispo County are within the area shown on plate 78, which, as shown by the index map (fig. 74), is in the northwest corner of the county. The only other important deposit is developed in the Rinconada mine, near Santa Margarita. Several other mineralized areas, a few of which are not described in this report, are scattered throughout San Luis Obispo County and the southern part of Monterey County (fig. 74), but they are small and relatively unproductive; it was not deemed advisable, therefore, to extend the areal mapping beyond the areas shown on plates 78 and 85.

Geologically the distribution of the cinnabar has been controlled for the most part by at least two major factors--the first a complex set of northwest-trending fault zones, and the second the presence of Franciscan and associated rocks. Most of the deposits are within the Franciscan formation, though the Bryson deposit is in Cretaceous rocks and the Oceanic deposit in Tertiary rocks. All occur in major fault zones or closely associated minor structural features.

Form and character

The deposits described in this report are characteristically irregular and pockety. There are two chief structural types--disseminated deposits and irregular veins. The disseminated type is exemplified by the Oceanic and Cambria mines, where cinnabar is disseminated through sandstone and serpentine along or close to a fault zone. Good examples of the vein type are seen in the Little Bonanza, La Libertad, and Rinconada mines. Some deposits, like the Klau and Mahoney, contain both veins and disseminations.

The veinlike deposits range from a few inches to 20 feet in width. Most of them are steep-dipping irregular lenses, few of which extend more than 200 or 300 feet horizontally or vertically. In some mines several such lenses are arranged en echelon (see pl. 83). Many of the ore bodies are transverse to the lineation of the enclosing fault breccia. Except in the Klau and Mahoney mines they are typically composed of silica-carbonate rock and are often bounded by shear planes or by masses of black gouge, or "alta." Some veins, notably those where silica-carbonate rock is poorly developed, grade into unaltered country rock. Cinnabar and its associated gangue minerals form irregular bunches within the vein matter, or occur as interlacing veinlets extending across the general strike of the vein.

Ore shoots

Structural control

So far as known, none of the veins or disseminated deposits contain workable ore throughout their extent. Instead, bodies of ore that are rich enough to mine, termed ore shoots, occur at various places within the main deposit. Most of these shoots are at places where the enclosing vein changes abruptly in dip or, less commonly, where it changes in strike. Most of them too occur where the veins dip at relatively low angles, doubtless because most of them are wider, hence more open, along low-dipping segments than along steeper ones. The character of the wall rocks surrounding the deposits has also influenced the deposition of ore. Ore shoots are much more likely to occur where the vein or disseminated deposit is bounded by gouge or by shaly rocks than where the wall rocks are porous or highly fractured.

Size and grade

The ore shoots vary widely in size and grade. The largest known individual shoot, that of the Oceanic mine, was 40 feet wide, 500 feet long, and 700 feet high and yielded 2 to 5 pounds of quicksilver to the ton. It has not yet been definitely bottomed. A shoot worked in the Cambria mine is reported to have been 40 feet wide, 180 feet long, and more than 100 feet high and to have yielded 7.6 pounds of metal to the ton. Several of the stopes in the Klau mine are nearly as large as the Cambria shoot. In most other mines the deposits are more irregular than those just mentioned and individual ore shoots are commonly smaller, ranging from 1 to 20 feet in width and from 10 to 150 feet in height and length. In most such deposits the grade of ore ranges between wide limits--perhaps 1 to 40 pounds of quicksilver to the ton. It is probably safe to say, however, that most of the ore produced in the district to date has yielded 3 to 10 pounds to the ton.

Manganese, chromite, and antimony deposits

Several small deposits of manganese and chromite and one of antimony occurring within the mapped areas seem to deserve mention.

Manganese oxides occur in lenses closely associated with the basalts in the Franciscan formation, and many of the chert lenses are stained with manganese oxides. The only deposit visited by the writers is on the 7X ranch, near the Klau mine.

Several small prospects in chromite-bearing serpentine are scattered through the area. The chromite occurs as disseminations and podlike segregations in the serpentine and is usually very pockety. The largest prospects visited are on the William Fitzhugh ranch, 5 miles up Santa Rosa Creek from Cambria.

The antimony deposit is on the Marquart ranch, near the headwaters of Steiner Creek and midway between the Oceanic and Cypress Mountain mines (pl. 78). Two short adits and a shallow shaft, all caved in 1940, explore a northeast-trending fracture zone in massive sandstone between two major faults. The zone is about 25 feet wide and contains several irregular quartz veins 1 inch to 18 inches thick, one of which is rich in stibnite and its oxidation products. Some ore is reported to have been shipped prior to 1900, but the prospect has been idle since. Showings of cinnabar occur in nearby silica-carbonate rock, but none is associated with the antimony deposit.

Quicksilver deposits

Origin

All the quicksilver deposits, as already said, are closely associated with strong fault zones, which have been intermittently active since Jurassic time. During or just after one of the later periods of movement, solutions from considerable depth rose along the faults and replaced the rock in many places with dense quartz and mixed carbonate. These solutions naturally sought openings in the rocks, but they performed most of their work in places where they met impervious barriers of shale. These barriers, or structural traps,[4] forced the solutions to move slowly and to cool sufficiently to deposit their mineral loads.

4/ Schuette, C. N., Occurrence of quicksilver ore bodies: Am. Inst. Min. Met. Eng. Trans. 1931, pp. 403-486; Am. Inst. Min. Met. Eng. Tech. Pub. 335, 88 pp., 1930.

At some time after the formation of the silica-carbonate rock, certainly after the Miocene epoch and probably much later, slight renewed movements produced fractures in the country rocks and in the silica-carbonate bodies. Solutions containing mercury, iron, sulphur, and other elements then rose along the faults and deposited cinnabar and its associated metallic and nonmetallic minerals in the newly formed fractures. Deposition was controlled in part by the decrease of temperature on approach to the surface and in part by structural conditions similar to those that controlled the formation of silica-carbonate rock.

There is much evidence that the deposits were of epithermal origin--formed, that is, at relatively low temperature and pressure. The reason why the deposits are virtually confined to Franciscan rocks and serpentine and their alteration product silica-carbonate rock is not wholly clear. The answer seems to lie in the fact that these older rocks are much more strongly fractured, hence much more permeable, than any of the younger rocks. The same reasoning applies to the silica-carbonate rock, which is more brittle and more easily fractured than most of the rocks in the district. It seems quite likely, however, that the chemical nature of the rocks or of the ground waters within them may have played some part in precipitating the solutions.

Reserves

Because of the geologic character of the ore deposits themselves and because many of the mines were inaccessible for detailed examination, it is impossible to estimate proved reserves of ore very closely. But it can at least be said that the reserves actually blocked out and ready for mining at any given time are very small and that most of the ore in sight in June 1940, when this report was written, will probably have been extracted before the report can be published.

With regard to reserves of probable or possible ore, the situation is somewhat different. There are ample indications that some of the productive shoots in known mines have not been exhausted, and almost as good indications that further exploration will uncover new shoots in some of them. Although many individual shoots have been exhausted, there is no proof that any entire deposit has been bottomed. This condition is most nearly approached in the 700-foot Oceanic ore shoot, where the ore on the lower levels is reported to have been leaner and to have contained more pyrite than that nearer the surface. In this deposit, as in others that were more accessible for study, it seems possible that the reported increase in pyrite reflects lack of oxidation rather than an actual increase of this mineral in the primary ore. The ore deposits in the district as a whole have a vertical range of more than 3,000 feet. The deepest work done so far extended 700 feet beneath the surface, and few of the mines are more than 200 feet deep. It seems reasonable to suppose that some deposits in favorable structural environments will be found to extend to depths of at least 1,000 or 1,200 feet.

Not only is it possible that new shoots of medium- to high-grade ore may be found, but there are several deposits of low-grade ore that have not been worked in the past but may be minable by modern, low-cost methods. The most prominent examples include the Oceanic, Rinconada, Pine Mountain group, and possibly the Klau-Mahoney and Bryson mines. The common practice of "gouging" rich pockets will doubtless render future operations more difficult and expensive than they would otherwise have been, but carefully conducted operations would tend to offset this difficulty. A vigorous prospecting campaign, properly conducted and possibly supplemented by drilling in favorable areas, will quite possibly result in the discovery of new deposits.

Several of the mine dumps that resulted from former operations contain cinnabar in unknown but probably workable quantities. Those of the Cambria and Oceanic mines, as well as those of some of the smaller mines, seem particularly to warrant consideration.

It seems probable that the total future production of the district may equal if not exceed the past production of nearly 70,000 flasks and that, given stable and profitable price levels, the annual production may well range between 1,000 and 3,000 flasks. A higher rate of production cannot reasonably be expected unless some large and entirely new deposit is discovered. It is clear that low or unsteady prices would cause production to drop below the lower figure mentioned.

Suggestions for prospecting

Several suggestions that may guide the search for new deposits or at least delimit the areas that are worthy of prospecting are fairly apparent from the above descriptions. Prospecting should be confined essentially to areas in which Franciscan rocks or bodies of serpentine are exposed at the surface. All known deposits are closely related to strong fault zones within these areas, and the possibility of finding new deposits is far better along these faults than elsewhere. Unmineralized parts of the fault zones can well be neglected and search confined to the parts in which the breccia is kaolinized or is partly altered to quartz and carbonate. Outcrops of silica-carbonate rock, nearly all of which are shown roughly to scale on plates 78 and 85, form particularly promising ground for prospecting, although many of them will doubtless be found to be barren. In other words, nearly all quicksilver deposits are intimately associated with silica-carbonate rock, but by no means all bodies of this rock contain workable deposits of quicksilver.

There seems little likelihood of discovering in the Tertiary rocks other deposits like that of the Oceanic mine, which was controlled by a rare, if not unique, set of structural conditions. The possibility should not be overlooked, however. Particular attention should be given to the Oceanic and similar faults that bring Tertiary rocks into contact with the Franciscan formation. Undiscovered deposits probably exist along faults in the Franciscan beneath covers of Cretaceous or Tertiary rocks, but the chance of discovering such deposits is remote.

Suggestions that may be of use in searching for new ore shoots within known mines or for finding extensions of known ore bodies are given below in the mine descriptions. Unfortunately, the structural factors that control the location and size of individual ore shoots are seldom apparent in advance of development. The only practical methods of hunting for shoots therefore seem to be to "follow the ore" or to prospect more or less blindly within known mineralized ground. In some places, carefully planned drilling may be of use in discovering or outlining new shoots.

