CALIFORNIA STATE MINING BUREAU
FERRY BUILDING, SAN FRANCISCO

FLETCHER HAMILTON — State Mineralogist

San Francisco] BULLETIN No. 78 [May, 1918

Quicksilver Resources of California

WITH A SECTION ON

METALLURGY AND ORE-DRESSING

By
WALTER W. BRADLEY, E. M.

CALIFORNIA STATE PRINTING OFFICE
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LETTER OF TRANSMITTAL.

To His Excellency, the HON. WILLIAM D. STEPHENS,
Governor of the State of California.

SIR: I have the honor to transmit herewith Bulletin No. 78 of the State Mining Bureau, on the Quicksilver Resources of California.

In addition to data relating to the mines and plants of the state, gained from field work of the Bureau's staff, this bulletin contains detailed information relative to the treatment of quicksilver ores. Much of this last-mentioned data is new, and the result of original research by the author, conducted in co-operation between the State Mining Bureau and the Department of Metallurgy of the University of California, with some data also from the U. S. Bureau of Mines Experiment Station.

California's quicksilver industry being a vital American resource in the present, great world-war, the issuance of this bulletin is particularly opportune at this time.

Respectfully submitted.

FLETCHER HAMILTON,
State Mineralogist.

May 22, 1918.

PREFACE.

The bulletin presented herewith is the combined results of several seasons' field work by the State Mining Bureau during the past four years, brought down to date by field observations of the author during September and October, 1917. It also includes the results of laboratory and mill-test investigations of the author relative to the ore-dressing and metallurgy of quicksilver. Because of the agitation for, and inquiries as to the possibilities of improved ore-dressing and metallurgical methods, and because of the desirability of publishing these results at an early date, most of the time of the author available for this work was given to a study of these phases of the subject rather than to a further detailed study of the geological phases. For these reasons, as to geological data we have drawn freely upon previously published reports, particularly the very detailed accounts of Becker[1] and Forstner[2], and have also utilized in part, quicksilver data in the more recent county reports[3] issued by the State Mining Bureau, as follows: Counties of Colusa, Fresno, Kings, Lake, Monterey, Napa, San Benito, Solano, Sonoma and Yolo, by the present author; Siskiyou and Trinity, by G. Chester Brown; San Benito and San Luis Obispo, by C. A. Logan; Santa Barbara and Santa Clara, by Emile Huguenin; Stanislaus, by F. L. Lowell.

The author wishes to here acknowledge the uniform courtesy of the various mine owners, operatives, and company officials, and especially the hearty co-operation of those who assisted with ore samples and suggestions during the course of our metallurgical investigations. Specific mention of these latter is given in the introduction to the section on metallurgy and ore-dressing.

WALTER W. BRADLEY.

San Francisco, May 15, 1918.

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[1]Becker, G. F., Geology of the quicksilver deposits of the Pacific Slope: U. S. Geol. Surv. Mon. XIII, 1888.
[2]Forstner, Wm., Quicksilver resources of California: Cal. State Min. Bur., Bull. 27, 1903.
[3]See under Bibliography.

PART I.

Chapter I.

INTRODUCTION.

USES.

The important uses of quicksilver are the recovery of gold and silver from ores by amalgamation, the manufacture of fulminate for explosive caps, of electrical appliances and scientific apparatus, and in the preparation of drugs, vermilion, and an anti-fouling paint for ships' bottoms. Another interesting use to which quicksilver is also put, though in which it is not 'consumed,' is as a floating bearing for the revolving lenses of lighthouses. About 600 pounds of quicksilver are required (depending on the size of the light)—being placed in a circular groove or channel. The lens or lighting unit is set on a pontoon which, in turn, rests and revolves on the mercury. As the metal is not consumed, the loss after installation is insignificant. By far the greatest consumption of quicksilver is in the manufacture of fulminate and of drugs. The increased adoption of the cyanide process in place of amalgamation in the treatment of gold and silver ores has materially decreased that demand for quicksilver of recent years, particularly in the western United States and in Mexico. The newest use for quicksilver is the introduction of a small amount into the cylinders of steam turbines to improve the vapor pressure and thus increase efficiency.

Quicksilver is an absolutely essential element at the present time from a military standpoint, as there have been produced as yet only partial commercial substitutes for it in the manufacture of fulminating caps for explosives. However, in order to reduce consumption of the fulminate, some potassium chlorate, picric acid, trinitro-toluol, or tetranitro-methalamine is at present being mixed with it.

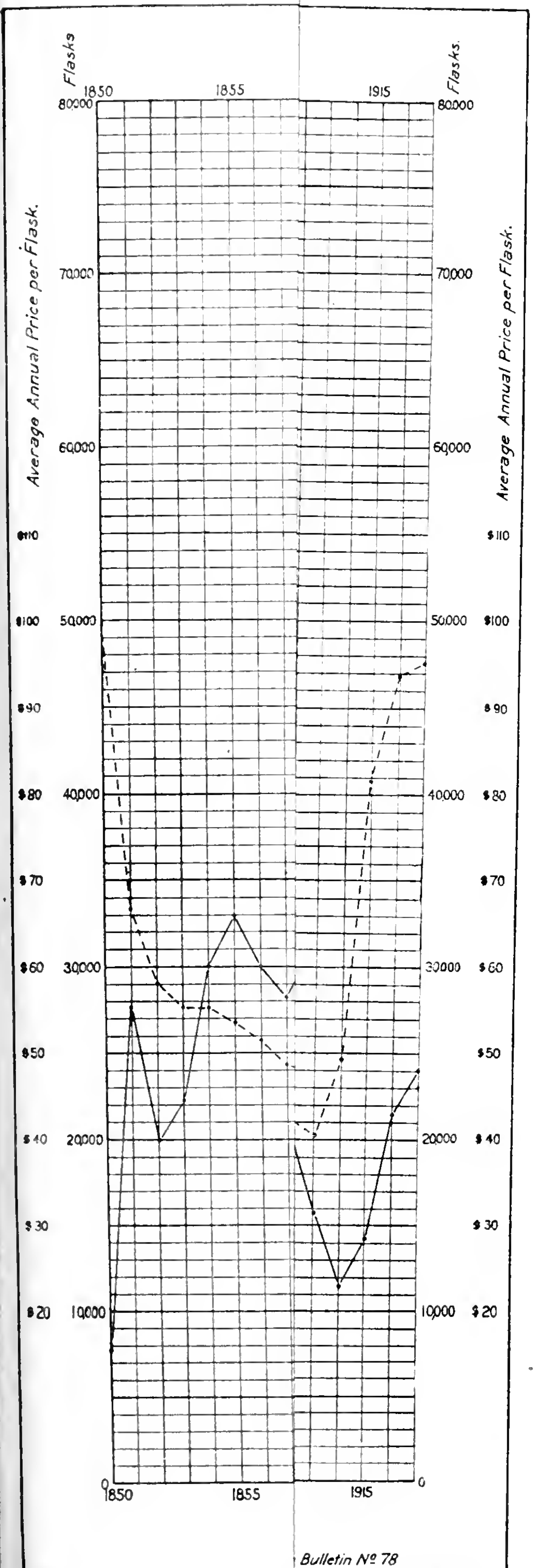
PRODUCTION and PRICES.

There are no available data on the quicksilver output of California earlier than for the year 1850, though the New Almaden mine in Santa Clara County was first worked in 1824, and has been in practically continuous operation since 1846 (the yield, however, being small the first two years). Total amount and value of the quicksilver production of California, as given in available records, is shown in the following tabulation, originally compiled by the writer[1] in the 1915 statistical bulletin of the State Mining Bureau. In compiling this table the following sources of information were used: For 1850-1883, table by J. B. Randol,

[1]Bradley, W. W., California mineral production for 1915: Cal. State Min. Bur., Bull. 71, p. 35, 1916.

in Report of State Mineralogist, IV, p. 336; 1883-1893, U. S. Geological Survey reports; 1894 to date, statistical bulletins of the State Mining Bureau; also State Mining Bureau, Bulletin 27, "Quicksilver Resources of California," 1903, reprinted 1908, p. 10. Previous to June, 1904, a 'flask' of quicksilver contained 76½ pounds (the equivalent of 75 *libras*, or Spanish 'pounds'), but since that date 75 pounds, net.

Photo No. 1. A shipment of 300 flasks of quicksilver from the New Idria Mine, San Benito County.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Flasks.
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1850
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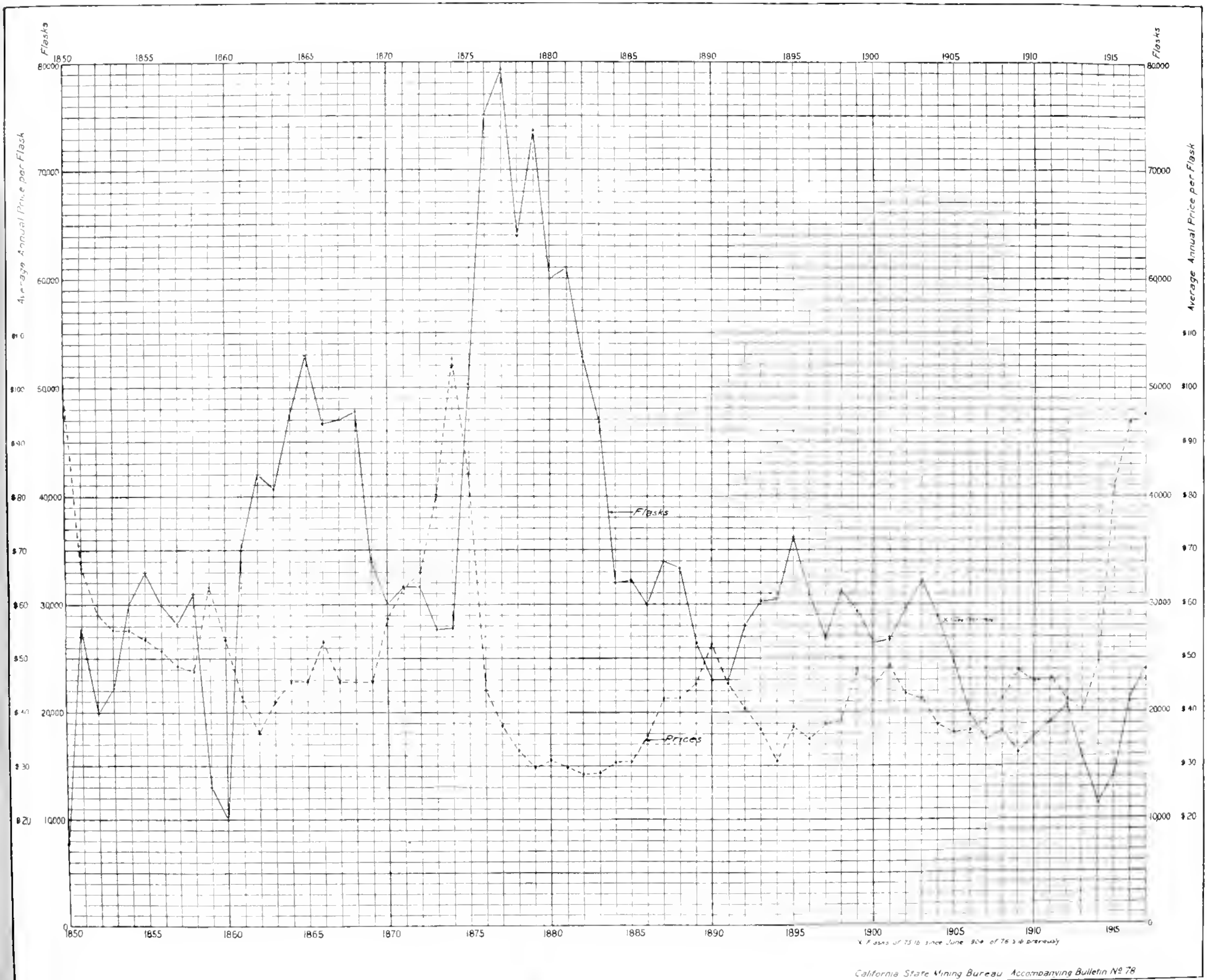
Bulletin No 78



PRODUCTION AND PRICE OF QUICKSILVER IN CALIFORNIA, 1850–1917.

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TOTAL QUICKSILVER PRODUCTION OF CALIFORNIA.

Year	Flasks	Value	Average price per flask	Year	Flasks	Value	Average price per flask
1850	7,723	$768,052	$99 45	1885	32,073	$986,245	$30 75
1851	27,779	1,859,248	66 93	1886	29,981	1,064,326	35 50
1852	20,000	1,166,600	58 33	1887	33,760	1,430,719	42 38
1853	22,284	1,235,648	55 45	1888	33,250	1,413,125	42 50
1854	30,004	1,663,722	55 45	1889	26,464	1,190,880	45 00
1855	33,000	1,767,150	53 55	1890	22,926	1,203,615	52 50
1856	30,000	1,549,500	51 65	1891	22,904	1,036,406	45 25
1857	28,204	1,374,381	48 73	1892	27,993	1,139,595	40 71
1858	31,000	1,482,730	47 83	1893	30,164	1,108,527	36 75
1859	13,000	820,690	63 13	1894	30,416	934,000	30 70
1860	10,000	535,500	53 55	1895	36,104	1,337,131	37 04
1861	35,000	1,471,750	42 05	1896	30,765	1,075,449	34 96
1862	42,000	1,526,700	36 35	1897	26,691	993,445	37 28
1863	40,531	1,705,544	42 08	1898	31,092	1,188,626	38 23
1864	47,489	2,179,745	45 90	1899	29,454	1,405,045	47 70
1865	53,000	2,432,700	45 90	1900	26,317	1,182,786	44 94
1866	46,550	2,473,202	53 13	1901	26,720	1,285,014	48 46
1867	47,000	2,157,300	45 90	1902	29,552	1,276,524	43 20
1868	47,728	2,190,715	45 90	1903	32,094	1,335,951	42 25
1869	33,811	1,551,925	45 90	1904	*28,876	1,086,323	37 62
1870	30,077	1,725,818	57 38	1905	24,655	886,081	35 94
1871	31,686	1,999,387	63 10	1906	19,516	712,334	36 50
1872	31,621	2,084,773	65 93	1907	17,379	663,178	38 16
1873	27,642	2,220,482	80 33	1908	18,039	763,520	42 33
1874	27,756	2,919,376	105 18	1909	16,217	773,788	47 71
1875	50,250	4,228,538	84 15	1910	17,665	799,002	45 23
1876	75,074	3,303,256	44 00	1911	19,109	879,205	46 01
1877	79,396	2,961,471	37 30	1912	20,600	866,024	42 04
1878	63,880	2,101,652	32 90	1913	15,661	630,042	40 23
1879	73,684	2,194,674	29 85	1914	11,373	557,846	49 05
1880	59,926	1,857,706	31 00	1915	14,199	1,157,449	81 52
1881	60,851	1,815,185	29 83	1916	21,427	2,003,425	93 50
1882	52,732	1,488,624	28 23	1917	24,382	2,396,466	98 29
1883	46,725	1,343,344	28 75				
1884	31,913	973,347	30 50	Totals	2,137,728	$101,992,560	

*Flasks of 75 pounds since June, 1904; of 76½ pounds previously.

The accompanying chart (Plate No. I), shows graphically the fluctuations in the annual output by flasks and the average annual prices. Previons to the high prices induced by the present war situation, the high-water mark in the price of quicksilver in California was reached in 1874 (the highest quotation being $118.55 per flask), with $105.18 the average San Francisco figure for that year. This was preceded by an average of $80.33 in 1873, and followed by $84.15 in 1875. The following year it dropped to $44.00. The low record sales price was $25.25 in 1879, but 1882 was the lowest year, with an average of $28.23. A study of the production chart (Plate I) reveals several interesting features. It will be noted that the two highly productive periods, 1861-1869 and 1875-1883, were accompanied by low prices, though each was immediately preceded by a sudden increase of price. The increased production at the present time is responding, in a measure, to the stimulus of the higher prices of the past three years; but, even at that, the production has not yet attained the level of the period

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1892-1904, a period of fair activity in quantity of output but of relatively low average prices. Some of the reasons for this failure to fully respond to this stimulus are discussed in succeeding paragraphs.

The changed economic status of quicksilver since the European war began led the writer to plot the second chart, herewith, (Plate II) of the average monthly San Francisco quotations since January, 1914, as published by the Mining and Scientific Press. The weekly averages are also shown, for the period of the record peak in December, 1915-April, 1916, and the highest day's quotation during the third week in February, 1916. During that period there were some actual, *bona fide* sales made in San Francisco at close to the $300 mark per flask; and at the same time a figure of $340 per flask was quoted on the New York market. The fall was as rapid as the rise, so that in spite of such previously unheard-of extremes, the average price for 1916 did not come up to the record of $105.18 for the year 1874. The chart (Plate II) shows most strikingly the sharp fluctuations in price.

As San Francisco is the primary domestic market for quicksilver, the average yearly quotations on this market were, previous to 1914, used by the State Mining Bureau (and the U. S. Geological Survey, also) in calculating the value of the state's output of this metal. However, because in 1915-1917 there was considerable speculation in quicksilver by parties other than the actual producers (particularly in 1916), and the price changes often rapid, so that quotations did not always mean sales, we have for these years taken for the average 'value' the average actual sales as reported to the State Mining Bureau by the producers. This gave us an average value of $81.52 per flask for the year, 1915, instead of the $85.80 average of quotations; $93.50 for 1916, instead of $125.89; and $98.29 for 1917, instead of $106.33.

PRESENT ECONOMIC SITUATION.

Recent consular reports[1] indicate that the output of the famous mines of Almaden, Spain, has decreased somewhat, and the expense of operation increased. These mines are owned by the government and operated under contract by lessees using convict labor. At the time of the above-mentioned report bids were being called for by the Minister of the Treasury for new leases for working the deposits, and additional capital expenditure and exploration work were to be required. The cost of production of quicksilver at Almaden is stated to have increased from $8.29 per flask in 1900 to $15.22 in 1915.

For two or three years previous to the outbreak of the European war, our normal peace-times consumption of quicksilver in the United States was approximately 25,000 flasks annually; and our domestic produc-

[1] U. S. Commerce Reports, No. 298, Dec. 20, 1916, p. 1079; Annual Series No. 15B, June 22, 1917, p. 33.

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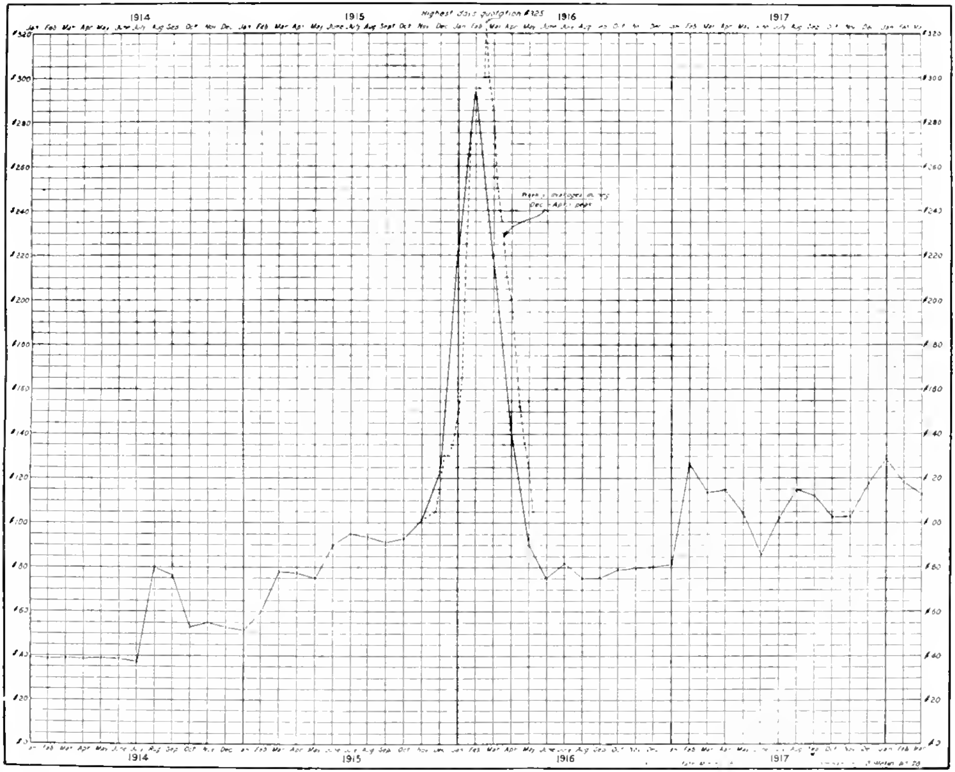

MONTHLY AVERAGE QUICKSILVER QUOTATIONS AT SAN FRANCISCO, CALIFORNIA, JANUARY, 1914–FEBRUARY, 1918, INCLUSIVE.

tion had fallen below 20,000 flasks per year (16,548 flasks in 1914, of which California produced 11,373 flasks). Of this 25,000 flask peace-time consumption, nearly 50 per cent went into the manufacture of fulminate for explosive, detonating caps for mining, quarrying, and sporting arms ammunition as well as military ammunition. Our domestic output being inadequate, partly because of the low price and the lower average tenor of the ores mined, necessitated the importation of several thousand flasks annually (6,300 in 1911; 1,100 in 1912; 2,280 in 1913; 8,200 in 1914). The enormous increase in munitions manufacture due to the war has obviously raised our requirements correspondingly. At the same time, imports from European sources have been, of course, curtailed, if not entirely cut off ere this.

The import duty of 10% *ad valorem* is not sufficient to protect our American miners against the competition of the convict-operated mines of Spain where quicksilver can be produced for as low as $8-$15 per flask, as noted above. Nor can we compete with the government-owned and operated mines of Idria, Austria, nor with the Italian mines where labor is also cheap. To give us proper protection the import duty should be at least 25% of the selling price in the United States, as *ad valorum* duties are based on cost values at the point of origin.

The present improvement in the price has increased the number of operating properties in California. Lower grade ores are being worked; and new methods of ore dressing and reduction are being tried, as discussed in the chapters herein on Metallurgy. But, in spite of the inducement of high prices, the output for the year 1917, was barely double that for 1914, both for California and for the entire United States; and, even at that, has not yet regained the level of the annual production for the years 1892-1904, though the prices for those years were relatively low. The most important, single reason for this is the lower grade of the ores, which in turn, requires a greater capital outlay for large-capacity equipment to handle commercial tonnages, and closer economy of operations. Capital hesitates to make such large investments where the maintenance of good prices is so uncertain. The conditions prevailing in the domestic quicksilver industry preceding the European war were well summarized by McCaskey[1] in 1912:

"Owing to the generally low prices prevailing, the domestic quicksilver industry was not particularly prosperous in 1912. The great majority of the producers are operating old mines in which high grade ore is now rarely encountered, and there were no new rich ore shoots reported for the year. In most cases special skill is required to prevent the plants running at a loss. * * * Although each well-developed property is equipped with its own plant and presumably run at lowest costs, the margin of profit in many cases is so small upon low-grade ores that during periods of low prices the mining activity is likely to be considerably curtailed. * * * It is true that further improvements in metallurgical treatment, particularly in preventing furnace losses, should result in a better margin of profit. But little

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improvement can be made with low market prices and uncertainty of ore supplies. The domestic market for quicksilver appears to demand from 20,000 to 25,000 flasks for consumption per annum. The foreign market is not profitable to American producers in competition with large European supplies available at lower prices. At low prices and normal output there is little importation, but at high prices importation of foreign supplies reacts to curtail output by cutting prices to a low margin of profit. It would seem, therefore, that unless rich ore, workable under favorable conditions at a large profit, be available, or industrial chemistry find new uses for the metal and an increase in domestic demand results thereby, the present producers must continue to operate under somewhat unfavorable conditions, and new producers and small mines must compete with established mines and plants now operated presumably at minimum costs and with special skill and knowledge of the art."

Accurate and reliable cost data as to mining and reduction of quicksilver in California are practically unobtainable except in the case of two or three of the larger operators. The others simply do not know what their per flask costs are, for lack of keeping properly segregated accounts. However, some approximations can be stated.

In 1914, the 'operating costs' of the larger companies amounted to about $35 per flask of quicksilver produced. This did not include interest, depreciation, amortization, etc. For the smaller operators the costs were relatively higher, and the market price having dropped to below $40 per flask ($37.50 average for July, 1914), but few properties were working. Present costs (January, 1918) are nearly doubled, even for the larger operators, and probably more than doubled for the smaller fellows.

Not only have the costs of supplies and labor increased all along the line, but it is extremely difficult to get or to keep skilled and reliable labor for either underground or reduction operations, in the quicksilver mines. This is in part due to the attractions offered by the extreme, high wages being paid at present in other lines, especially in the copper mines. This, too, is coupled with a decreasing efficiency of the laborers due to their increasing 'independence' and the spread of the 'I. W. W.' spirit among them.

The continued maintenance of the present output is problematical, not only by reason of the foregoing circumstances, but from the standpoint of the uncertainties of the deposits themselves. With two exceptions (New Almaden mine, lowest level 2450 feet below outcrop; and New Idria mine, lowest level 1060 feet below outcrop), the deposits are rather shallow.

Writing in 1887, Becker[1] took a somewhat similar view:

"I can not say that the future of the quicksilver industry on the Pacific slope seems to me to be very hopeful. The trouble is not in the lack of cinnabar, but in the mechanical disintegration of the country effected by the Post-Neocomian upheaval. To this are due the great irregularity of the deposits, the dissemination of cinnabar in minute fissures, or as 'paints,' in the language of miners, and the small average size of the deep-seated veins. Deposits may somewhere be found in firmer or less fissured rock, but there only can strong, simple fissure veins be expected to prevail in depth. Such deposits are exceptional everywhere. In the Almaden district [Spain] ore is known to occur at over seventy points, but at only one of them was the accumulation great enough to supply the world with mercury for thousands of years. The

[1]Becker, G. F., Geology of the quicksilver deposits of the Pacific Slope: U. S. Geol. Surv., Mon. XIII, pp. 417-418, 1888.

Santa Barbara, at Huancavelica [Peru], too, was one of over forty known deposits in the same district. Systematic and intelligent prospecting is even more needful in mines on the Coast Ranges of California than elsewhere, and the special attention of superintendents should be directed to a study of the fissure system. This will almost invariably be complex, and can be satisfactorily made out only by daily study as the work progresses. When a large part of the mine is abandoned or closed, it is often impossible to find the key to the true distribution of the fissures and of the ore chambers which accompany them. Helpless groping, discouragement, and often abandonment of property which probably contains treasures often follow. An increase of geological skill in the management of quicksilver mines would do much to offset the unfortunately capricious distribution of ore. Good civil and mechanical engineering is necessary, but not sufficient, to make the best of a quicksilver mine, nor can occasional assistance supply the place of enlightened daily study of geological structure. There is nothing novel in this warning, nor is there any probability that so trite a piece of common sense will be heeded."

This may seem a somewhat pessimistic view to take of the situation, but the record of annual production since that time shows that Becker was not very far wrong. The districts here, in which from a geological standpoint other and new deposits might be looked for, are almost entirely held now under agricultural patents, so that there is no inducement for the prospector to search for undiscovered ore bodies. The average tenor of the ores now being worked is extremely low, the larger operators handling materials which carry but 0.3%–0.7% mercury.

Under the circumstances, to allow at least a 25% margin of profit over total costs is decidedly conservative at the present time. With a production cost approximating $80 per flask for the 'average operator,' this would mean a minimum sales price of $100 per flask. We consider that at the present time a price of $100–$150 per flask is not unreasonable. Without a maintenance of these prices, the maintenance of the output is very uncertain.*

One particular item of operation expense that has raised, in addition to the labor situation noted above, is that of fuel. Forstner[1] showed figures in 1903 of from $3.50 per cord for pine to $5 per cord for oak, in the more favorably situated districts. Present costs are as much as 50% in excess of the above, depending on the locality.

"Quicksilver furnaces are great consumers of wood, and even those mines which are located in well-timbered regions find the cost of their fuel steadily increasing. Only in exceptional cases can mines get their cordwood delivered for $3.50 per cord; generally the price is higher, in some cases double that figure. Hence most of the quicksilver mine managers are eagerly looking for a substitute for cordwood as fuel in their furnaces. Up to the present time, however, this has not been found."

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*Since the above was written, the Federal Government is taking 40% of the domestic quicksilver production at a specified price of $105 per flask. Producers are permitted to obtain whatever price they may from other consumers. Since which time, the quotations in the open market have ranged between $110 and $115 per flask.

[1]Forstner, Wm., Quicksilver resources of California: Cal. State Min. Bur., Bull. 27, pp. 10, et al., 1903.

Since Forstner wrote the above a commercial substitute for cordwood has been found in crude petroleum. Fuel oil has now been in use for a number of years at the New Idria mine, San Benito County, and more recently adopted at New Almaden, Santa Clara County; at the Cloverdale and Great Eastern mines, Sonoma County; and for firing a 12-pipe retort at the Cuddeback mine, Kern County. Fuel-oil prices are at the present writing practically double what they were three years ago. Further details as to fuel and other costs are given elsewhere herein in the accounts of individual properties.

CHAPTER 2.

GENERAL GEOLOGY OF THE DEPOSITS

AND THEORIES OF ORE DEPOSITION.

Geographical distribution.

The quicksilver districts of California, which have thus far proven of commercial interest are mainly in the Coast Ranges, from Lake County on the north to Santa Barbara County on the south. Other, scattered occurrences, some of which have yielded commercial quantities of the metal, will be noted on the outline map (Plate III), as being in Del Norte, Siskiyou, Trinity, Shasta, El Dorado, Kern, and San Bernardino counties. It will also be noted that the Sonoma-Lake-Colusa-Napa occurrences form a more concentrated grouping than those to the south of San Francisco Bay. The southern string, though more scattered, includes the largest two single quicksilver producers of North America, New Almaden and New Idria.

GEOLOGIC FORMATIONS of the MIDDLE COAST RANGES.

The geologic formations of the middle Coast Ranges of California have been summarized by Lawson,[1] as follows:

"The middle Coast Ranges of California, * * * are composed of many different kinds of rock, both igneous and sedimentary. The geologic history of the region is varied, including records of deposition, erosion, diastrophism, and volcanic eruptions, and the geologic structure is correspondingly complex and interesting.

* * * * * * *

"The oldest known rocks are certain quartzites, limestones, and crystalline schists, which are best exposed in the Santa Cruz, Santa Lucia, and Gabilan ranges. The age of these rocks is not yet known, but some of them are probably early Mesozoic and some are possibly Paleozoic.

"These older rocks are intruded by the granitic and dioritic rocks of the ranges just mentioned and their extensions northward through Montara Mountain, the Farallon Islands, and the Point Reyes Peninsula as far as Bodega Head.

"Upon the eroded surface of the complex of plutonic and metamorphic rocks rests the Franciscan group, composed chiefly of sandstones, radiolarian chert, foraminiferal limestone, and lavas, associated with which are intrusive masses of spheroidal basalt and serpentinized peridotite. These rocks are widely distributed in the middle Coast Ranges, occurring notably in the Mount Hamilton and Mount Diablo ranges, about the Bay of San Francisco, and in areas north of the bay.

"Upon the Franciscan group the Shasta series (Lower Cretaceous) rests in unconformable relation, and upon this group lies the Chico formation (Upper Cretaceous). These Cretaceous formations were once coextensive with the territory now occupied by the present Coast Ranges, and although removed by erosion over large areas where the Franciscan and older rocks now appear at the surface, they still constitute one of the largest elements in the stratigraphy of the region. They are composed chiefly of shales and sandstones and in the ranges north of the bay have a measured thickness of between 5 and 6 miles. The Eocene rocks, which succeed the Chico, are much less widely distributed. They comprise two assemblages of sandstones and shales known as the Martinez and the Tejon formations, which near the Bay of San Francisco aggregate between 4,000 and 5,000 feet in thickness and in the area farther south are probably much thicker. Evidences of uncomformity between the Eocene and Cretaceous rocks have been observed in some places, but the discordance is not very pronounced. The fossil faunas of the two series are, however, very different.

"Some strata referable to the Oligocene series have been observed and recorded, but the next great group of rocks is of Miocene age and is known as the Monterey group. The formations of this group have a wider distribution south of the Bay of San Francisco than those of Eocene age, and in some places they rest directly upon Cretaceous or older rocks, neither the Martinez nor the Tejon intervening. The most characteristic feature of the group is its content of bituminous shale, with which nearly all the oil of California is directly or indirectly associated. These shales alternate with sandstones, and the basal formation of the group is at many places conglomeratic. The group attains a thickness of several thousand feet, and in areas

[1]Lawson, A. C., U. S. Geol. Survey Geol. Atlas, San Francisco Folio (No. 193), pp. 3-4, 1914.

where it rests upon the Eocene the superposition is uncomformable. The rocks of this group were doubtless originally deposited over the greater part of the area of the Coast Ranges from the Bay of San Francisco southward, but since their deformation and uplift they have been extensively eroded. Their remnants, however, form a considerable element of the stratigraphy of the region.

"The next overlying formation, the San Pablo, is unconformable with the Monterey group and is much less widely distributed. In its southern areas the discordance is strongly marked, but in some of the northern areas it is scarcely discernible. The rocks, which are chiefly marine sandstones that are locally intermixed with tuffs, are found on both flanks of the Coast Ranges. Their thickness in the best-known sections ranges from 1500 to 2000 feet.

"Above the San Pablo unconformably, but in few places resting directly upon it, lies the Merced formation, a thick accumulation of marine sandstones, clays, and conglomerates, which were laid down in Pliocene time in deep local troughs that sank as fast as the sediments were deposited. These basins of Pliocene marine deposits were apparently confined to the coastal side of the Coast Range region. On the inland side of that region similar geosynclinal troughs were developed to corresponding depths, in which accumulated fluviatile and lacustral sediments, constituting the Orinda formation. The Orinda and Merced formations are each more than a mile thick. Interstratified with the beds of both formations are layers of volcanic ash.

"Upon the Orinda and Merced lie various lavas and volcanic tuffs alternating with lacustral clays, limestones, and sandstones. Of these lacustral formations, the Siesta (Pliocene) and the Campus (Pleistocene) are the most extensive.

"The later Quaternary formations comprise marine shell beds, sands, and clays overlain by a thick deposit of alluvium that is rich in the bones of extinct Mammalia."

AGE OF THE ORE DEPOSITS.

The principal Californian quicksilver deposits are mainly in the Franciscan (Jurassic?) formations, with some also in the adjacent Knoxville (Lower Cretaceous). In the earlier geological writings,[2] the 'quicksilver series' was designated as being 'Neocomian,' 'Neocomian metamorphic,' 'Cretaceous metamorphic,' and 'the Metamorphic Series.' Though occurring largely in these Jurassic-Cretaceous rocks, the age of the quicksilver mineralization is, in the majority of the deposits, certainly much later. In some cases, it is even as late as Quaternary.

The comparative youth of quicksilver ore deposits, elsewhere, as well as in California,[3]

"is attested by the fact that many of them are found in sedimentary or volcanic rocks of Tertiary or Quaternary age. They are not confined to these rocks, however, and may, in fact, occur in rocks of any composition or age. Sandstones, shales, limestone, serpentine, granite, andesite, rhyolite, or basalt may harbor the ores, and the character of the surrounding rocks seems to have little influence on the value of the deposits.

"The California belt contains ores in Jurassic, Cretaceous, and Tertiary sandstones and shale, in serpentine, and in late Tertiary or Quaternary basalt and andesite."

At the Sulphur Bank mine in Lake County, the cinnabar deposits extend from the Knoxville sandstones and shales of the lower levels up through the overlying Quaternary basalt, and is, in fact, conceded to be still depositing[4] from the thermal waters so much discussed in published accounts of this mine.

Whitney[5] writing in 1865 says:

"In regard to the geological position of the cinnabar deposits of California, it may be added, that this ore has been found by us in many localities, and in formations of nearly every age. It occurs in the Sierra Nevada and in the southern part of the State in strata of Triassic age, and on the eastern slope of the Sierra, probably in rocks of the same age. In the Coast Ranges it has been found in the Tertiary; but, as far as yet known, there are no large and valuable deposits except in the Cretaceous, in which position the localities which have been discovered, and where the ore is known to exist, in small quantity at least, are very numerous, extending in a line with the metamorphic Cretaceous from New Idria to Clear Lake."

[2]See Whitney, Becker, Forstner and Lawson, in the various references noted under Bibliography.

[3]Lindgren, Waldemar, Mineral deposits, p. 461, 1913.

[4]Becker, G. F., Geology of the quicksilver deposits of the Pacific Slope: U. S. Geol. Surv. Mon. XIII, pp. 263, 270, 1888.

[5]Whitney, J. D., Geology of California: Geol. Surv. of Cal., Vol. I, p. 68, 1865.

Following a discussion of the geology of the European quicksilver deposits, Beck[6] states:

"The greatest cinnabar deposits outside of Europe are those of California. * * * The deposits are mainly in the Coast Range, formed of folded metamorphosed Neocomian (Early Cretaceous) slates, with later intrusions of granite, quartz porphyry, andesite, rhyolite, and basalt. The tilting and dynamo-metamorphism of the Neocomian strata (*Aucella* beds) took place as early as the Middle Cretaceous, and was repeated with accompanying volcanic eruptions. These eruptions, with which the quicksilver deposits are genetically connected continue into post-Pliocene time.

"The deposits consist of very irregular veins, often as the chambered veins described by Becker, or forming stock-like bodies which extend laterally from the lode into the shattered or porous country rock."

Becker[7] distinguishes three principal periods of igneous intrusions to which the ore deposition is genetically related: 1. pre-Pliocene, during which large masses of andesite were ejected,—a bluish-gray rock containing pyroxene and feldspar crystals embedded in a ground-mass of feldspar and magnetite. 2. A later andesitic eruption, near the close of the Pliocene, and belonging to a special group having trachytic physical characteristics, for which he proposes the name 'asperites.' Rhyolite, probably younger than the andesites, is found near New Almaden and in the northwestern part of San Luis Obispo County. 3. Basalt eruptions belonging to the Quaternary and more recent periods.

THE FRANCISCAN GROUP.

The age of the Franciscan formations has not yet been positively determined to the complete satisfaction of all geologists. Not only is the paleontological evidence extremely meager and contradictory, but the stratigraphic evidence is curiously self-contradictory and leads to a conclusion that few geologists may be willing to accept.[8] There are exposures of the Knoxville series (Lower Cretaceous) which rest unconformably upon the eroded surface of the deformed and locally metamorphosed rocks of the Franciscan. These would indicate that the Franciscan is pre-Cretaceous. Franciscan rocks are found in portions of the southern Coast Ranges resting unconformably upon a complex that includes a granitic rock which can be traced continuously from the Coast Ranges around to a connection with the 'granite' of the southern Sierra Nevada. This granite is mapped and described as of post-Jurassic origin. It has also been observed that: 1. The sandstones of the Franciscan group are composed very largely of granitic debris. 2. At no place has the granite been observed to be intrusive in the Franciscan. 3. The intrusive relation of the granite to the older rocks is clearly shown at many localities; as, included fragments of these older rocks are common in the granite; but no Franciscan fragments have been thus found in the granite, "although the radiolarian

[6]Beck, Richard, Die Lehre von den Erzlagerstätten: edition of 1903, translated by W. H. Weed, The nature of ore deposits, vol. 2, p. 359, 1905.
[7]*op. cit.*, pp. 152, *et seq.*, 1888.
[8]Lawson, A. C., U. S. Geol. Surv. Geol. Atlas, San Francisco Folio (No. 193), p. 7, 1914.

cherts are well adapted to preservation as inclusions, as is shown by the fact that they are common in the rocks that intrude the Franciscan strata." 4. The pre-granitic rocks are generally metamorphosed, and consist chiefly of marbles, quartzites, and schists, none of which resemble the Franciscan strata. 5. The local metamorphism in the Franciscan is due to basic irruptives, and not granitic intrusions. These considerations lead to the conclusion that the Franciscan is post-granitic. This being the case

[9]"and accepting the view that the granitic rocks of the Coast Ranges are continuous with and of the same age as the granite of the Sierra Nevada, we must conclude that the Franciscan group is post-Jurassic. This conslusion is clearly in conflict with that drawn from the fact that the Franciscan lies unconformably below the Knoxville (Lower Cretaceous). At present there appears to be no way of harmonizing the conflict without (1) either extending the geologic time at the interval between the recognized Cretaceous and the Jurassic, an extension that should not be made without the justification of more thorough investigation, or (2) assuming a period of batholithic development in the Coast Ranges that was distinct from and older than that in the Sierra Nevada, an assumption that should also not be made without further and fuller investigation."

The Franciscan group (named from San Francisco, where it occurs in extensive exposures and from which it was first described[10]) comprises.[11]

"(1) a voluminous accumulation of sedimentary formations, some of them clearly marine, others doubtfully so; (2) some intercalated lavas of contemporary age; and (3) certain crystalline schists produced by the metamorphism of both the sedimentary and the igneous rocks.

"The formations of the Franciscan group are pierced at many points by igneous intrusives, which are so intimately associated with the sedimentary rocks, both as to age and as to distribution, that they constitute one of the most characteristic features of the group * * * these intrusives produced the metamorphism that formed the crystalline schists and so gave to the Franciscan group one of its most interesting features.

"The sedimentary rocks of the group comprise (1) sandstones, conglomerates, and shales; (2) limestone; and (3) radiolarian cherts. The igneous rocks are (1) basalt or diabase, in many places having a strongly pronounced spheroidal or ellipsoidal structure, (2) periodotites,, which have in general become thoroughly serpentinized. The dominant rock in the crystalline schists is glaucophane schist, which is so abundant in them that the schists as a whole are commonly referred to as 'the glaucophane schists,' although other varieties of crystalline schist are associated with them."

With reference to these intrusives, Smith[12] says:

"There are in the Franciscan great masses of serpentine and numerous smaller areas of dyke rocks, mapped with the formation, though they are intrusive in it, and therefore younger."

It is a notable fact, and one of which the genetic connection to the quicksilver deposits is not yet definitely solved, that many, if not nearly all, of the mines in California are either at or near the contact of some of these serpentine bodies. Some are within the serpentine itself, but not the more important ones, at least so far as commercial development to date is concerned.

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[9]Lawson, A. C., *op. cit.* p. 7.

[10]Lawson, A. C., Sketch of the geology of the San Francisco Peninsula: U. S. Geol. Surv. 15th Ann. Rep., pp. 399-476, 1895.

[11]Lawson, A. C., U. S. Geol. Surv. Geol. Atlas, San Francisco Folio (No. 193), p. 1, 1914.

[12]Smith, J. P., The geologic formations of California: Cal. State Min. Bur., Bull. 72, p. 32, 1916.

CHARACTER and AGE of EUROPEAN QUICKSILVER DEPOSITS.

For purposes of comparison, the following summaries relative to the deposits of Spain and Austria are here quoted. Beck[13] states that the deposits at Almaden, Spain, consist of three quartzite beds impregnated with cinnabar, the beds being of a mean thickness of 26 to 32 feet. Their richness increased with depth to below 863 feet. (Lindgren[14] in 1913 says: "down to 1300 feet.")

"The rocks consist of steeply upturned shales of Silurian and Devonian age, with intercalated quartzites, which weather out in steep rocky outcrops. The strata are often interrupted by diabases and huge intercalations of igneous rocks."

As to Idria, Austria:[15]

"The deposits occur in an area of Alpine Triassic rocks, which have been disturbed at this locality in a very complicated way by a number of faults and overthrusts, and have been broken into a group of fault blocks, with northwest strike. * * * The quicksilver deposits of Idria consist only in small part of true veins, being mainly impregnations in country rock which are in part connected with large, well-defined fissures, though this is no longer demonstrable, owing to the removal of material from the workings. They appear to form stratiform deposits. In both fissures and impregnations the mineralogic character of the deposit is simple. Cinnabar is the predominant ore. * * * The quicksilver ores, therefore, in the most important part of the Idria mines, have impregnated extensive masses of completely disintegrated rock, and have more or less saturated either highly porous or specially bituminous beds which acted as filters. The real channels of supply are not revealed. As the dislocations of the region are of Tertiary (probably Eocene) age it follows that the impregnation with quicksilver compounds is of very youthful age."

With reference also to Idria, Lindgren[16] states that

"The ore bodies, which apparently do not extend below a depth of 1000 feet, in places follow the stratifications. * * * The ores are usually designated as 'impregnations' in shale or marls, but small veins and stockworks are also found especially in the dolomite. The age of deposition is certainly post-Cretaceous, probably Tertiary."

It will be noted from the foregoing that these, the greatest two quicksilver deposits of the world, likewise their worthy namesakes in California, are relatively shallow in depth when we compare them with many of the well-known gold or copper mines, the world over.

THE ORE DEPOSITION.

The earlier theory of the deposition of quicksilver ores (particularly cinnabar and native mercury) ascribed it to pneumatolitic action—that is, by vapors and by sublimation. Following the experiments of Christy[17] and Becker,[18] it is now generally accepted that the majority of such ore-bodies, if not all, are the result of hydro-thermal deposition; and that the hot springs which were the agencies for the deposition either accompanied or followed immediately after periods of volcanic activity or other igneous intrusions.

[13]Beck, Richard, Die Lehr von den Erzlagerstätten, 1909, vol. 1, pp. 519-522; edition of 1903 (pp. 355-366) translated by W. H. Weed: The nature of ore deposits, vol. 2, pp. 350-351, 1905.
See also: De Launay, Traité de Metallogenie, vol. 2, 1893, pp. 672-680.
[14]Lindgren, Waldemar: Mineral deposits, p. 465, 1913.
[15]Beck-Weed trans., *op. cit.* p. 352.
[16]*op. cit.* p. 466.
[17]Christy, S. B., On the genesis of cinnabar deposits: Am. Jour. Sci., 3d ser. vol. 17, pp. 453-463, 1879.
[18]Becker, G. F., Geology of the quicksilver deposits of the Pacific Slope: U. S. Geol. Surv., Mon. XIII, pp. 419-450, 473-475.

According to Becker[19]

"In any one quicksilver bearing region, such as the Coast Ranges of California or inner Austria, it is difficult to avoid ascribing a common source to the ore. This can not be the adjoining rocks, for they are most various. On the other hand, granitoid rocks seem everywhere to underlie the superficial, more heterogeneous formations, within a very few miles of the surface. The evidence is overwhelming that in many cases quicksilver ores were deposited from thermal springs of volcanic origin; and the analogy between the deposits is so great that, in the absence of positive evidence of a different origin, the probabilities are in favor of the hypothesis of a similar origin for all of them. This does not imply that all quicksilver deposits are of the same age; those of Almaden for example, seem to be far older than most or perhaps any of the California deposits. Assuming that the quicksilver ores have been deposited from hot springs due to volcanism, it would seem that cinnabar might be classed as a volcanic emanation. In that case, however, one would look for this ore as a component of lavas and in craters. It is not certainly known to occur in this way, and if it exists in this association it must be very rare. It seems to follow that the volcanic springs must have leached the quicksilver from deep-seated rocks of very wide distribution, *i. e.*, either from the granitic masses or from some unknown infragranitic rocks overlying the foci of volcanic activity.

"To account for the limited areas in which quicksilver occurs it must further be supposed either that the volcanic emanations are not everywhere charged with solvents for quicksilver, or that the rocks overlying the volcanic foci do not everywhere contain quicksilver. Each of these suppositions involves a certain amount of irregularity in subterranean conditions. This, however, is not of itself a stumbling-block, since the mere existence of mountain ranges forbids the hypothesis of uniformity within scores of miles from the surface."

Lindgren[20] summarizes similar views, in the following:

"The uniform character of the quicksilver deposits points to a common genesis for all of them. The earlier belief that the ores were products of sublimation is generally abandoned, for the usual mode of occurrence, with minerals of aqueous origin, such as calcite, opal, chalcedony, and often barite, is decidedly opposed to such a view. Becker has pointed out that, as the character of the enclosing rocks has little influence on the deposits, they are most probably derived from a common, deep-seated source. Their structure indicates deposition near the surface, as does also the physiographic evidence at many places—for instance, where the ore appears in the crevices of Quaternary and little-eroded lava flows.

"When it is noted that hot springs and volcanic surface flows are present in almost all regions of importance (except Almaden in Spain, Idria in Austria, and Nikitowka in Russia), and that cinnabar in considerable quantities is associated with undoubted spring deposits, or is actually deposited in hot springs, the argument becomes very strong indeed that such hot springs have formed the majority of the deposits. For the few deposits that have no such clear connection with volcanic rocks—for instance, those mentioned above—the characteristic mineral association still holds good, and we are forced to the hypothesis that volcanism and hot-spring action are the causes of these also, though the products of the igneous activity may have failed to reach the surface and the hot springs may have subsided."

The last statement in the above quotation would apply particularly to the Great Eastern mine in Sonoma County, California, the one notable example in this state not visibly connected, either intimately or within a few miles, with volcanic or intrusive igneous rocks.

Forstner[21] notes that:

* * * "It is a striking fact that most of the prominent mines north of San Francisco are in close proximity to basaltic or relatively recent eruptions, as for instance: The Aetna mines, a basalt dike on the Silver Bow claim, and basalt in the Star claim; the Oathill mine, a large basalt body in close vicinity to the mine; the Corona and Twin Peaks mines, between the basalt of Oathill and that of the Howell Mountains; the Great Western, a body of basalt south and in close proximity to the mine; the Sulphur Bank, basalt all around the mine; the Manhattan, surrounded by basalt to the east and north; the Boston, within half a mile of the basalt in the Manhattan ground.

"In the southern field the geological conditions vary very much. In the New Idria district no definitely post-Tertiary igneous rocks can be found, and those rocks which show indications of igneous origin are so altered that it requires microscopic study of the rocks to determine whether they are altered eruptives or sedimentaries. In the Stayton district the country rock near the ore deposition is prominently basaltic, sometimes closely related to Becker's asperites. In San Luis Obispo County, in the Pine Mountain, Adelaide, and Oceanic districts, the scattered exposures of igneous rock are of rhyolite. In Santa Clara County the only eruptive rock in the neighborhood of the ore deposits is rhyolite."

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[19] Becker, G. F., Quicksilver ore deposits: U. S. Geol. Surv. Min. Res. for 1892, p. 157, 1893.

[20] Lindgren, Waldemar, Mineral deposits, p. 469, 1913.

[21] Forstner, William, Quicksilver resources of California: Cal. State Min. Bur., Bull. 27, p. 21, 1903.

Solubility of Cinnabar.

After recounting the experiments and experiences of a considerable number of investigators relative to the solubility and syntheses of the sulphides of mercury, Clarke[22] gives the following summary of their data:

"It will be noticed that several of the syntheses of cinnabar involve the solubility of mercuric sulphide in solutions of alkaline sulphides or sulphydrates. On this subject, apart from synthetic considerations, there is a copious literature. * * * The solubility of the mercuric sulphide manifestly depends upon considerations of temperature, pressure, concentration, and the nature of the solutions employed, whether neutral salts, sulphydrates, or polysulphides. That mercuric sulphide is precipitated again by dilution has been shown by various observers, and Becker reports admixtures of metallic mercury in the sulphide thus thrown down. Here, then, we have a possible explanation of the frequent association of free mercury and the black metacinnabarite, although relief of pressure may be in some cases the equivalent of dilution as a precipitant. Organic matter, also, is a probable agent of reduction, by which the metal is liberated. Bituminous substances, such as idrialite, napalite, etc., are commonly associated with cinnabar; and at the Phoenix mine in California an inflammable gas issuing from cracks in the rocks was found by W. H. Melville to have" 61.49% of CH_4 in its composition.

"The hydrocarbon CH_4, it must be observed, is the first member of the paraffin series, to which some bitumens belong. Becker has shown that hydrocarbons will precipitate mercuric sulphide from its alkaline solutions, first, probably, as metacinnabarite, which is afterwards slowly transformed into cinnabar. Another suggestion, due to A. Schrauf, who has studied the occurrence of mercury ores in Idria, is that the metal may be liberated by the direct dissociation of cinnabar vapor. He also ascribes the formation of some metacinnabarite to the action of hydrogen sulphide upon native mercury. Here again we are reminded that the same point may be reached by more than one road."

The chemical characteristics of mercury are further discussed in the section of this present bulletin on metallurgy (see *post*).

FORM OF THE DEPOSITS.

The forms of the deposits vary in much the same way that those of other metallic ores vary, with the hardness, porosity, etc. of the enclosing rocks, and with the extent and character of the fractures invaded by the ore-bearing solutions. Quicksilver ore bodies are found as fissure veins, reticulated veins, stockworks, the 'chambered veins' of Becker, impregnations, and placers. With reference to the form of the deposits, Becker[23] observes that it has often been asserted that quicksilver ores do not form deposits similar to those of the ores of other metals, but that he can find no evidence of this. With reference to chambered veins, he states:[24]

"In many cases the deposits occupy zones of broken country rock and can not be regarded as simple veins. They may be divided into stocks, stockworks, etc., but nearly or quite everywhere the various ore chambe.s are connected by fissures in such a way that the whole deposit may be better considered as consisting of fissures with excrescent chambers. I have suggested the term 'chambered veins' for such occurrences as distinguished from simple fissure veins. In such deposits one may distinguish lateral chambers and cap chambers according to the relations which the ore chambers bear to the main fissure. These terms have met the approval of some mining engineers. No better or more important instance of a chambered vein can be given than the deposits of New Almaden.

"It is only under very exceptional circumstances that disturbances in the earth result in the formation of a single fissure. Much more frequently a system of parallel fissures is produced which, when filled with ore, forms a system of parallel veins. A 'Gangzug' or system of linked veins seems to occur in rocks which present somewhat irregular resistance under the action of forces such as would produce a system of parallel fissures if the rock presented uniform resistance."

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[22]Clarke, F. W., The data of geochemistry: U. S. Geol. Surv., Bull. 616, p. 667, 1916.
[23]U. S. Geol. Survey., Mon. XIII, p. 472.
[24]U. S. Geol. Surv., Min. Res. for 1892, p. 158.

While, as described above, the forms of quicksilver ore-bodies do not differ essentially from the forms known and recognized in the cases of the other precious and semi-precious metals, they do differ in one very important feature—that of depth. As is noted in preceding paragraphs[25], the most famous quicksilver mines of the world, Almaden, (Spain), Idria, (Austria), New Almaden and New Idria in California, have been worked to depths of only 1300′, 1000′, 2450′ and 1060′ respectively; and with the exception of the first-named have all apparently bottomed their ore-bodies. In California, but few of the quicksilver mines have been worked to depths greater than 500 feet below their outcrops. The superficial nature of quicksilver ore deposits is more fully realized, when we consider the fact that many gold and copper mines, the world over, are being profitably worked at depths exceeding 2000 feet, and some even down to nearly 6000 feet.

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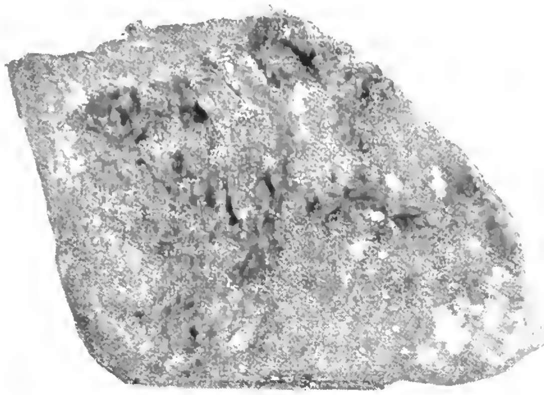
[25]See p. 21.

A.



B.

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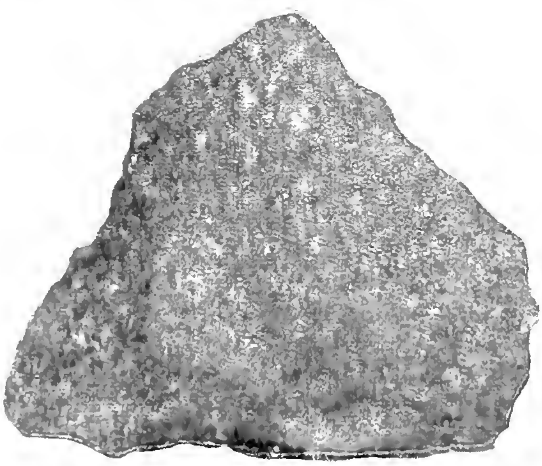

A. Coarse cinnabar crystals from Culver-Baer Mine, Sonoma County, California.

B. Minutely disseminated cinnabar in silica of recemented breccia, from Goldbank Mine, near Winnemucca, Nevada.

C. Massive cinnabar from New Almaden Mine, Santa Clara County, California.

CHAPTER 3.

MERCURY MINERALS.

Although mercury is a component of more than twenty distinct mineral species, there are but three of them that can be considered of commercial value—cinnabar, native quicksilver, and metacinnabarite. Of these, more than 95% of the world's output is obtained from the sulphide, cinnabar.

Cinnabar—Hg S. (Mercury 86.2% : sulphur 13.8%). Color, cochineal-red, often inclining to brownish red and lead-gray. Streak, scarlet. Transparent to opaque. Luster adamantine, inclining to metallic when dark-colored, and to dull in friable and less distinctly crystalline or 'earthy' varieties. Hexagonal-rhombohedral-trapezohedral. Crystals usually rhombohedral or thick tabular in habit, according to Dana[1] rarely showing trapezohedral faces; also acicular prismatic. In crystalline incrustations, granular, massive; sometimes as an earthy coating ('paint'). The writer has a hand specimen from the Culver-Baer Mine, Sonoma County, California, (see Plate IV) showing beautiful, transparent, somewhat tabular crystals, up to a quarter-inch across.

Cleavage: prismatic perfect. Fracture subconchoidal, uneven. Somewhat sectile. Hardness—2.0–2.5. Specific gravity—8.0–8.2.

Hepatic Cinnabar or Liver Ore, contains some carbon and clay; color and streak brownish.

Cinnabar's most frequent occurrence, in California at least, is in metamorphic sandstones and shales at or near the contact of an igneous rock (more often serpentine, which is an alteration form of the original rock), and in serpentine. It is generally conceded to have been deposited by solfataric waters carrying the sulphide in solution, impregnating the sandstones and filling cavities among the brecciated masses. Due to silification accompanying or following, much opal and chalcedony are often present. In some cases observed by the writer, notably the Goldbank Mine ore, which is described elsewhere herein, (see p. 288, *post*), apparently the cinnabar and the silica have been deposited simultaneously. There is some question as to whether the earthy or 'paint' variety of cinnabar is not crypto-crystalline or even amorphous.[2] Specimens have been examined under the microscope which showed no crystal form at 200 diameters magnification; but possibly a still higher magnification would resolve it. Investigators seem to be not all agreed that there is such a thing as an 'amorphous' mineral.[3]

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[1] Dana, E. S., Textbook of Mineralogy, 1899, p. 293.
[2] See Becker, G. F., re Sulphur Bank, in U. S. G. S., Mon. XIII, p. 257.
[3] See Am. Jour. Sci. XLI, 1916, pp. 490, 491.

Metacinnabarite—the black sulphide of mercury, has the same chemical formula as cinnabar, Hg S; but is grayish black in color; streak, black; and crystallizes in the isometric system, tetrahedral. It usually occurs massive, and often stated to be amorphous. It readily recrystallizes into cinnabar under certain conditions. Metacinnabarite was first reported from the old Redington Mine at Knoxville, Napa County, California, in 1872 and occurred there in considerable quantities; but has since been found at a number of other localities in this State. It has a hardness of 3.0, and specific gravity of 7.8; being slightly harder and lighter than cinnabar.

Native Mercury—Hg. It occurs to some extent in many quicksilver mines, accompanying cinnabar, not often in large quantities, but generally in disseminated fine liquid globules. In California it seems to be characteristic of the quicksilver ore deposits within certain serpentine areas, rather than those outside of the serpentine.

The less important mercury minerals, occurrences of which have been noted in California are:

Amalgam—a native alloy of mercury and gold was reported from Mariposa County by Sonnenschein,[4] and from Nevada County by Lindgren.[5] The silver amalgams, *Arquerite* of Coquimbo, Chile ($Ag_{12}Hg$) and *Kongsbergite* of Norway ($Ag_{32}Hg$ or $Ag_{36}Hg$) have not been reported as occurring in California.

Calomel—Horn Quicksilver, mercurous chloride, Hg_2Cl_2. Tetragonal. Color, white, gray, brown; Adamantine luster; hardness 1.0–2.0; specific gravity 6.48. Mercury 84.9%; chlorine 75.1%. Sometimes found in small, clear, colorless crystals, and in white crystalline coatings in cinnabar districts. It has been reported from Napa and San Mateo counties.[6]

Coccinite—iodide of mercury, Hg I. Color reddish brown. Reported with stibnite in Kern County, by J. D. Dana.[7]

Coloradoite—telluride of mercury, Hg Te. Rare. Massive, granular. Color, iron-black; metallic luster; hardness, 3; specific gravity, 8.63. Identified with other tellurides from the Norwegian Mine, Tuolumne County by Hillebrand.[8]

Eglestonite—oxychloride of mercury, Hg_4Cl_2O. Isometric, in minute crystals. Color, yellowish brown, changing to black. Resinous to adamantine luster; hardness, 2–3; specific gravity 8.33. This rare mineral has been identified from San Mateo County, by Rogers.[9] Its

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[4]Sonnenschein, F., Zeits. der geolog. Gesellsch, Vol. VI, p. 243, 1854. See also Eakle, A. S., Minerals of California: Cal. State Min. Bur. Bull. 67, p. 15, 1914.

[5]Lindgren, Waldemar, U. S. G. S., Ann. Rep. 17, Pt. 2, p. 13. See also Eakle, A. S., *op. cit.* p. 15.

[6]Cal. State Min. Bur., Bull. 67, p. 57.

[7]System of Mineralogy, 1868. See also Eakle, A. S., Minerals of California: Cal. State Min. Bur. Bull. 67, p. 61.

[8]Hillebrand, Amer. Jour. Sci., 1899, Vol. VIII, p. 295. See also Eakle, A. S., Minerals of California: Cal. State Min. Bur. Bull. 67, p. 59, 1914.

[9]Rogers, A. F., Amer. Jour. Sci., 1911, Vol. 32, p. 18. See also Eakle, A. S., *op. cit.* p. 61.

most noteworthy occurrence is in the Terlingua quicksilver district, Texas, in association with those other oxides and oxychlorides, kleinite, montroydite and terlinguaite, described hereinafter, and also calomel.

Tiemannite—selenide of mercury, Hg Se. Isometric, tetrahedral. Generally massive. Color dark lead-gray; streak black; hardness 2.5; specific gravity 8.30–8.47. Though this selenide is not common, some large masses of it have been found in association with cinnabar, notably in the Abbott Mine, Lake County, California, and in the Lucky Boy Mine, Piute County, Utah, the latter yielding quicksilver on a commercial scale for some time, in 1887, according to Becker.[10] In California it has also been noted in Orange and Santa Clara counties,[11] and in the Socrates Mine, Sonoma County.

In addition to the above described mercury minerals, the following have been noted elsewhere but not as yet reported occurring in California:

Ammiolite—a doubtful antimonite of mercury, with some copper, sulphur and iron, from Chile. An earthy powder color deep red or scarlet. Possibly antimonate of copper mixed with mercuric sulphide.

Barcenite—related to *Ammiolite*, but contains no copper. Possibly antimonate of mercury. Rare.

Guadalcázarite—a sulphide of mercury similar to metacinnabarite with a portion of the sulphur replaced by selenium. Some zinc is stated also to be present, but probably not essential. From Guadalcázar, Mexico.

Kleinite—"possibly a mixture of mercury-ammonium chloride, NHg_2Cl in great preponderance, with an oxychloride and a sulphate or oxysulphate of mercury."[12] From Terlingua, Texas, associated with eglestonite and montroydite. The original color of this mineral in the mine is almost canary yellow, but it deepens slightly to reddish yellow or orange on exposure to light, regaining the lighter shade after returning to the dark. Occurs mostly in small, distinct crystals, hexagonal, and showing a good basal cleavage. Luster adamantine to greasy. Hardness 3.5; specific gravity 7.98.

Lehrbachite—a combination of selenide of mercury and of lead. Massive, granular; specific gravity 7.8; color lead-gray to iron-black. From Lehrbach in the Harz Mountains, Germany.

Leviglianite—an iron bearing guadalcázarite.

Livingstonite—a mercury-antimony sulphide, $HgS.\ 2Sb_2S_3$. Resembles stibnite in form. Color, lead-gray; streak, red; hardness 2.0; specific gravity 4.81. From Huitzuco, Mexico.

Magnolite—mercurous tellurate, $Hg\ Te_2\ O_4$.

[10]Becker, G. F., U. S. G. S., Mon. XIII, p. 385.
[11]Cal. State Min. Bur. Bull. 67, p. 47.
[12]Hillebrand, W. F. and Schaller, W. T., The mercury minerals of Terlingua, Texas; U. S. G. S., Bull. 405, p. 19, 1909.

Montroydite—oxide of mercury, HgO containing mercury 92.6%, oxygen 7.4%. Occurs in prismatic crystals, some distorted, flattened, also worm-like forms. Color, from deep red almost black, through dark orange to pale yellow. Luster vitreous, inclining to adamantine. Crystallization, orthorhombic; cleavage perfect parallel to the brachypinacoid. From Terlingua, Texas, associated with eglestonite, kleinite and terlinguaite.[13]

Onofrite—a sulphide of mercury with part of the sulphur replaced by selenium, Hg (S,Se), containing up to 6.5% selenium. Sometimes associated with tiemannite. From San Onofre, Mexico, and Marysvale, Utah.

Terlinguaite—oxychloride of mercury, Hg_2 ClO. Color, "sulphur-yellow, olive green of varying shades, and brown, of which the sulphur-yellow probably changes to the olive-green."[14] Hardness 2–3; specific gravity, about 8.7. Occurs as distinct crystals, as a crystalline crust, and as a yellow powder. The powder darkens on exposure to light. Cleavage perfect, parallel to rear unit orthodome. From Terlingua, Texas, associated with eglestonite, kleinite and montroydite.

Tocornalite—iodide of silver and mercury. Color pale yellow; granular and massive.

ASSOCIATED and GANGUE MINERALS.

The principal associated and gangue minerals in California quicksilver ores are: pyrite, marcasite, chalcedony, opal, dolomite, serpentine, quartz, petroleum and bitumens. Millerite, barite, magnesite, pyrargyrite, pyrolusite, stibnite, redingtonite, knoxvillite, native sulphur and gold, have also been noted as occurring in association with certain cinnabar deposits in this State.

The following table compiled by Becker[15] shows the principal minerals and gangues, reported from nearly thirty of the most important mines and districts of both hemispheres, and is here given so that

"the reader may see at a glance both the frequency with which quicksilver is found in company with a given metallic or earthy mineral and the particular combination in a given district. The table is necessarily imperfect, since the reports are in many cases lacking in fullness. The attempt is also made to distinguish the relative frequency of the minerals noted so far as the reports enable one to judge. * * * Blanks represent the absence of reports, for it would manifestly be impossible to demonstrate the absence of any mineral in any deposit. * * *

[13] Hillebrand & Schaller, U. S. G. S., Bull. 405.
[14] Hillebrand & Schaller, *op. cit.*, p. 85.
[15] Becker, G. F., Quicksilver ore deposits: U. S. Geol. Surv., Min. Res. of U. S. for 1892, p. 115, 1893.

MINERALS ASSOCIATED WITH QUICKSILVER ORES.

p prevalent; the mineral usually accompanies the ore or is present in great quantity in the mine.
a abundant; a considerable part of the ore is characterized by the mineral.
o occasional; presence easily verified but quantity small.
r rare; seldom found or present in very minute quantities relatively to quicksilver.
Blanks indicate no report.