MINING DISTRICTS

The ore deposits of the area fall naturally into seven groups, both geographically and geologically. These are here termed districts, though the names of districts are not used here exactly in accordance with the usage adopted in earlier reports. Adequate examination of many of the mines was impossible either because they were caved or because their ore bodies had been mined out. Some of the descriptions below lack essential details either because no detailed maps or records were made, or preserved, during periods of mine operation or because certain owners and lessees refused permission to publish

Records of mines in San Luis Obispo

District and mines	Location (Mount Diablo meridian) T.S.	R.E.	Sec.	Owner[1]	Address	Altitude[2] (feet)
Cambria-Oceanic:						
Cambria	26	8	36	H. Carhart[4]	Pasadena	750
Fitzhugh	27	9	24	Wm. Fitzhugh	Cambria	1,200
Oceanic	27	9	15,21	Anglo-American Mining Co.[6]		750
Vulture	27	9	24	Rudolph Mora	Cambria	1,000
Wittenburg	27	9	8	W. Warren	....do	750
Marquart	27	9	3	J. L. Marquart	....do	1,700
Klau-Mahoney:						
Capitola	26	10	33	Mrs. E. W. Carson	San Luis Obispo	1,100
Klau	26	10	33	Klau Mines, Inc.	San Francisco	1,150
Mahoney	26	10	33	M. I. O'Toole[8]	Gilroy	1,250
William Tell	26	10	32	C. C. Thompson	Adelaida	1,050
Madrone-Cypress Mountain:						
Cypress Mountain group	27	9	1,2	....(?)	....(?)	2,500
Kismet group	27	10	7	....(?)	....(?)	2,200
La Libertad	27	10	21	C. C. Thompson	Adelaida	1,750
Little Bonanza group	27	10	17	E. Merrifield and others.	....do	2,000
Madrone	27	10	22	H. Marquart	Cayucos	2,000
Rinconada:						
Rinconada	30	14	21,28	Mrs. Theresa Bell	Santa Margarita	2,000
Deer Trail	32	16	32	M. H. Stevens	San Luis Obispo	....
Pine Mountain:						
Buckeye	26	8	3	Hearst Sunical Land & Packing Corp.[9]	San Francisco	2,950
Doty	26	8	14	Joe Bianchi	Cambria	2,500
Hamilton	26	9	30	W. Warren	....do	1,000
Keystone	26	8	23	Phelan Land Co.[9]	....do	1,100
Little Almaden	26	8	10	Hearst Sunical Land & Packing Corp.[9]	San Francisco	2,800
Ocean View	26	8	3	....do.[9]	....do	3,000
Pine Mountain	26	8	3	....do.[9]	....do	3,000
Quien Sabe	26	8	14	Joe Bianchi	Cambria	2,600
Warren	26	9	30	W. Warren	....do	1,000
Williams	26	8	24	T. Williams	....do	2,650
San Carpoforo:						
Dutra	24	6	27	Hearst Sunical Land & Packing Corp.	San Francisco	1,850
North Star	25	6	13	....do	....do	....
Polar Star	25	6	13	Walter Harris	Paso Robles	400
Sunset View	25	6	13	Hearst Sunical Land & Packing Corp.	San Francisco	....
Bryson:						
Bryson	24	8	7	Victor Botts	Paso Robles	1,100

1/Ownership as listed accords with the best information available in June 1940. A few ownerships possibly include only surface rights. All addresses given are in California.
2/Above sea level.
3/L, large, 1,000 flasks or more; M, medium, 100 to 999 flasks; S, small, 10 to 99 flasks; VS, very small, 1 to 9 flasks.
4/Thompson, lessee in June 1940.

and Monterey Counties, California

Production estimated (flasks)3/	Years active	Workings, approximate length (feet)	Workings accessible in 1940 (feet)	Vertical extent of known ore, approximate (feet)	Methods of reduction
4,135+	1903-17, 1940	3,900 5/	50	150	Retort.
VS	1915	800	None	(?)	None.
38,000	1865, 1875-82, 1902-20, 1927-32, 1934-38, 1940	13,000	500	800	100-ton rotary furnace.
S	1915, 1933	200	30	50	Retort.7/
VS	1900	Mostly open pits.	....	(?)	Do.7/
None	....	None........	....	(?)	None.
M	1913, 1915-16, 1918	300	None	100	Do.
17,800+	1868-78, 1895-1912, 1917-23, 1924, 1927-40	24,000	3,000+	400	50-ton rotary furnace.
M	1900-1903, 1929-30, 1935, 1938-40	1,200	1,000	100	25-ton rotary furnace.
VS	1900	(?)	None	(?)	None.
None	1900	(?)	None	(?)	Do.
None	1903	25	25	(?)	Do.
M-L(?)	?-1901-3, 1915-16, 1935, 1940	1,300	1,300	200	Retort and 15-ton rotary furnace.
L	1862, 1900, 1902-5, 1915-16, 1931-34, 1937-38, 1940	3,000	2,400	250	Retort.
S	1900	250	250	125	Do.7/
L	1872-?-83, 1897, 1915, 1923, 1925-26, 1929, 1934-37	7,000+	7,000+	200	50-ton rotary furnace.
M	1916, 1928, 1932,1935-36, 1938-39, 1940	....	....	....	Retort.
VS	1903	400	20	50	None.
S(?)	1905, 1917	250	100	100	Do.
S	1915?	1,000+?	None	(?)	Do.
60	1875, 1916-17, 1940	300	20	50	Retort.
S(?)	1871-?-1903	15-foot tunnel;mostly open pits.	15	50	Do.7/
M	1871-?-1903	3,000	200	250	Do.7/
S(?)	1871-?-1903	200	None	10	None.
S	1905-?-1917	350	None	200	Do.
None	1940	Open pit....	....	10	Do.
None	1915, 1940	....do......	....	5	Do.
(?)	(?)	....	....	....	
(?)	1870-?-1900	....	....	....	
S	1870-?-1900, 1935, 1939	50-foot tunnel plus open cuts.	50	150	Retort.
(?)	(?)	....	....	....	
S(?)	?-1939-40	200	200	50	Retort.

5/1,800 feet in lower workings; 2,100 feet in upper workings.
6/A. J. Bruce, lessee in June 1940.
7/Old retort not in working condition.
8/Buena Vista Mining Co., lessee in June 1940.
9/O. E. Hanno and H. G. Tripp, lessees in 1940.

available data. These deficiencies were offset in part by the excellent summary descriptions that have been published by the California Division of Mines.[5] The table on pages 548 and 549 presents the available facts relating to matters other than geology for all the mines. In the geologic description that follows, the mining districts are considered in an order determined by their location, and the mines of each district are described in alphabetic order.

Cambria-Oceanic district

Geology

The controlling structure of the Cambria-Oceanic district is the Oceanic fault zone. In general this is the narrowest of all the major fault zones mapped in the area. Rhyolite crops out along the zone near the Cambria mine, on Black Mountain, and between the Fitzhugh and Mora ranches, a mile east of the Oceanic mine. Just north of the Cambria mine the zone appears to split into several faults, which were not traced beyond the ridge between San Simeon and Pico Creeks. Another split occurs on the ridge southeast of Steiner Creek, where at least two prominent branches can be traced across the creek. The more southerly of these dies out in the Tertiary sedimentary beds; the other continues beyond the Cambria mine. The Oceanic fault zone in general strikes about N. 40°-45° W. Locally its dip is steeply to the northeast, but the usual dip is to the southwest at angles of 60° to almost 90°. For nearly all of its length it separates Tertiary rocks on the south from Franciscan rocks on the north. Several ore deposits, including those worked by

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5/ Forstner, William, The quicksilver resources of California: California State Min. Bur. Bull. 27, pp. 149-168, 1903. Bradley, W. W., Quicksilver resources of California: California State Min. Bur. Bull. 78, pp. 124-149, 1918. Ransome, A. L., and Kellogg, J. L., Quicksilver resources of California: California Jour. Mines and Geology, vol. 35, no. 4, pp. 430-447, 1939 [1940].

the Cambria, Oceanic, and several smaller mines, occur along the fault zone. Even between the Vulture mine and Black Mountain, where the zone is rather narrow, it is sparsely mineralized, as shown by a few scattered outcrops of silica-carbonate rock. Quartz, mixed carbonates, cinnabar, and pyrite are rather widely distributed between the Vulture and Cambria mines, the largest concentration being at the Oceanic mine. From the ridge northwest of the Oceanic to the Cambria there is considerable silica-carbonate rock, some of which contains cinnabar.

Mines and prospects

Cambria.--The Cambria mine, which ranks third in production among the mines described, is on San Simeon Creek and is easily reached by road from Cambria, 6 miles distant. In June 1940 all the original workings were caved, though an attempt was

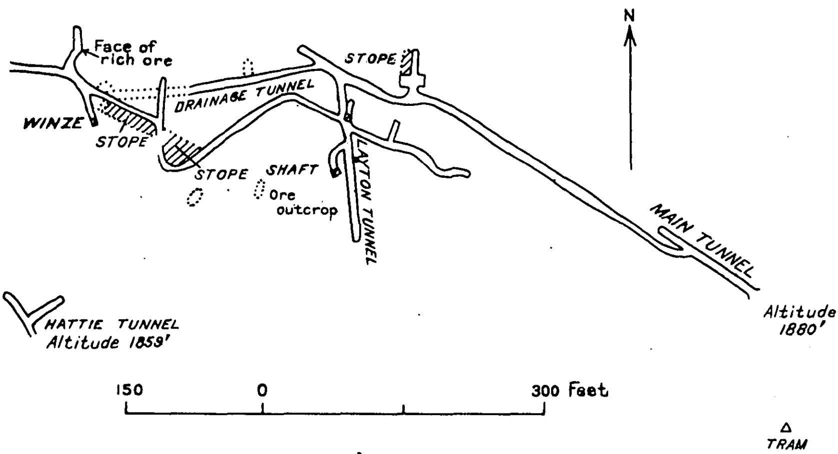


Figure 76.--Plat of Red Hill workings, Cambria mine. (From California State Min. Bur. Bull. 78, p. 129, 1918.

being made to reopen the lower levels of the mine. The property has two distinct sets of workings (fig. 76), the lower one being the oldest and most productive. The country rock is entirely serpentine, which is somewhat silicified in the lower workings and partly altered to silica-carbonate rock in the upper. The serpentine is a sheetlike mass that caps Red Mountain (pl. 78, section A-A'). It is cut by northwest-trending faults associated with the main Oceanic fault zone, which splits into several branches in this vicinity.

The ore has been deposited along parts of at least three of these minor faults, all of which appear to dip to the northeast at low angles. The lowermost of the veins was opened by the original tunnels and the uppermost by the Red Hill workings; an intermediate vein has not been explored. Two types of ore have been mined. That from the lower mine is a slightly silicified serpentine in which the cinnabar is disseminated and fills fractures. Small quantities of cinnabar fill fractures in veinlets of altered asbestos. The wall rock adjacent to the vein contains a little finely disseminated cinnabar. In the upper workings the ore occurs as rich bunches and small veinlets in a more highly altered serpentine, or silica-carbonate rock, and is more like the typical ores in altered serpentine found in other mines of this district.