Deposits	Bitumen	Free sulphur	Stibnite	Other antimonial ores	Realgar	Mispickel	Gold	Silver ores	Galena	Chalcopyrite	Zincblende	Pyrite or marcasite	Millerite	Quartz	Calcite	Gypsum	Fluorspar	Barite	Borax
Ebenezer, Kicking Horse Pass, B. C.							r					p			p				
Sulphur Bank, California	o	p					r			r		p		p	a				a
Manzanita Mine, California	a	p	a				p			a		p		p	a				
Knoxville District, California	o	r	o				r			r		p	r	p	o				r
Ætna District, California	a											p	o	p	a				
Napa Consolidated Mine, California	a											p		p	a			r	
Great Eastern Mine, California	a											p		p					
Great Western Mine, California	a											p		p					
Elephant Vein, California				p				p				p		p					
New Almaden Mine, California	o					r	r			r		p		a	a				
New Idria Mine, California	r											p		p	a				
Steamboat Springs, Nevada		a		p	p		o	o	o	o	r	a	r	a	a				a
Guadalcázar, Mexico		o							r			p			p	a	a		
Huitzuco, Mexico			a	c				r						p		a			
Huancavelica, Peru					a	a			r			p			p			a	
Mieres, Spain					a	a						p							
Santander, Spain									p		p								
Almaden, Spain	o									r		a		p				o	
Deposits in Algeria								a	p		p								
Cape Corso, Corsica		o	p								o	a		a					
Vallalta, Italy												p				p			
Mt. Amiata, Italy	o	r			r							p		o	p	a			
Rhenish Bavaria, Germany	o							r	r	o		p		a	p			a	
Idria, Austria	a											p		a	a		r	r	
Copper mines, Hungary				p				r				a		p				o	
Thihuthal, Transylvania									o		o	a		o	p				
Avala, Servia									r			p	o	p	a			o	
Tagora and Gading, Borneo			a									p			p			a	

"Gangue minerals.—Whenever a quicksilver district has been at all fully reported upon it appears that either quartz (frequently associated with hydrous silica) or calcite accompanies the ore, and in the greater number of the cases both of these minerals are present in varying proportions. Not unusually dolmite also is present, as at New Almaden and at Idria. Ferrous carbonate is also met with. Relatively rare are barite and fluorspar. Barite is found in the Napa Consolidated, and thus far not elsewhere in California. It is also reported from near Lewiston, Utah, and from Guatemala. Barite occurs at Huancavelica. At Almaden a small part of the ore is accompanied by the same mineral, and Prof. Schrauf reports it from Idria. It was found in the deposits of the Palatinate and at Avala, as well as in Bohemia at Horowitz, in Hungary and in Borneo. Fluorspar is said to accompany cinnabar at Guadalcázar, La Tolfa in Italy, and at Idria. Gypsum, like fluorspar, is infrequent. I am not aware of its presence in the California mines, though it is common enough in the regions surrounding some of them. It is one of the gangue minerals at Guadalcázar and Huitzuco in Mexico, and at the Vallalta and Monte Amiata mines in Italy. A part of the gypsum is perhaps of secondary origin.

"Borax is interesting in association with cinnabar because generally recognized as an indication of volcanic origin. It occurs at Sulphur Bank, Knoxville and Steamboat Springs, but has not elsewhere been definitely recognized. It is probable that examination would reveal it in the hot springs of the Aetna district, and at the Manzanita. The solubility of borax of course militates against its appearance, excepting where solfatarism is active."

Chapter 4.

CALIFORNIA DISTRICTS.

The general distribution of the quicksilver deposits in California may be noted on the outline map (Plate III). The two main subdivisions are the groups north of San Francisco Bay, and those to the south. The other, outlying districts are each in a single county, and with the exception of a recent prospect in southeastern San Bernardino County, there are none south of Santa Barbara or the Tehachapi. Though the occurrence of cinnabar has been noted at several localities in the Sierra Nevada, at only one of these (Bernard mine, El Dorado County) has there been any commercial production recorded. The main northern subdivision comprises the following districts: Mayacmas, Clear Lake, Sulphur Creek, and Knoxville; with the Bella Union-La Joya, and the St. Johns-Hastings forming two somewhat isolated districts to the south of the others. The groups to the south of San Francisco Bay are separated by much longer intervals than those to the north, the principal districts being New Almaden, New Idria, northwestern San Luis Obispo County, and Los Prietos. A description of the general geology and topography of these more important districts, is here taken up in the order above named. Descriptions of other localities or subdivisions are taken up under the various counties. The individual mines and plants are discussed, by counties, in alphabetical order.

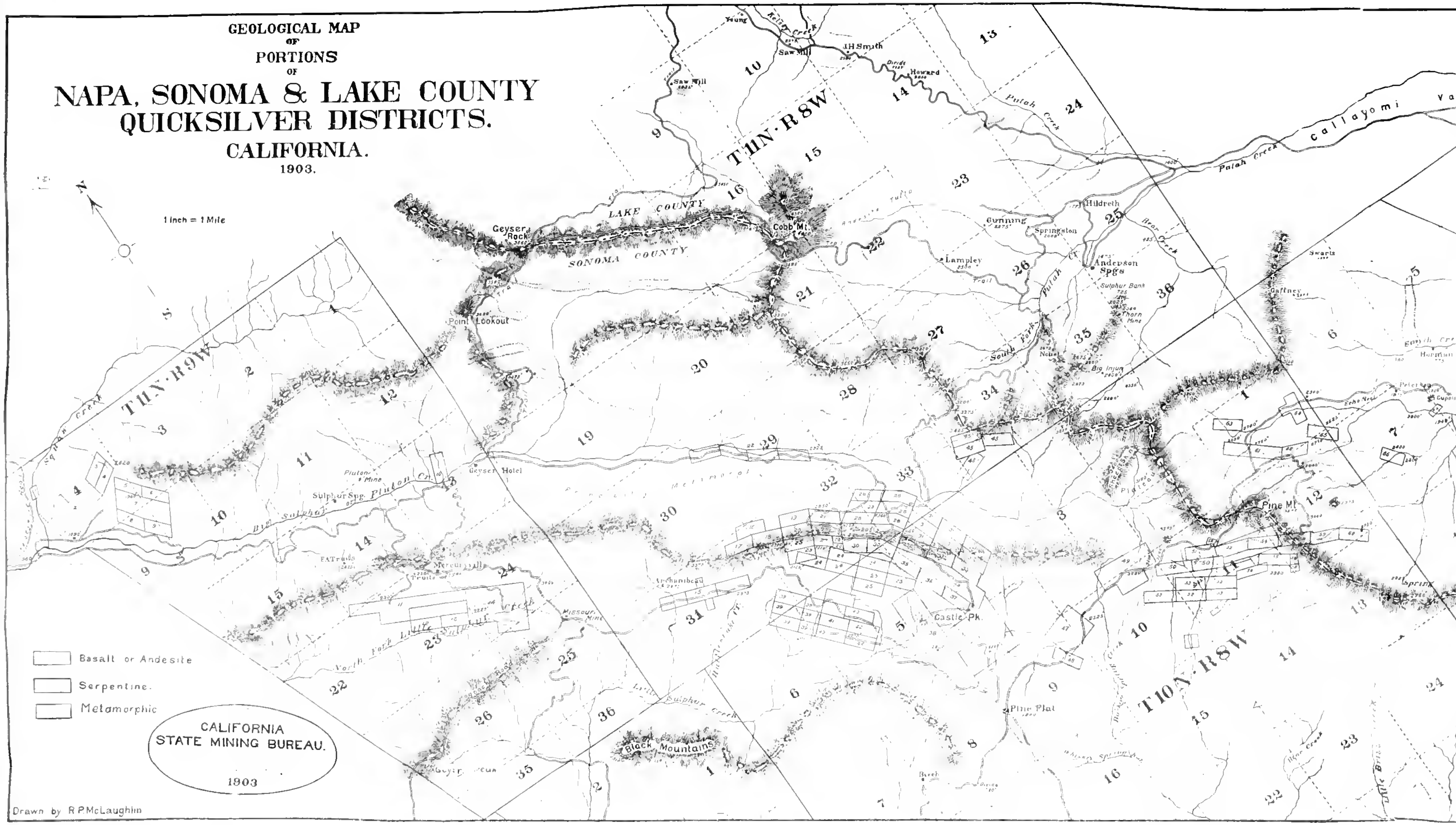
MAYACMAS DISTRICT.

The Mayacmas district is so called from the Mayacmas Range of which Mount St. Helena and Cobb Mountain are the most prominent points. It embraces parts of Napa, Lake and Sonoma counties, as will be noted by the accompanying geological map (Plate V), reprinted from Bulletin No. 27 of the State Mining Bureau. The quicksilver deposits are found on both sides of the range, the main belt crossing it near Pine Mountain between Mount St. Helena and Cobb Mountain. The eastern section lies north of the range, and the western section, south of it. The following general description of the district is given by Forstner:[1]

"The general trend of the belt is northwest. In its southeastern part, in Napa County, it is in very close proximity to a region of very intense and probably prolonged eruptive action, covering Tertiary and post-Tertiary periods. The center of eruptions in this region was probably in the territory bounded by Mount St. Helena, the Twin Peaks (or Sugar Loaves), and High Peak; the flows have, however, spread over a large adjoining territory. Outside of this are found a great many other eruptive bodies in this district, of which the more prominent are: The basalt body on Oathill, some smaller ones in the territory of the Ætna Consolidated Company, and andesitic eruptive body northeast of Oathill, Pine Mountain, Cobb Mountain, and others. This district is hence a region of intense eruptive action. Large masses of lava have covered parts of it, and while partly eroded, extensive sheets of tuff cover at present parts of it to a greater or less depth, and make it very difficult to determine the limits of the cores of igneous rocks. The present deeply carved topography of the region is largely governed by the erosion of this capping.

[1]Forstner, William, Quicksilver Resources of California: Cal. State Min. Bur. Bull. 27, pp. 35–39, 1903.

set, including lagging, from $2.50 to $2.75; timbers, 7 cents per linear foot; lagging, 3½ cents apiece; sawed square sets at mill, $2.15; lagging, 15 at 7 cents, $1.05; cordwood averages from $2.50 to $3 per cord.



Geology by Wm. Forstner, E. M.

MAYACMAS DIST[RICT]

No.	Name of Mine.	
1	Sunrise.	Cloverdale Mine.
2	Cloverdale.	
3	Mercury.	
4	Manzanita.	
5	Albian.	
6	Mattole.	
7	Mount Vernon.	
8	Philadelphia.	
9	Waterloo.	

No.	Name of Mine.	
10	Geyser, Sulphur.	
11	Black Bear Group.	
12	Pluton Den.	
13	Clyde.	
14	Culver—Baer Group.	
15	Rattlesnake.	
16	Tunnel Site.	
17	Incandescent.	
18	Almaden.	

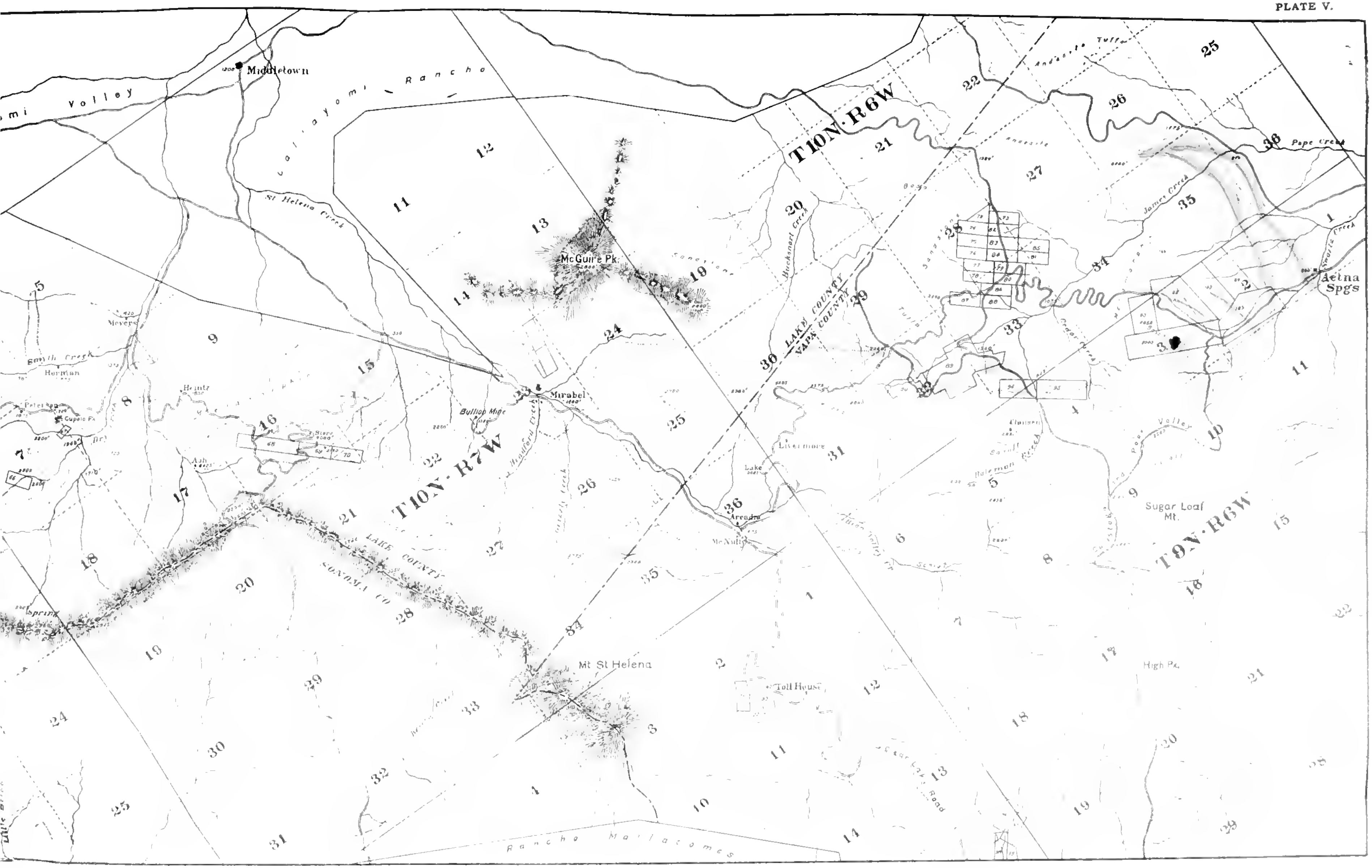
No.	Name of Mine.	
19	Mate.	Eureka Con.
20	Eureka Nos. 1 and 2.	
21	Captain.	
22	—	
23	Cedar.	
24	Quicksilver.	Crown Point Q. Mining Co.
25	Queen Group.	
26	Lookout.	
27	Diamond.	
28	Mercury.	

No.	Name of Mine	
29	Socrates.	
30	Mercury.	
31	Great Northern.	
32	Hope.	Crown Point Q. Mining Co.
33	Hope.	
34	Denver.	
35	—	Lucky Stone Group.
36	—	
37	—	
38	Hurley.	

No.	Name of Mine.	
39	Pacific.	
40	Hercules.	Crown Point Quicksilver Mining Co.
41	Sonoma.	
42	—	
43	—	
44	—	
45	Pontiac.	
46	Pontiac.	
47	Boston.	
48	Empire.	

No.	Name of Mine.	
49	Double Star.	
50	Occidental.	
51	Healdsburg.	
52	Edith.	
53	Cinnabar King Group.	
54	Eugenie.	Bacon Con.
55	Maud.	
56	Dragon.	
57	Napa.	

Reprinted from Bulletin No. 27.



DISTRICT.

No.	Name of Mine.	
	...f Mine.	
	...oup.	
	... Con.	

No.	Name of Mine.	
58	St. George.	Bacon Con
59	Golden Gate.	Bacon Con
60	Eagle.	Bacon Con
61	Helen.	
62	Young America.	
63	Chicago.	
64	Wall Street.	
65	Jewess.	
66	Middletown.	
67	Middletown.	
68	Gem.	Great Western.
69	Great Eastern.	Great Western.
70	Hope.	Great Western.
71	Liverpool Con.	Standard Q. Co.
72	Eureka Con.	Napa Consolidated.
73	Eureka Con.	Napa Consolidated.
74	Eureka Con.	Napa Consolidated.
75	Eureka Con.	Napa Consolidated.
76	Eureka Con.	Napa Consolidated.
77	Eureka Con.	Napa Consolidated.
78	Eureka Con.	Napa Consolidated.
79	Eureka Con.	Napa Consolidated.
80	Eureka Con.	Napa Consolidated.
81	Contention.	Napa Consolidated.
82	Minnesota.	Napa Consolidated.
83	Manzanita.	Napa Consolidated.
84	Mercury.	Napa Consolidated.
85	Bone.	Napa Consolidated.
86	Fanny.	Napa Consolidated.
87	Osceola.	Napa Consolidated.
88	South Side.	Napa Consolidated.
89	Corona.	
90	Napa Con.	
91	—	
92	Beecher.	
93	New Granada.	
94	Twin Peak.	
95	Twin Peak.	
96	Ida Easly.	
97	Old Discovery.	
98	Twin Quartz.	
99	Good Enough.	
100	Silver Bow.	Aetna Con.
101	Phoenix.	Aetna Con.
102	Red Hill.	Aetna Con.
103	Starr.	Aetna Con.
104	Pope.	Aetna Con.
105	Washington.	Aetna Con.

...tin No. 27.

Forstner, William; …
Bull. 27, pp. 35 39, 1903.

"The older rocks are mainly represented by sandstones, sometimes nearly unaltered, sometimes thoroughly altered into schists, with all intermediary gradations. Serpentine is very prominent, mostly a hard, dry variety, in places disintegrated and pulverized by weathering, showing as large bare spots along the ranges. Even where not bare, the serpentine can be detected at a distance by a sparse vegetation, while on the balance of the surface a very close growth of brush or grass is found. The relation of the serpentine to the quicksilver deposits is not clear. Most of these are associated with, or in close proximity to, serpentine; but others, like those at Oathill and Cloverdale, are entirely away from the serpentine and where the serpentine is very prominent and continuous over a certain width, no deposits of any value have been found; as, for instance, between Oathill and the Mirabel around the head of Bucksnorter Creek; on the ridge between Bear Creek and Dry Creek; on the main ridge between the headwaters of Dry Creek and Briggs Creek. Neither are workable quicksilver deposits found in the serpentine. Where serpentine is associated with any deposits, these are always contact deposits, while both the Oathill and Cloverdale mines are in the sandstone.

"The quicksilver deposits appear from their association with the opaline rock, which is presumably an alteration product of serpentine by silicification, to be related to the serpentine to a certain extent. The fact that, where it is very wide, no paying deposits have been found, would indicate, however, that either the sandstones contain the primary disseminated metal, which is concentrated through some process of secondary concentration, or else in the large bodies of serpentine the concentration took place only in those parts affected by contact metamorphism. While this holds true only for the southeastern part of the district, it must be remarked that in the northwestern part, in Dry Creek and Pine Flat districts, there is in many cases an undoubted relation between the quicksilver occurrence and igneous actions. In the Dry Creek district the only deposit of any ascertained consequence is the Helen, which lies very close to the tuffs of Pine Mountain. There are undoubted signs of igneous rocks in the Pine Flat district on both sides of Big Sulphur Creek some of these igneous dikes run, as far as determined, in a direction which would bring them near the ore deposits of the Eureka mine; others were found near the Cloverdale mine. For a great number of deposits, these relations are not yet determined. Considering the intimate relation of quicksilver deposits and aqueo-igneous actions and the general geological conditions in this region, it may, however, be expected that, at least, laccolitic relations exist there.

"Between the Corona and St. Helena Creek, a distance of four miles in an air line, along the headwaters of Bucksnorter Creek, the belt of serpentine is very wide. Between St. Helena Creek and Bucksnorter Creek the Standard Quicksilver Mining Company has in the last few years spent a considerable sum of money prospecting, but so far without any favorable result.

"To the west of the Great Western mine are the headwaters of Dry Creek, a bowl-form basin nearly encircled by the main ridge and by a ridge dividing Dry Creek from the drainage of Putah Creek. Serpentine is very prominent in a great portion of the Dry Creek basin, and again barren of any workable deposits of cinnabar, notwithstanding some very prominent, peculiar croppings, standing out boldly in the serpentine. These croppings, especially prominent in the Wall Street and Jewess grounds, consist of a network of white quartz seams, mostly thin amorph quartz, with occasional concretions of botryoidal form; the ground mass is a light yellow-brown, ochreous mass; this material is locally called 'dry bone,' and so far as yet observed, never indicates a workable ore deposit. The same is found on the Bacon Consolidated and Cinnabar King ground (Pine Mountain), and also in the Double Star mine (Pine Flat). (Lawson's silica-carbonate sinter.)

"Pine Mountain is a mass of andesitic tuff, most probably with an eruptive core, of small dimensions and very steep sides, and entirely disconnected from the Mount St. Helena and the Mount Cobb groups of eruptives. Its main ridge is not over 25 feet wide, and about 300 feet long; elevation, 3475 feet. The tuff is of a light grayish color, and has spread over a part of the adjacent ravines. No signs of basaltic rock could be found on the ridge. The Helen mine is situated on the eastern slope; near the edge of the tuff, and on the southwestern, western and northwestern slopes are located a series of mines, comprising the Cinnabar King and Bacon group of mines. The northwestern slope is very steep and partly covered by tuff, which covers alternate beds of serpentine and metamorphosed sandstones. At the contacts wide belts of croppings show, partly in place, partly covering the side hill with large bowlders. These croppings resemble very much those of the Wall Street and Jewess. In the cañon continuing below the old road from Middletown to Pine Flat a very well-defined cropping on the contact of serpentine and sandstone is seen. A great amount of work has been done here; remnants of old shafts and tunnels are found everywhere on the hillsides, but all work is now abandoned. Several pockets of very rich cinnabar ore were found at different points on the surface, but none appear to have been found persistent in depth.

"The headwaters of Putah Creek are situated in a basin on the south slope of Mount Cobb. In this basin are a great number of hot springs, of which Anderson Springs are by far the most prominent. These springs generally contain a great amount of sulphur, and in several places sulphur deposition and rock decomposition by sulphurous fumes are taking place. Here, as in other parts of the district, cinnabar deposition does not occur in or close to those places where hot waters and vapors reach the surface. There are no cinnabar mines in this basin—only a few prospects, which can scarcely be said to give, up to the present, much promise of turning into mines; a condition partly due to insufficient development.

"The mines around Mount St. Helena have a considerable supply of timber in their vicinity, although the Ætna, Oathill, Corona, Mirabel, and Great Western mines have made serious inroads on the supply. The Oathill mine is the only one having a sawmill. The other mines must use round timbers, or get their timbers from the sawmills in Lake County at the foot of Mount Cobb. In the Pine Flat district, the timber supply is rather scant. There is one sawmill in the district. Round timbers cost per set, including lagging, from \$2.50 to \$2.75; timbers, 7 cents per linear foot; lagging, 3½ cents apiece; sawed square sets at mill, \$2.15; lagging, 15 at 7 cents, \$1.05; cordwood averages from \$2.50 to \$3 per cord.

"This district connects by several good roads with railroads. The southeastern and central parts, by three roads to Calistoga—one from Oathill, the toll road from Middletown, and the toll road from the Great Western mine; distances, from 12 to 20 miles. The northwestern part connects with Calistoga and Healdsburg, and for the most extreme northwestern portion also with Cloverdale; distances, from 16 to 20 miles."

The above prices are as of 1903, and they are quoted here because they furnish an interesting comparison with present figures which are much higher.

CLEAR LAKE DISTRICT.

The Clear Lake district comprises the mines around the southern half of Clear Lake, the only important producer of which has been the famous Sulphur Bank mine. This territory has been a region of intense volcanic activity, a considerable part of it having been at one time covered by lava flows. There are several periods of eruptions, the ejected lavas being of different compositions.

[2]"Mount Konocti is formed by later andesites, which are also found to the northeast of the lower part of Clear Lake; but in the close neighborhood of Sulphur Bank the eruptives are principally, but not exclusively, basalts. These latter eruptions must have been recent, the basalt overlying the Quaternary Cache Lake beds. To the northeast of the lava flows in this district is a very extensive belt of serpentine; but the rocks underlying the lava flows are, north of Putah Creek, prominently sandstones and shales." (See geological map—Plate VI.)

The district finds its railroad outlet, via Middletown, through Calistoga, from which Lower Lake is 33 miles distant. Nearby sources of timber are limited, but fair supplies of cordwood are available.

SULPHUR CREEK DISTRICT.

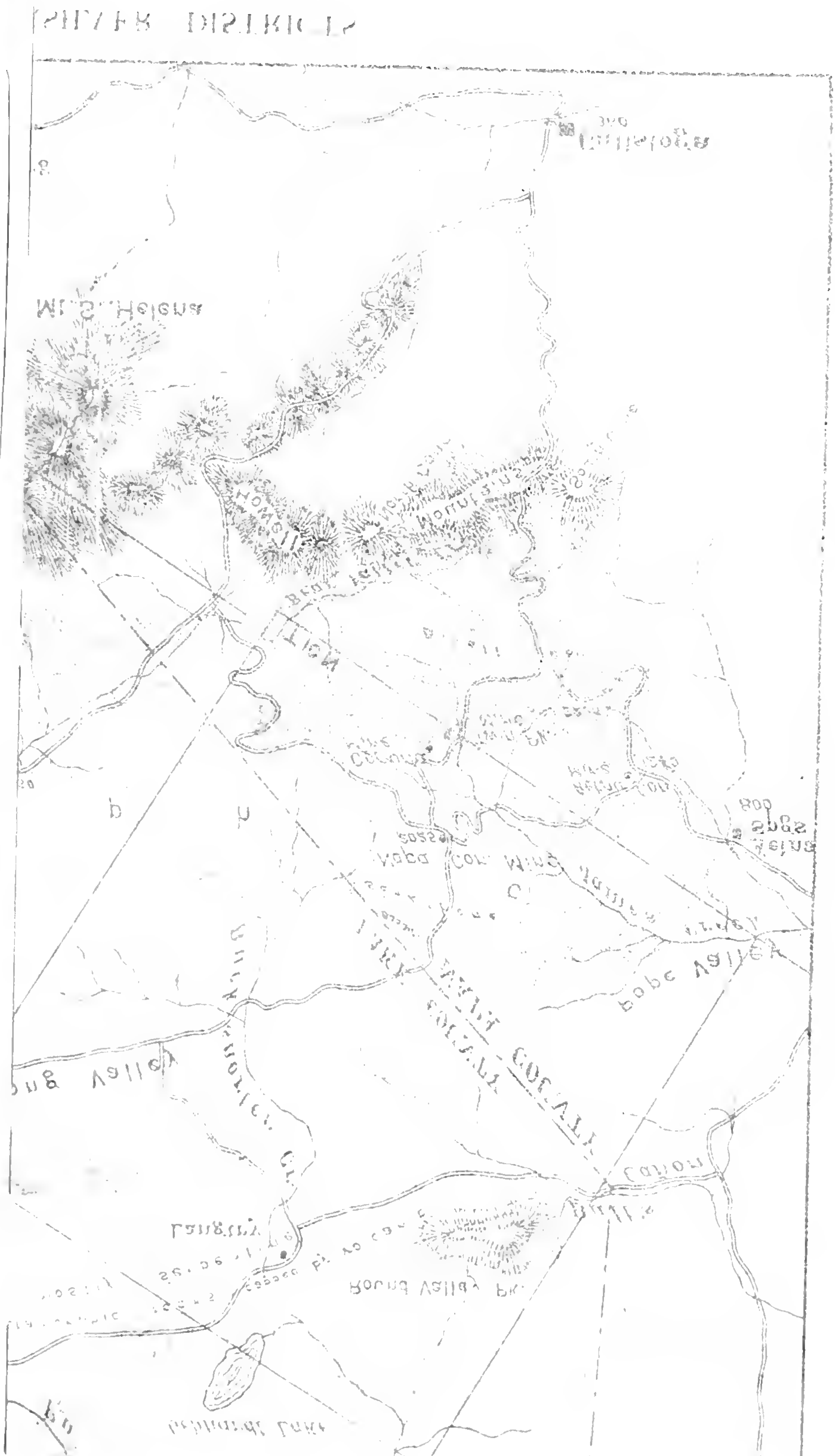
The Sulphur Creek district lies to the east of the Clear Lake district, on the line between Lake and Colusa counties, and comprising the upper part of Sulphur Creek above Wilbur Springs. This region has been considerably eroded, and the ridge near the Abbott mine, forming the watershed between Cache Creek and Bear Creek, is in places covered with gravel, some of the pebbles being derived from igneous rocks.

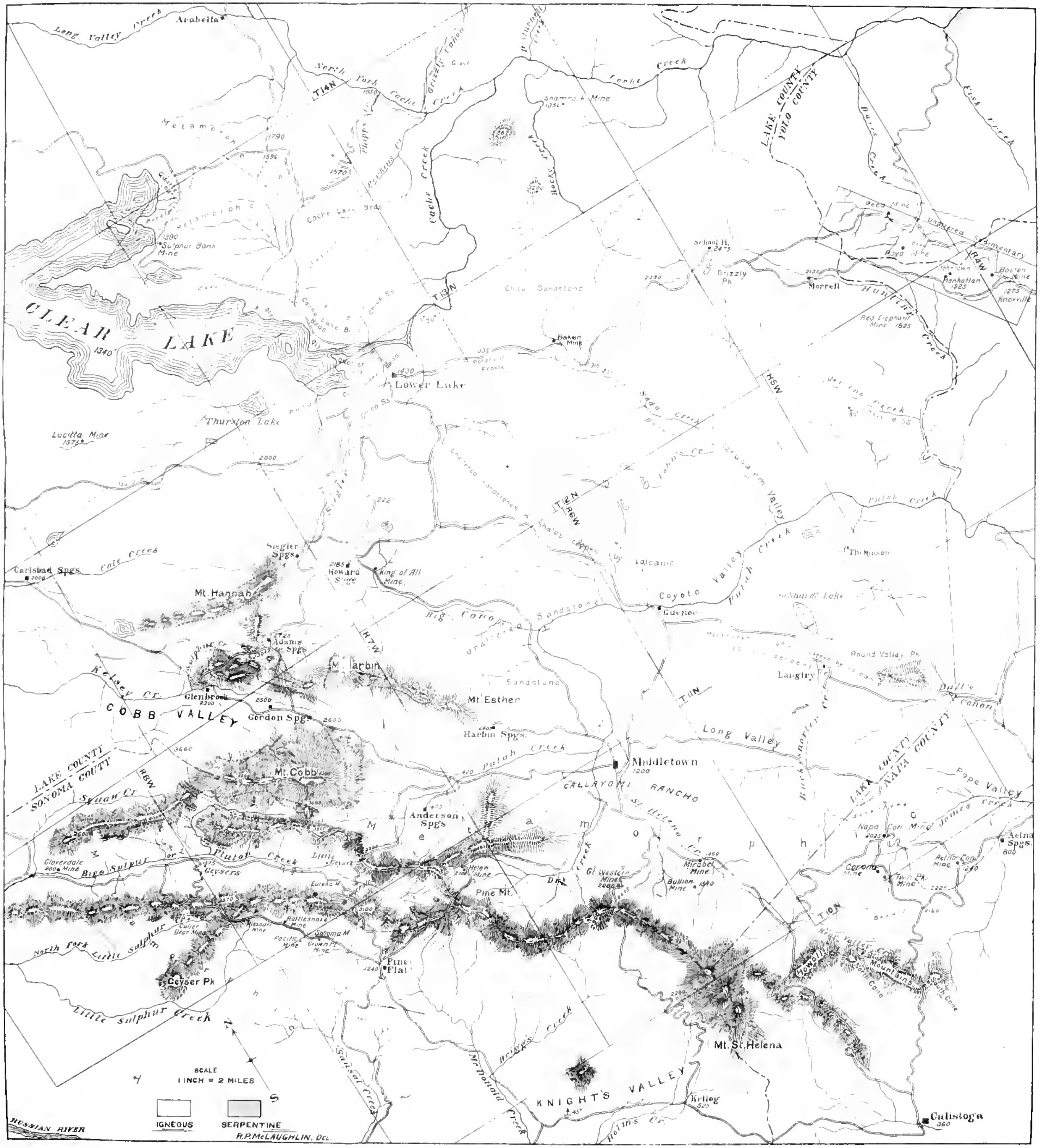
[3]"Two nearly parallel belts of serpentine run through the district [see map, Plate VII] with a northwest trend. The western runs partly on above-mentioned divide; the serpentine is very siliceous in character and rather opaline. On its eastern contact with a belt of rather soft sandstone lies a zone of crushed opaline. To the west of this serpentine, between it and the adjoining shales, is a zone of a light gray or yellow material, containing inclusions (varying in size from small pebbles to bowlders of considerable size) of obsidian, chalcedonite, and opalinized serpentine. The matrix of this breccia is a tuff, or better, a tuffoid (a tuff altered by regional metamorphism, according to Mügge). The same material is found in the Elgin mine.

"The surface of this serpentine has been leached by acidic waters, leaving a peculiar hard, siliceous material of a light bluish-gray color, full of cavities, and occurring in thin slabs. Near the surface the serpentine is generally not silicified, but the ledge matter is largely a much crushed opaline rock, more friable and less hard than the opaline in the tuffoid. This serpentine belt is not very long and is surrounded by shales and argillaceous sandstones. To the east is a wider and more continuous serpentine belt, at the western contact of which are located the Wide Awake, Empire, and Manzanita mines.

"The shales contain bitumen, sometimes forming heavy oil, and sometimes lighter gaseous hydrocarbons. The waters percolating through these formations are often charged with hydrogen sulphide. Occasionally they form hot springs. A hot sulphur spring at Blanck's Hotel was cut off by the Wide Awake shaft when the latter was sunk from the 200 to the 300 foot level, at a distance of 1300 feet from the spring, and a depth of about 300 feet below the spring, and never reappeared, cold water now issuing from the same spring. This proves that this spring was caused by hot ascending waters, following a gentle slope of about 1300 feet horizontal

[2]Forstner, *op. cit.* p. 39.
[3]Forstner, *op. cit.* pp. 40–42.

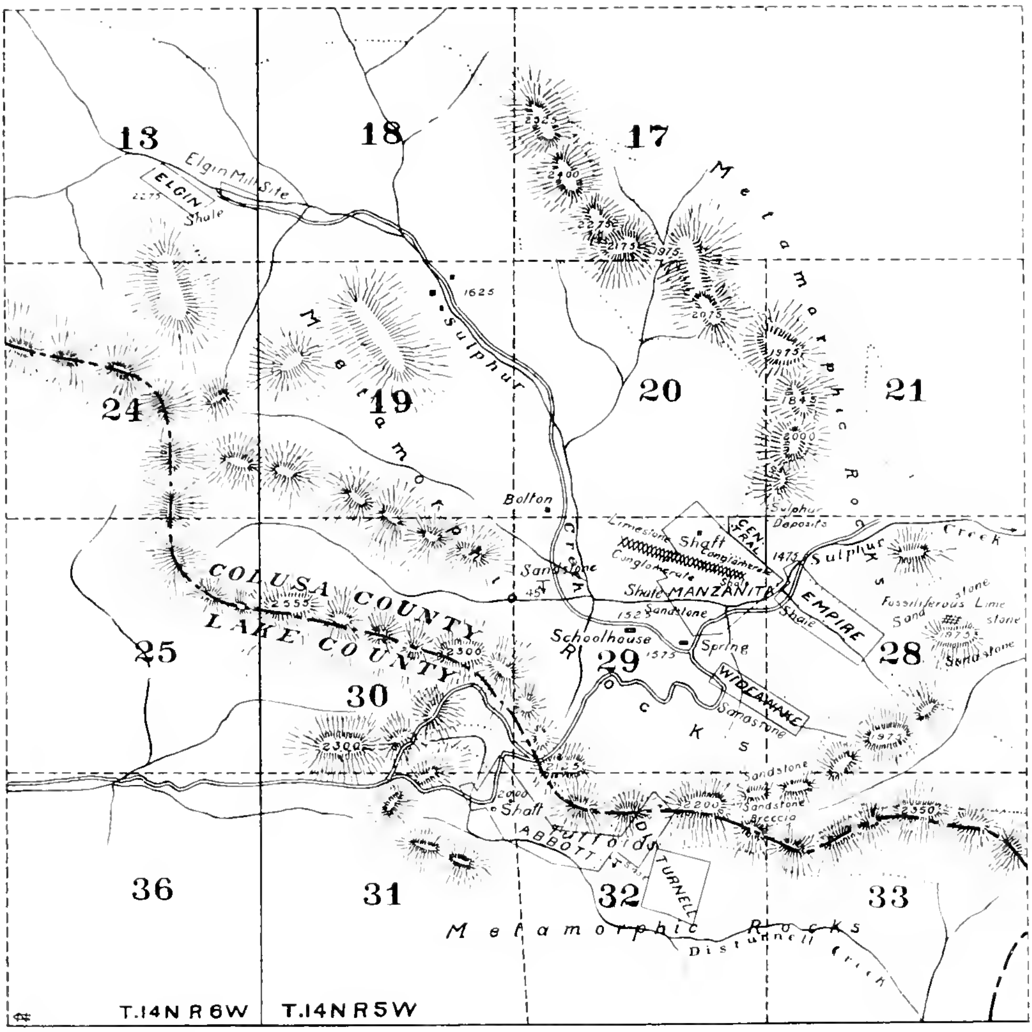




GEOLOGICAL MAP OF NAPA, SONOMA, LAKE, AND YOLO COUNTY QUICKSILVER DISTRICTS

UNNAMED IGNEOUS AREAS ARE EITHER ANDESITE OR ASPERITE

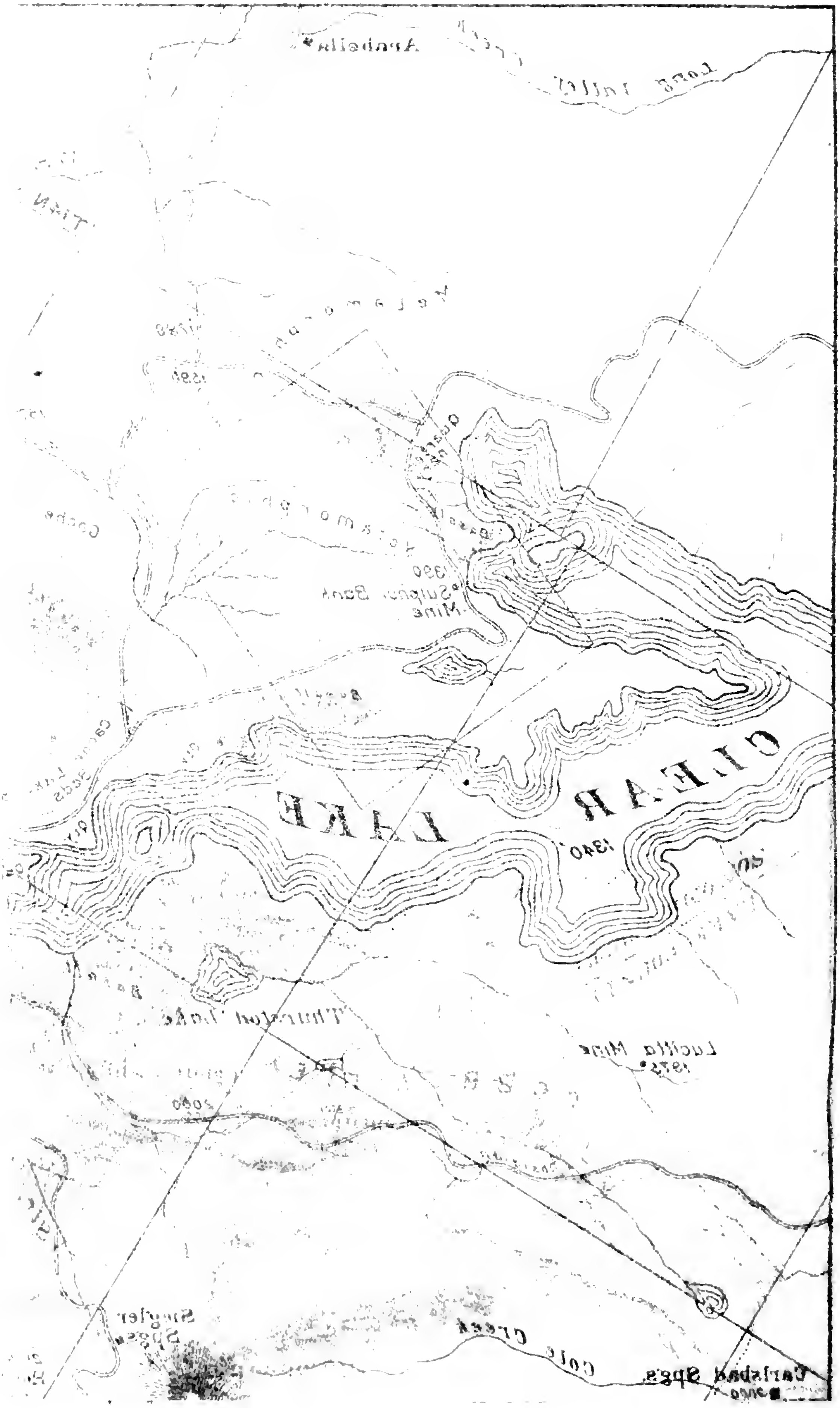
Reprinted from Bulletin No. 27

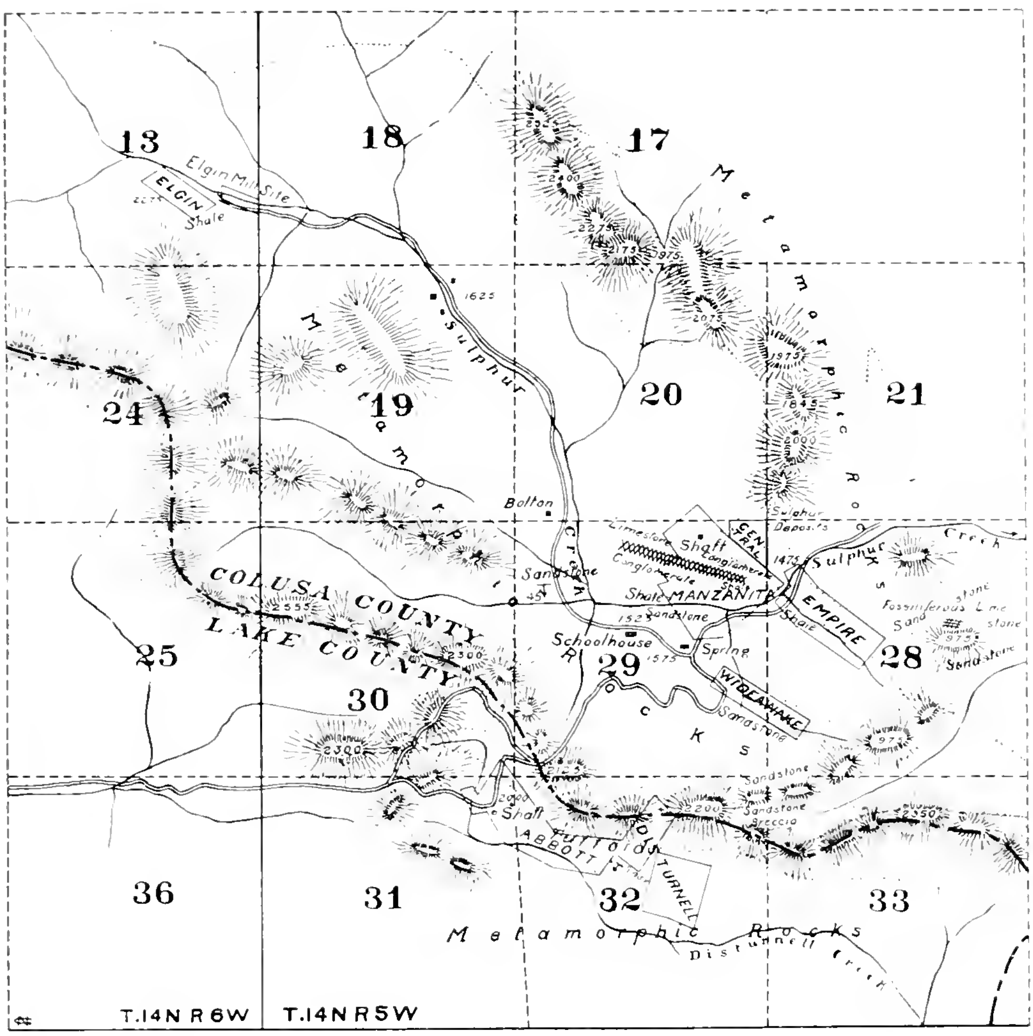


Green=Serpentine.

Geological Map of Sulphur Creek District, in Colusa and Lake Counties.

Reprinted from Bulletin No. 27.


CLEAR LAKE
1340
Sulphur Bank Mine
Thurston Lake
Lucitta Mine
Cole Creek
Carlsbad Spgs.
Siegler Spgs.
Arabella
Long Valley



Green=Serpentine.

Geological Map of Sulphur Creek District, in Colusa and Lake Counties.

Reprinted from Bulletin No. 27.

to 300 feet vertical. The great amount of mineralized waters, the siliceous sinters and sulphur deposits formed by extinct solfataric springs, and the still existing hot sulphur springs, indicate strong irruptive action. As no igneous rocks appear at the surface in the immediate neighborhood, this may have been laccolitic. In the bed of Sulphur Creek a conglomerate is constantly forming, the pebbles in the creek being cemented by deposits from the water which is charged with sulphur and sulpho-salts.

"The shales and sandstones occur unaltered and in various stages of alteration. A belt of limestone passes through the Manzanita property, course southeast, adjoining to the west a belt of conglomerate, a water formation, similar to that now forming in the bed of Sulphur Creek. About three fourths of a mile farther on, in the same direction, but without any surface connection with this limestone, is found a small body of fossiliferous limestone, with fossils of the Cretaceous age (*Rhynchonella whitneyi*)."

Timber is scarce, cordwood (oak) is high, and the roads are rather heavy for hauling. The nearest railroad point is Williams, 26 miles to the east.

KNOXVILLE DISTRICT.

The Knoxville district is mainly in the northeast corner of Napa County, and includes also the adjacent portions of Lake and Yolo counties. There is a body of basalt closely associated with the two principal mines, the Knoxville (formerly Boston) and the Manhattan.

[4]"The Manhattan is in contact therewith, and the Boston is in close proximity and practically in line with the direction of the main fissure through which the basalt was ejected. This basalt is the only eruptive body coming to the surface in the district, and lies on the contact between the large belt of serpentine which runs in a southeasterly direction from Cache Creek and the unaltered Neocomian to the northeast thereof. This serpentine belt, which reaches into Napa County and is several miles wide, contains, as far as yet ascertained, only sporadic signs of cinnabar ore, and it is very doubtful if any workable deposits will ever be found therein."

Timber has to be hauled from Lower Lake, there being none around Knoxville, though supplies of both pine and oak cordwood are obtainable at fair prices. The nearest railroad point is Rumsey, 15 miles northeastward, over a difficult road as a deep cañon has to be crossed. Generally supplies are hauled from St. Helena or Winters, via Monticello, each about 35 miles distant.

NEW ALMADEN DISTRICT.

This, the most important quicksilver district in the state in point of total output to date, is about 12 miles east of south from San Jose, and includes the Guadalupe mine, in addition to the New Almaden company's properties. These mines are in a ridge just back of the foothill spurs which form the western boundary of the Santa Clara Valley at this point, this ridge being a continuation of the Gabilan Range from San Benito County to the south. South of Mine Hill, this ridge is cut through by the sharp cañon of Arroyo de Las Animas; and, decreasing gradually in elevation in its northwest trend, it is cut off northwest of the Guadalupe mine by the cañon of Los Capitancillos Creek.

Being wholly within Santa Clara County, the further description of the geology and topography of the New Almaden district is taken up under the county heading (see *post*).

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[4]Forstner, *op. cit.*, p. 42.

NEW IDRIA DISTRICT.

The New Idria district, second only to New Almaden in point of total production to date, is situated in the Diablo Range in the southeastern corner of San Benito County, a portion of the county which, previous to 1888, was included in Fresno County. There are in reality two other, but less important, districts in eastern San Benito County; but as all three are almost entirely within the boundaries of this county, their description is detailed under the county heading.

SAN LUIS OBISPO DISTRICTS.

The Oceanic, Adelaide, Pine Mountain, and San Carpojaro districts are all adjacent, and somewhat closely grouped in the northwestern part of San Luis Obispo County. They are located in zones along the ridges and spurs of the Santa Lucia Range, and are separated by more or less barren sections of country.

[5]"In the northwestern part of this territory near Pine Mountain there is a line of cones formed of rhyolite, having a general northwestern direction. The cones, while close together, are not connected at the surface. Near Pine Mountain, among the debris of the rhyolite covering the slopes of the cones, are found bowlders of diorite, indicating prior igneous eruptions.

"In the Adelaide and Oceanic districts some scattered exposures of rhyolite are found, which have no apparent relation to each other; hence nothing can be inferred relative to the dislocations which caused these eruptions. The serpentine lies principally on the west slope of the main ridge, where it has caused enormous slides, due to its deterioration by atmospheric influences. Its principal exposure is at Cypress Mountain, where, at several places, its contact can be seen with the underlying partly altered sandstones. The entire appearance of the serpentine mass tends to the supposition that it is an altered peridotite. In one place on the northwest slope of the mountain some signs of induration by contact metamorphism of the adjoining sandstone can be found. The Franciscan series are prominently represented by sandstones, which are very irregular in texture, grading from entirely unaltered arkose sandstones into completely metamorphosed sandstones, nearly, if not entirely, quartzite, and these various phases are intimately mixed, without any traceable system of gradation."

Further data on these districts are given under San Luis Obispo County. The railroad point for the Adelaide district is Paso Robles, from 16 to 20 miles distant to the east. For the Oceanic district, freight is received by steamers to San Simeon, 13 miles distant, while mail goes by stage from San Luis Obispo via Morro and Cambria. For the country to the south of Cambria and the Oceanic mine, the shipping point is the port of Cayucos. The Pine Mountain and San Carpojaro districts ship through San Simeon.

LOS PRIETOS DISTRICT.

Los Prietos district is in the Santa Ynez Mountains, Santa Barbara County, about 8 miles due north of Santa Barbara. As the district is wholly within that county, it is further described under that heading.

OTHER DISTRICTS.

As the other, scattered districts, are each within a single county, their descriptions are taken up under the county headings. Some of them are not at present commercially producing.

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[5]Forstner, *op. cit.* p. 149.

MINES AND PLANTS.

ALPHABETICALLY BY COUNTIES.

ALAMEDA COUNTY.

There has been no commercial production of quicksilver from this county; but an occurrence described by Lawson[1] is worthy of note.

"On the west slope of the Berkeley Hills, north of Berkeley, cinnabar has been found in a silicified rhyolite fault breccia that outcrops as a prominent knob. Assay of samples taken from the outcrop showed that the rock contains 0.5 per cent of quicksilver. On the slopes below this, however, loose fragments of much richer ore have been found. No attempt has been made to prospect the deposit."

Bibl.: CAL. STATE MIN. BUR., Report XI, p. 121. U. S. G. S., San Francisco Folio (No. 193), p. 22.

CALAVERAS COUNTY.

The occurrence of cinnabar has been noted[2] in the Oro y Plata, or Blue Wing mine, north of Murphy, in a quartz vein

"in limestone close to the contact with the Calaveras schists. * * * Cinnabar, stibnite, and galena are present in the ore, and it is said to contain copper."

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[1]Lawson, A. C., U. S. Geol. Surv. Geol. Atlas, San Francisco Folio (No. 193) p. 22. 1914.

[2]Turner, H. W., and Ransome, F. L., Geologic Atlas of U. S.; U. S. Geol. Surv., Big Trees Folio (No. 51), p. 6. 1898.

COLUSA COUNTY.

The difficulties of mining here due to the hot waters could probably Sulphur Creek district, the general geology of which is described in a preceding section.[3] The Abbott mine, also in this district, is just over the boundary line in Lake County, and so listed under that county.

The following table shows the recorded output of quicksilver in Colusa County, from 1875, the earliest available figures.

Quicksilver Production of Colusa County.

Year	Flasks	Value	Year	Flasks	Value
1875	700	$58,905	1904	*400	$16,526
1876	407	17,908	1905	326	12,231
1877	166	17,382	1906	--------	--------
1878	--------	--------	1907	17	648
1895	1	40	1908	21	900
1896	58	2,051	1909	11	545
1897	43	1,510	1910	--------	--------
1898	--------	--------	1911	5	230
1899	--------	--------	1912	--------	--------
1900	275	12,359	1916	25	2,438
1901	235	10,575	1917	--------	--------
1902	605	26,100			
1903	510	21,708	Totals	4,105	$202,059

*Flasks of 75 pounds since June, 1904; of 76½ pounds previously.

Elgin Mine. New Elgin Quicksilver Mining Company, owner; W. S. Norman, president, Spokane, Washington. S. H. Smith, superintendent, Wilbur Springs. This property, consisting of one claim, a mill site and 160 acres of patented land, is at the head of Sulphur Creek, in Sec. 13, T. 14 N., R. 6 W., about 4 miles northwest from Wilbur Springs postoffice. Except for small yields in 1908, 1909, and 1916, the property has been idle for many years, until the present reopening. During 1917, from 4 to 6 men were employed on development work. One important difficulty in working this mine has been the hot sulphur water present. From the 'lower' tunnel, which is 500 feet above the bottom of the cañon, a stream of hot salino-sulphur water (see Photo No. 2) flows over 40,000 gallons per 24 hours. Its temperature is 138° F., and the odors of both sulphuretted hydrogen and ammonia are noticeable. It is strongly saline and is said to carry about 2000 grains of mineral matter per gallon. There is a considerable deposit of flour sulphur along the edges of the stream, as shown by the photograph. Higher up near the top of the ridge there is another similar spring, temperature 152° F., which also has a strong flow.

The difficulties of mining here due to the hot waters could probably be minimized (if not entirely obviated) by driving a drainage adit

[3] See p. 32, *ante*.

from the creek level, as the present 'lower' tunnel is 500 feet above the retorts, as already noted. It is stated that such is the present intention. The ledge matter is a black to white opaline rock (the black resembling obsidian) in an altered tuff, with cinnabar and an abundance of native sulphur crystals. In fact, so highly impregnated are parts of the formation here with sulphur (resembling the famous Sul-

Photo No. 2. Hot salino-sulphur water flowing from tunnel of Elgin mine, at head of Sulphur Creek, Colusa County.

phur Bank mine in Lake County), that in the early history of the Elgin attempts were made to produce sulphur commercially by distillation. The mine is equipped with a Fitzgerald retort furnace, and a partly dismantled mill containing a #5 Dodge crusher, 8 Colorado bumping tables, and one Wilfley table. Concentration was tried during the operations of 1908–1909. Many of the old dumps are said to show assays of 0.3%–0.4% mercury.

Bibliography: CAL. STATE MIN. BUR., Reports VI, Pt. 1, p. 136; XI, p. 182; XII, p. 359; XIII, p. 594; XIV, pp. 182–184, 188, 189, 196; Chapter rep. bien. period, 1913–1914, pp. 10–12, 16, 17, 24; Bull. 27, p. 43. U. S. G. S., Min. Res. 1907, Pt. I, p. 679; 1908, Pt. I, p. 685; 1909, Pt. I, p. 552. MIN. RES. W. OF ROCKY MTS., 1875, p. 14; 1876, p. 20.

Empire-Central Groups. Empire Consolidated Quicksilver Mining Company, Mrs. Emma B. Boggess et al., Wilbur Springs, owners. These two groups of claims are in Sec. 28, T. 14 N., R. 5 W., near Wilbur Springs, and were at one time, some years ago, operated in conjunction with the Abbott mine. It was reported under option in 1917, with a prospect of work being resumed.

Bibl.: CAL. STATE MIN. BUR. Reports XI, p. 186; XIII, p. 594; XIV, p. 189; Chapter rep. bien. period, 1913–1914, p. 17; Bull. 27, p. 43.

Manzanita Mine. Cerise Gold Mining Company, owner; J. E. Simpson, president, Orland; Chas. L. Austin, superintendent, Wilbur Springs. This mine, for some years past owned as a part of the adjacent hot springs resort property, was taken over early in 1917, by the present owners jointly with the neighboring old Cherry gold mine. A mill was built to treat the gold ore by amalgamation and concentration, to be followed by the addition of equipment for recovery of cinnabar and its reduction. Shortly after completion this plant was destroyed by fire, September 3, 1917; but is reported to have since been rebuilt. At present writing, it is idle on account of litigation. Water for the mill is pumped 8000 feet from Bear Creek. Mining will be by open-cuts. Power is obtained by two 50-h.p. Diesel-type crude-oil engines for the mill, and a 12-h.p. engine for the pump. A 6′x16′ Hardinge mill, and 4 Senn pan-motion amalgamators were installed.

By reason of the Manzanita's ore carrying an important percentage of gold as well as cinnabar, in its earlier history the mine was worked for its gold content. While gold has been found at other places associated with mercury in small quantities (usually little more than a trace), the Manzanita mine is the one notable quicksilver mine of the world where there has been a sufficient percentage of gold to work the ore at times for that metal alone. The major portion of Colusa County's gold output[1] to date has come from Manzanita. The first recorded mention of this gold occurrence was by Whitney[2] in 1865, who tells of being shown specimens of rounded and water-worn masses

[1]See Cal. State Min. Bur., Report XIV, p. 176, 1915.
[2]Whitney, J. D., Geology of California: Geol. Surv. of Cal., vol. I, p. 92, 1865.

of pure cinnabar, with specks of native gold enclosed in them, and that "considerable quantities of this remarkable combination of ore and metal are said to have been washed out from the bed of a creek in the cañon at that place." The rocks are metamorphosed beds of the Knoxville[3] series, consisting of thin-bedded, highly altered, and contorted, shaly sandstones, a part of them somewhat serpentinized. The waters of the hot springs nearby are highly charged with sulphuretted hydrogen, sodium chloride, and also contain ammonia and borax.

The total quicksilver production of the mine approximates 2,000 flasks, the most of which was obtained by means of concentration during the eight years up to 1912. This plant is described in the section of the present bulletin under metallurgy.[4] The mine has been idle since, and the workings largely inaccessible. Relative to the geological evidence then visible underground, Forstner[5] in 1903 wrote:

"In the mine near the shaft a whitish friable material (leached sandstone) carries sensible amounts of cinnabar. The ledge is very winding in both strike and dip; the accompanying gouge is also very irregular. The hanging-wall shale is in places altered to a whitish material very similar to that above mentioned. The ledge material, especially in the lower 150-foot level, is principally chalcedonite. In places conglomerate is found on the foot wall of the ledge, but it is doubtful if the real foot wall has been reached. This deposit shows plainly that it is the result of deposition out of solfataric waters, as well in the ore body as by their action on the adjacent rocks. To the west of the deposit lies a belt of limestone, adjoining at the west to a belt of conglomerate."

Bibl.: Cal. State Min. Bur., Reports V., p. 96; VI, Pt. I, p. 33; VIII, pp. 157, 159; X, pp. 159, 161; XI, p. 184; XII, pp. 100, 359; XIII, pp. 126, 594; XIV, pp. 189–191; Chapter rep. bien. period, 1913–1914, pp. 17–18; Bull. 27, pp. 44, 198, 202. Geol. Surv. of Cal., Geol., Vol. I, p. 92; U. S. G. S., Mon. XIII, p. 367; Min. Res. 1892, p. 147; 1902, p. 252; 1907, Pt. I, p. 679; 1908, Pt. I, p. 685; 1909, Pt. I, p. 552; 1911, Pt. I, p. 901. Eng. & Mining Jour., Vol. 96, p. 783. Min. & Sci. Press, Vol. 115, Oct. 13, 1917, p. 24 adv.

Wide Awake Consolidated Group (Buckeye). This mine, originally known as the Buckeye, is owned by G. A. Martin, Shreve Building, San Francisco. It is about a mile from Wilbur Springs, and south of the creek, in Sec. 29, T. 14 N., R. 5 W., 26 miles southwest from Williams. It is on the opposite (east) side of the ridge from the Abbott mine. The property has been idle since 1901, and the shaft (500 feet deep) is now filled with water.

This mine first appeared in the producing list in 1875. After having been closed for a number of years, it was reopened in 1896 and yielded a small output for a time. The ore, carrying cinnabar, was found at and near the contact between serpentine and shale, strike northwest, dip southwest about 60°. It is stated that this contact

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[3]Becker, G. F., Geology of the quicksilver deposits of the Pacific Slope: U. S. Geol. Surv., Mon. XIII, p. 367, 1888.
[4]See p. 330, *post*.
[5]Forstner, William, Quicksilver Resources of California: Cal. State Min. Bur., Bull. 27, p. 45, 1903.

has been traced for about a mile in the company's ground, though the croppings are more prominent near the plant. It was worked by both tunnels and shaft, the latter being sunk in the shale. The vein matter was found up to five feet wide, mostly soft, with the shale hanging-wall well defined, while the values were slightly disseminated into the serpentine footwall. The reduction equipment includes a 24-ton Scott fine-ore furnace.

Bibl.: CAL. STATE MIN. BUR., Reports XI, p. 187; R. XIII, p. 594; XIV, p. 190; Chapter rep. bien. period, 1913–1914, p. 18; Bull. 27, p. 45. GEOL. SURV. OF CAL., Geol. Vol. II, p. 124. MIN. RES. W. OF ROCKY MTS., 1875, p. 14; 1876, p. 20. U. S. G. S. Mon. XIII, p. 368; Min. Res. 1908, Pt. I, p. 685.

Wilbur Hill Mine. Wilbur Springs Company, owner, Wilbur Springs, postoffice. It is on Sulphur Creek between Wilbur Springs and the Manzanita mine, being in Sec. 28, T. 14 N., R. 5 W., 25 miles southwest from Williams. A small output of quicksilver was made in 1916, with a concentrator and retort; but only development work has been done since.

CONTRA COSTA COUNTY.

Quicksilver was at one time mined on the eastern slope of the north peak of Mt. Diablo, in Sec. 29, T. 1 N., R. 1 E., associated with serpentine and black opal. There are sulphur springs, nearby. During the late seventies the **Ryne** mine is said to have produced as high as 85 flasks per month, for a time. The occurrences are limited in extent, and there has been no work done for a number of years.

Bibl.: CAL. STATE MIN. BUR., Report VIII, p. 162; Bull. 27, p. 195. U. S. G. S., Mon. XIII, p. 378.

DEL NORTE COUNTY.

Diamond Creek Cinnabar Co. J. W. Ehrman, I. L. Cole, and J. L. Taggart, Monumental, Calif., owners. This group consists of three unpatented claims located on the headwaters of Diamond Creek, four miles south of the California-Oregon Line and eighteen miles from Monumental, all but three miles being by road. The presence of cinnabar here is said to have been known to the early placer miners, who resorted to it in the '50's for their quicksilver supply. The group was relocated in 1916. The ore occurs in quartz between serpentine walls, and makes in rich bunches, with a general N-S trend. The owners have traced the outcrop 400 yards and have an orebody eight feet wide. So far, they have been able to do only a little hand mining near the surface, two of the owners working. During the past summer they installed a three-pipe Johnson-McKay retort, having a capacity of 500 pounds of ore. The charge is retorted for six hours so that the daily capacity is one ton. The first ton of ore treated is reported to have yielded nearly one-half flask of mercury. The average of the ore is stated to carry 1%–2% mercury.

Bibl.: CAL. STATE MIN. BUR., Reports XI, p. 198; XIV, p. 390; Chapter rep. bien. period, 1913–1914, p. 20; Bull. 27, p. 195. U. S. G. S., Mon. XIII, p. 366. MIN. & SCI. PRESS, vol. 29, Aug. 15, 1874.

EL DORADO COUNTY.

Bernard Cinnabar Mine (originally called the **Amador**). Bernard Cinnabar Mining Company, owner; Leon C. Osteyee, secretary, 127 Montgomery Street, San Francisco; John C. Jens, Belmont, lessee. It is on Fanny Creek, in Sec. 4, T. 8 N., R. 10 E., M. D. M., 2 miles west of Nashville and about 8 miles from Shingle Springs on the Sacramento and Placerville Railroad. There is a good wagon road from Shingle Springs to the mine. The deposit is a bedded vein in slates and quartzitic rocks;[1] and the cinnabar, accompanied by pyrite, occupies interstitial spaces. There is a belt of serpentine about 1/4 mile to the west. The mine was first opened up in the 60's and some quicksilver produced; then reopened in 1903, when only development work was done. It has been idle since. The mineral zone is stated to show a width of 20′–50′ along the surface, and in the open cuts. There is a vertical shaft, 75 feet deep, connecting with the lower adit which is in 117 feet. Near that point some stoping has been done. The present lessee is preparing to reopen the mine, this coming spring.

Bibl.: Cal. State Min. Bur., Reports XII, p. 359; XV, p. 306; Chapter rep. bien. period, 1915–1916, p. 36; Bull. 27, p. 190. U. S. G. S. Mon. XIII, p. 384; Placerville Folio (No. 3), p. 3. Geol. Surv. of Cal., Auriferous Gravels, p. 367. Min. & Sci. Press, vol. 31, p. 718, 1875.

[1]Becker, G. F., Geology of the quicksilver deposits of the Pacific Slope: U. S. G. S., Mon. XIII, p. 384, 1888.

FRESNO COUNTY.

In the various earlier reports and papers, it is to be noted that the mines of the New Idria district were described as being in Fresno County; but in 1888, the county boundary was changed, so that New Idria is now in San Benito County. The quicksilver localities within the present boundaries of Fresno County are along its western edge, in the eastern foothills of the Diablo Range.

Recorded quicksilver production of Fresno County (for New Idria district, see under San Benito County), is shown in the following tabulation. As the figures of earlier years were small and scattering, they were included under the designation of "Various Mines" in published tables.

Quicksilver Production of Fresno County.

Year	Flasks	Value	Year	Flasks	Value
1912	336	$14,125	1916	*	*
1913	375	15,086	1917	*10	*$875
1914	148	7,259			
1915			Totals	869	$37,345

*Figures for 1916 and 1917 combined to conceal output of a single producer.

Archer Mine. Joseph Byles & Sons, Coalinga, owners; Ben J. Byles, manager. This group of six claims located in 1904, is in Secs. 2 and 3, T. 18 S., R 13 E., M. D. M., 28 miles northwest of Coalinga, and near the Mexican mine. Up to 1916, a small amount of quicksilver was produced, using a retort consisting of six 9-inch pipes. A Johnson-McKay retort has since been built; and selected ore is treated; but it is stated that there is considerable low-grade material in sight. The ore carries cinnabar and pyrite, the country rocks being serpentine and slate. There are five tunnels ranging up to 200 feet in length, and several open cuts.

Bibl.: Cal. State Min. Bur., Report XIV, p. 462; Chapter rep. bien. period, 1913–1914, p. 36.

Mexican Mine. Antonio Urrutia et al., Panoche, owners. This group of three claims in Sec. 22, T. 18 S., R. 13 E., northwest of Coalinga, and nine miles southeast of New Idria, was originally located in the sixties. Development work consists of several adits and some surface cuts. The vein is in sandstone of the Franciscan series close to its contact with the overlying Panoche formation, and carries cinnabar associated with silica and oxides of iron, the oxidation product of iron sulphides. Only assessment work has been done of recent years.

Bibl.: Cal. State Min. Bur., Report XIV, p. 462; Chapter rep. bien. period, 1913–1914, p. 36; Bull. 27, pp. 119, 120. U. S. G. S., Bull. 603, p. 207.