The lower workings are reported to explore a single ore shoot 8 to 40 feet in width, 180 feet in length, and as much as 150 feet in height. It is not known whether the ore was bottomed in either of the main deposits, though it is said in the older reports [6] that the lower workings were abandoned because the ore gave out. Other sources report that the ore was stoped up from the main level and not explored at depth and that the mine was abandoned because of the difficulty experienced in holding heavy ground. The ore in this vein is reliably reported to have contained 7.6 pounds of quicksilver to the ton. No information is available as to the shape of the ore shoots or as to the conditions in the upper mine at the time it was abandoned.

6/ Bradley, W. W., op. cit., p. 128.

Any opinion as to the future of this mine must be reserved until the old workings are reopened. In June 1940 lessees were producing a little ore from a part of the lower vein that had not been stoped to the surface during the earlier work. Only a small tonnage was in sight. Some quicksilver could doubtless be recovered from the old dumps of the mine, as parts of them contain abundant fragments of rich ore that was only partly burned.

Fitzhugh ranch.--The Fitzhugh ranch prospect is on the William Fitzhugh ranch, 8 miles east of Cambria, on the Santa Rosa Creek road. The mine, which lies wholly within serpentine, is just north of the Oceanic fault zone and is half a mile west of the Vulture mine.

The cinnabar forms little clouds of disseminated grains in serpentine and is associated with a translucent, waxy-appearing mineral that was not identified. A tunnel, now caved, was driven in a northerly direction for a reported distance of 800 feet. The ore is very low in grade, and there is no record of any metal having been produced.

Oceanic.--The Oceanic mine, 5 miles by a paved highway up Santa Rosa Creek from Cambria, is one of the oldest in the district and has produced nearly as much quicksilver as all the other deposits in the county combined. It is the only important mine in the district that is in the Tertiary rocks. In June 1940 the old dumps were being reworked, but no mining was being done and the only accessible underground working was the main, or 400, level, which is tightly timbered and lagged. All geologic data therefore had to be derived from surface observations and from such reports and mine maps as were available. (See fig. 77.)

The mine workings are almost wholly in Miocene sandstones, sandy siltstones, and sill-like intrusive bodies of gabbroic diabase. To the northeast these rocks are in fault contact with Franciscan sandstone, shale, and serpentine. The Tertiary beds strike N. 65° W. and have a northeasterly dip, which increases

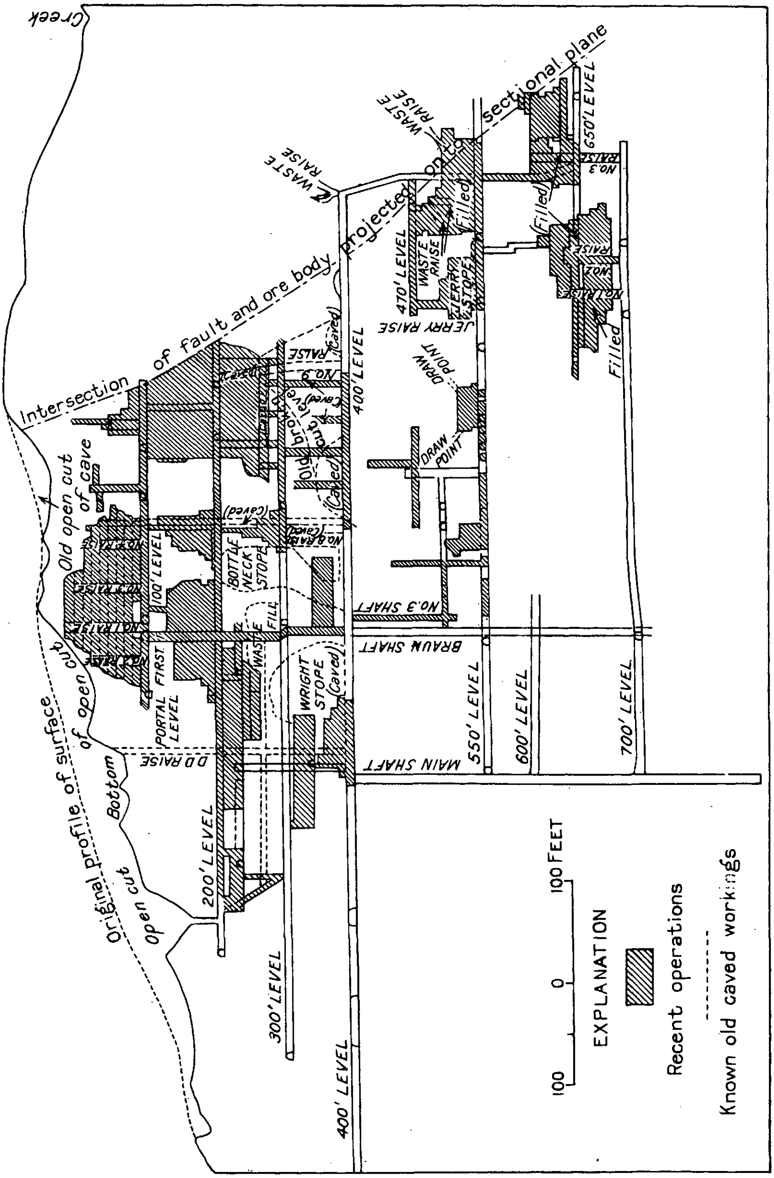


Figure 77.—Longitudinal section through Oceanic mine. (Reprinted from California Jour. Mines and Geology, vol. 31, p. 444, 1935, with slight modification.)

from 30° to almost 90° at the fault and even becomes overturned. The fault between the Tertiary and Franciscan rocks strikes N. 45°-60° W. and has steep dips, in most places to the southwest but locally to the northeast. Sections drawn from the mine maps reveal a change from a vertical dip at the surface to a northeast dip and thence a reversal to the southwest as the 800 level is approached. The strike of the fault is also curved in such a way that the fault surface is saucerlike, with the concavity toward the southwest.

The ore shoot strikes about N. 65° W., like the Tertiary beds, and pitches southeastward about 45°. It has been explored through a pitch length of more than 800 feet; it has a maximum horizontal extent along the strike of 500 feet and a thickness of 15 to 40 feet. Although the ore shoot proper extends only to the fault, a crosscut driven north on the 700 level for 40 feet into the serpentine is reported to have penetrated 9 feet of ore that apparently was deposited in the fault zone. It thus seems probable that some, at least, of the faulting occurred before the deposition of the cinnabar. The maps of the 800 level indicate that no ore was discovered at this depth, but this does not necessarily indicate that the ore shoot was exhausted at depth, for a projection of the ore shoot from the upper levels would fall to the south of all development work that was done on the 800 level.

The ore is of two distinct types. The first, known as the high-grade type, is a medium-grained sandstone that contains disseminated cinnabar. The second type is a sandy siltstone containing almond-shaped "nuggets" of cinnabar, replacements of fossil shells by cinnabar, and some native mercury which is associated with the cinnabar. Pyrite is an unusually abundant gangue mineral, particularly in the lower levels, and the deposit is also characterized by a comparative lack of the quartz and calcite so common in other mines of the district.

The ore of the Oceanic has not been exhausted, and several thousand tons of low-grade ore, averaging 2 to 3 pounds of quicksilver to the ton, is probably still available for mining. Additional reserves, particularly to the south on the 800 level, might possibly be proved by systematic development. High costs and other mining problems attendant on work at the lower levels would seem to be the main drawback to future production.

Vulture.--The Vulture mine is about 2 miles east of the Oceanic, in the same major fault zone. The property can be reached through the ranch of Rudolph Mora, 10 miles east of Cambria, on the Santa Rosa Creek road. Two tunnels driven into the hill in an attempt to find ore at depth were apparently unsuccessful. The ore produced was taken from several small open pits.

The ore occurs in a highly brecciated zone in serpentine. Rhyolite has intruded the main Oceanic fault zone nearby. The cinnabar occurs in small botryoidal globules on fracture surfaces of the breccia. Associated with it is a large amount of limonite, which gives the breccia a dark-brown iron color. The ore is of low grade, and less than 10 flasks of quicksilver have been produced from the surface pits.

Klau-Mahoney district

Geology

The Klau-Mahoney district, which is about 17 miles from Paso Robles by a good road, includes the Klau mine, the second largest producer in San Luis Obispo County. The structure of the district differs from that of most of the other districts described, in that the major faults strike nearly due east and at least two of them dip at low angles toward the south. The country rocks are of Franciscan, Cretaceous, and Tertiary age. All these rocks have been faulted, and the district is near the common intersection of several faults, some of which were not mapped. The faults differ in extent and age. One of the three greatest, the Las Tablas fault, strikes about N. 80° W., parallel in general to Las Tablas Creek, and in the vicinity of the Klau-Mahoney mines it dips almost vertically. It separates Tertiary rocks on the north from Franciscan on the south. It is not mineralized. South of the Las Tablas fault are two older ones, which have much wider zones of fracture. These fault zones trend from due east to N. 75° W. and dip 40°-60° W. Both are mineralized, especially the southernmost, along which the Klau and Mahoney mines are located. Near the mines this fault zone dips about 50°-60° S. and has a width at the surface of as much as 1,000 feet. In both the Klau and Mahoney mines the breccia is largely shale and much of it is kaolinized.

Silica-carbonate rock is abundant along other parts of the fault but rare in the mines. A striking feature of the district is a sill-like mass of serpentine, just west of the Klau mine, which dips about 30° S. and appears as if plastered on the hillside. Hydrothermal solutions have altered its top and bottom to silica-carbonate rock. This body affords one of the best examples in the district of complete gradation from serpentine to silica-carbonate rock. (See pl. 80.)

The two major faults can be traced for only a short distance eastward from the Mahoney mine to a place where they apparently pass beneath Tertiary limestone. Westward from the mine they can be traced for several miles, beyond which they probably swing northwestward to parallel or join the other major northwest-trending zones.

Mines

Capitola.--The Capitola mine, which lies a quarter of a mile southeast of the Klau and is a part of the Klau properties, has produced only a small amount of quicksilver. The workings, which are caved, are said to consist of a 260-foot tunnel from which ore was stoped for the last 70 feet. The workings are in the same breccia zone as those at the Klau mine. The ore shoots were also apparently similar to those at the Klau mine, though they probably contained even more clay and pyrite. The property has not been worked since 1934.

Klau.--The Klau mine, opened in 1868, is second only to the Oceanic mine as a producer of quicksilver in San Luis Obispo County. It is easily reached by 17 miles of good road from Paso Robles. Many miles of tunnels, shafts, and crosscuts have been driven in the property, but most of these are now caved or unsafe for examination. Some geologic facts relating to the caved workings were obtained from surface observations and old mine maps. A considerable amount of open-pit work has been done on the property, but the mine has been chiefly developed from a 450-foot inclined shaft near the center of the property. (See pl. 81.)

The mine is entirely in a south-dipping kaolinized fault breccia, which consists mainly of shale and contains minor amounts of sandstone, chert, and silica-carbonate rock. This breccia is here at least 1,000 feet wide. The mine workings for the most part followed minor shear planes that trend northwestward and dip steeply northeast.