New Mercy Mining and Development Co. (formerly Mercey Mining & Development Co.; also **Pacific Quicksilver Co.**; includes properties and claims formerly known under names of Providential, Arambide and Aurecoechea, Mercy, Croxon). A. R. Warthen et al., owners; J. Norrish, manager, Los Baños, c/o Mercey Hot Springs stage. This group includes eighteen claims and five mill sites on a branch of Little

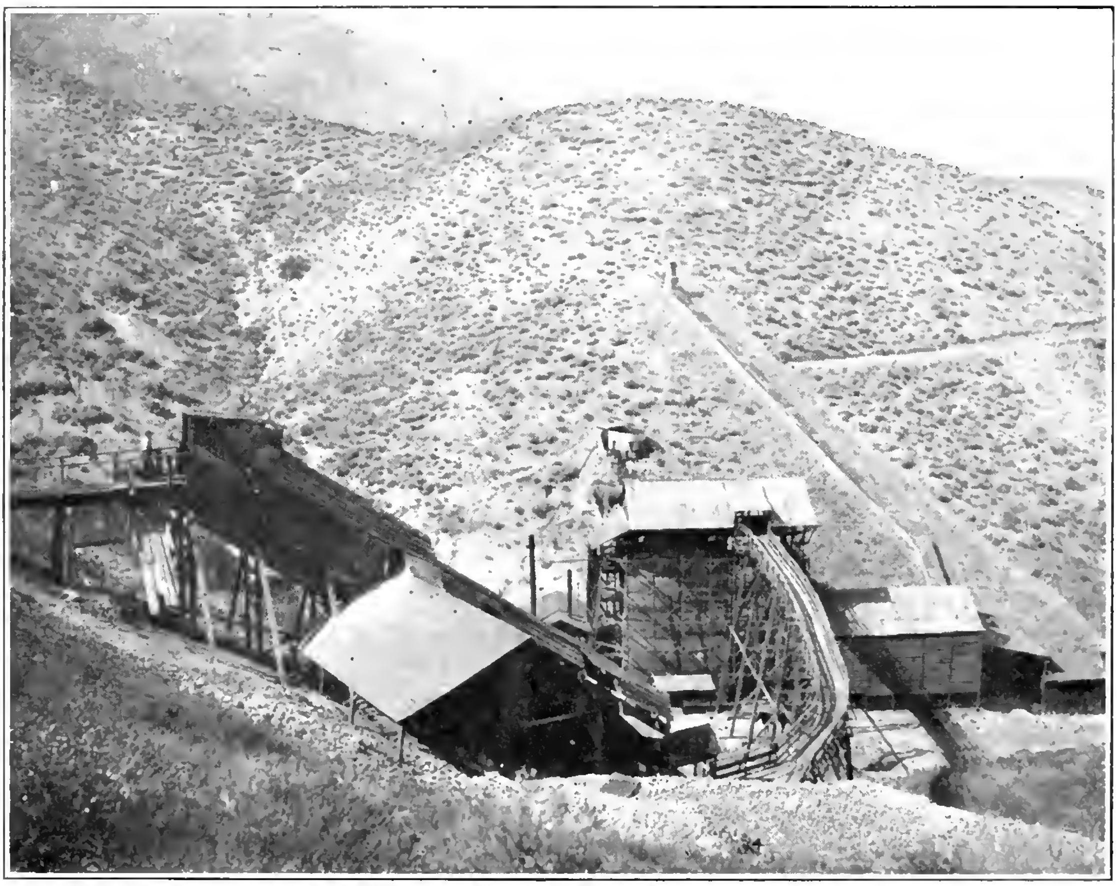


Photo No. 3. Furnace at New Mercy (Pacific) Quicksilver Mine, Fresno County.

Panoche Creek, in Secs. 32 and 33, T. 13 S., R. 10 E., and Sec. 5, T. 14 S., R. 10 E., 25 miles southwest of South Dos Palos on the Southern Pacific Railroad, and 29½ miles from Los Baños. Elevation 1600 to 2000 feet (U. S. G. S). The first work is said to have been done here about 1860. The Pacific Quicksilver Company operated the property from 1911 to the end of 1914; since which time it has been idle until late in 1917. The country rock is principally a metamorphic sandstone, and the ore occurs in a series of leached zones with quartz and ochre. Relatively little cinnabar can be seen except on panning.

when the ochreous material is observed to yield a good percentage of concentrate. There is a little pyrite with the cinnabar.

Formerly the principal work was done on the Providential and Gabilan claims, but in September, 1914, the ore supply was being drawn from the Arambide from a new shoot uncovered in the preceding spring. Here the values occur in a series of small veins and stringers over a width of 24 feet, striking east of south and dipping about 60° E. On this claim there is a 100-foot shaft and 400 feet of adits; and on the Aurecoechea 3000 feet of work, including a 150-foot shaft.

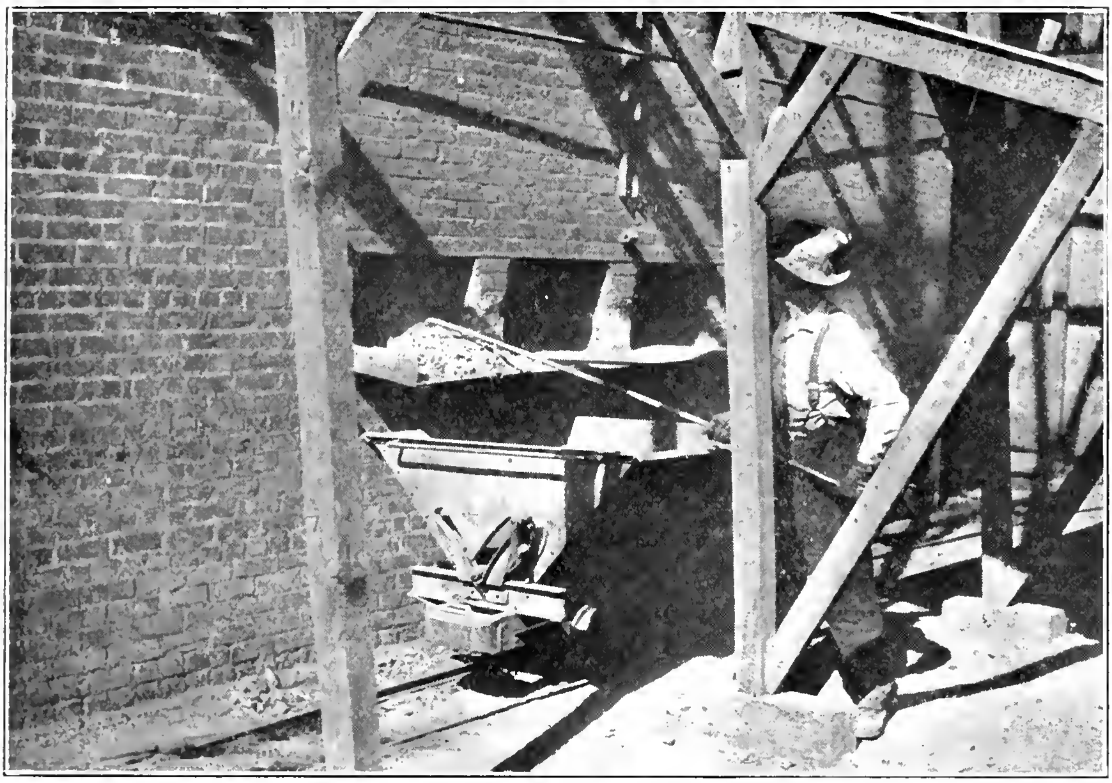


Photo No. 4. Drawing off burned ore, New Mercy (Pacific) Quicksilver Mine, Fresno County.

The reduction equipment includes a 24-ton Scott fine-ore furnace (see Photo No. 3), and two 'D' retorts with a capacity of 300 pounds each. They are oil fired. In 1914, crude oil cost 88 cents to $1.10 per barrel delivered at South Dos Palos, plus $1.17 per barrel freight to the mine. The furnace is 4 tiles long, 50 tiles high, with a 4-inch spacing. The condensers consist of 14 brick chambers and 6 Knox-Osborne cast-iron chambers, the latter being connected in between No. 2 and No. 3 of the brick series (see Photo No. 58, *post*). From the mine the ore was hauled about ¼ mile in a bottom-dump wagon onto an ore bin, from which it was trammed to the jaw crusher (run by a small steam engine), then trammed to the furnace. The burned ore was drawn off into a side-tipping steel car (see Photo No. 4), and trammed to the dump.

Bibl.: CAL. STATE MIN. BUR., Report XIV, pp. 462–464; Chapter rep. bien. period, 1913–1914, pp. 36–48; Bull. No. 27, pp. 119, 121. U. S. G. S., Mon. XIII, p. 380; Min. Res., 1912, Pt. I, p. 939; 1913, Pt. I, p. 204; Bull. 603, p. 207.

GLENN COUNTY.

Cinnabar has been reported on the J. M. Nye ranch, southwest of Fruto, and on the Turner ranch west of Elk Creek postoffice. Not developed.

Bibl.: CAL. STATE MIN. BUR., Report XII, p. 360; XIV, p. 199; Chapter rep. bien. period, 1913-1914, p. 27.

HUMBOLDT COUNTY.

E. F. Wilder, Orleans, has locations made about 1915, in Mill Creek district, near Orleans Bar on a vein carrying cinnabar; but so far only a small amount of development work has been done.

INYO COUNTY.

Small amounts of both cinnabar and metacinnabarite have been noted in the **Cerro Gordo** mine,[1] near Keeler, but apparently not in commercial quantities.

A vein in limestone containing cinnabar and metacinnabarite has been noted[2] on one of the claims of the **Chloride Cliff** mine in the Funeral Mountains west of Rhyolite, Nevada. An 80-foot tunnel has been driven on the vein, exposing some fair ore; but no quicksilver has been produced. Owned by J. I. Crowell, Donald Findley, and Chas. Parsons, of Rhyolite, Nev.

Bibl.: CAL. STATE MIN. BUR., Bull. 67, pp. 32, 34; Mines & Min. Res. of Alpine, Inyo & Mono counties, p. 117 (also Report XV, p. 121, in press). U. S. G. S., Bull. 61.

[1] Melville, W. H. & Lindgren, W., Contributions to the mineralogy of the Pacific Coast: U. S. Geol. Surv. Bull. 61, 1890.

[2] Waring, C. A., & Huguenin, Emile, Mines & Min. Res. of Inyo County: Cal. State Min. Bur., Biennial report 1915–1916, p. 117, 1917. Also in Report XV, p. 121, 1918.

KERN COUNTY.

Quicksilver production in Kern County began in 1916, following the discovery of cinnabar in workable quantities close to the famous Tehachapi Loop of the Southern Pacific railroad, near the town of the same name. Slightly over 300 flasks have been produced to the end of 1917, with two mines in operation, the major portion of the output coming from the Cuddeback.

Cuddeback Cinnabar Mine. J. P. Cuddeback, Tehachapi, owner; Cuddeback Cinnabar Company, lessee, Tehachapi; A. J. Blackley, president. The mine is on land owned under an agricultural patent, being in Sec. 27, T. 31 S., R. 32 E., M. D. M., 3 mi. from Woodford

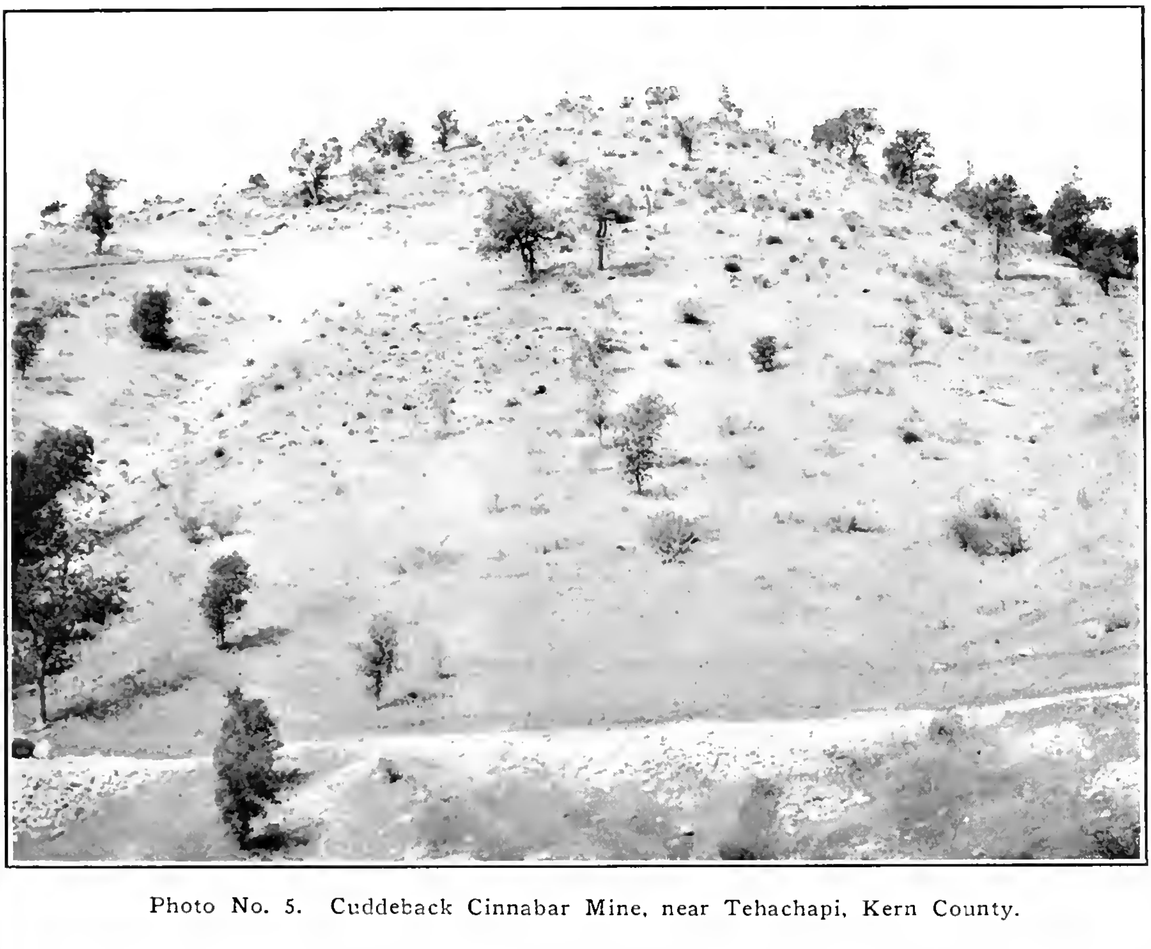


Photo No. 5. Cuddeback Cinnabar Mine, near Tehachapi, Kern County.

(Keene, post office) station on the Southern Pacific, and a half mile by road from the main county highway at the Loop. The country rock for several miles around is granite, and the white rhyolite dike traversing the granite with a nearly E.-W. strike is plainly visible from the passing trains (see Photo No. 5.—the dike crosses the hill from left to right, just above the dumps), though the outcrop is not a bold one. The dip is N., about 45°; and the width is at least 60 feet where most of the work has been done. The dike rock is a somewhat porous, finely granular, porphyritic rhyolite, showing quartz and orthoclase phenocrysts under the microscope (see Photo No. 6). Cinnabar crystals are disseminated through the ground-mass, in some places to such an extent as to give the whole rock a pink color, macroscopically. Portions of the rock which are white, and to the unaided eye apparently barren, show finely disseminated cinnabar under the glass. From this, the writer presumes that a considerable portion of the dike would pay to mine and reduce with a large furnace equipment which could economically treat a large tonnage of low-grade ore. Of course, this can be definitely determined only by a careful sampling across the full width of the dike.

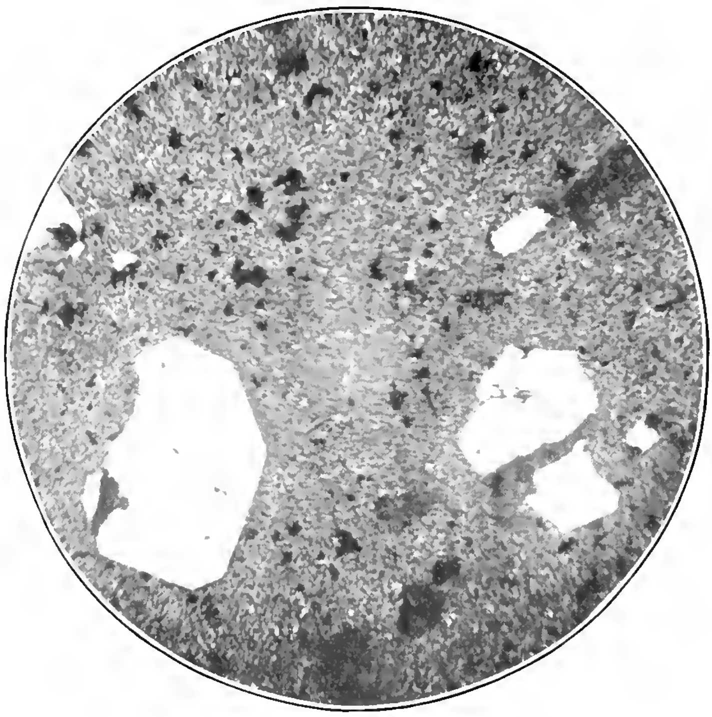


Photo No. 6. Micro-photograph of porphyritic rhyolite carrying cinnabar, from Cuddeback Mine. The black specks are cinnabar. ×60 diam. magnification. Photo by S. A. Tibbetts.

The richer accumulations of ore appear to be associated with certain cross-fissures in the dike which are marked by the presence of brown clay seams. The mineralizing solutions apparently came up through these fissures, spread out into and impregnated the somewhat porous rhyolite, similarly to the impregnated sandstone ores as at Oat Hill, Napa County. So far as observed, the rhyolite is but little altered, and the adjacent granite is fairly fresh. At this point, the mineralized portion of the dike is ⅛ mile long; and though the dike itself is traceable beyond, it seems not to show enough cinnabar to be workable beyond. The development work consists of several short adits, crosscuts, drifts, small stopes, and open cuts; and when visited in September, 1917, a depth of about 50 feet below the outcrop had been attained in a drift and stope around the point of the hill to the right of the photograph (No. 5). Reduction equipment consists of a 12-pipe Johnson-McKay retort, oil-fired. There were also a 6 h. p. gas engine, and a small jaw crusher.

Bibl.: Min. & Sci. Press, Vol. 114, p. 79, Jan. 20, 1917.

Fickert-Durnal Mine. J. P. Cuddeback, Tehachapi, owner; Phillip Fickert, Bakersfield, and J. A. Durnal, Tehachapi, lessees. This prospect, like the above-described, is also on the Cuddeback ranch property, being a mile southeast, in SW. ¼ of SW. ¼ of Sec. 26, T. 31 S., R. 32 E., M. D. M., 4 miles from Woodford and about 7 miles from Tehachapi. It is only a half-mile off the main county highway. The ore occurs in an altered igneous dike rock, traversing the granite with a NW.-SE. strike and a dip NE. There is a brecciated zone at least 18 feet wide, and the rock is so much altered that it is difficult to determine its original character; though some less altered portions resemble a felsite. The cinnabar is in part disseminated and in part in seams in the altered dike material. There is a little associated pyrite. The granite, particularly on the footwall, is considerably disintegrated. Developments consisted mainly of 3 short adit drifts, and a 25-foot shaft near the bed of the ravine which had become filled with water. A 6-pipe Johnson-McKay retort had just been completed and was being fired-up (September 20, 1917), oil being used for fuel.

Tardy Claims. Jack Tardy is stated to have located in January, 1917, a group of claims 20 miles from Mojave, 2½ miles west of Cinco and ¼ mile above the Los Angeles Aqueduct. Cinnabar is reported to occur in an igneous dike in granite, resembling the Cuddeback occurrence. Undeveloped.

KINGS COUNTY.

The quicksilver district of Kings County is at its extreme western end in the corner formed between Fresno and Monterey counties. It is on the eastern edge of Table Mountain which extends northwesterly through that part of Monterey and forms a portion of the boundary with Kings. Table Mountain is principally of serpentine. Parkfield, Monterey County, is the nearest town, 14 miles distant; which, in turn, is 27 miles from the railroad at San Miguel on the west.

The recorded production of quicksilver in Kings County is shown by the following tabulation:

Quicksilver Production of Kings County.

Year	Flasks	Value	Year	Flasks	Value
1905	250	$9,000	1913		
1906			1914		
1907			1915	*	*
1908			1916	*480	*$43,580
1909			1917		
1910	100	4,525			
1911			Totals	830	$57,105
1912					

*Figures for 1915 and 1916 combined to conceal output of a single mine.

Dawson Pit. H. Dawson, Lemoore, owner. This is a quicksilver prospect on patented land in the NW. ¼, Sec. 28, T. 23 S., R. 16 E., near the Kings company ground. Only a small amount of development work has been done.

Bibl.: Cal. State Min. Bur., Report XIV, p. 528; Bull. No. 27, p. 122; Chapter rep. bien. period, 1913–1914, p. 102.

Fair View Group. G. H. French and J. A. Greenlaw, Parkfield, owners. In the SW. ¼, Sec. 28, T. 23 S., R. 16 E. Assessments only.

Bibl.: Cal. State Min. Bur., Report XIV, p. 529; Chapter rep. bien. period, 1913–1914, p. 103; Bull. No. 27, p. 122.

Francis Claims (see Kings Quicksilver Mining Company).

Kings Quicksilver Mining Company, Ltd. Wm. Gray, president; W. P. Darsh, secretary; office, 520 King street, London, Ontario, Canada. A. A. Lewis, superintendent, Parkfield. This property includes the Segregation and Summit claims owned by C. F. Francis of Parkfield, under bond, besides a number of claims located by members of the company on adjoining ground. The group is principally in Sec. 20, T. 23 S., R. 16 E., 14 miles by road east of Parkfield and 40 miles north of east from San Miguel on the Coast Division of the Southern Pacific Railroad. Elevation 3100 feet (bar.) at the lower tunnel.

The country rocks are serpentine, shale and metamorphic sandstone. The ore values occur in a crushed zone, in part as stockworks, carrying cinnabar and native mercury with some calcite. In the upper level this zone shows about 35 feet wide, with strike southeast and dip 45° to 50° SW., and in September, 1914, had been drifted on for 70 feet. The upper adit was in 700 feet (part crosscut and part drift), with two raises to the surface and one winze of 85 feet to the lower adit. The latter has 850 feet of work and reaches a depth of 200 feet below the outcrop. Hand drills and augers were used.

The mine was originally worked about 1902, and again in 1905 and 1910, during which operations it is credited with a total output valued at over $13,000. The reduction equipment consisted of a series of pipe

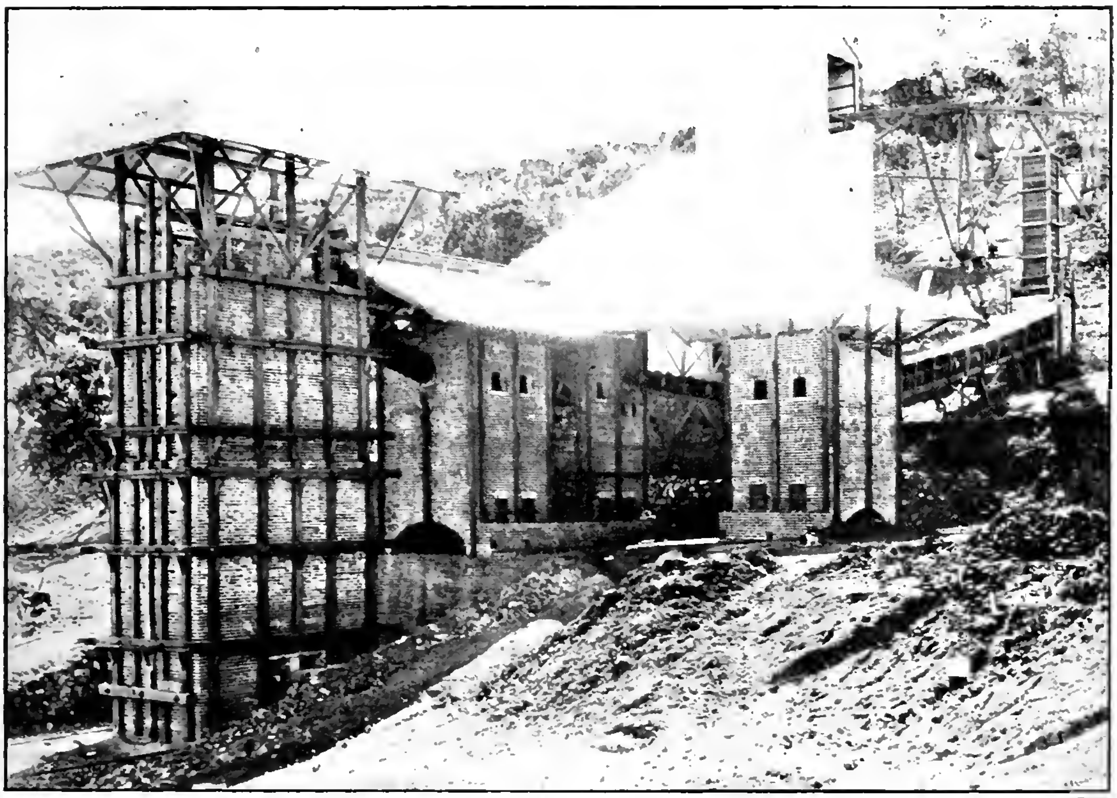


Photo No. 7. Ten-ton Scott fine-ore furnace and condensers, Kings Quicksilver Mining Company, Ltd., Kings County.

retorts. The present company in 1914 completed a 10-ton Scott fine-ore furnace (see Photo No. 7), with brick condensers, which was operated with some interruptions up to the close of 1916. The bricks were burned in a field kiln at the mine. A concentrating mill was also built, and operated for some months. This is described in the section under Concentration.[1] The mill and the rock breaker were driven by a 25 h. p. crude-oil engine; and the furnace blower by a 4 h. p. distillate engine. During the summer of 1917, the Scott furnace was utilized by the King Magnesite Co., to calcine magnesite from their deposit

[1]See p. 338, *post.*

nearby. The property is at present (February, 1918) under option to the Patriquin Brothers of Parkfield, who propose to reopen it the coming spring.

Bibl.: CAL. STATE MIN. BUR., Report XIV, p. 529–530; Chapter rep. bien. period, 1913–1914, pp. 103–104; Bull. No. 27, p. 122. U. S. G. S., Min. Res. 1902, p. 253; 1912, Pt. I, p. 939; 1913, Pt. I, p. 204.

LAKE COUNTY.

Prospecting and exploitation of quicksilver deposits in Lake County began in the early sixties, and the Abbott mine was a producer as early as 1870. There was no notable production, however, until 1873. As will be noted by reference to the table of production, quicksilver mining was most active in this county from 1875 to 1882. There was a revival between the years 1891 and 1896; but beginning with 1905 there was a rapid decline, until it reached an almost insignificant figure just preceding the present improved market. There were but two producers in 1913—the Helen and the Wall Street, both of them being near Middletown. It may be noted here that in some of the early reports and press notices the Knoxville mines (Manhattan, Lake, Redington, Boston) were erroneously referred to as being located in Lake County. They are in Napa County.

There are four recognized quicksilver districts either wholly or in part located in Lake County: (1) *Mayacmas*, the largest, is in southwestern Lake and extends over into northeastern Sonoma and northwestern Napa; (2) *Clear Lake* district is around the eastern, southern, and southwestern sides of Clear Lake; (3) *Knoxville* district is at the junction of Lake, Yolo, and Napa, being principally in the last named; (4) *Sulphur Creek* district is almost wholly in Colusa but includes the Abbott mine which is on the eastern edge of Lake County. The general geology of these districts is described in preceding paragraphs at the beginning of this chapter.[1]

The recorded quicksilver yield of Lake County is shown in the following tabulation. The actual production is known to be in excess of these figures, due the production of some of the smaller mines previous to 1894 being included with mines of other counties, unapportioned, under the designation, "various mines." For many years quicksilver was the premier mineral in output for the county; but between 1903 and 1914, it was surpassed by mineral water.

[1]See pp. 30–33, *ante*.

Quicksilver Production of Lake County.

Year	Flasks	Value	Year	Flasks	Value
1873	880	$70,790	1897	3,585	$134,546
1874	1,695	178,280	1898	1,729	64,746
1875	8,821	743,287	1899	2,954	128,179
1876	14,199	624,756	1900	3,165	127,345
1877	18,100	675,130	1901	4,395	211,324
1878	14,428	474,681	1902	3,611	161,568
1879	15,582	309,303	1903	2,595	106,397
1880	17,148	531,588	1904	*2,854	109,719
1881	17,393	518,833	1905	1,462	51,937
1882	10,193	287,748	1906	1,066	38,909
1883	6,481	186,329	1907	802	30,604
1884	4,182	127,551	1908	1,300	54,951
1885	4,765	146,524	1909	1,075	56,277
1886	3,498	124,179	1910	1,048	47,422
1887	4,307	182,509	1911	899	41,363
1888	6,636	282,030	1912	209	8,786
1889	4,713	212,085	1913	395	15,891
1890	4,232	222,180	1914	331	16,236
1891	4,975	225,119	1915	492	41,660
1892	11,140	453,509	1916	1,399	130,806
1893	9,731	357,614	1917	1,067	107,071
1894	12,471	382,954			
1895	12,856	465,074	Totals	251,166	$9,700,274
1896	6,307	232,484			

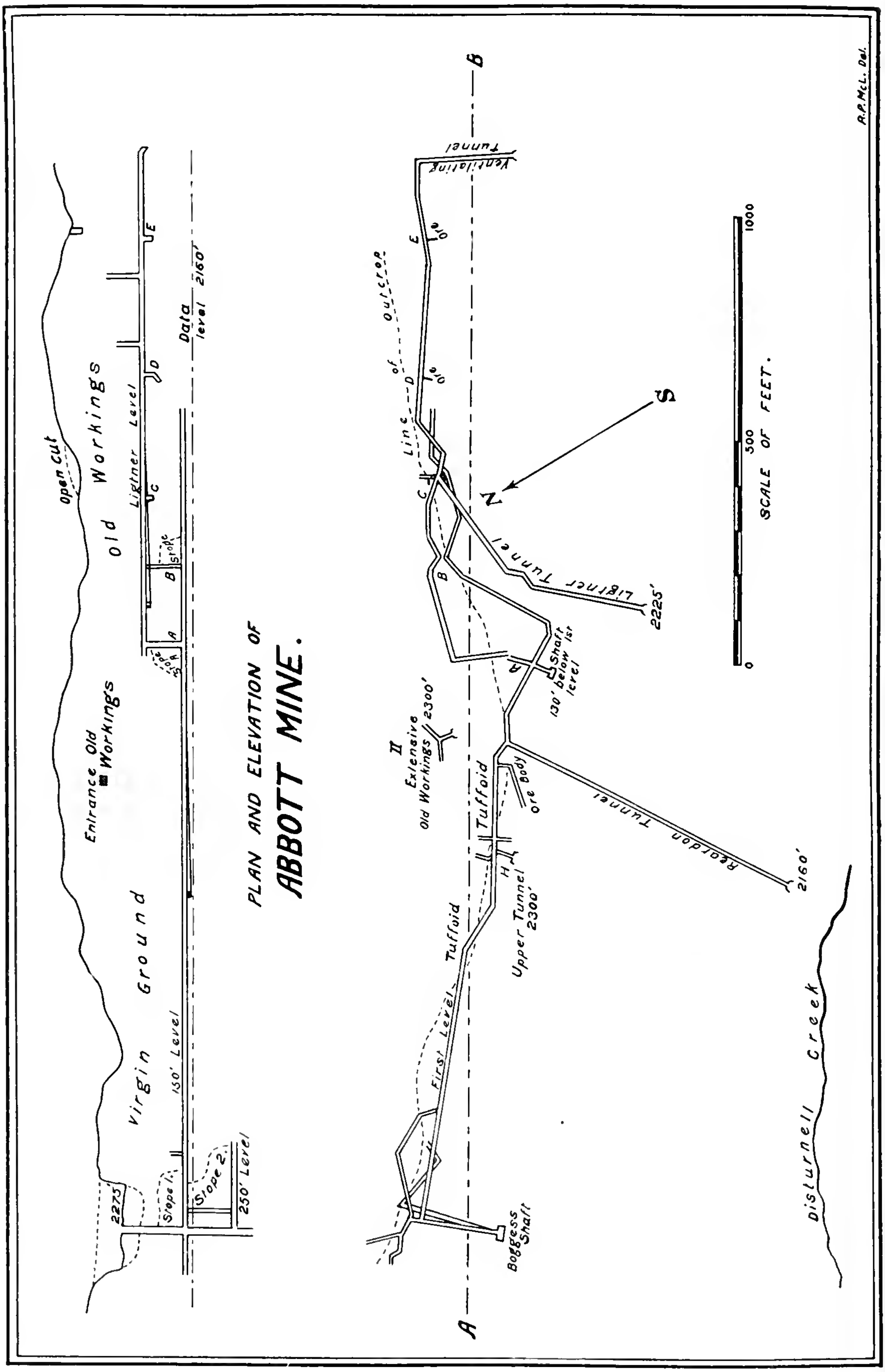
*Flasks of 75 pounds since June, 1904, instead of 76½ pounds as previously.

Abbott Mine. R. A. Boggess et al., Wilbur Springs, owners. The Abbott group is on the eastern border of Lake County, in Sec. 32, T 14 N., R. 5 W., about two miles in an air line and three by the road from Wilbur Springs post office, Colusa County. It includes also, the old Disturnell. This group was formerly operated by the Empire Consolidated Quicksilver Mining Campany; but the property has been in litigation at various times, and apparently is still not fully settled. The mine was discovered in 1862 and began production in 1870, continuing to 1879; then idle from 1879 to 1889; and again operated, for a period of sixteen years, till closed down in 1906; since which it has been idle except for a short period, February 1916, to Mar. 17, 1917. The mine is credited with a total production to date, of 30,845 flasks. During 1916, the ore treated was obtained from an old glory hole and by working over some of the old dumps. The underground workings are quite extensive, the greatest depth, however, being only 350 feet below the collar of the 'Boggess' shaft (see Plate VIII). There have been no important developments underground, since Forstner's[1] report.

"This mine lies on the southwestern contact of a serpentine belt, strike northwest, with a shale country rock, occasionally sandstone. The serpentine varies in width from a few hundred feet to a quarter of a mile, and is about 2½ miles long. To the northeast is a belt of sandstone, rather narrow in the southern portion, but widening rapidly going northward. * * * The serpentine is interstratified with beds of shales and sandstone * * *; the same alternations are found underground. * * * The map of the mine workings indicates that they follow generally the line of contact of the tuffoid, with the shales lying west thereof. * * * The shales west of the serpentine contain some hydrocarbons. In places petroleum is found; in others, gases of light inflammable hydrocarbons emanate from the rock or bubble up through the water * * * The cinnabar ore forms in these bands of serpentine, more especially in close proximity to the tuffoid; exceptionally the ore is found in the shale. The gangue is generally strongly crushed opaline. Metacinnabarite occurs occasionally, * * * The cinnabar is disseminated through the crushed opaline, partly as face metal, but also in seams and pockets. The ore zones contain a great amount of iron sulphides, * * * Very little gouge is found between the ore bodies and the walls. The ground in the ore zones and in the shales is often swelling, but the tuffoid stands very well."