The ore occurs in stockworks or networks, most of which are bounded by definite slips marked in places by greenish gouge but some of which grade into barren rock. The ore shoots appear to pinch both laterally and vertically. They dip steeply north and apparently are controlled by minor fractures, transverse to the main fault. The vein zones are in general nearly parallel. The gangue of the ore shoots is shale breccia with some green gouge and other clayey material. Pyrite and marcasite are fairly abundant and are commonly associated with the veinlets and irregular masses of dark-red crystalline cinnabar.

Several ore shoots have been bottomed and completely worked out, but others are being continually developed. As most of them have been discovered by accident, others may be found in depth or in the area between the Klau and Mahoney mines. A carefully planned drilling program would seem warranted. The Klau ore is of fairly high grade, averaging 8 pounds of quicksilver to the ton in June 1940.

Mahoney (Buena Vista).--The Mahoney, or Buena Vista, mine lies about half a mile northeast of the Klau mine. It has not been a large or steady producer. The workings, most of which are accessible, are shown in figure 78.

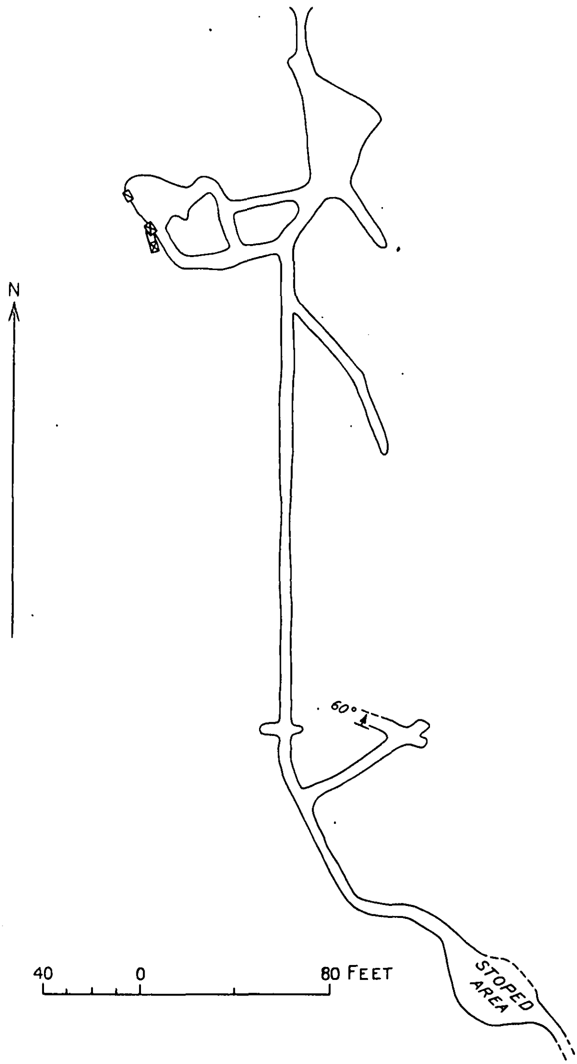


Figure 78.—Map of Mahoney mine workings.

The Mahoney is in the same breccia zone as the Klau mine, which it resembles in the character of its ore deposits and in its general geologic relations. The ore shoots occur in a strongly kaolinized breccia of shale. Most of them have indefinite limits, but some are definitely bounded by northwest-trending shear planes. The cinnabar occurs as stringers and disseminations in the shale breccia or as blebs, intimately associated with much pyrite, in masses of white to green clay. The mine contained at least four ore shoots that have been stoped out. These shoots appear to have been controlled by a series of nearly parallel minor shear planes, but the evidence is not conclusive. They are in general roughly lenticular and relatively small. More shoots may yet be discovered in the property.

Carefully planned drilling from the present workings toward the Klau mine would seem the best way to determine the future possibilities of the mine.

William Tell.--The William Tell mine lies about half a mile west of the Klau and on the same major fault. The workings are entirely caved, and no production has been reported; but extensive outcrops of silica-carbonate rock suggest that further exploration may possibly be warranted.

Madrone-Cypress Mountain belt

Geology

The Madrone-Cypress Mountain belt lies just northeast of the crest of the Santa Lucia Range. It trends northwestward, parallel to the range, across the southwest quarter of the Adelaida quadrangle. The Pine Mountain fault zone is probably the northwestward continuation of the belt, although the connection cannot be clearly established. Structurally the belt is an irregular zone of highly sheared and altered Franciscan rocks that varies in width from 100 to 1,000 feet. It has in general a vertical dip, and its outcrop is for the most part straight though locally sinuous and irregular. As shown on the geologic map (pl. 78), all the known ore deposits occur in wide parts of the fault zone and are closely associated with silica-carbonate rock. North and west of Cypress Mountain are several small bodies of rhyolite, some of which have been intruded into the breccia, but at least one, the most northerly, may be a surface flow. No cinnabar was seen in association with the rhyolite, though some may possibly have been found in the old tunnels of the Cypress Mountain group.

Intensive prospecting along the belt might lead to new discoveries of ore in other parts of the zone, but this does not seem likely, for past prospecting appears to have been fairly thorough. It is more likely that new ore bodies will be found in the areas already known to be mineralized.

Mines and prospects

Cypress Mountain group.--The Cypress Mountain claims lie due north of Cypress Mountain and near the largest exposure of rhyolite along the belt. They are reached by 2½ miles of poor trail from the nearest road. Very little can be ascertained as to the amount of work done or conditions encountered underground, for the workings are completely caved. No cinnabar was found by the present party either in place or on the dumps, but according to Forstner [7] some was encountered in a tunnel in the northwest corner of section 1.

Kismet group.--The Kismet group of claims, which is little known and practically undeveloped, lies between the Little Bonanza and Cypress Mountain groups. It is on the main fault zone, near a small rhyolite plug. It contains outcrops of silica-carbonate rock, but very little cinnabar has been found in them.

7/ Forstner, William, op. cit., p. 156.

La Libertad.--The La Libertad mine--which will henceforth be called, in order to avoid an awkward clash of idioms, the Libertad mine--is about 22 miles from Paso Robles and 14 miles from Cambria, by fairly good roads. Its production is not known but may have been as much as 1,000 flasks. Local residents report that much of the quicksilver produced during the early history of the mine was recovered by retorting boulders of high-grade float. The mine workings, nearly all of which were accessible in 1940, are shown on plate 82.

As shown on plates 78 and 82, the mine lies within the Madrone-Cypress Mountain fault belt. With the exception of some silica-carbonate rock, serpentine, and a small body of unserpentinized basic igneous rock that crops out a short distance southeast of the main mine, the country rock consists of strongly brecciated Franciscan sediments. Most of the shear planes trend northwest, parallel to the fault zone, but the breccia is crisscrossed by numerous irregular veinlets of carbonate and quartz. Several bodies of silica-carbonate rock, two of them relatively large, crop out on the surface, and many smaller masses are exposed in the mine. Most of these bodies, whose texture shows them to be derived from serpentine, are elongate and are at least partly bounded by shear planes, but neither the shears nor the bodies themselves show any systematic orientation relative to each other or to the enclosing fault zone.

The principal mine workings develop a single irregular vein in silica-carbonate rock that trends a few degrees north of west, at an acute angle with the main fault. The vein zone dips steeply northward in most places, but in places the north dips are as low as 30°, and in other places the dip is toward the south. The average dip of the vein in its developed part is nearly vertical. The walls of the vein are almost everywhere sharply defined and marked by a few inches to 3 feet of black gouge or "alta," but locally, as in parts of the large stope on the lower or 1,663-foot level, the transition from vein to country rock is gradual. The vein pinches and swells because of its highly irregular strike and dip, its thickness varying from less than a foot to 30 feet or more.

The vein matter consists largely of quartz and carbonate, but the proportion of carbonate to quartz is somewhat higher than in average silica-carbonate rock, so that the ore is relatively soft. It contains much bright-green material, which imparts a lively green tint to most of the rock. Light- to dark-red cinnabar is widespread. Some of it is disseminated, or coats the walls of minor fractures, but most of it is associated with minor amounts of quartz in networks of small veins, few of them more than 1/8 inch in width. Late veins of quartz and calcite cut the ore in many places. Pyrite is present locally but is nowhere abundant.

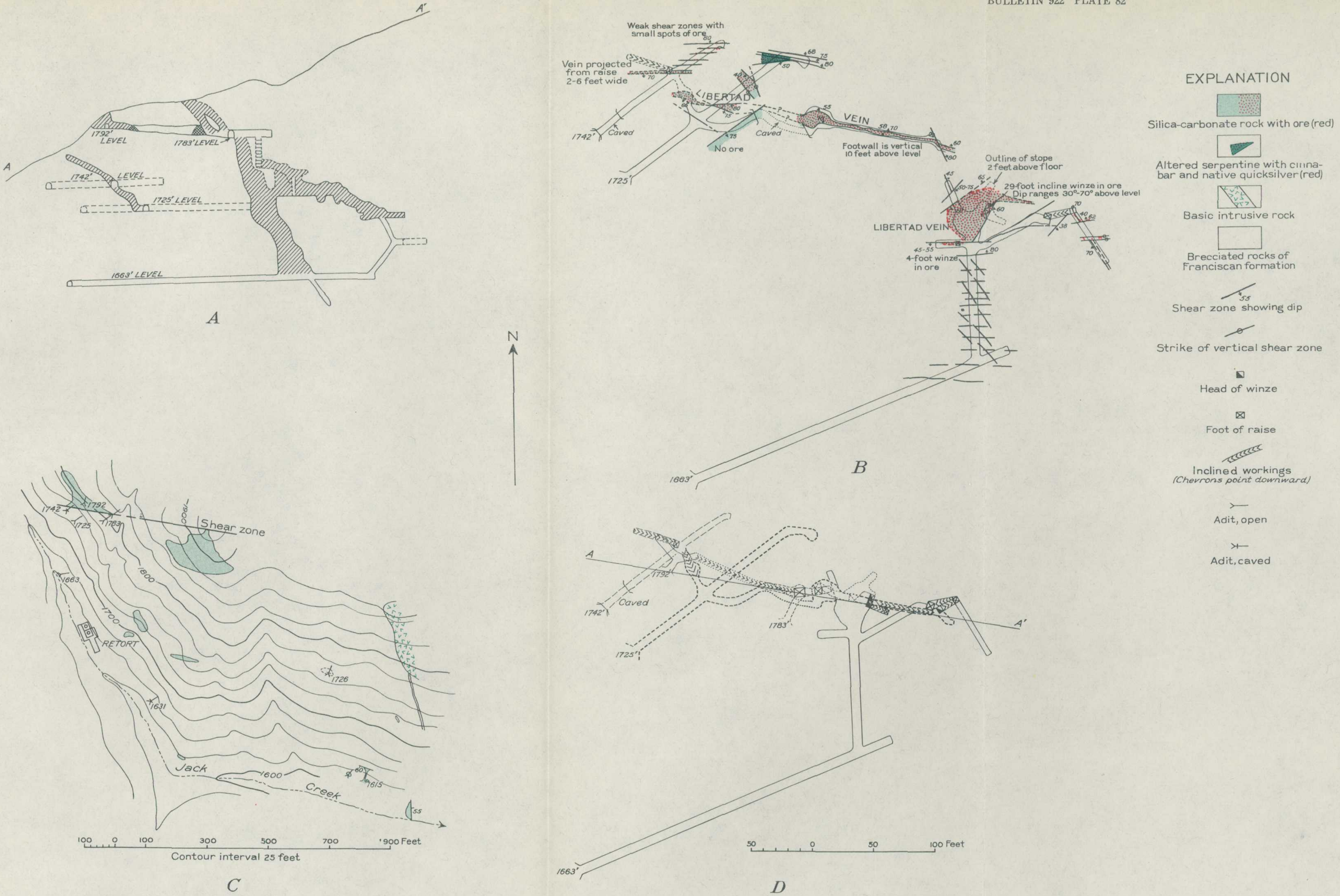
The geologic map and section (pl. 82, A and B) show clearly that most of the ore produced by the Libertad mine has been taken from a single short ore shoot that pitches steeply to the east. It has been developed through a vertical range of 170 feet, or 210 feet on the pitch, and is believed to extend even deeper, for the bottom of the winze below the lower level is reliably reported by the owner to have been in good ore. The main shoot is obviously controlled by a sharp change in the vein's direction. Local concentrations of ore within the shoot also occur at places where the vein changes in strike or dip and are commonly associated with low dips. The grade of the ore that has been produced is not known, but some of it is reported to have been very rich, and little of it seems to have contained less than 5 pounds of quicksilver to the ton.