[1]Forstner, William, The quicksilver resources of California: Cal. State Min Bur., Bull. 27, pp. 46–48, 1903.

PLATE VIII.



Reprinted from Bulletin No. 27.

The reduction equipment consists of a 48-ton Scott furnace, with an ore drier located between the crusher and furnace. Present reports (March, 1918) are that the property is being refinanced, and will be reopened.

Bibl.: CAL. STATE MIN. BUR., Reports IV, p. 336 (table); XI, p. 239; XII, p. 360; XIII, p. 595; XIV, p. 229; Chapter rep. bien. period, 1913-1914, p. 57; Bull. 27, pp. 46-48, 227; Reg. of Mines, Lake County, p. 3. U. S. G. S., Mon. XIII, p. 368; Min. Res. 1902. GEOL. SURV. OF CAL., Geology, vol. II, p. 124. MIN. RES. W. OF ROCKY MTS., 1876, p. 19.

Anderson Prospects, owned by members of the Anderson family of Anderson Springs. They are in Secs. 25 and 35, T. 11 N., R. 8 W., near Middletown. They have not been previously developed but are now (March, 1918) being opened up by R. B. Crowell, lessee, under the name of Big Chief.

Bibl.: CAL. STATE MIN. BUR., Bull. 27, p. 48: Rep. XIV, p. 230; Chapter rep. bien. period, 1913–1914, p. 58.

Bacon. Abandoned. Reg. of Mines, Lake County, p. 3: Rep. IV, p. 336 (table); XIV, p. 230; Chapter rep. bien. period, 1913–1914, p. 58.

Baker Mine. Baker Quicksilver Company, owner; A. R. Short, president, 1100 Delmas Ave., San Jose. The group consists of two patented claims, Baker and Trade, and 65 acres of agricultural patented land adjoining on the east side of Soda Creek, in Sec. 16, T. 12 N., R. 6 W., 6 miles southeast of Lower Lake. The county road passes near the mine. The Baker was first worked at least as early as 1870, and has been operated at various times in a small way. Present operations were begun in 1916 when the dumps were worked over with a screening and concentrating plant and some surface ore taken out in an open cut. The earlier underground workings are caved. In 1917, a two-compartment incline shaft has been sunk 100 feet, and drifting is now being started. The topography in this vicinity is characterized by a series of rolling ridges and small valleys with longitudinal axes approximately north and south. There is a sparse growth of oak and pine timber.

There are two ore zones, with strike varying from N. 20°, W., to N. 60° W., and dip of 45° NE. The ore bodies showing widths of 10′ to 20′, are stated to be in altered shale at a contact with serpentine, both being overlain by sandstone. No. 1, or the West vein, is traceable on the surface for about 4000 feet; and No. 2, or the East vein, is 75 feet distant, being traceable from near the southeast end of the

Baker claim to the northwest end of the group. The cinnabar occurs disseminated in a zone of crushed and altered material, with occasional high-grade pockets, and associated with iron sulphide and metacinnabarite. From assays reported, the average of the material as a whole appears low grade. Most of the development has been done on No. 1 vein.

Mining equipment consists of gasoline hoist, pump and blower. Surface ore is being taken from an open-cut, sluiced through a revolving screen, and the fines passed over concentrating tables. Water is piped 2,000 feet from Soda Creek, with a raise of 140 feet. The concentrates are reduced in a 7-pipe retort. At present 5 men are employed.

Bibl.: CAL. STATE MIN. BUR., Reports XI, p. 67; XII, p. 360; XIII, p. 595; XIV, p. 230; Chapter rep. bien. period, 1913–1914, 58; Bull. 27, p. 49; Reg. of Mines of Lake Co., p. 3. U. S. G. S., Mon. XIII, p. 368. GEOL. SURV. OF CAL., Geology, vol. II, p. 125.

Big Injun Mine (includes Big Injun and Digger Injun claims). Peake, Miller, et al. (Union Construction Co.), owners, 604 Mission St., San Francisco; R. B. Crowell, Middletown, buying under lease and option. This group, consisting of the Big Injun and 8 other claims, is in the S. ½ of Sec. 35, T. 11 N., R. 8 W., M. D. M., 7 miles northwest from Middletown and a mile south of Castle Hot Springs by sled road. There is an automobile road as far as Castle Springs. The outcrop was discovered about 1873, by 'Injun Jeff'. It had been worked occasionally in a small way, but was idle for some years preceding its being reopened by the present lessee in 1916. The mine is apparently on a contact of serpentine and sandstone, but the formations are considerably broken up at this point. There are two 'veins' or ore zones, the principal development having been done on the eastern one. The strike is NW., and dip SW. The width varies up to 30 feet, with ore shoots showing 1′–4′ wide. The hanging-wall is somewhat heavy to hold, especially in winter. The ore is characterized by the presence of considerable native mercury with cinnabar; and the gangue minerals are quartz and dolomite. There are 3 main crosscut adits, the lowest being in 550′, reaching a depth of 150′ below the outcrop. At 350′ in on this crosscut there is a hot sulphur spring. The ore is treated in two 'D' retorts, 700 pounds per charge, 3 charges per 24 hours. A water-spray was at one time tried in the condenser, but discontinued because of flouring the quicksilver. The condensing system on each retort consists of 20 feet of 6-inch thick-wall cast-iron pipe, and a vertical wood-stave tank 3′ diam. x 8′ high, (see Photo No. 8) with a concrete floor. There is also a shaking screen and a Standard concentrating table, which are used to dress low-grade ore, during the winter months. A revolving screen will be added. The fines from the screen go to the table. The ore retorted during 10 months up to September, 1917, yielded an average of 2% mercury. Wood consumed was 20 cords per month, at a cost of: $2 for cutting, 50¢ stumpage, and $3 hauling, per cord. An average of 12 men were employed, 6 of whom were underground @ $3 per day.

Bibl.: CAL. STATE MIN. BUR., Report XIV, p. 230; Bull. 27, p. 50; Chapter rep. bien. period. 1913–1914, p. 58.

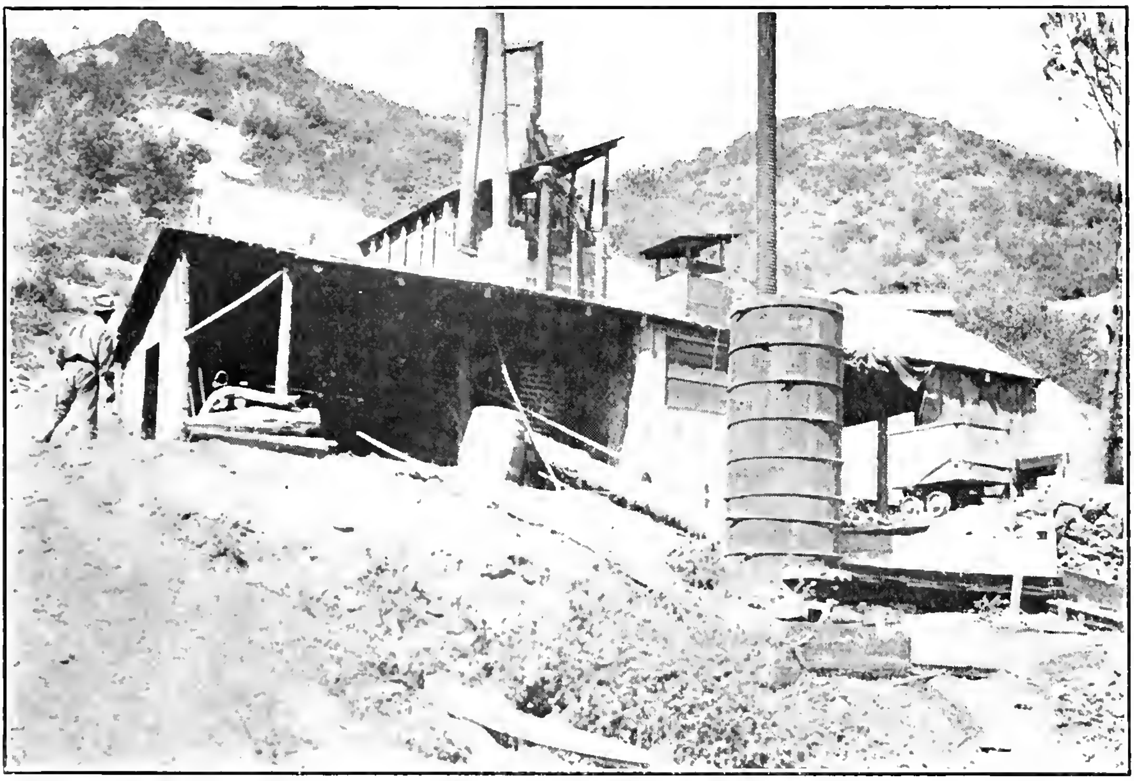


Photo No. 8. Retorts and condensers at the Big Injun Mine, near Middletown, Lake County.

The **Bullion Mine** is 4 miles southwest of Middletown, between the Mirabel and Great Western. Ben H. Otto, J. W. Wrieden, and Chas. Elliott, owners, Middletown. It was formerly worked by the Mirabel Company, and had been abandoned for several years, but was relocated in August, 1913. In the spring of 1917, a few flasks of quicksilver were produced by concentrating old dump material with hand rockers. The concentrates were retorted. Some development work was also carried on.

Bibl.: CAL. STATE MIN. BUR., Reports XII, p. 360; XIII, p. 595; XIV, p. 230; Chapter rep. bien. period, 1913–1914, p. 58; Bull. 27, pp. 60, 61.

Chicago Mine (originally known as the Pittsburg[1]; also Ural). This property is owned by the Chicago Quicksilver Mining Company, 522 Bank of San Jose Building, San Jose, Cal. It is in Sec. 1, T. 10 N., R. 8 W., about ½ mile west of the Wall Street mine, near Middletown. It has been idle for some time. The last operations here were in 1911 on the construction of a fine-ore furnace of 15 tons capacity, with concrete walls. The furnace was not finished, and consequently never operated. It would be interesting to note the behavior of the concrete when heated. It looks to be an experiment with rather a doubtful outcome.

Bibl.: CAL. STATE MIN. BUR., Reports XIII, p. 595; XIV, p. 230; Chapter rep. bien. period, 1913–1914, p. 58; Bull. 27, p. 51; Reg. of Mines, Lake County, p. 3; U. S. G. S. Min. Res. of U. S. 1909, Part I, p. 552; 1910, Part I, p. 697; 1911, Part I, p. 901; 1912, Part I, p. 940.

Great Western Mine. H. M. Newhall & Co., owners, Newhall Building, San Francisco. It is 4 miles southwest of Middletown, and two miles northwest of the Mirabel mine, at an elevation of 1860 feet. This mine has, so far, had the longest continuous record as a producer of any quicksilver mine in Lake County. It was opened up in 1873, and was a constant producer up to 1909, being credited with a total yield, to date, of 98,316 flasks. A few flasks were recovered in 1912 in cleaning-up around the old furnaces; and, again, in 1916, by a lessee with one Standard table, washing and concentrating material from some of the dumps. The former operating company has been disincorporated, the furnaces torn down, and the mine abandoned as worked out. In 1916 and 1917, some chromite was shipped from lenses opened up by lessees, in a body of serpentine on the property. As might be expected from its output record, the Great Western mine has extensive underground workings, and to a depth of 750 feet. The mine and its geology are described at some length in the reports noted under Bibliography. The general strike of the ore body was northwest, with a dip of about 70° SW. The footwall is a very hard sedimentary rock altered by silicification,[2] locally called 'greenstone'; and the hanging wall, at least at the surface is serpentine. The ledge matter was formed by a series of thin beds of chert, having their bedding planes parallel to the strike of the ledge and interstratified with clay seams. This chert was locally called 'quartzite.' The dip of the serpentine being flatter than that of the ledge matter, the intervening space was filled with a black 'alta.' The cinnabar occurred in an irregular manner, generally in seams, and as face metal in the fractures of

[1]Whitney, J. D., Geology of California: Geol. Surv. of Cal., vol. I, p. 90, 1865.
[2]Forstner, William, The quicksilver resources of California: Cal. State Min. Bur., Bull. 27, p. 51, 1903.

the chert, but in the richer spots disseminated through the chert itself, associated with pyrite. The main working shaft was sunk vertically in the footwall. The property was equipped with a 40-ton Litchfield furnace.

Bibl.: Cal. State Min. Bur., Reports X, p. 270; XI, p. 64; XII, p. 361; XIII, p. 595; XIV, p. 231; Chapter rep. bien. period, 1913–1914, p. 59; Bull. 27, pp. 52–55; Reg. of Mines, Lake County, p. 3. U. S. G. S., Mon. XIII, pp. 358–362, 470; Min. Res. of U. S., 1883, 1884, 1892, 1902, 1906, 1907, Part I; 1908, Part I; 1909, Part I; 1912, Part I. Min. Res. W. of Rocky Mtns., 1874, 1875, 1876.

The old **Hays** mine in the E. ½ of NE. ¼ of Sec. 18, T. 10 N., R. 7 W. (?), M. D. M., near Middletown, has been idle for many years. Some fair looking pieces of ore are reported to have been picked up on the dump. Mr. ——— Knapp, owner, Oakland; Geo. Lewis, agent, Middletown.

Helen Mine (originally called '**Dead Broke**'[1]; one time known as the **American**. Andrew Rocca, owner, Middletown; Andrew Rocca, Jr., superintendent and manager. This mine is in Sec. 1, T. 10 N., R. 8 W., M. D. M., 6 miles west of Middletown, at an elevation of 2675 feet (barometric reading at bottom of furnace). It consists of two claims, the Helen and the Austin, which were patented in 1874 by Pushbecker, later sold to the American company and to the present owner in 1900. The property includes between 600 and 700 acres (partly timbered) besides the mineral claims' area. The timber, somewhat scattered for the most part, consists of pine, oak, madrone, and 'fir' (Douglas spruce, *Pseudotsuga taxifolia*). The mine is at the head of the north branch of Dry Creek. The first recorded production of the Helen mine was 128 flasks in 1873, and it is credited with a total yield of something over 6,000 flasks to date.

The mineralized ledge is up to 100 feet wide, with an average of 30 feet. It is at the contact of serpentine with sandstone and slate, and has a black gouge on the hanging-wall. The vein outcrop is prominent, and strikes N. 40° W., dipping 30° to 40° S. There are three main levels at present operated, being by tunnels, one of which is in 2,000 feet giving a depth of 316 feet below the outcrop. The ore shoots are from 70′ to 100′ long, and 5′–10′ wide. The ledge has been proven underground by drifting, for 1000 feet in length. The ore is cinnabar, intermixed with pyrite, and occurs in seams, sometimes an inch or two thick, of solid cinnabar. These seams are approximately parallel to the ledge, and are crossed at high angles by other and rather minute ore seams. The serpentine is in part silicified and carries lenses of

[1]Whitney, J. D., Geology of California; Geol. Surv. of Cal., vol. I, p. 89, 1865.

hard, fine-grained black 'jasperoid.' On the outcrop, some ore has been stoped out to the surface. Mining is conducted by square-set stoping, being 75% by overhand and 25% by underhand stoping. The ore is trammed, horse-drawn, from mine to furnace in trains carrying 3 tons per trip.

Both the mine and the furnace have been steadily in operation for some years past, at present having 25 men at work—12 underground, 6 on top, and 6 on the furnace. The furnace is a 50-ton Scott (see Photo No. 9), and has special condenser arrangements designed by Mr.

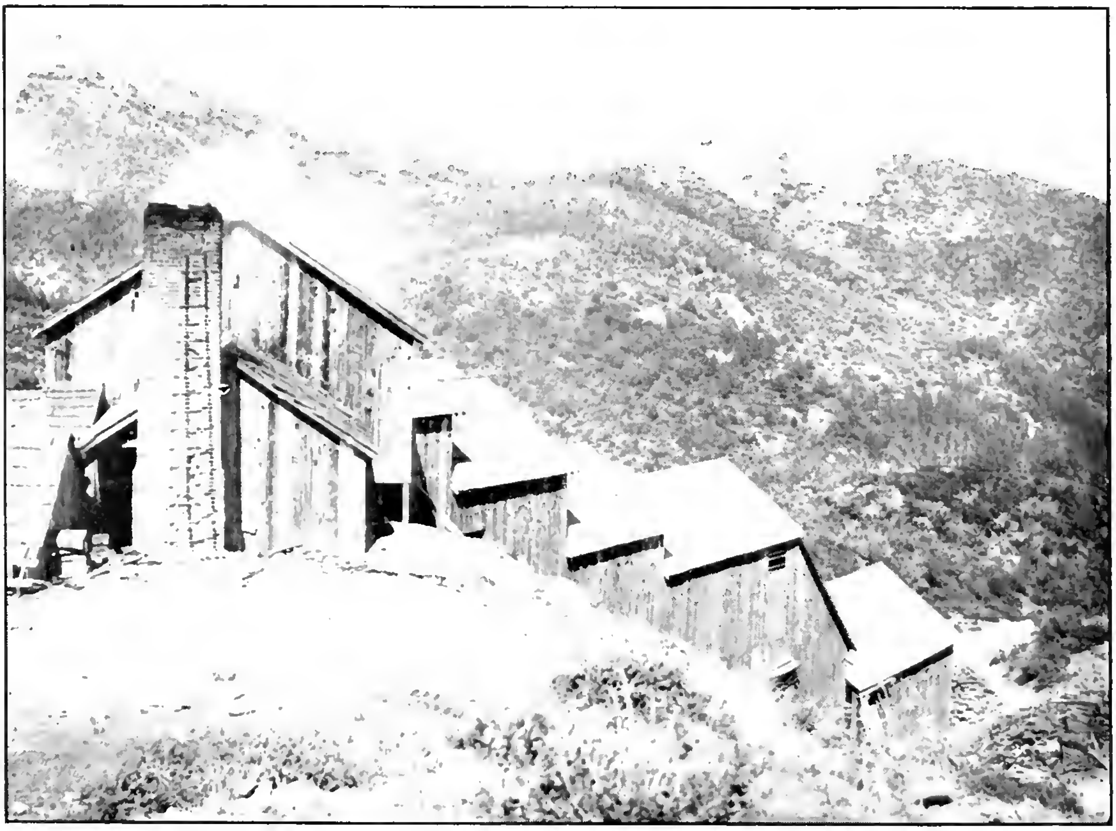


Photo No. 9. Fifty-ton Scott furnace at the Helen Mine, near Middletown, Lake County. Old dumps of the Wall Street Mine in the distance.

Rocca, in which the draft is controlled by dampers. It is said to work satisfactorily. The owner states that the ore being reduced averages 0.6% quicksilver, and that he can handle at a profit ore carrying down to 0.25% of the metal. Soot from the condensers, and occasional small lots of rich ore are treated in a 'D' retort of 750 pounds capacity. A small gasoline engine, run intermittently, furnishes power for the rock breaker. The furnace consumes 1¼ cords of firewood per 24 hours. The mine equipment includes a 25 h. p., type NB, Fairbanks-Morse oil engine, and a 25 h. p. or "100 cu. ft. of free air per minute," Ingersoll-Rand class E R I compressor. This oil engine is stated to operate at a cost of 20¢ per horsepower-day. Operating costs are given at $4.10 per ton of ore, distributed as follows: development $2.20; mining

\$1.15; treatment 60¢; general 15¢. An 80% recovery is claimed. As the upper parts of the mine are difficult to work on account of water in the wet season, only the lower levels are worked during the winter months.

Bibl.: CAL. STATE MIN. BUR., Reports XII, p. 362; XIV, pp. 231–233; Chapter rep. bien. period, 1913–1914, pp. 59–61; Bull. 27, pp. 55–57; Reg. of Mines, Lake County, p. 3. U. S. G. S., Mon. XIII, p. 375; Min. Res. 1902; 1907, Part I; 1908, Part I; 1909, Part I; 1911, Part I, p. 901; 1912, Part I, pp. 940–942; 1915, Part I, p. 269. MIN. RES. W. OF ROCKY MTNS., 1874, p. 30. GEOL. SURV. OF CAL., Geol. vol. I, p. 89.

Jewess Prospect (also known as **Franklin**). It is near the Helen and Wall Street mines, but so far as known has never produced any quicksilver. Idle for several years.

Bibl.: CAL. STATE MIN. BUR., Report XIV, p. 233; Bull. 27, p. 57; Chapter rep. bien. period, 1913–1914, p. 61.

Lucitta Mine (also known locally as the **Uncle Sam**). Mount Sam Mining Co., owner; Theo. A. Bell, president, 701 Crocker Building, San Francisco. This group of four claims is located on the south slope of Mount Konocti (or Uncle Sam), in Secs. 20 and 21, T. 13 N., R. 8 W., M. D. M., about 7 miles southeast of Kelseyville. The mine has not been worked recently nor has it reported any production for several years past. The formation, here, is mainly igneous,[1] boulders of andesites being prominent, the intervening material being a decomposed tuff bleached by solfataric action. White beds of leached metamorphic shales are found in these igneous masses, and occasional bodies of clay. In the lower tunnel cinnabar had been deposited on the face of the boulders of ore. A small prospect opening near the dump of Tunnel No. 2, showed solfataric action, and formations similar to those at the surface at the Sulphur Bank mine.

Bibl.: CAL. STATE MIN. BUR., Reports V, p. 96; XIV, p. 233; Chapter rep. bien. period, 1913–1914, p. 61; Bull. 27, p. 58; Reg. of Mines, Lake County, p. 3.

The **Maypole** prospect, 7 miles west of Middletown, has been abandoned.

Bibl.: CAL. STATE MIN. BUR., Reports XIII, p. 596; XIV, p. 233; Chapter rep. bien. period, 1913–1914, p. 61.

[1]Forstner, Wm., The quicksilver resources of California: Cal. State Min. Bur., Bull. 27, p. 58, 1903.

The **Middletown** prospect, half a mile southwest from the Jewess, has been abandoned.

Bibl.: CAL. STATE MIN. BUR., Report XIV, p. 233; Chapter rep. bien. period, 1913–1914, p. 61; Bull. 27, p. 59.

Mirabel Mine (Bradford). This mine, 4 miles south of Middletown, was opened up in 1887, as the Bradford, and later renamed Mirabel, being owned by the Standard Quicksilver Company. J. McL. Harvey, Calistoga, is agent. For ten years it was one of the important producers of Lake County, but in 1897 was abandoned as worked out; and the mine has filled with water. In 1908, a small production was reported as having been made from a clean-up around the old furnace; and in 1916, a similar, small output was made with a concentrating table working on material from the dump and from around the furnace. The property is credited with a total yield of about 30,600 flasks. Underground, a vertical depth of 500 feet was reached, with 22,500 linear feet of drifts, and 750 feet of shaft work. More extended descriptions of the mine and its geology will be found in the references noted under Bibliography.

Bibl.: CAL. STATE MIN. BUR., Reports VIII, p. 325; X, p. 270; XI, p. 64; XII, p. 361; XIII, p. 595; XIV, p. 233; Chapter rep. bien. period, 1913–1914, p. 61; Reg. of Mines, Lake County, p. 3; Bull. 27, pp. 60–61. U. S. G. S., Mon. XIII, p. 375; Min. Res. 1888, p. 97; 1891, p. 117; 1892, p. 160. TRANS. A. I. M. E., XXII, p. 86.

Red Elephant Prospect. W. G. Tremper, owner, Lower Lake. It is in Sec. 3, T. 11 N., R. 5 W., M. D. M., near the Napa County line ½ mile west of Knoxville. Only sufficient development, mostly surface work, has been done to cover annual assessments, since its location about 1898. One shaft is down 28 feet. The ore zone is stated to be 20′–40′ wide, and has been proven on the surface for a length of 300 feet. The country is mainly serpentine, much of it being thoroughly weathered to an ochre. There is no reduction equipment.

Bibl.: CAL. STATE MIN. BUR., Report XIV, p. 234; Chapter rep. bien. period, 1913-1914, p. 62; Bull. 27, p. 92; Reg. of Mines, Lake County, p. 3.

Red Rock and **Silver Rock Claims.** Henry B. Weiper and Henry Schalehli, owners, Lower Lake. This group of claims located in 1916, is in Sec. 17, T. 12 N., R. 6 W., M. D. M., 5 miles from Lower Lake, on the road to Morgan Valley, and near the Baker mine. Only a small amount of development work has so far been done. Cinnabar occurs in an ochreous ledge about 10 feet wide on the surface. This ochreous material could probably be concentrated on tables without much crushing, if a sufficient water-supply could be obtained. It appears to be from a very thoroughly weathered serpentine. The cinnabar is distinctly crystalline, but mostly rather fine grained.

Rich Hill Prospect. Henry Hardester, Middletown, has a quicksilver prospect in Sec. 19, T. 10 N., R. 6 W., M. D. M., southeast of Middletown and near the Oat Hill mine. The ore body is stated to show 6′–7′ wide, in sandstone; and a shaft has been sunk 106′.

Shamrock Prospect. This group of two claims is on Rocky Creek, a branch of Cache Creek, in Sec. 23, T. 13 N., R. 6 W., about 10 miles northeast of Lower Lake. It is owned by the Shamrock Development Company (Jas. Daly, W. P. Swift et al.), Napa. The property is idle.

Bibl.: CAL. STATE MIN. BUR., Report XIV, p. 234; Chapter rep. bien. period, 1913–1914, p. 62; Bull. 27, p. 60; Reg. of Mines, Lake County, p. 3.

Sulphur Bank Mine. Geo. T. Ruddock, owner, 433 California Street, San Francisco; Sulphur Bank Association (a co-partnership), 817 Crocker Building, San Francisco, operators under a lease and bond; H. W. Gould, general superintendent; N. J. Martin, superintendent at the mine. This mine is one of the notable and much written-about quicksilver mines of the world. It is extremely interesting from many standpoints—those of chemistry, mineralogy and geology, as well as metallurgy and mining. It was first worked in 1865 for sulphur, and in the four years to and including 1868 produced a total of nearly 2,000,000 pounds of that mineral, valued at $53,500. The property was at that time owned by the California Borax Company which during the same period was also producing borax from Borax Lake, near-by. The two are still intact and the land has been leased out as part of a cattle range for some years.

During the time of working the surface cuts for sulphur, some difficulty was experienced in refining the material because of the presence of cinnabar, which darkened the product. The proportion of cinnabar increased with depth. Cost of transportation to the market and a rapid fall in the price of sulphur caused a cessation of operations, but the mine was reopened and developed for its quicksilver in 1873, being a steady and important producer until 1883. After four years of idleness, work was resumed and continued until 1897, when it was again shut down. In 1899 the mine was reopened and worked until December, 1905, the shaft being kept unwatered until June, 1906, since which time it has been idle until the recent surface work herein described. As a producer of quicksilver, the Sulphur Bank mine is credited with a total output of approximately 92,400 flasks. It is said that at the

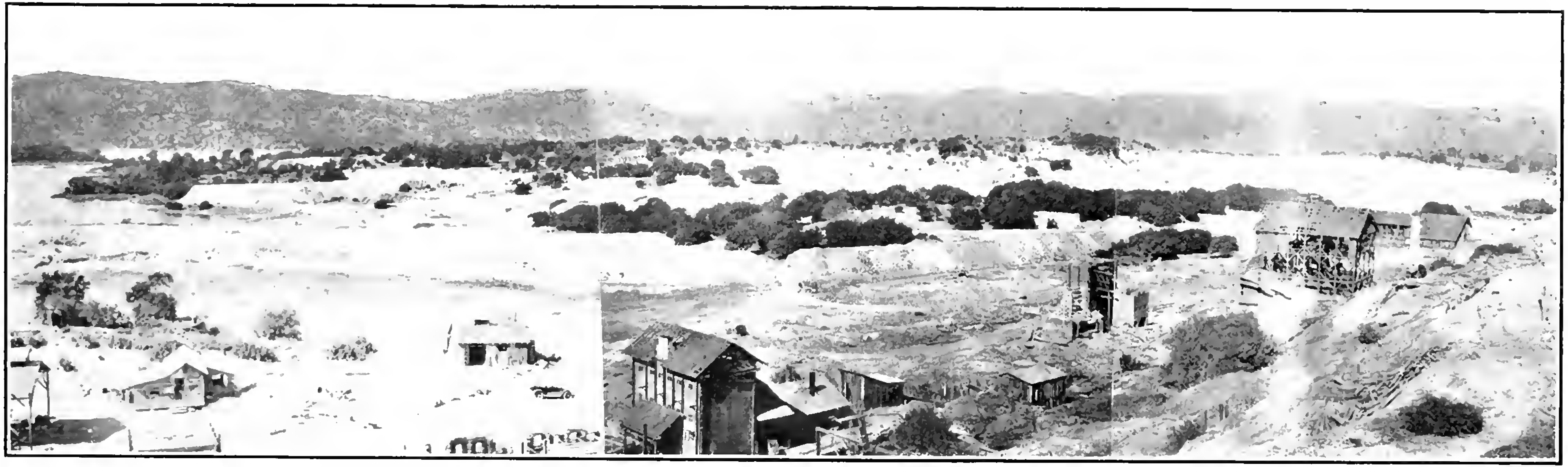


Photo No. 10. Panoramic view of the Sulphur Bank Mine, Lake County, showing surface workings and dumps. Looking northerly.

time of the last closing down of the mine (due to financial troubles as well as the increasing difficulties of ventilation and pumping in consequence of the hot waters and deleterious gases) they had opened up a good body of high-grade ore underground from the Empire shaft.

The Sulphur Bank is a low, rounded hill (see Photo No. 10), on the eastern shore of Clear Lake in Sec. 6, T. 13 N., R. 7 W., about 10 miles

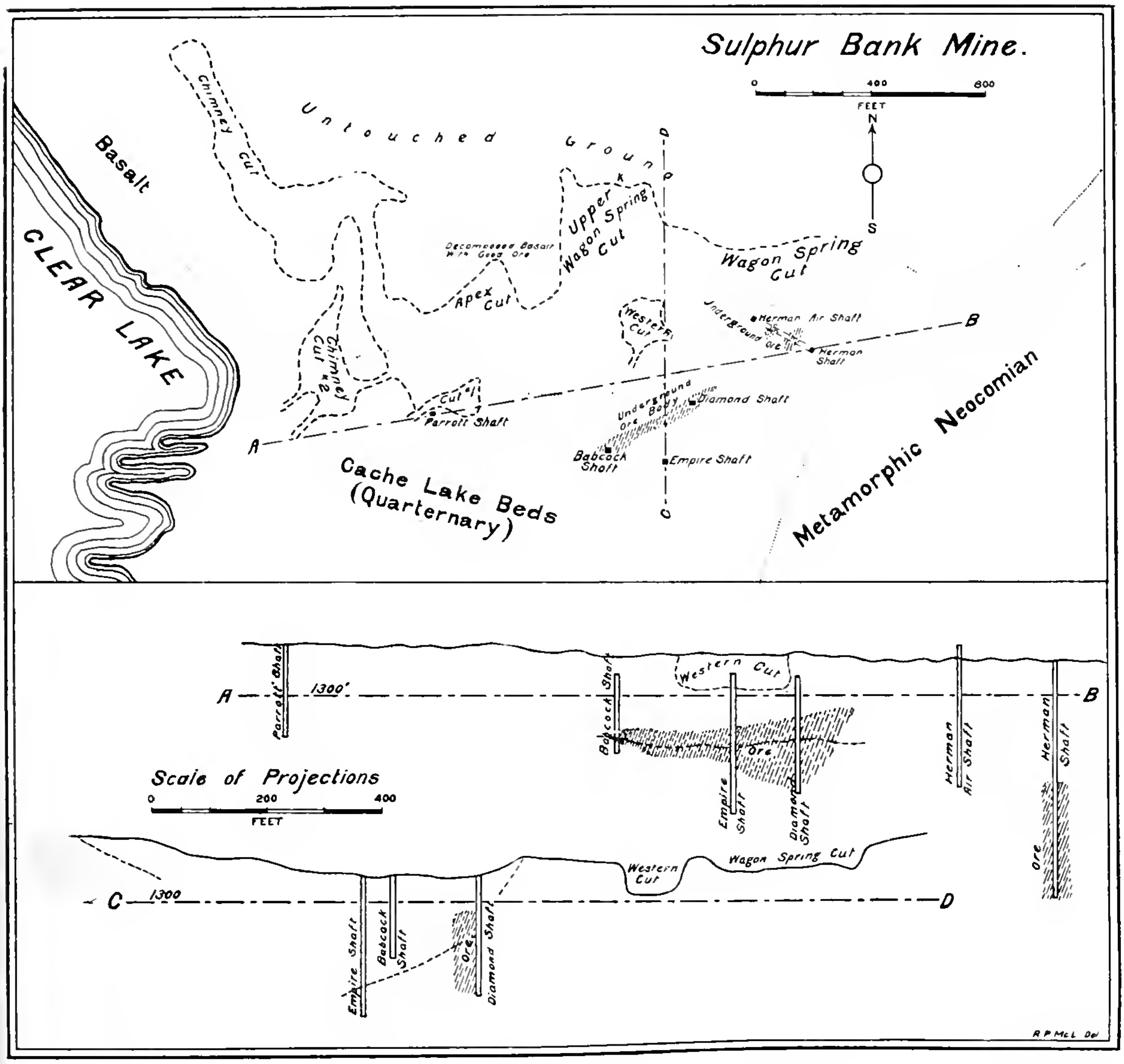
Photo No. 11. Exfoliation of basalt at Sulphur Bank Mine, due to solfataric action. Photo by Emile Huguenin.

north of Lower Lake. It is also reached by launch from Lakeport. The elevation is 1350 feet at the lake level. The old surface cuts much resemble those of a placer mine with its tailings piles of boulders, except that over it all is a pulverulent, white powdery material, the result of the continuing decomposition of the rocks by the solfataric vapors and waters still present. The glare is almost blinding on a sunny day. The rounded boulders due to concentric decomposition, as described by Becker[1] can be plainly seen (see Photo No. 11). The evidences of solfataric activity are numerous and striking. Iron rails, nails, cables, etc., are sulphurized and oxidized. Wood is blackened and rotted. There are abundant sulphur crystals in crevices and flour sulphur around vents where vapors are issuing. At the mouth of an abandoned shaft, now caved, near the eastern edge of the surface workings (either the Hermann shaft or Hermann air shaft—see Plate IX, reprinted from Bulletin 27, p. 62), hot, moist, sulphurous gases are still escaping, and under a noticeable pressure.

Photo No. 12. Hot springs in bottom of "Western Cut," Sulphur Bank Mine.

The odor of sulphur dioxide is very strong, so that it was difficult to breathe while placing a thermometer in one of the openings to observe the temperature. It showed 168° F.—this being at the surface. Becker[2] recorded temperatures up to 176° F. at a depth of 300 feet. The rocks about the opening and protruding sticks of timber are heavily coated with a deposit of flour sulphur. There is a sound as of a roaring furnace from below. How any one could breathe in such an atmosphere, much less work, is a matter for wonderment. There was a dead rat lying at one of the openings. At the upper end of the

[1]Becker, G. F., Geology of the quicksilver deposits of the Pacific Slope: U. S. G. S., Mon. XIII, p. 256, 1888.
[2]*Op. cit.*, p. 259.



Geological Map of Sulphur Bank Mine, Lake County.

Reprinted from Bulletin No. 27.

'Western Cut,' there are a number of warm springs with considerable excess gas escaping with the water—the whole having the appearance of a series of boiling cauldrons. (Photo No. 12.) The appearance is deceiving, however, as the temperatures are much lower than one would expect. The following temperatures were obtained by the writer: 84° F.; 108° (water inky, with a black deposit forming about it); 100°; 97° (in upper corner). The Empire shaft (the latest sunk) was filled with water to within 15 feet of the collar at the time, and escaping gases were bubbling up through the water.

"The gases escaping from the waters are carbon dioxide, hydrogen sulphide, sulphur dioxide, and marsh gas. The waters contain chiefly carbonates, borates, and chlorides of sodium, potassium and ammonium; but alkaline sulphides are also present."[3]

As to the mode of occurrence of cinnabar at Sulphur Bank, it is well summarized by Becker,[4] as follows:

"It does not occur in sensible quantities at or near the surface, but is found to a considerable extent mixed with sulphur in the lower portion of the zone of oxidation. The principal deposits are below this level. They are found in the more or less decomposed basalt, in the underlying recent lake bottom, and in the Knoxville shales and sandstones. The cinnabar is associated chiefly with silica, in part crystalline and in part amorphous. In the lava it appears as small seams, which commonly follow either the original cracks between the blocks or the concentric surfaces of the decomposed masses. In the lake deposits below the basalt the cinnabar is found as impregnations or irregular seams. In the workings from the Herman shaft the ore occurs exactly as it does in most of the quicksilver mines of California, more or less completely filling interstices in shattered rock masses. * * * Dr. Melville has found small quantities of gold and copper in the marcasite accompanying the cinnabar. * * * The intimate association of the ore with the sulphur, opal, quartz, pyrite, and to a smaller extent with calcite, is amply sufficient to show that it has been deposited from water."

Also:[5]

"Excepting for the solfataric springs the underground mine at Sulphur Bank resembles the other principal quicksilver mines of California. * * * This fact is an important one, for it proves that deposits indistinguishable from those found in the Redington, New Almaden, and other mines may be formed in the same manner as those at Sulphur Bank, by precipitation from hot springs of volcanic origin."

At the "Little Sulphur Bank," above ½ mile south of Borax Lake, some prospecting has been done. Here, the same sulphurous odors are noticeable as at Sulphur Bank. The property was formerly equipped with a Knox-Osborne 25-ton furnace, 3 Hüttner-Scott furnaces of 40, 17 and 30 tons, respectively, and a battery of 9 'D' retorts. Some quicksilver was produced during 1915, 1916, and early in 1917, before the present operators began work, by retorting material obtained in tearing down the old furnaces.

The present operators built a concentrating plant, utilizing a revolving screen and 4 Deister-Overstrom tables, which they have been using as a test-unit to work out an ore-dressing scheme for the material in the extensive dumps. This plant and its accomplishments up to the time of the author's visit (September, 1917) are described in detail in the section of this bulletin on Metallurgy.[6] As there recounted, much difficulty was experienced in retorting the concentrates on account of the considerable percentage of native, free sulphur present, forming a

[3]Becker, *op. cit.*, p. 463.
[4]*Op. cit.*, p. 257.
[5]*Op. cit.*, p. 263.
[6]See p. 346, *post*.

matte with the iron of the retorts. Two 12-pipe banks of Johnson-McKay retorts were then in use, and a battery of 4 'D' retorts was being built. Oak and manzanita were being used for fuel at a cost of $4.50 per cord at the retort, divided as follows: $2 cutting; 50¢ stumpage; $2 hauling. This was expected soon to increase. An assaying and chemical laboratory is maintained, and the various products are sampled, so that a careful watch is kept on all of the current conditions and developments. Since the mine was visited, we are informed that a revolving furnace is being installed, which it is hoped will solve the roasting difficulties. For the present at least, no underground work is planned, there being several hundred thousand tons at the surface, estimated as material available for treatment by the proposed methods. Practically all of the dumps in sight (see Photo No. 10) and some over the hill on the north side, have concentratable values in cinnabar. The material can be cheaply excavated with a steam shovel and transported to the mill by motor trucks, as it will have to be moved distances up to $\frac{1}{3}$ mile and raised to the top of the mill bin.

The development of their scheme of ore-dressing and reduction here will be watched with much interest.

Bibl.: CAL. STATE MIN. BUR., Reports IV, pp. 157, 330, 336, 339; V, p. 96; VI, Part I, p. 136; VIII, p. 324; X, pp. 238, 239; XI, p. 63; XII, p. 363; XIII, p. 597; XIV, pp. 234–238, 240; Chapter rep. bien. period, 1913–1914, pp. 62–66, 68; Bull. 27, pp. 61–70; Reg. of Mines, Lake County, p. 3. U. S. G. S., Mon. XIII, pp. 251–270, 463; Min. Res., 1883, pp. 394–397; 1884, p. 492; 1892, pp. 146, 148, 160; 1902, pp. 251, 252; Water Sup. Pap. 338, pp. 98–99. GEOL. SURV. OF CAL., Geol., Vol. I, p. 99. Trans. A. I. M. E., XXIII, pp. 225 *et seq.*; XXXIII, p. 751; Genesis of Ore Dep., pp. 32, 66, 256. MIN. RES., W. OF ROCKY MTS., 1868, p. 266; 1876, p. 20. AM. JOUR. OF SCI., Vol. XXIV, 3d Ser., pp. 23 *et seq.*

Thorn Mine (Bear Cañon). It is west of Middletown, in Sec. 36, T. 11 N., R. 8 W., near Anderson Springs; Thorn Bros., owners. Only assessment work was done for several years, but it is said no ore bodies of consequence have been developed. In 1909, a small production was reported from ore taken out during development work, but nothing has been done since.

Bibl.: CAL. STATE MIN. BUR., Report XIV, p. 239; Chapter rep. bien. period, 1913–1914, p. 66; Bull. 27, p. 70. U. S. G. S., Min. Res. 1909, Part I, p. 552.

Utopia Mine. The Utopia is on the eastern shore of Clear Lake in Sec. 25, T. 15 N., R. 9 W., near Bartlett Landing, northeast from Lakeport. It is owned by the Utopia Quicksilver Mining Company of Lakeport; A. Spurr, secretary. It has not been operated in recent years, as it is said they were driven out by water, the orebody running under the lake.

Bibl.: CAL. STATE MIN. BUR., Reports XIII, p. 597; XIV, p. 239; Chapter rep. bien. period, 1913–1914, p. 67; Bull. 27, p. 70; Reg. of Mines, Lake County, p. 3.

Wall Street Mine (originally **Cincinnati**).[1] This mine was a producer as early as 1875, about which time it was patented, but abandoned by the original owners in 1878. The present owner, W. H. Parsons, acquired the property in 1898, by purchase of tax title from the State, and has been reporting an output of a few flasks of quicksilver annually for the past twelve years. It is located in Sec. 1, T. 10 N., R. 8 W., on a branch of Dry Creek, 6 miles west of Middletown. The elevation is 2275 feet (bar.) on the road at the retort. The property includes the Kearsarge group of 3 patented claims, whose principal value is for water supply and timber. The old workings are largely inaccessible. The owner works the mine single-handed, with occasionally an additional man, assisted by a packhorse for handling ore, timbers and firewood. The Wall Street mine is about ½ mile down the cañon from the Helen mine ore-body from which it appears to have been broken by a northeast-southwest fault. Their main mineralized ledges have several characteristics in common and are marked by similar, prominent outcrops. The Wall Street, however, has a considerable proportion of native quicksilver which does not appear at the other. There is a narrow quartz vein in the main ledge near its hanging-wall side, and parallel to its dip—30° SW. The vein, which has a comb structure, carries in its numerous cavities and pores much native metal. Parsons states that the serpentine from 1 to 3 feet above and below the quartz carries some 4% of both native metal and cinnabar in about equal proportions. The silicified ore-bearing serpentine lies above the softer serpentine and carries the quartz vein, cinnabar, pyrite, and lenses of jasperoid. In the mill there is a 20 h. p. Westinghouse compressor (being a locomotive air-brake pump, 9½″ diam. x 10″ stroke), steam driven, which furnishes power for an air hammer drill in underground work. There is also a small Chilian mill, and two homemade, table concentrators, said to have a capacity of 3½ tons per day. Some of the soft ore is concentrated, but the jasperoid and disseminated ores are retorted direct. One 'D' retort is used—14 inches high, 30 inches wide and 8 feet long—which consumes 1½ cords of firewood per flask of quicksilver produced. This retort has a capacity of

[1]Whitney, J. D., Geology of California: Geol. Surv. of Cal., vol. I, p. 89, 1865.

600 pounds of ore per day. The old company is said to have expended $100,000 and produced 140 flasks. The total output to the end of 1917 has been approximately 350 flasks.

Bibl.: Cal. State Min. Bur., Report IV, p. 183; V, p. 26; VI, Pt. I, p. 110; XII, p. 362; XIII, p. 597; XIV, p. 239; Chapter rep. bien. period, 1913–1914, p. 67; Bull. 27, p. 71; Reg. of Mines Lake County, p. 3. U. S. G. S., Mon. XIII, p. 375; Min. Res. 1907, Part I, p. 679; 1908, Part I, p. 686; 1909, Part I, p. 552; 1910, Part I, p. 698; 1911, Part I, p. 901; 1912, Part I, p. 940. Geol. Surv. of Cal., Geol. vol. I, p. 89.

White Elephant Prospect (formerly **King of All Group**). Arthur Copsey and Ed Rush, owners, Middletown. This group of 2 unpatented claims is in Secs. 29 and 32, T. 12 N., R. 7 W., about 10 miles north of Middletown, and 1 mile southeast of Howard Springs. None but assessment work has been done for several years. There are two crosscuts of 40 feet each, and some short drifts. A retort was built early in 1917, but so far no quicksilver has yet been reduced. This mine is situated in a belt of serpentine, having a general northwest trend. Bad Cañon Creek runs through the group and cuts through the serpentine to the underlying schist. The wall rock in the lower tunnel is in places much decomposed, showing the action of solfataric waters. To the northeast of the serpentine lies a large body of tuffs and volcanic boulders. Howard hot springs, a region of strong solfataric action, as above noted, is only a mile distant.

Bibl.: Cal. State Min. Bur., Report XIV, p. 233; Chapter rep. bien. period, 1913–1914, p. 61; Bull. 27, p. 57; Reg. of Mines, Lake County, p. 3. U. S. G. S., Min. Res. 1912, Part I, p. 940.

LOS ANGELES COUNTY.

The occurrence of traces of quicksilver has been reported near Lake Elizabeth, northeast of Saugus; but no body of commercial consequence appears to have been found, and no development work done.

Bibl.: U. S. G. S., Mon. XIII, p. 383.

MARIN COUNTY.

A quicksilver-bearing ochreous material was at one time reported[1] at Point Reyes, but no commercial development has taken place there.

There is an occurrence of low-grade cinnabar-bearing material near San Rafael (?). From samples shown the writer, it appears to have been a silicified serpentine, now much oxidized and weathered.

[1]Min. & Sci. Press, Feb. 27, 1875, p. 130; also in U. S. G. S., Mon. XIII, p. 379.

MARIPOSA COUNTY.

There is a 6-inch quartz ledge on the Merced River near Coulterville that has a N.-S. strike, and carries on its footwall side a thin seam of quartz containing crystallized cinnabar. It is not in sufficient quantity to be of commercial value for quicksilver; but it is stated that Chinese between 1850 and 1860 utilized crystals from this vein for vermilion.

Bibl.: Cal. State Min. Bur., Report XIV, p. 602; Chapter rep. bien. period, 1913–1914, p. 176. U. S. G. S., Mon. XIII, p. 383. Geol. Surv. of Cal., Geol., vol. I, p. 230.

MENDOCINO COUNTY.

Occident Mine (originally **Amrillo—? Amarillo**; also known as **Wise's Mine**). W. H. M. Smallman, owner, 560 Powell Street, San Francisco. It is in Lot 39, Sec. 6, T. 12 N., R. 11 W., M. D. M., 7 miles southwest of Hopland, and 4½ miles from the State Highway. It was originally located in the 70's under the name of Amarillo (the company's stock certificate read 'Amrillo'), but patented in 1883 as the Occident. Local legend says that the mine was worked by the Mexicans before the American occupation. There are various dumps and other evidences of old workings. Some work was done on this property in 1875, and again for several years preceding 1907. The only definite record of commercial output is 50 flasks in 1906. There has been no work done since, except a small amount of prospecting. The ore was retorted. Most of the workings are now caved. The ore is in an ochreous, weathered serpentine material, similar to that found at so many of the quicksilver mines in California. Opaline silica is associated. The formation is considerably brecciated. Some further development work will be started this spring.

Bibl.: Min. Res. W. of Rocky Mts., 1875, p. 14. U. S. G. S., Min. Res., 1906, p. 492; 1907, Part I, p. 679.

MERCED COUNTY.

The Stayton quicksilver district is at the junction of San Benito, Santa Clara, and Merced counties. Portions of some of the properties are on the Merced side of the county line; but as the principal groups and workings are in San Benito County, they are described under that heading.

MODOC COUNTY.

Modoc Cinnabar Group. A. H. Dixon and Charles Kirkpatrick, owners, Lakeview, Oregon. This recently located prospect is 3½ miles southeast of Willow Ranch station on the Nevada-California-Oregon Railroad, and close to the main county road, at an elevation of about 5000 feet. The country rock is stated to be volcanic and the vein of soft gouge-like material 18″–20″ wide, carrying cinnabar. There is a good supply of timber and water at hand. Development work has just begun, and a small retort built. Dixon states that the material so far tested in the retort yielded from 6 to 8 pounds of quicksilver per 100 pounds of ore.

Quicksilver ore has also been reported 25 miles southeast of Cedarville, but there has been no work done recently.

Bibl.: U. S. G. S., Min. Res., 1902, p. 252.

MONO COUNTY.

In the Museum of the State Mining Bureau, there is a specimen (#10340) of ore showing beautiful cinnabar crystals, from 5 miles NNE. of Bodie. The material is high grade. The gangue mineral appears to be mainly calcite, and there are some globules of native mercury present. The country rock is apparently an altered igneous or metamorphic rock, as there are a couple patches of chloritic mineral attached to the specimen. In the locality to which this specimen is credited there is a small plateau of volcanic material underlain by metamorphic rocks. There has been no commercial development of this quicksilver occurrence.

Bibl.: Cal. State Min. Bur., Bull. 67, p. 35.

MONTEREY COUNTY.

The quicksilver properties in Monterey County from which commercial production has thus far come, are associated with the area of serpentine near Parkfield in the southeastern corner of the county. Nearly the entire output of the district, 530 flasks, to date has come from one mine, the Patriquin.

Several quicksilver prospects have been reported in the southwest corner of the county, north of Mount Mars near the coast, and northwest of the producing districts of San Luis Obispo County, but little development work has ever been done there.

Dutro Mine. F. D. Martinez, owner, Santa Maria. It is at the head of the west fork of San Carpojaro Creek in the SW. ¼ of SE. ¼ of Sec. 28, T. 24 S., R. 6 E., M. D. M. Idle for sevearl years; 100′ shaft and 40′ drift, caved.

Bibl.: CAL. STATE MIN. BUR., Report XV, 613; Chapter rep. bien. period, 1915–1916, p. 19; Bull. 27, p. 124.

Monte Cristo Group. W. D. Cruikshank et al., are reported to have located quicksilver claims near Gorda. So far only assessment work has been done.

Patriquin-Gillett Quicksilver Mining Company. Henry Ludeke, Jr., owner, Parkfield; Lewis & A. G. Patriquin, Nathan Gillett, lessees. It is on agricultural patented land in Sec. 1, T. 23 S., R. 14 E., M. D. M., 5½ miles north of Parkfield at an elevation of 2400 feet (U. S. G. S.). The ore body is a southeasterly continuation of the mineralized zone of the Patriquin mine which is above it on the same ridge to the northwest of Table Mountain. There is a black 'alta' on the footwall, and the vein shows a width of 6″ to 3′. There are 6 or 7 crosscuts having lengths up to 35′, with a total of 150′ of work. Reduction equipment consists of a 'D' retort built in April, 1917, and which is operated occasionally. A few flasks of quicksilver were produced in 1917.

Patriquin Quicksilver Mine (one time called **Pitt**; also **Cholame-Parkfield**; and **Parkfield**). Louis, A. G. & Mrs. L. S. Patriquin, and J. W. B. Anderson, owners, Parkfield. This group of four claims and two fractions is in Sec. 2, T. 23 S., R. 14 E., 6 miles north of Parkfield; elevation 3000′ (bar.) at the middle tunnel. It was first worked about 1873, by a Mr. Pitts, who is said to have produced 60 flasks of quicksilver, using a small mud-plastered furnace. In 1913, about $6,000 worth of development work was done by a lessee, but no ore reduced. The mine has now been in steady operation since its reopening in 1915. It is credited with a total production of 511 flasks to the end of 1917.

The country rocks are serpentine and Franciscan metamorphic sandstone. The ore body is a zone containing parallel stringers of cinnabar with the intervening rock and its fractures more or less impregnated with the mineral. It is in part stockwork. The vein filling is quartz, opaline silica, and chalcedony, and much of the serpentine is silicified. The cinnabar occurs mainly in the fractures, as distinct crystals, not as 'paint.' There is also some metacinnabarite, pyrite, and calcite associated. There are two ore zones with a ridge (see Photo. No. 13) of serpentine between them, the north one being 100′ wide, and the other

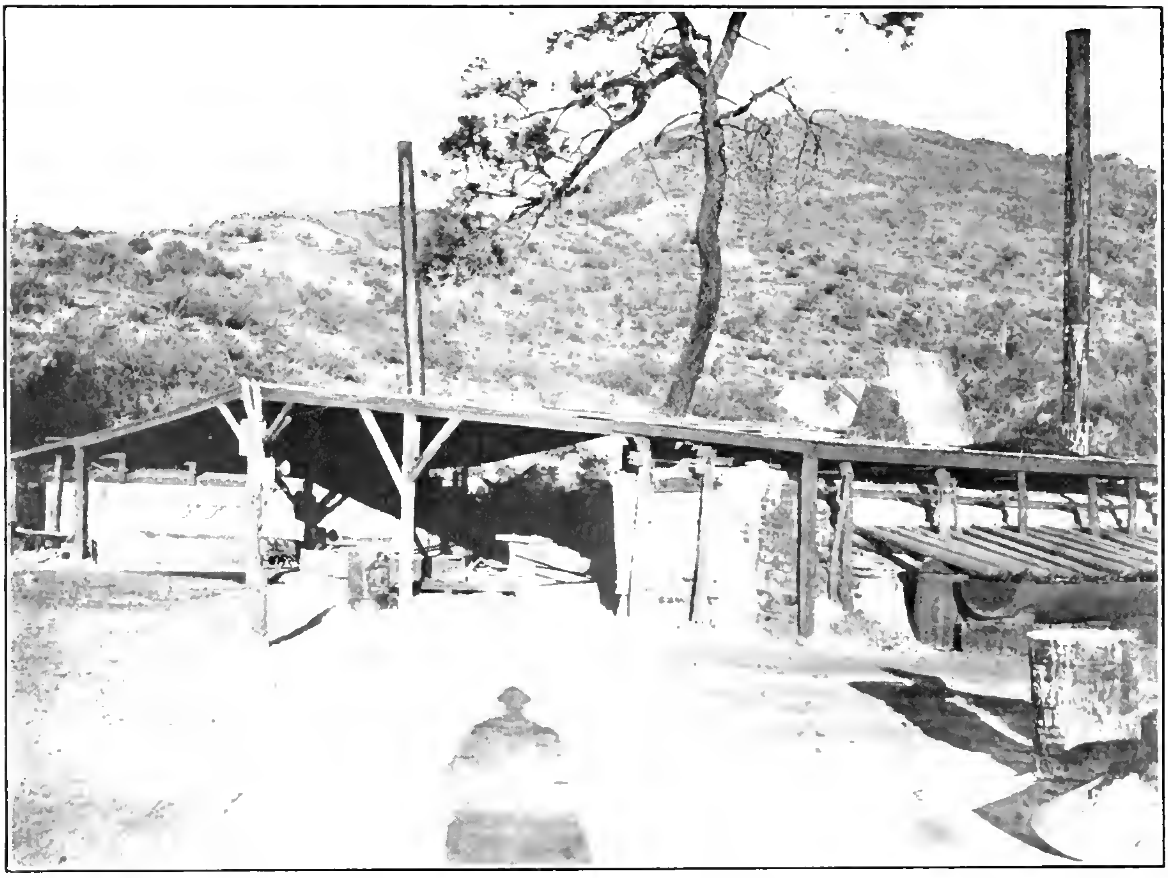


Photo No. 13. Patriquin Mine, near Parkfield, Monterey County. Mine on ridge in background; retorts in foreground.

wider. The strike is N. 73 W., and the dip about 65° N. In these areas the surface soil yields cinnabar by panning. On the south vein at the west end, an old tunnel in 800′ is stated to cross-cut six shoots, none of which have been drifted on. There is another adit in 950′, 500′ of which is a drift. The ore of the south vein is harder and less oxidized. On the north vein, the middle adit crosscuts the ore zone for over 100′. Most of the production to date has come from the north side. The ore is extracted by adits and stopes, and the workings are somewhat irregular, because of following the high-grade shoots in order to maintain a retorting grade. There is much material being left which would pay to put through a large furnace. It seems a pity to gouge a property like this for a retort, when with a Scott furnace or other large-capacity plant, the mine could be systematically developed, more cheaply operated, and its life doubtless prolonged. Some of the shoots have been stoped out up to 10 feet wide. The coarse ore, being mostly low grade, is sorted out onto the dump and the fine ore with occasional high-grade lumps is trammed to the retort. Water is obtained from a spring and the lower tunnel; but most of the mine workings are dry.

Reduction equipment consists of 2 banks of Johnson-McKay 12-pipe retorts (see Photo No. 13; also Photos 43 and 62, *post*). No water is used for cooling the condenser pipes, yet they keep cool except for the first 2 feet next to the retort. This feature is discussed elsewhere herein under the section on Metallurgy.[1] When visited they were charging 3 scoops per charge per pipe, each pipe being charged twice a day, or 240 pounds of ore per pipe per 24 hours. The nearly 3 tons of ore treated per day by the two banks was yielding 1½ to 2 flasks of quicksilver or a content of 2%–2.6% mercury. About 200 pounds of lime per week was being added, at a cost of $3 per bbl. (180 lb.) delivered at the retorts. Wood costs approximately $5 per cord at the retorts, and an average of 1½ cords are consumed per 24 hours (less of oak, but more when using pine). The condenser pipes are scraped out every other day—i.e. 1 bank each day—and about ½ flask of metal obtained thereby each time. Most of the metal is stated to condense in the upper part of the pipe, and soot forms at about a foot from the retort. Samples of the burned ore are panned occasionally and are stated to show a fairly clean extraction. Nine men are employed, including 3 at the retorts.

Bibl.: Cal. State Min. Bur., Report XV, p. 613; Chapter rep. bien. period, 1915–1916, p. 19; Bull. 27, p. 123. U. S. G. S., Min. Res. 1915, Part I, p. 269.

Table Mountain Claim. G. W. White, owner, Parkfield. This prospect is on Table Mountain in Sec. 30, T. 23 S., R. 16 E., about 9 miles east of Parkfield; elevation 3000′ (U. S. G. S). Cinnabar occurs with opaline silica in serpentine. Idle except for assessments. A 12-pipe retort was built in 1916, and two or three flasks of quicksilver produced.

Bibl.: Cal. State Min. Bur., Report XV, p. 614; Chapter rep. bien. period, 1915–1916, p. 20; Bull. No. 27, p. 124.

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[1] See p. 257, *post.*

NAPA COUNTY.

Development work began on the quicksilver mines of both the Knoxville and the Pope Valley sections about 1860. In the former, the Lake mine (afterward merged with the Manhattan) was the pioneer, followed closely by the Redington mine; and in the latter district, the Valley mine (now a part of the Ætna mineral springs property) was the first. Although the industry has had its ups and downs, Napa County was one of California's most important quicksilver producers from 1864 to 1903, from which later date the decline was very rapid until the present revival. The available published records show for Napa County, to the end of 1917, a total value of quicksilver produced of practically $15,200,000. That this value is below the actual output is known, as the product of some of the mines was included in the earlier reports of the state's production, under 'various mines.' In fact, the Knoxville mines alone are said to have yielded $17,000,000 in quicksilver, while Oat Hill is credited with another $5,000,000, to say nothing of the Ætna and others.

The following tabulation gives the recorded production of quicksilver in Napa County, annually since 1863:

Quicksilver Production of Napa County.

Year	Flasks	Value	Year	Flasks	Value
Manhattan Mine			1890	3,934	$206,535
output 1863 to 1876	3,594	$235,876	1891	4,896	221,544
1862	444	16,139	1892	8,612	350,595
1863	852	35,852	1893	11,505	422,809
1864	2,714	124,573	1894	9,705	298,016
1865	3,545	162,716	1895	9,318	372,500
1866	2,254	119,755	1896	11,411	403,031
1867	7,862	360,866	1897	12,281	459,753
1868	9,808	450,187	1898	12,368	472,972
1869	6,598	302,848	1899	11,696	598,322
1870	5,766	330,853	1900	8,724	403,500
1871	4,098	258,581	1901	7,798	388,176
1872	4,876	321,475	1902	7,142	304,474
1873	5,266	423,018	1903	7,859	333,006
1874	11,705	1,231,132	1904	*5,328	199,586
1875	9,453	795,470	1905	4,853	171,910
1876	11,303	497,332	1906	2,380	86,870
1877	13,127	489,637	1907	2,500	95,400
1878	10,810	355,649	1908	2,340	98,912
1879	9,446	281,961	1909	1,625	80,535
1880	6,830	211,730	1910	646	29,231
1881	7,746	231,063	1911	140	6,441
1882	9,013	254,467	1912	287	12,065
1883	7,784	223,790	1913	287	11,546
1884	5,188	158,234	1914	240	11,772
1885	3,891	119,648	1915	507	45,224
1886	5,656	200,788	1916	1,150	107,525
1887	6,247	261,717	1917	834	78,320
1888	5,150	218,875			
1889	5,402	243,090	Totals	336,794	$15,190,895

*Flasks of 75 lb. since June, 1904; of 76½ lb. previously.

Ætna Quicksilver Mine (formerly **Ætna Consolidated,** one time called **Pope Valley**). Lawley Brothers, owners, Calistoga; California Mines Development Corporation, lessee, 441 Monadnock Bldg., San Francisco; E. B. De Golia, president; E. B. Frost, superintendent. The Ætna group is at the southeast end of the Mayacmas district near the head of a branch of Pope Creek, on the ridge separating it from James Creek. It is in Secs. 2 and 3, T. 9 N., R. 6 W., 2 miles southeast from the Oat Hill mine and 9 miles northeast of Calistoga, though St. Helena (18 miles) is its railroad shipping point on account of better roads and easier grades. Post office is Ætna Springs. The group consists of Phoenix, Silver Bow, Red Hill, Washington, Pope, and Star claims, all patented. Quicksilver ore is said to have been discovered here in 1854 by Lawley; and the property was operated in 1863 by the Hamilton Quicksilver Mining Company.[1] It was later sold to Haufmeister et al., then to the Ætna Consolidated Quicksilver Company; then in 1904 to the present owners. The earliest production was from the Phoenix. The most important producing periods of the Ætna group were between 1877 and 1887, and for about six years beginning with 1892. The available records credit this group with a total output of at least 45,580 flasks to the end of 1917. The last two or three years that the Ætna Consolidated Company had the mine mainly prospecting was done. In 1910–1912, a small production was made from clean-up by lessees around the old furnaces, and the retorting of small lots of sorted ore. Concentration operations at the Ætna mine during 1913–1917, under the Soderhjelm and Gibson leases are described elsewhere herein[2] under the heading of Metallurgy. In addition to their concentrates, the lessees retorted occasional lots of sorted ore from the mine. Late in 1916, the 60-ton Scott furnace was rehabilitated. The present company has been operating the property since September 1, 1917.

Extended descriptions of the geology and the underground workings are given by Becker[3] and by Forstner.[4]

According to the latter:

"The serpentine in this region appears to be underlaid by sandstone, being a break above tunnel No. 2 in the Phoenix claim. Tunnel No. 7 runs toward a basalt dike, which breaks through to the surface, and reaches the contact at a depth of from 800 to 1000 feet. This dike shows at the surface for a length of about 1000 feet; the underground works [in the Silver Bow claim] which run around the dike show it to be surrounded by sandstone. The basalt is cut off at the surface by the same serpentine showing" at tunnel No. 2; "but from the fact that the latter does not go through the sandstone, the surface indications are not convincing that this basalt dike does not connect with the main seat of eruption, having uplifted the serpentine and broken through the sandstone. The tuff surrounding the basalt is more siliceous and probably older than the basalt. It overlies the sandstone but not the serpentine, confirming the above supposition. The tuff overlying the serpentine has probably been eroded. For some reason, in this region the tuff is invariably found overlying the sandstone but not the serpentine. In the Star claim another short dike of basalt, about 100 feet long, has been followed at its contact with the sandstone to a depth of 600 feet.

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[1]Whitney, J. D., Geology of California: Geol. Surv. of Cal., vol. I, p. 91, 1865.

[2]See p. 336, *post*.

[3]Becker, G. F., Geology of the quicksilver deposits of the Pacific Slope: U. S. G. S., Mon. XIII, pp. 354, 371–374, 1888.

[4]Forstner, Wm., Quicksilver resources of California: Cal. State Min. Bur., Bull. 27, pp. 72–76, 1903.

"The Washington shaft disclosed a boss of serpentine, which carried a good body of ore, while in the sandstone but little ore was found. In the Phoenix workings, at tunnel No. 9, only sandstone was found underground in the Red Hill, while the surface of that claim is almost entirely covered by serpentine and its allied opaline rock; a winze sunk from this tunnel follows a contact between igneous rock and sandstone to a depth of 1000 feet.

"All the sandstone in this neighborhood contains some cinnabar disseminated through it; but so far workable ore deposits have only been found near the igneous rocks and the serpentine."

The sandstone in the Silver Bow is fossiliferous. The writer has a specimen from there showing Rhyncenella (?), on and around which, and disseminated in the sandstone are specks of cinnabar. Of mineralogical interest, it may be mentioned here that the nickel sulphide millerite, has been noted in the Aetna mine associated with cinnabar; also metacinnabarite, and the hydrocarbon, napalite, a mineral wax. In the 'Tooth-ache vein,' which is a cross fissure on the Phoenix, the cinnabar exhibits the prismatic habit in the form of bright-red needle-like crystals whose color is in striking contrast to the green of the decomposed serpentine in the fractures of which they occur. There is very little pyrite in the Aetna ore. In parts of the ore there is considerable 'paint' cinnabar, which is of very light weight, being a mere film on fracture faces. On the No. 7½ level, there is a breccia which has been recemented by opaline silica and cinnabar.

In the Star mine, the shaft reaches a depth of 800 feet, and in the Silver Bow the tunnel (No. 9, in 3557 feet) attains a depth of 900 feet below the outcrop. No. 7 tunnel (7226 feet long) starts in the Phoenix and goes into the Silver Bow, while No. 9 (200 feet lower) starts in the Star and is driven into the Silver Bow. It was in the Silver Bow ground tapped by these two tunnels that the largest and most important ore body of the group was found, during the Aetna Consolidated regime. Above the No. 7 the vein was not over 3 or 4 feet wide, and with a steep dip. At that depth it flattened out, and widened to 20 feet between walls, extending to the No. 9—a veritable bonanza. The Phoenix vein system strikes N. 80° W. When visited by the writer in September, 1917, most of the ore was being taken from No. 1 Glory Hole on the Phoenix. There appears still to be considerable ore in the old stopes and workings which will pay to put through the Scott furnace. From the glory hole the ore was being trammed out and hoisted to a large storage and loading bin, from which it was hauled in a bottom-dump wagon (about 4 tons capacity) down the hill to an intermediate bin; thence trammed to the crusher and bin above the furnace. (See Photo No. 14.) The grizzly (1″ aperture) is on wheels and can be moved across from end to end of the ore bin. It is expected later on to reopen one of the lower tunnels, and drive a raise up into the present point of working; after which the ore will be trammed direct to the furnace bins, without requiring the wagon haul.