Several small bodies of ore-bearing material not connected with the main vein are present in the mine, but none of them are rich enough to be workable. Most of them are narrow shear zones marked by a little silica-carbonate rock or by veinlets of cinnabar. The most interesting one is in the intermediate or 1,725-foot tunnel, where a small irregular body of altered serpentine contains disseminated specks of cinnabar and a little native mercury. The partly caved shaft near Jack Creek, 1,400 feet southeast of the main mine (pl. 82, C), is reported to have developed a narrow vein rich in cinnabar and metacinnabar. This vein is clearly distinct from the Libertad vein, but no further knowledge of its character or extent is available.

In June 1940 little or no commercial ore was in sight and the mine was temporarily inactive, but further exploration seems nevertheless to be warranted. It might be worth while to follow the main ore shoot downward or to search for additional ore shoots along the eastward extension of the vein zone or in other parts of the hill.

Little Bonanza group.--The Little Bonanza group, which includes the Little Bonanza, Alice, Modoc, and other claims, is just northeast of the summit of the Santa Lucia Range. It is connected by good roads with both Paso Robles and Cambria. The Little Bonanza is among the six most important mines in the county and was the first to be discovered. The accompanying maps (pl. 83) show essentially all the accessible workings. The properties are entirely within the fault breccia of the Madrone-Cypress Mountain belt.

The greatest amount of work has been done on the Little Bonanza, which has yielded considerable quantities of good ore. Three main ore bodies have been worked from a 600-foot adit that trends N. 77° E. from the portal. On the other properties several small bodies have been opened from small adits and open stopes.

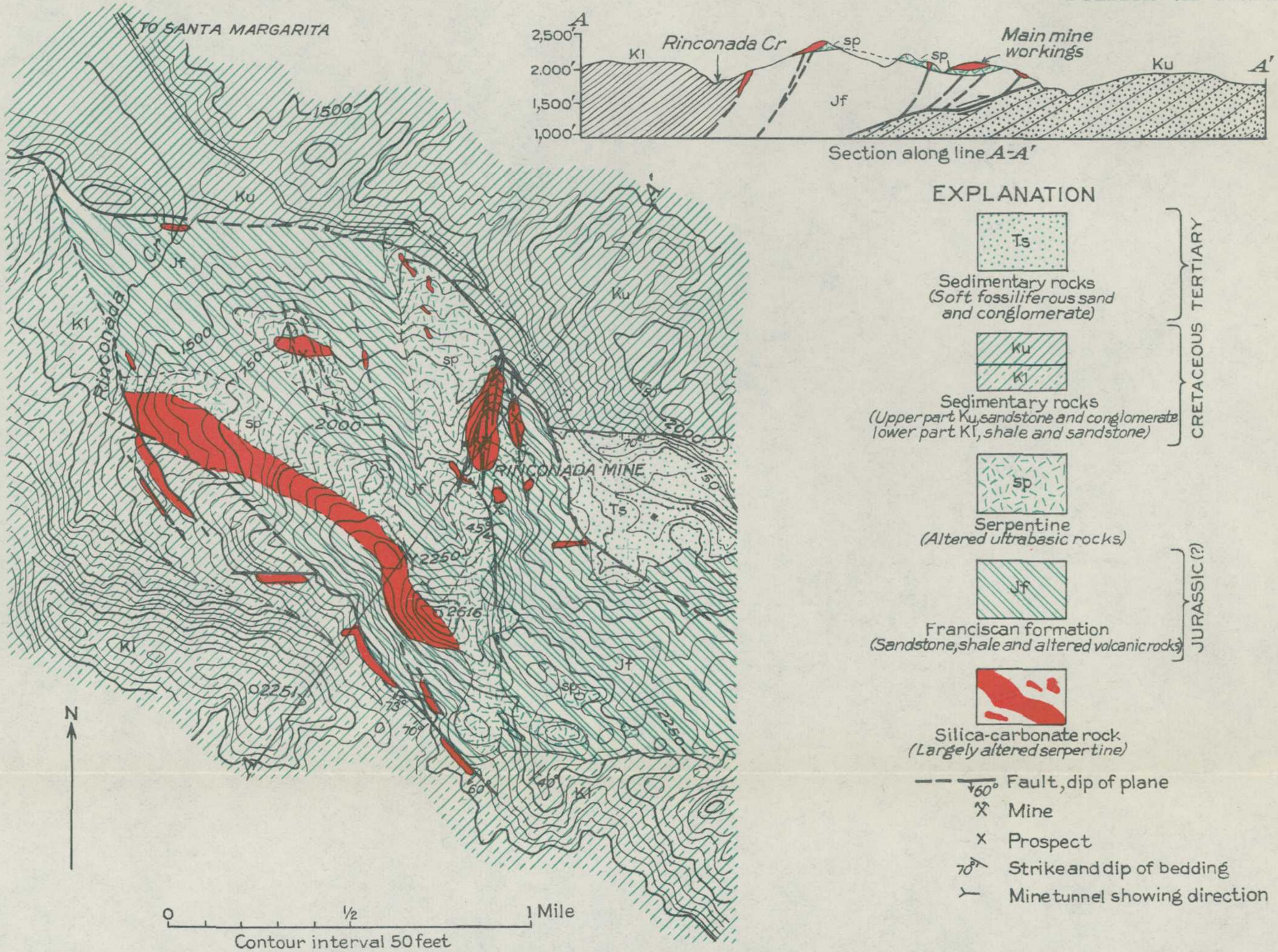


GEOLOGIC MAP AND SECTIONS OF THE LIBERTAD MINE AND VICINITY

A. VERTICAL SECTION-PROJECTION ALONG LINE A-A; B. MAIN LEVELS; C. AREAL GEOLOGY IN VICINITY OF MINE; D. COMPOSITE MAP OF WORKINGS

TYPICAL FAULT BRECCIA, AS EXPOSED IN MAIN TUNNEL OF LITTLE BONANZA MINE.

Note how shale and gouge wrap around fragments of sandstone (gray) and silica-carbonate rock (white). The silica-carbonate rock beneath the chute is part of the Little Bonanza vein.



GEOLOGIC MAP AND SECTION OF THE RINCONADA MINE AND VICINITY

The larger veins trend eastward and consist of discontinuous podlike masses of silica-carbonate rock and brecciated chert, arranged in steplike fashion. (See pl. 84.) Most of them dip about 40° N., though along local "rolls" the dips are as low as 20°. The ore shoots occur along these flat-dipping segments, where the veins are commonly wider than elsewhere. The shoots pitch about 45° E. Small pockets of good ore occur at some places in the hanging wall. Most of the high-grade ore, which forms rich bunches in the veins, is coarsely crystalline deep-red cinnabar associated with silica-carbonate rock. The lower vein in the Little Bonanza is mostly brecciated chert and contains average to low-grade ore in which cinnabar coats fracture surfaces. Throughout the mine the cinnabar occurs as veinlets or bunches of crystalline material, as "paint" on fracture surfaces, and intimately mixed with chalcedonic quartz. The constituents of the gangue, in order of abundance, are quartz, mixed carbonates, pyrite or marcasite, kaolin, green gouge, and hydrocarbons. The hydrocarbons are said to give trouble in the metallurgy of the ores. Most of the ore taken from the mine was in high-grade pockets, the position of which was nearly impossible to predict in advance of development.

There is very little ore in sight in the present workings of the Bonanza, but this does not necessarily mean that the deposit is exhausted. The lower vein (pl. 83) may possibly widen and become richer at depth. It is also possible that the Little Bonanza hill contains several other ore bodies, but only careful exploration could prove it.

Madrone.--The Madrone mine, which is the most southeasterly of those in the Madrone-Cypress Mountain belt, lies about half a mile southeast of the Libertad mine and may be reached by trail from either that mine or the Marquart ranch. The workings consist of a 125-foot vertical shaft and a 50-foot tunnel, both of which are open but in dangerous condition. The country rock is fault breccia, serpentine, and silica-carbonate rock.

The ore is in silica-carbonate rock and is very similar to that at the Bonanza mine. Very little could be ascertained as to the nature of the ore shoots, but they are reported to have produced some quicksilver with a Johnson-McKay retort. The average grade of the ore is low, although the early reports mention the presence of some small rich bunches. Free quicksilver is reported to have been found in the top soil around the mine. The property was last worked about 1900. The presence of a large body of silica-carbonate rock that contains scattered showings of cinnabar in several places suggests that further cautious prospecting would be justified.

Rinconada district

Geology

The Rinconada district comprises several widely scattered mines and prospects in the southern part of San Luis Obispo County. These are far removed from the main productive area in the northwestern part of the county, but they are on the same structural trend as the deposits there. Only two mines, the Rinconada and the Deer Trail, warrant description. The geology of the Rinconada mine and its vicinity is shown on plate 85.

Mines

Deer Trail.--The Deer Trail mine is 7 miles south of Hausana and 20 miles from Arroyo Grande, in southern San Luis Obispo County. The property was not visited, but the country rock is shown on the State geologic map to be Franciscan and is reported to be a metamorphosed and brecciated sandstone.[8] The ore consists of cinnabar enclosed in coarsely crystalline

8/ Bradley, W. W., op. cit., p. 133.

aggregates of calcite and is said to be extremely pockety. The deposit was discovered in 1915 but has been worked only now and then for short periods.

Rinconada.--The Rinconada mine, one of the larger producers in San Luis Obispo County, is easily reached from Santa Margarita over 11 miles of good roads. In addition to the extensive

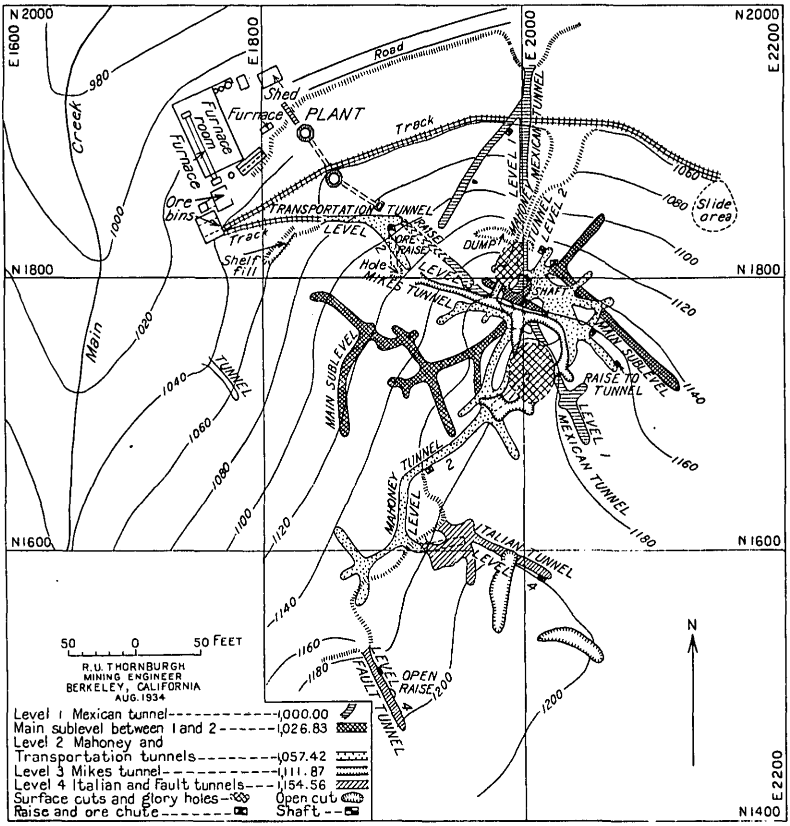


Figure 79.—Map of Rinconada mine. (Reprinted from California Jour. Mines and Geology, vol. 31, p. 452, 1935.)

workings shown in figure 79, the property has innumerable smaller open cuts and short adits, which have served to explore near-surface conditions over a large area. Except for minor exploratory work, the mine was inactive in 1940.

The geologic relations in the vicinity of the mine are shown in plan and section on plate 85. There it can be seen that a thick block of Franciscan rocks has been thrust over upper Cretaceous and Tertiary rocks along a northwest-trending fault that dips to the south at low angles. Lower Cretaceous shales have been brought against the upper, or southwest, margin of the block along a more steeply dipping fault that is doubtless related to the main thrust fault. The Franciscan is capped in many places by remnants of a warped sheet of serpentine. The upper part of this sheet is extensively altered to silica-carbonate rock, and similar rock has also replaced fault breccia in several places along the subsidiary fault that separates Franciscan from Lower Cretaceous shales.

With the exception of a few small widely scattered showings, the ore deposits are confined to the two bodies of silica-carbonate rock in the immediate vicinity of the Rinconada mine (pl. 85). There the rocks are cut by two sets of minor fractures. The stronger fractures strike from N. 10° W. to N. 20° E.; the others which are much weaker, strike northwestward. All of them are irregular in strike, and even more so in dip. The ore deposits, which consist of cinnabar and metacinnabar with pyrite and other minerals in a highly siliceous gangue, are intimately related to these fractures, more especially to those that trend north to north-northeast. Evidence of mineralization is so widespread that nearly every piece of rock over an area of about 12 acres shows cinnabar colors or yields them on panning. One principal ore shoot and several small ones have been worked. These are largely controlled by changes in dip of the enclosing fractures, but one occurred near the intersection of two strong fractures. Other ore shoots that do not crop out at the surface may possibly exist. Whether any of these extend beneath the sheet of altered serpentine is very uncertain. The widespread occurrence of cinnabar indicates that the ground merits further exploration and thorough sampling to determine whether it contains a large low-grade deposit.

Pine Mountain district

Geology

The Pine Mountain district, which includes the main ridge of Pine Mountain and its western flank, extends from the headwaters of San Simeon Creek, south of Rocky Butte, to a point about half a mile north of Pine Mountain proper. Here, as in most of the other districts, the major structural trend is northwesterly. A major fault zone, here called the Pine Mountain fault zone, extending along the east side of the ridge

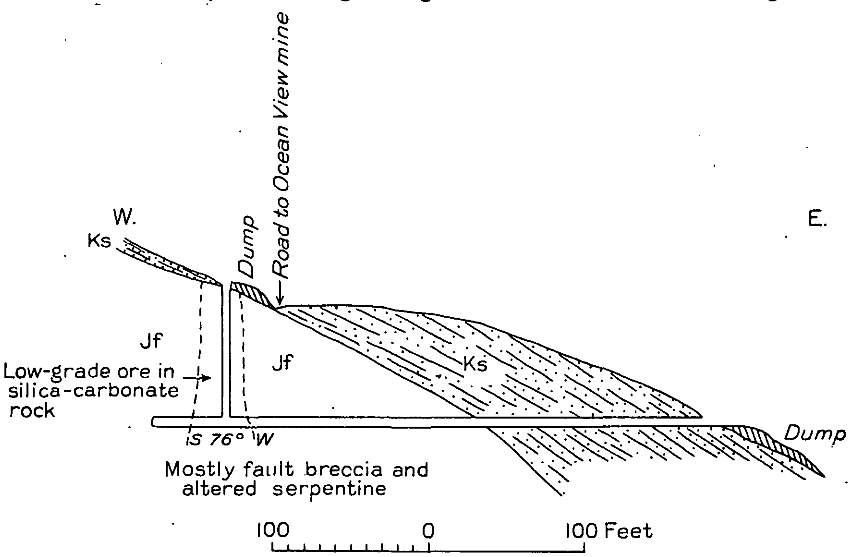


Figure 80.—Diagrammatic cross section through Buckeye mine. Jf, Franciscan formation; Ks, Cretaceous shale. (Underground data from California State Min. Bur. Bull. 27, pp. 152-153, 1903.)

separates Cretaceous rocks on the east from Franciscan on the west. A thin mantle of Cretaceous rocks overlaps the fault zone, in the vicinity of the Buckeye and Ocean View mines, which indicates that the major movement took place within Cretaceous time. (See fig. 80.) The elongate masses of rhyolite that form the tops of Rocky Butte, Pine Mountain, and several other lesser peaks have been intruded into this fault zone, completely filling it in places. Including the rhyolite, the zone is locally as much as 2,000 feet wide.

Between the Little Almaden mine and a point about half a mile northwest of the Ocean View, a total distance of 2 miles, there are considerable quantities of silica-carbonate rock in which cinnabar is widely but unevenly distributed. The richest known deposits in the district have been partly explored by the Ocean View, Buckeye, Pine Mountain, and Little Almaden mines, and undiscovered deposits may be hidden beneath slide rock or the mantle of Cretaceous shale. In part, at least, this fault zone represents the northwesterly extension of the Madrone-Cypress Mountain belt. It can be traced northwestward several miles beyond the Ocean View mine, but it is not mineralized there.

On the southwest flank of Pine Mountain, serpentine and Franciscan rocks are cut by a complex system of closely related northwest-trending faults, several of which are partly filled with rhyolite in the vicinity of Rocky Butte. The broadest and strongest individual fault can be traced from the Warren ranch prospect on San Simeon Creek to a point about a mile beyond the Keystone mine. The fault belt is limited on the southwest by a major fault along the east edge of the serpentine mass at Red Mountain. Poor exposures and numerous landslides prevent accurate mapping of most of the individual faults even within the mineralized area, which extends from near San Simeon Creek to the Doty mine. Southeast and northwest of this area the faults are virtually unmineralized and exposures are very poor, so that only a few scattered outcrops of fault breccia, whose relations to each other are uncertain, could be found.

Mines and prospects

Buckeye.--The Buckeye mine lies about half a mile southeast of the Ocean View and can be reached by a fair road. It is in the Pine Mountain fault zone, and its ore is similar to that of the Ocean View. The workings are mostly caved, and such ore as can be found on the dumps is of low grade. It consists of silica-carbonate rock containing finely disseminated cinnabar. Most of the workings apparently traversed barren Cretaceous shales, which overlie the fault zone in this locality and were but little affected by later fault movements. (See fig. 80.)

Doty.--The Doty mine, just north of the North Fork of Pico Creek, can be reached only by means of dim and almost impassable trails from Pine Mountain or Marmalejo Flats (see pl. 78). Little is known of its production or history beyond the fact that it had been inactive for many years prior to early 1940, when the claims were relocated. There was no activity in June 1940, and neither of the two adits, about 25 feet apart vertically, which explore the deposit, was then in condition to be examined safely. The lower one branches near the portal, one branch trending N. 35° E. for a distance of about 100 feet and the other trending N. 10° W. for about 40 feet. The upper adit trends due north for about 100 feet.

The mine explores the southwestern edge of a narrow elongate block of serpentine, which lies between two strong zones of fault breccia and is altered to silica-carbonate rock in many places. Specimens of ore on the dump consist of coarsely granular serpentine that has been almost completely replaced by carbonate and a minor quantity of quartz. Dark-gray to black wavy streaks are characteristic, as are veinlets of bright-pink dense quartz. Small amounts of cinnabar, and possibly of metacinnabar, form blebs and fill fractures. All the cinnabar seen is dark red and crystalline, but the ore in general is of low grade.

Hamilton.--The Hamilton mine, on the northwest side of San Simeon Creek, is easily accessible by means of a good secondary road. It has produced little if any ore, and nothing is known of its history; but the presence of seven or more caved tunnels, each of them 100 to 500 feet long, gives evidence that the deposit has been rather elaborately explored.

The main workings are all in a broad northwest-trending fault breccia consisting of strongly kaolinized sandstone and shale. Veinlets of brown carbonate are widespread, and there are a few small lenses of silica-carbonate rock. No ore was found in place or on the dumps, but according to the present owner some good ore was exposed in the uppermost workings. An ill-defined cross fault that is exposed on the ridge just southwest of the main mine seems to offer some promise, for it contains several fair-sized bodies of silica-carbonate rock in which crystalline cinnabar, accompanied by hydrocarbon compounds, can be seen in many places. This part of the deposit has been explored only by three shallow surface cuts.

Keystone.--The Keystone mine can be reached by road from San Simeon Creek. Except for a little exploratory work done during the first World War, the mine has not been worked since 1875, when it yielded 60 flasks of quicksilver. The old work-

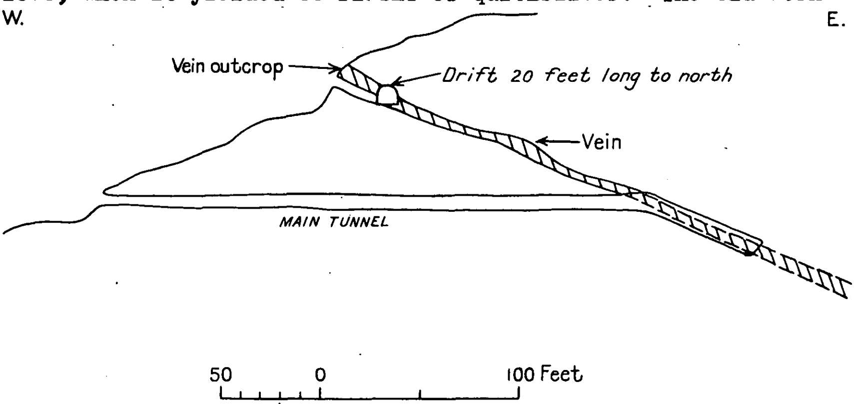
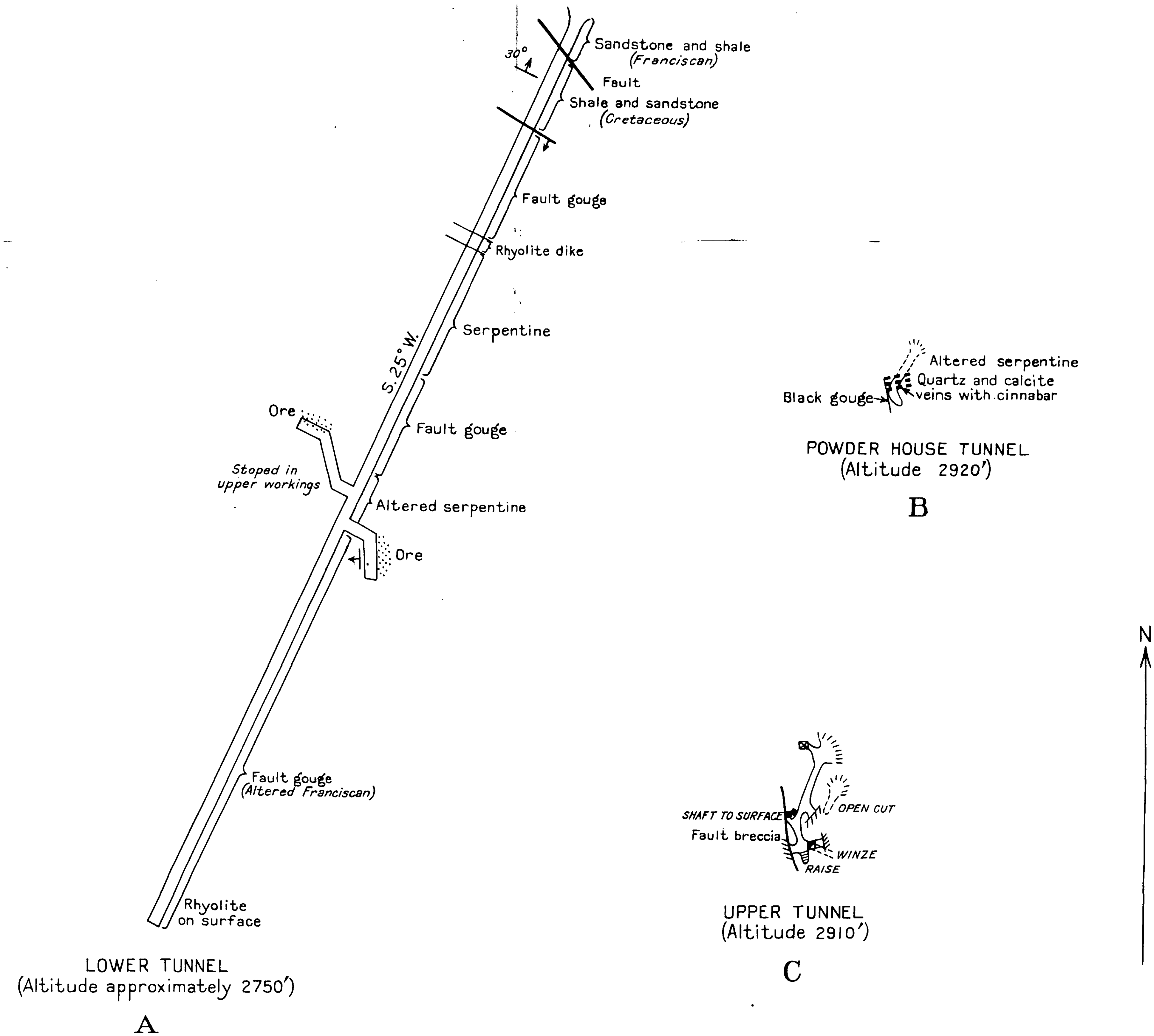


Figure 81.—Sketch section of Keystone mine showing probable relation of ore and workings.

ings, which are reported to have consisted of a 300-foot adit and a 50-foot winze, were caved at the time of examination. In June 1940 (fig. 81) plans had been made to reopen the lower workings, and ore from the outcrop was being burned in a small retort.



MAP OF PRINCIPAL WORKINGS, OCEAN VIEW MINE

200 0 400 FEET

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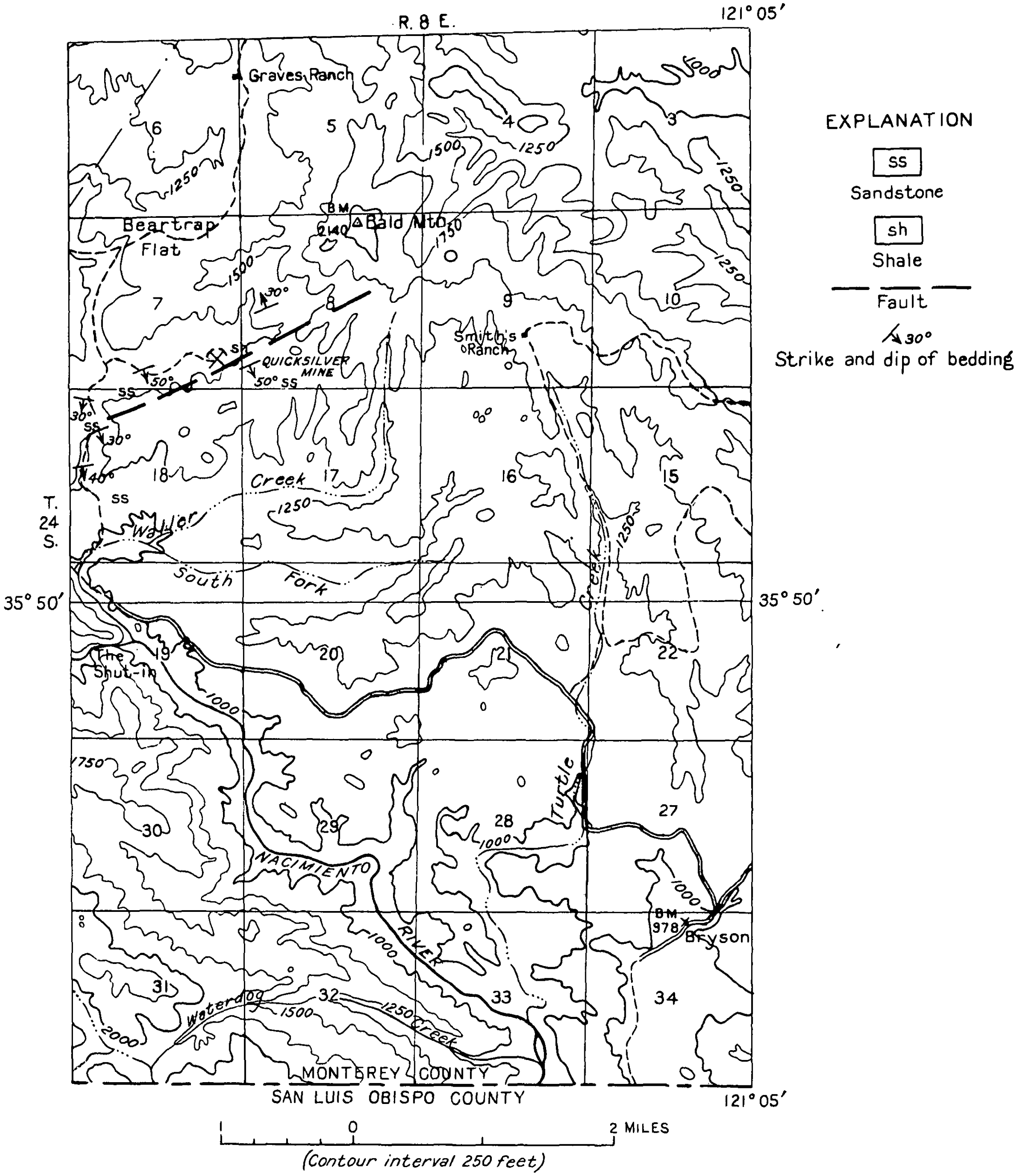

MAP SHOWING LOCATION AND GEOLOGY OF BRYSON DISTRICT

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Geologic relations at this mine are obscure because of the generally poor exposures in its vicinity. The ore deposit seems to be within or very close to a strong northwestward-trending fault zone. Its outcrop consists of a slab of silica-carbonate rock, 5 to 12 feet thick, that dips 20° to 35° into the hill and is flanked above and below by slightly mineralized fault breccia. The silica-carbonate rock contains small veins, rich bunches, and disseminations of crystalline cinnabar. Some of the ore that was extracted in June 1940 yielded as much as 20 pounds of quicksilver to the ton. The existence of good ore at the surface and reports that even richer ore was extracted from the winze on the lower level both seem to indicate that further exploration and development are advisable.

Little Almaden.--The Little Almaden prospect is the most southeasterly of the properties along Pine Mountain ridge. It lies about a mile southeast of the Ocean View mine and may be reached by road. The workings are largely open pits in a sheet of silica-carbonate rock that forms the upper part of an eastward-dipping sill-like mass of serpentine. The outcrop covers about 2 acres, and the maximum thickness of the sheet is about 20 feet. The ore is similar in character to that of the Ocean View, but that seen was of low grade. There is some possibility that the body of mineralized rock may dip eastward into the major fault zone and that some workable ore may be found at depth.

Ocean View.--The Ocean View mine is the most northwesterly and is also the most important of the Pine Mountain group. The workings are situated on the north side of Pine Mountain and can be reached by road. Early in 1940 few of the original 2,500 feet of tunnels, shafts, and crosscuts were accessible for examination, though plans were under way for reopening the mine and for extensive exploration. Available information in regard to the workings is shown on plate 86. The map of the lower tunnel is taken from Forstner,[9] with geologic interpretations and additions by the present writers.

Surface observations indicate that the mine is close to the intersection of two faults. One of them strikes N. 80° W. and is vertical or dips steeply toward the north. It separates Franciscan rocks on the north from Cretaceous on the south. The other fault, which trends N. 50° W., is part of the very broad Pine Mountain fault zone. It is filled by intrusive rhyolite at several places. The nearby intersection of these two faults may account for the concentration of cinnabar at the mine.

The first-mentioned fault is not mineralized; all the ore deposits lie along the other fault and within Pine Mountain fault zone. The ore is all in silica-carbonate rock derived from serpentine. Most of the cinnabar occurs in highly siliceous veins and veinlets, but some of it is disseminated. A few irregular masses of very rich ore, some of them a foot or more in diameter, can be found in the dumps. In these crystalline cinnabar is invariably associated with coarse-grained carbonate rather than with siliceous gangue. Nothing could be observed as to the nature of the ore shoots in this mine, but on early maps the ore bodies are shown to range from 10 to 15 feet in width and to dip steeply to the southwest.

No reliable predictions as to the amount or grade of available ore can be made. The widespread occurrence of cinnabar-bearing silica-carbonate rock and the medium- to high-grade character of much of the ore in place and on the dumps seem to justify the belief that further exploration is advisable; but the cost of prospecting for new ore bodies, or of mining out the ore bodies already partly developed, would doubtless be relatively high.

9/ Forstner, William, op. cit., p. 164.

Pine Mountain.--The Pine Mountain prospect is in the Pine Mountain fault zone, a few hundred feet south of the Buckeye mine. In addition to a 200-foot tunnel mentioned by Forstner,[10] the property was explored by several shorter adits and open cuts. Only one of the cuts exposed ore in place in 1940, but considerable ore can be found on the dumps. One or more comparatively large bodies of silica-carbonate rock are poorly exposed at the surface. The ore consists of streaks and irregular veinlets of brilliant-red cinnabar intimately mixed with a dense siliceous gangue. Pyrite is widely but sparingly distributed. Because of its highly siliceous character, the ore is doubtless lower in grade than it appears at first glance. Some of the ore will certainly yield at least 8 pounds of quicksilver to the ton, however, and further cautious exploration and development seem advisable.

Quien Sabe.--The Quien Sabe mine, on the south side of the North Fork of Pico Creek, like the nearby Doty mine, is accessible only by poor dim trails. It had been inactive for some years prior to 1940, and the principal workings, which are reported to consist of a 100-foot shaft and a 200-foot crosscut tunnel 230 feet below the shaft and 750 feet from it horizontally, were caved at the time of examination. Several open cuts are reported by Forstner [11] to have been situated a few hundred feet southwest of the shaft, but they were not found by the writers.

The mine is similar in most respects to the Doty mine, described above. The shaft and crosscut adit explore the northeastern side of the same body of serpentine as the Doty workings, which is here bounded by a broad zone of gougy fault breccia. The above-mentioned open cuts were along the southwestern side of this body, on a parallel fault. No ore was seen, but

10/ Forstner, William, op. cit., p. 165.
11/ Forstner, William, idem.

extensive bodies of silica-carbonate rock crop out along both sides of the serpentine. The ore was probably similar to that of the Doty.

Warren.--The Warren prospect is a new discovery on the Walter Warren ranch, about 5 miles above the mouth of San Simeon Creek. The workings, which are small open cuts, are on an east-west ridge directly across San Simeon Creek from the Hamilton mine and along the southwesterly edge of the fault zone explored by that mine. Cinnabar occurs in a body of brecciated chert as fillings or coatings along fracture surfaces and is in general of fair to low grade. No confident statement as to the size, shape, or grade of the ore body can be made prior to further development work.

Williams.--About half a mile east of the Keystone mine and in a broad northwest-trending fault zone, a hitherto undescribed body of very high grade coarsely crystalline cinnabar ore was found by the writers on what is known as the Williams prospect. The ore forms rich pockets in a vein, striking northwest and dipping 30° to 40° E., that is exposed for a few feet in an old trench but not exposed elsewhere. The lateral and vertical extent of the ore is thus unknown, but the showings are rich enough to warrant additional work.

San Carpoforo district

Geology

The San Carpoforo district lies northwest of the Pine Mountain district, in the northwest corner of San Luis Obispo County and the southern part of Monterey County. It is reached by a trail up San Carpoforo Creek from State Highway 1. The district has been relatively unproductive, though the deposits were first discovered in 1870. Prominent northwestward-trending faults, which probably are continuous with the Pine Mountain zone, affect the Franciscan rocks, in which all the mines are located. The Franciscan formation is represented in this district mostly by a typical grayish-green somewhat silicified sandstone. Two groups of widely separated claims cover the mineralized areas (see fig. 82), which are located on northwestward-trending fault zones.

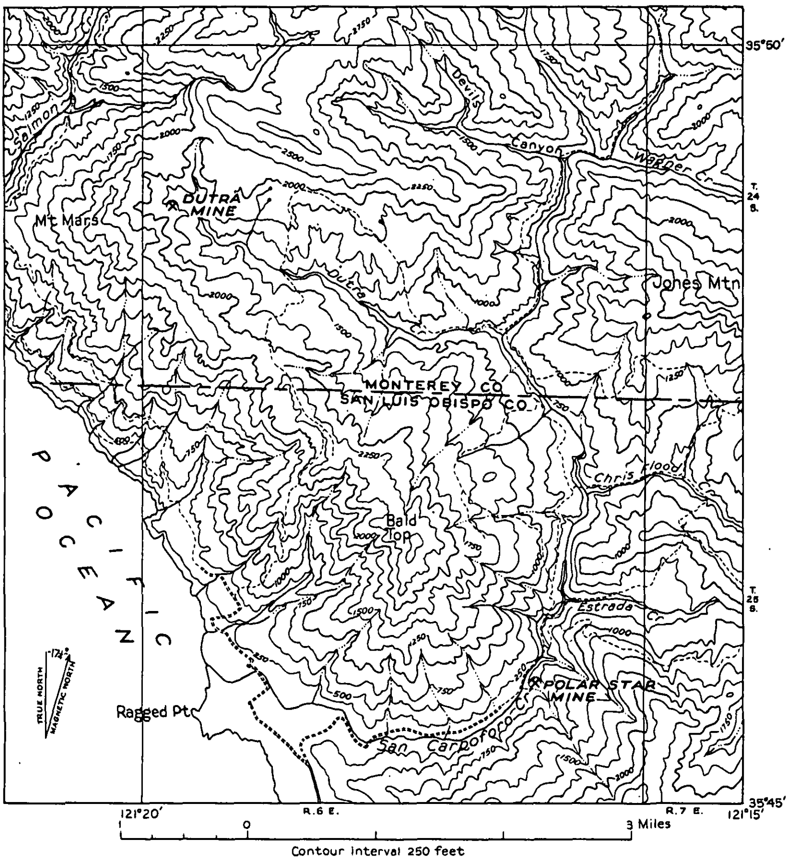

Figure 82.—Map showing location of San Carpoforo district.

Mines and prospects

Dutra.--The Dutra mine is at the head of Dutra Creek, a branch of San Carpoforo Creek, about 8 miles by trail east of State Highway 1, in southern Monterey County. The deposit was discovered about 1870 and was worked intermittently until about

1900. It is reported that between 10 and 15 flasks of quicksilver were produced, from ore of rather low grade. The property was not visited, but the workings are said to consist of two tunnels, both partly caved, and one open cut.

A fault zone about 100 feet wide, exposed for 300 feet along the strike, has been altered to silica-carbonate rock in the vicinity of the mine. Cinnabar occurs in the silica-carbonate rock, and some is disseminated in the sandstone country rock.

North Star.--The North Star claims lie southeast of the Polar Star and probably in the major fault zone. No production from them has been reported, and they have not been worked since 1900.

Polar Star.--The Polar Star lies about 3 miles upstream from the mouth of San Carpoforo Creek and about 100 feet higher than the creek bed. The deposit was discovered in 1870 and was worked from then until 1939. Production has been small, and nearly all the quicksilver produced was derived from float or surface ore, some of which is said to have been very rich. Because the steep slopes are much encumbered by landslides it is very difficult to reach bedrock, and the veins from which the cinnabar is derived have not yet been found, although the northwestward-trending fault zone that contains them is exposed in several places. A tunnel driven 50 feet into fault gouge was accessible in 1940 but had encountered no ore. The gangue of the ore, like that of much other ore in the region, is fairly siliceous silica-carbonate rock. The surface indications would seem to justify continued development work, but much exploration would be required to determine the character and size of the deposits.

Sunset View.--The Sunset View lies southeast of the North Star. No production from it has been reported.

Bryson district

Only one ore deposit is known in the Bryson district, which is several miles north and east of the main productive area in San Luis Obispo County (fig. 74 and pl. 87). This deposit is on the south side of Sycamore Creek, a tributary of the Nacie-mento River, 4 miles northwest of Bryson by air line but about 8 miles distant over the present road and trail. The deposit has been worked intermittently for several years, and an unknown but probably small amount of quicksilver has been produced from an 8-pipe retort. The mine was inactive in June 1940 but had been worked by the owner for a short time earlier in the year. The mine workings, which consist of 10 or more open cuts and crosscut adits from 10 to 100 feet in length, explore an area of several hundred square yards through a vertical range of about 100 feet.

The rocks exposed in the vicinity of the mine consist of coarse-grained conglomeratic sandstone and bituminous shale and siltstone. All are of late Cretaceous age. The principal structural feature is a northeastward-trending fault zone, which brings coarse-grained sandstone on its southeast side against shale on the northwest. According to Taliaferro [12] this is a tear fault that extends between two major northward-trending thrust faults. At and near the mine the fault zone dips 45° to 80° NW., or nearly parallel to the hill slope on which the mine is situated, and is from 10 to 50 feet thick. The rocks within it are sheared and brecciated in verying degree.

Cinnabar is widely distributed as scales and crusts along fractures in the breccia. Crystalline pyrite also is wide-spread, but none was seen in close association with cinnabar. Many pieces of coarsely crystalline white calcite were found in

12/ Taliaferro, N. L., personal communication.

ore piles near the old retort. These contain considerable quantities of cinnabar as grains along cleavage planes and as crystals and grains in vugs. The soil on the hill slope near the mine and the stream gravels of Sycamore Creek are known to contain grains and nuggets of nearly pure cinnabar in places. All indications thus seem to point to the possible presence of a relatively large body of low-grade ore, but this could be proved only by further sampling and exploration.

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