The reduction equipment consists of a 60-ton Scott fine-ore furnace to which are connected three series of condensers. The first series is of brick, consisting of 10 compartments, each 14′x38′x12′ average height (the top being sloped). Next is a series of 10 cast-iron chambers similar to the Knox-Osborne type, 3′ wide x 9′ long x 5′ and 4′ high, the slope being on the bottom; with an interior baffle extending 2/3 of the way down from the top; and connected by vitrified pipe (see Photo No. 64, *post*). The third series consists of 2 rectangular, wooden chambers 10′x18′x9′. The fuel used is wood. The blower is

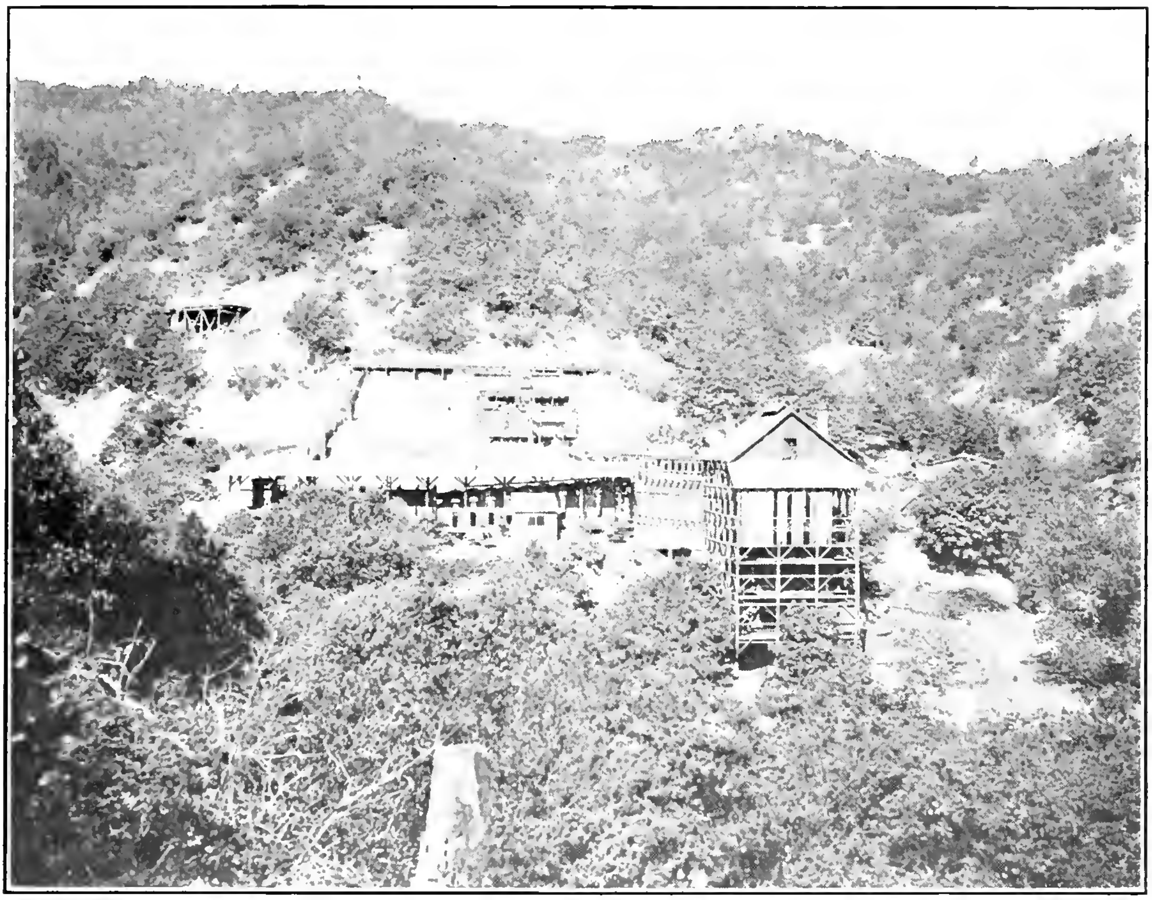


Photo No. 14. Bins and furnace plant at the Ætna Mine, Lake County.

driven by a 1½ h. p. gas engine and the rock breaker by a 15 h. p. Fairbanks-Morse, type Z, 350 r. p. m., oil engine, using a grade of fuel oil just below distillate, at a cost of 60¢–70¢ per 8-hour day. The high-grade soot from the condensers is worked on an inclined plate, and the residue washed over riffles and through a series of baffle boxes. There were 30 men employed, miners being paid $3.50 per day, and muckers $3.00.

Bibl.: Cal. State Min. Bur., Reports V, p. 96; XI, p. 72; XII, p. 362; XIII, p. 597; XIV, pp. 284–286; Chapter rep. bien. period, 1913–1914; pp. 111–114; Bull. 27, pp. 72–76. U. S. G. S., Mon. XIII, pp. 354, 371–374; Min. Res. 1884, p. 492;

1892, p. 148; 1902, p. 252; 1909, Pt. I, p. 553; 1910, Pt. I, p. 698; 1911, Pt. I, p. 901; 1912, Pt. I, p. 942; 1913, Pt. I, p. 205; 1914, Pt. I, p. 326; 1915, Pt. I, p. 269. MIN. RES. W. OF ROCKY MTS., 1872, p. 523; 1873, p. 11; 1874, p. 30; 1876, p. 20. GEOL. SURV. OF CAL., Geol. vol. I, p. 91. ENG. & MIN. JOUR., Nov. 1, 1913, p. 828.

Ætna Extension Claims. Chas. A. Lawley, owner, Calistoga. It is on the south side of James Creek, adjoining or near to the Ætna group, being in SE. ¼ of SE. ¼ of Sec. 33, also S. ½ of SW. ¼ and Lot 2 of Sec. 34, also Lots 1 and 2 of Sec. 35, all in T. 10 N., R. 6 W., M. D. M. In January, 1916, this property was leased to D. S. Llewellyn, but there is no record of any quicksilver being produced and it is now idle. Apparently only a small amount of development work has been done.

Bella Union Mine. Bella Union Quicksilver Company, owner; W. H. Hamilton, attorney, No. 556 Mills Building, San Francisco; Rutherford Mining Company, lessee; H. A. Broughton, manager, Rialto Building, San Francisco. This group includes the Bella Union and Oakville mines in Sec. 20, T. 7 N., R. 5 W., M. D. M., just on the edge of the Napa Valley, 1½ miles west of Oakville; elevation 500 feet. The Oakville was a producer in 1872–1873 (about 400 flasks) and the Bella Union is credited with 271 flasks in 1876; but the exact total figures are not available. The total output to date for the group has been at least 825 flasks. The ore carries cinnabar with pyrite, quartz and calcite in serpentine, largely, and a metamorphosed rock (possibly a sedimentary) which seems to be in process of serpentinization. Chlorite, an end product of the weathering of the serpentine, is noticeably present. The cinnabar is coarsely crystalline and massive, occurring in part as veinlets. The strike of the vein appears to be W. of N., and the dip is about 40° W. In the winter of 1909–1910, under a working bond for the purchase of the mine, certain of the old tunnels were re-opened, exposing some good ore; but the contract lapsed for failure to continue operations. Early in 1916, the mine was again leased, and has been operated at intervals since, being at present (March, 1918) idle.

In 1916, the two old Neate coarse-ore furnaces (see Photo No. 46, *post*) were repaired and used for a short time. This was followed by concentration equipment. First, tables were tried; then, flotation; and finally, the two combined. With the last-named, the installation included a ball-mill, K. & K. circular, flotation machine, and two Deister-Overstrom tables. The underflow of the K. & K. machine went to the tables, and the overflow froth with its concentrate was carried by a launder to a settling tank. The plant was driven by a 20 h. p. Western gas engine. The concentrates were roasted in a 10-pipe Johnson-McKay retort, burning wood. Following the shutting-down of this plant, the retorts were run for a time on sorted ore, and 6 men were employed. When visited by the writer in September, 1917, a Lillard furnace (a vertical, continuous-feed retort) was being built.[1] It is stated that at present (March, 1918) the property is idle.

Bibl.: CAL. STATE MIN. BUR., Reports IV, p. 336 (table); X, p. 362; XII, p. 364; XIII, p. 599; XIV, p. 286; Chapter rep. bien. period, 1913–1914, p. 114; Bull. 27, p. 76. U. S. G. S., Mon. XIII, p. 377; Min. Res. 1909, Pt. I, p. 553; 1915, Pt. I, p. 269. MIN. RES. W. OF ROCKY MTS., 1873, p. 11; 1874, p. 30.

Calistoga Hot Springs. There is a flat, semi-marsh area of 200 acres or more on the eastern side of Napa Creek at Calistoga, in which hot sulphur springs occur. It is only necessary to dig down a foot or two anywhere in this area to get hot water. In places, the mud is said to have shown native quicksilver on panning.[2]

Corona Mine. Vallejo Quicksilver Mining Company, owner; J. B. McCauley, president; E. J. McCauley, secretary, 409 Carolina St., Vallejo. It is in Secs. 32 and 33, T. 10 N., R. 6 W., 9 miles southeast of Middletown, between the Oat Hill mine on the northeast and Twin Peaks mine on the south; elevation, 2200 feet (barometric reading). The Corona was opened up in 1895, but closed down in 1906, following a heavy winter, being driven out by water in excess of the pumping capacity. They also had furnace troubles on account of the large amount of pyrite occurring with the cinnabar. The pyrite rendered the ore self-burning, making it difficult to regulate the furnace temperatures, and the condensing. A white powder (probably sulphate of mercury) formed as an incrustation in the condensers, the result of reaction between the released quicksilver and SO_3 gas. This incrustation had to be broken out and retorted. The furnace, of the Scott type, with the walls built in part of volcanic tuff quarried nearby, is of 50 tons capacity. The mine has since been idle except for some production made in 1916 by retorting ore taken out in the course of prospecting work during that year. Figures of the total output of the Corona are not available, but it is claimed to have been approximately 5000 flasks.

[1]See p. 217, *post.*
[2]Cal. State Min. Bur., Report XIII, p. 514, 1896.

The Corona mine is on the contact of the Oat Hill sandstone and a serpentine belt (see Plate X). According to Forstner,[1] who visited the mine when it was open and in operation:

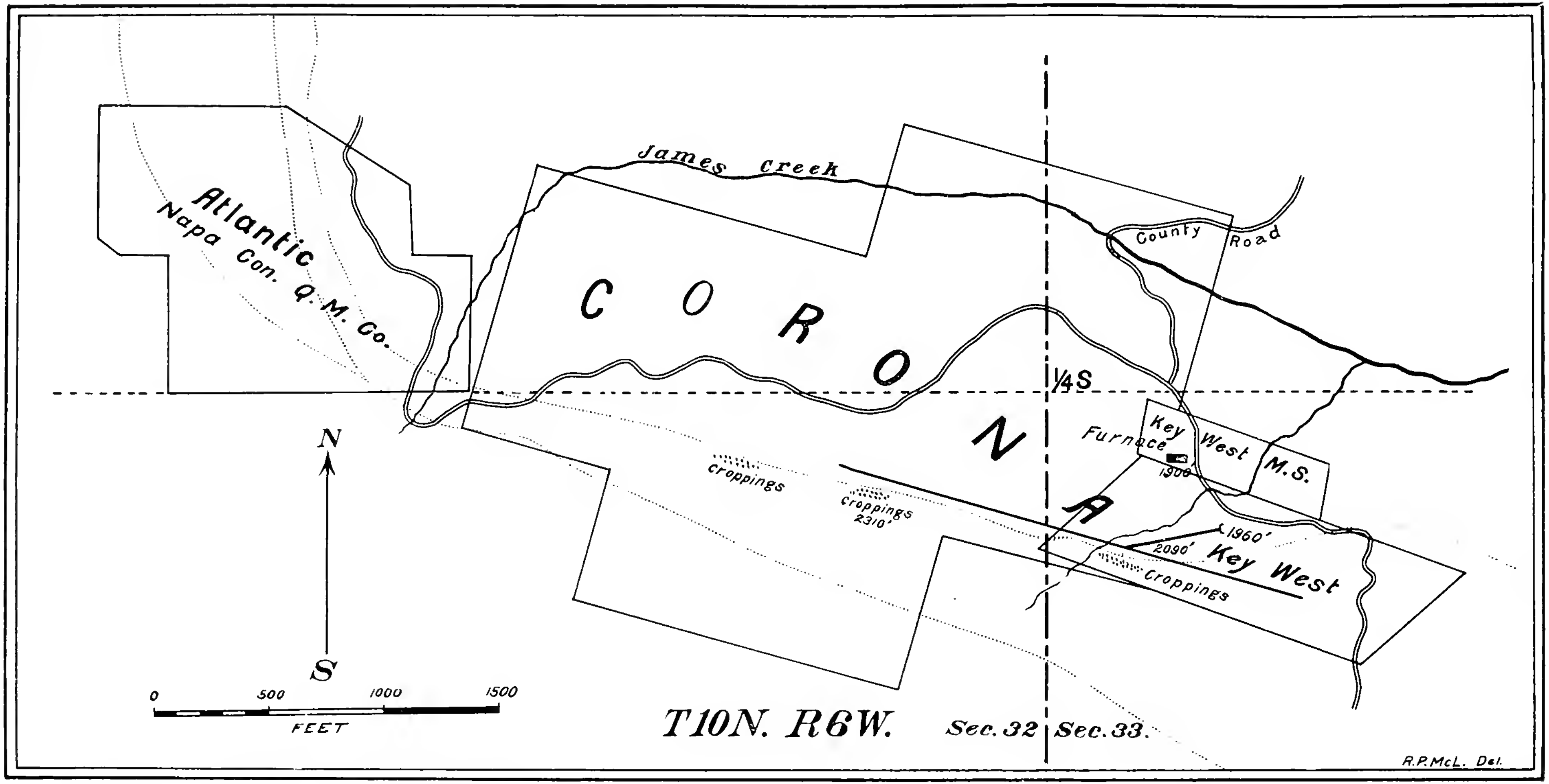
> "The ore occurs in a zone of black chert rock, lying between a sandstone footwall and probably a serpentine hanging wall. The general strike of the zone is N. 15° W. Three ore shoots show at the surface. The development consists mainly in a level which enters the hill running very nearly west and cross-cutting the sandstone footwall for about 400 feet. The sandstone here is mixed with some shales. At 400 feet, the tunnel cuts the vein and follows it about 800 feet to the southeast, and 1300 feet to the northwest. The tunnel cuts the vein at the southeasterly ore shoot, with about 130 feet of backs. The workable ore body here is from 10′ to 15′ wide, the cinnabar forming in fissures running through the opaline rock. Underlying the latter is a white talc, wherein pieces of white and gray rock are found, determined as phthanite, indicating that originally a body of shales overlaid the sandstone and were silicified, probably by the same solution which formed the overlying chert beds. This ore shoot has in the past produced some rich ore. * * *; development work being centralized on the middle ore shoot, which the tunnel cuts at a depth of 350 feet below the surface. A vertical shaft, 100 feet deep, has been sunk from the tunnel level on this shoot. The tunnel is driven northwest to cut the third ore shoot. Part of the tunnel is driven northwest to cut the third ore shoot. Part of the tunnel is run in the sandstone footwall, determining its persistency, but no crosscut has been run into the hanging wall. A very soft decomposed material overlying the ore body was crosscut to a width of 35 feet, without finding unaltered material; hence the assumption of a serpentine hanging wall rests on surface indications. The black chert wherein the ore makes is from 40 to 45 feet wide; * * * The central ore shoot has been opened for a length of 160 feet, and has been persistent in depth from the surface to the present depth of 450 feet. The cinnabar forms occasionally in such hard and compact material that it can scarcely be understood how it found access to its place of deposition."

Bibl.: CAL. STATE MIN. BUR., Reports XIII, p. 597; XIV, p. 287; Chapter rep. bien. period, 1913–1914, p. 114; Bull. 27, pp. 79, 206, 207. U. S. G. S., Min. Res., 1902, p. 252; 1908, Pt. I, p. 686.

James Creek Placers. Several men, operating in a small way with rockers have, during the past three years, been concentrating cinnabar from the stream gravels in James Creek for several miles below the Oat Hill mine and in part near Aetna Springs. This material has come largely through erosion by winter rains of the extensive Oat Hill dumps during their exposure of many years. **Lindblom Bros.**, leasing on land owned by Mrs. M. Patton, Calistoga, just below Oat Hill, have been the principal producers by this method. In 1916, they (two men) were making as high as 30–40 pounds of concentrates per 8-hour day, which yielded 30%–40% mercury in a retort consisting of two 4″ pipes. Among those working farther down the creek and near Ætna Springs were: A. Marro, Joe Paulishich, Bert and Henry Wells.

Knoxville Mine (Boston, Redington). Berryessa Cattle Company, owner; George Holcomb, president, Reno, Nevada; C. S. Wheeler, secretary. It was recently sold to the present owners by F. E. Johnston of Napa who had owned it since the Boston company ceased operations. This mine, known for years as the Redington, and later as the Boston, was first called 'Excelsior'[2] being owned by the N. L. C. R. Mining Company. It was discovered in cutting a grade for a highway, and

[1]*Op. cit.*, p. 79.
[2]Whitney, J. D., Geology of California; Geol. Surv. of Cal., vol. 1, p. 92, 1865.



Green=Serpentine. Red=tuff. Yellow=Metamorphic Rock.

Geological Map of Corona Mine, Napa County.

Reprinted from Bulletin No. 27.

first appears in the producing column with 444 flasks in 1862. In 1867, the company was reorganized as the Redington Quicksilver Company. The mine continued an important producer up to 1883. From that time to 1893 the output was only nominal (126 to 881 flasks per year), followed by five years of prosperity, since which, with the exception of 1908, the production has been small. The recorded total has been 116,204 flasks to the end of 1917, exceeded in California (which also means the United States) by only three mines—New Almaden, New Idria and Oat Hill. It is at Knoxville in the northeast corner of Napa County, though the 'town' is now non-existent. The mine is mainly in Secs. 6 and 7, T. 11 N., R. 4 W., M. D. M., and is 41 miles from the railroad at Winters. It is north of Monticello and 21 miles southeast of Lower Lake. As there is a considerable acreage of patented land connected with the property, it has been used mainly as a cattle range for several years past.

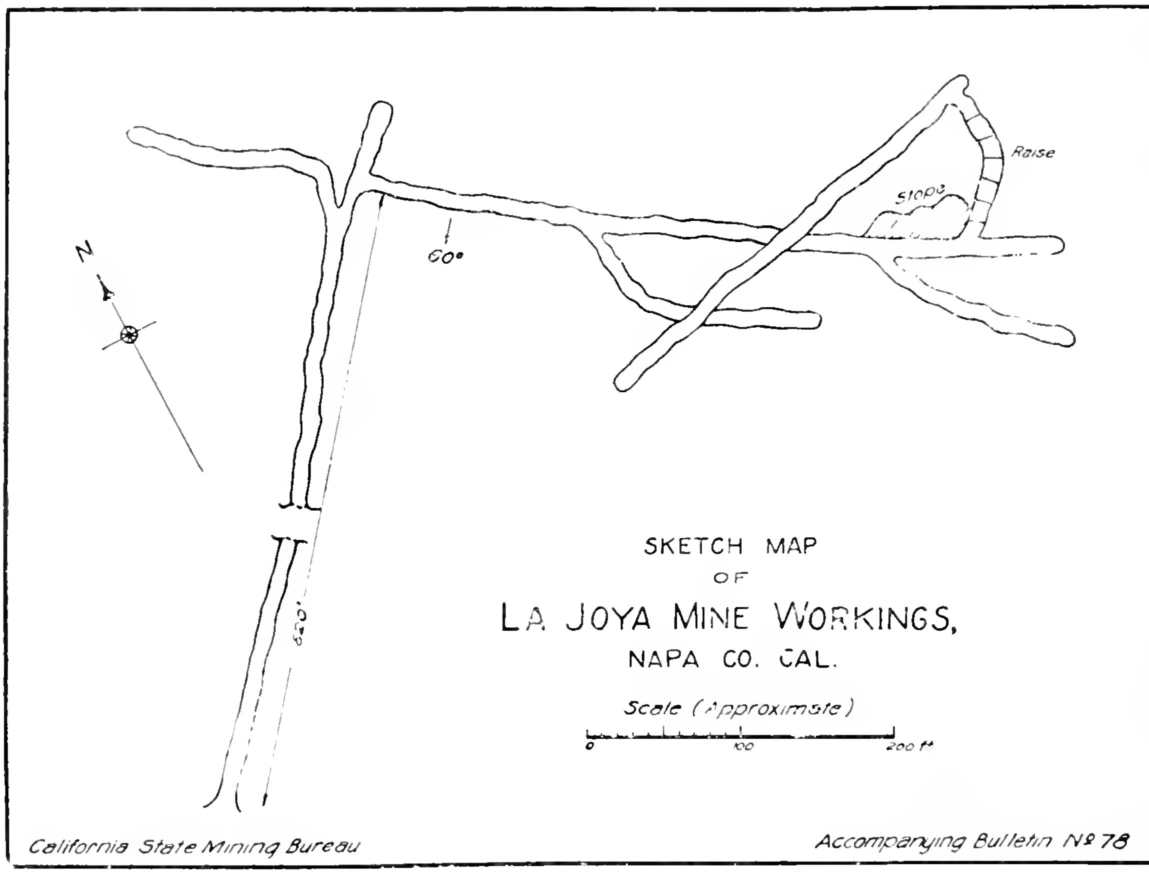
The geology and the underground workings are described in detail in several of the reports noted under Bibliography. There are three parallel, principal veins in the mineralized zone, and enclosed in serpentine. The cinnabar is associated with pyrite and quartz, and was often found in columnar and acicular forms, the gangue mineral being principally a black opal, in part resembling obsidian. Metacinnabarite is also an associate. Knoxvillite and redingtonite, complex hydrous sulphates of chromium, iron, et al., were first identified from this mine. Sulphurous waters in the mine are said to have caused trouble with iron pipes and machinery. When visited by the writer in September, 1913, one 'D' retort was in operation, putting through a little sorted ore with material from the old Scott fine-ore furnace, which was being torn down. The ore was from the 150-foot level of the intermediate shaft (west of a line between the two older shafts), where a small body of fair grade ore was being blocked out. Three men underground (one miner, singlehand drilling, and two muckers) with five on top (including foreman and Chinese cook) were at work. Ore was hauled by wagon to the retort. Similar operations were continued to the end of 1916, when production of quicksilver ceased; though some prospecting was done with two men in 1917. Extensive tailings dumps around and below the furnaces indicate the former activity of this mine, which at one time employed over 600 men. During the seventies, the Redington Company had a contract with the Comstock mines for 400 flasks of quicksilver per month.

Bibl.: Cal. State Min. Bur., Reports IV, pp. 179, 261, 289, 317, 329, 336 (table), 339, 340; VI, Pt. I, p. 122; X, p. 358; XI, pp. 69–71; XII, p. 363; XIII, p. 599; XIV, p. 287; Chapter rep. bien. period, 1913–1914, p. 115; Bull. 27, pp. 76–79. U. S. G. S.,

Mon. XIII, pp. 10, 271–290, 464; Min. Res., 1883, pp. 394–396; 1884, p. 492; 1892, pp. 148, 160; 1902, p. 251; 1907–1912 (inc.), Pt. I. Geol. Surv. of Cal., Geol. vol. I, pp. 92, 99; vol. II, pp. 128–132. Min. Res. W. of Rocky Mts., 1867, p. 178; 1868, p. 264; 1871–1876 (inc.) Trans. A. I. M. E., Vol. III, pp. 279, 285, 292, 301.

La Joya Mine. James Rennie, owner, Blythe, Cal., or care Olympic Club, San Francisco; West Coast Investment Company, operator under lease and bond. Howard A. Broughton, manager, Rialto Building, San Francisco. It is in Sec. 24, T. 7 N., R. 6 W., M. D. M., 6 miles

PLATE XI.



west of Oakville, by a road which is fair in summer, but heavy in winter. The property consists of 11 claims and fractions, all patented, divided into two groups known as La Joya Consolidated Mine and La Joya #2 Consolidated, respectively; a total area of 184.58 acres. The Accident claim at the west end of the first-named group is under lease to Frank Hooks, Oakville, who, in September, 1917, had 30 feet of tunnel driven, with some cinnabar showing in a siliceous gangue. The La Joya property had been idle many years, but was reopened in 1915, the present operators taking charge in July, 1916. A total of 405 flasks of quicksilver have been produced to the end of 1917, not including the earlier day operations, as those figures were not segregated.

The vein is in a much-altered serpentine, but there is a contact with sandstone nearby. The strike is northwest and the dip southwest rather flat; average width 6′, but in the 'Big Stope' it is up to 6 sets (36′) wide. There is another, smaller vein in the hanging wall. The cinnabar is mostly crystalline, with a little pyrite, and the gangue is largely siliceous, both chalcedony and quartz being present. Chlorite, characteristic as an end product of the weathering of serpentine, is

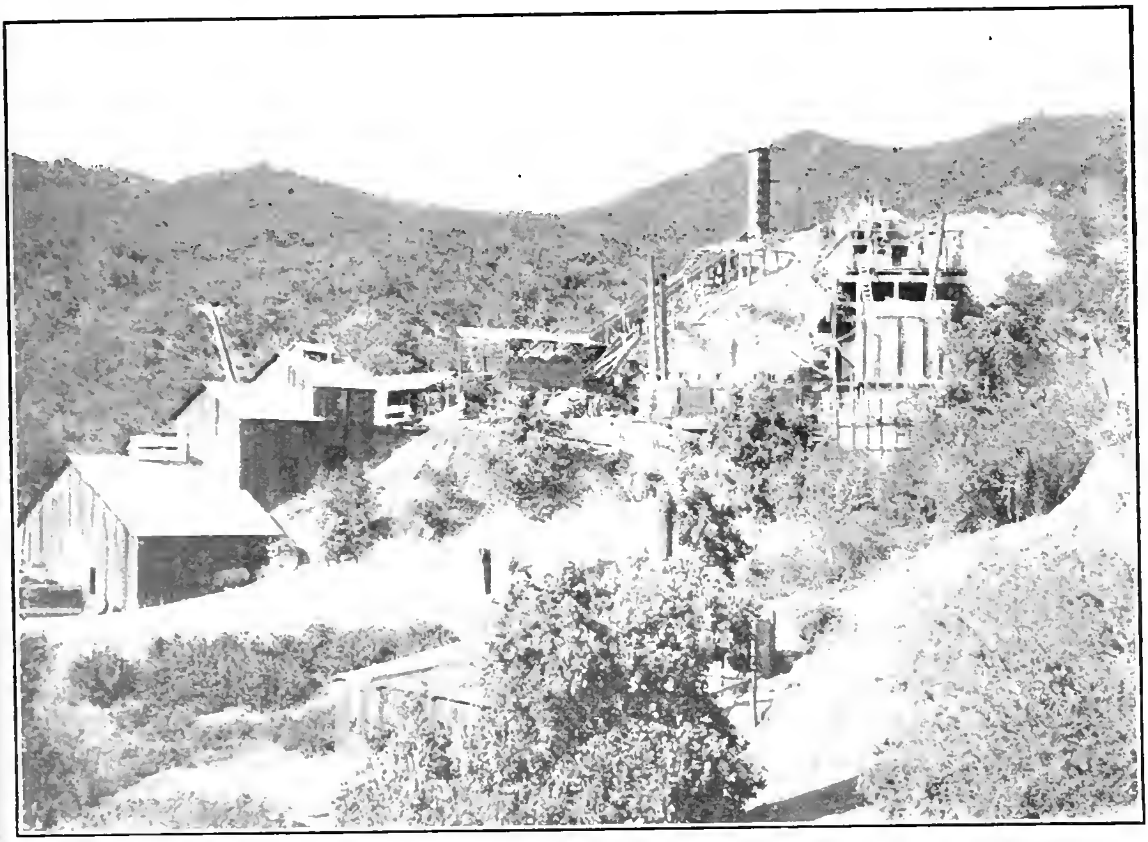


Photo No. 15. Furnaces at La Joya Mine, Napa County. Fitzgerald furnace in buildings at left; Livingston at right; and retorts on bench between.

abundant. A little native mercury has been noted. The main adit was driven 820′ to crosscut the vein, which has been drifted on for a length of 400 feet. (See sketch map, Plate XI.) This is at a depth of 250′–300′ below the outcrop. Ore is being broken by raises and stopes.

A Fitzgerald furnace was built some years ago. This was supposedly an inclined retort,[1] but it appeared to the writer to have been operated like a Livermore furnace, with the flames passing along the top of the ore instead of outside the ore-chamber as designed. This furnace in March–May, 1917, was treating 6 tons per day with a yield of 1 flask of quicksilver daily. It is stated that at first there was condensation of quicksilver in the upper part of the ore chamber, following which a

[1]See p. 216, *post;* also Forstner, *op. cit.*, pp. 204, 305.

blower was added. More quicksilver was thereafter recovered and the capacity of the furnace was increased, but the stack loss was also noticeably increased as shown by a gold-piece test of the escaping gases. From retort tests, the ore then being treated was estimated to carry 1% Hg; and a sample sent to the writer, assayed 2% Hg. A 12-pipe Johnson-McKay retort was built, and utilized the greater part of the year 1917. This treated 3 tons of ore, daily. A pipe was discharged and refilled every 45 min., giving a 9-hour cycle; and 3/4 cord of wood was consumed per 24 hours, at a cost of $6.50 per cord. Wood is obtained from the surrounding hills and packed in by burros. When visited by the writer in September, 1917, a Livingston furnace,[1] calculated to treat 20–25 tons per day was being installed (see Photo No. 15). We are informed, its use has now (March, 1918) been discontinued, as it did not prove satisfactory. In September, 1917, 24 men were employed, of whom 9 were underground. Equipment includes a jaw crusher driven by a 9 h. p. gas engine.

Bibl.: CAL. STATE MIN. BUR., Report XIV, p. 288; Chapter rep. bien. period, 1913–1914, p. 116; Bull. 27, p. 80.

Manhattan Mine (Lake). R. B. Knox and Hugo D. Newhouse, owners, 819 Pacific Building, San Francisco. This group, formerly owned by the Lake Mining Company, includes the old Lake mine, and the Porphyry mine, and is in Sec. 1, T. 11 N., R. 5 W., and Sec. 36, T. 12 N., R. 5 W., M. D. M., 1 mile northwest of Knoxville and 20 miles southeast from Lower Lake. The nearest railroad point is Rumsey to the eastward. The total area is about 350 acres. The mine was first worked in 1862, the place being then known as Johntown, and the ore reduced in the furnaces of the Redington mine. It was idle from 1877 to 1884, from which time to 1905 it was again in the producing list. Some work was done in 1916, from which production resulted. The total recorded yield of the group has been 15,979 flasks of quicksilver.

The mine and its geology have been described at considerable length in previous reports, particularly by Becker[2] and by Forstner,[3] the following being quoted from the latter:

"The study of this mine is especially interesting in regard to the relation of igneous rock and the ore deposition. The ore deposits are found in a belt having a general northwestern direction, lying between basalt to the northeast and serpentine to the southwest. The basalt does not show at the surface in a continuous line; * * * The territory between the basalt and the serpentine is almost entirely covered by tuff, except in * * * [3] places: * * *.

"The underlying country rock is an altered Neocomian,[4] crushed and altered into a material which is found through the entire mine in various conditions of hardness. * * * This material is locally called 'mudrock,' and is found also in other mines. * * * On contact of the mudrock and the basalt occurs a breccia * * *.

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[1]See p. 217, *post.*

[2]Becker, G. F., Geology of the quicksilver deposits of the Pacific Slope: U. S. Geol. Surv., Mon. XIII, pp. 282, 464, 1888.

[3]Forstner, William, Quicksilver resources of California: Cal. State Min. Bur., Bull. 27, pp. 81–89, 1903.

[4]Becker, *op. cit.*, p. 464

"Underground explorations have proven that the surface indications in many instances do not represent underground conditions. * * * One fact is, however, beyond doubt: The eruptive actions are intimately connected with the ore deposition. Through the serpentine runs a very prominent cropping of opaline material, near its northeastern boundary, which cropping is almost continuous to the Boston [Knoxville] mine, where large ore bodies have been found therein. A great amount of exploration work has been done on these croppings without disclosing any ore, until recently a seam of fair ore, from 6 to 12 inches wide, has been discovered therein, about 400 feet southeast of the furnace.

"All the territory between the basalt and the serpentine shows the action of mineral springs, which have formed large beds of sinter and other siliceous material.

* * * * * * *

"The absence of ore deposits in the serpentine must be noted. * * * the ore deposits are all contiguous to the basalt and do not extend to any distance from it, except in the St. Quentin deposit, where the cinnabar has been deposited from solfataric waters, which must have been related to the basalt. * * * Considering that the Boston and Manhattan deposits are only one mile interdistant, and that from the topography it might be inferred that while not appearing at the surface, the vent through which the basalt extruded in the Manhattan persists toward the Boston, the entirely different nature of ore formation in these two lines is very noteworthy.

"It is to be regretted that in no place in the Manhattan mine has the commercial development of the ore deposits caused the underground works to be run in a manner to determine the vent of the basalt extrusion, or whether on or near this vent deposits of greater persistence in depth would be found. The fact that every deposit as yet opened in this mine terminates in depth with the basalt, justifies the expectation that such persistence might be the case.

"The irregular basalt occurrences found in the mine are probably intrusions, which follow pre-existing fissures, joints, bedding planes, or contacts, which would account for the lack of heat effect on the adjoining rocks by these igneous intrusives."

There is occasionally a little pyrite, sulphur, and stibnite associated with the cinnabar. The maximum width of the ore body as worked was 100′, at the surface; while the width was 6′ at the 200′ level. There are 3 series of fissures: N-S, E-W, and NW-SE, the dip averaging about 60°. There is no distinct footwall. On Lake #4 claim, the hanging wall is sandstone. There is a shaft down 206′, with levels at 106′, 156′, and 206′. Equipment includes: boiler and hoist; 20-ton Knox-Osborne coarse-ore furnace; 24-ton Knox-Osborne fine-ore furnace; and a retort.

Knox writes that:

"This mine has been worked superficially only, and no definite ore system has been developed. The deposits, usually largest at the surface, diminished in size and value with depth and became unprofitable at from 25′ to 125′ from the surface.

"The outcrops were large and open pits twelve in number cover possibly four or five acres in aggregate area.

"The cinnabar has evidently been deposited by springs resulting from regional volcanic activity.

"Any revival of this property will demand considerable work, and a large amount of intelligence, if an extensive ore system is to be found beneath the basaltic surface. No attempt has been made to open at any depth."

Bibl.: Cal. State Min. Bur., Reports IV, p. 336 (table); V, p. 95; VI, Pt. I, p. 33; VIII, p. 412; XI, pp. 71, 72; XII, p. 363; XIII, p. 598; XIV, p. 288; Chapter rep. bien. period, 1913–1914, p. 116; Bull. 27, pp. 81–89. Geol. Surv. of Cal., Geol. vol. I, p. 92; vol. II, pp. 126–128. Min. Res. W. of Rocky Mts., 1867, p. 178; 1871, p. 15; 1874, p. 30; 1876, p. 20. U. S. G. S., Mon. XIII, pp. 282, 464; Min. Res., 1892, pp. 147, 160; 1902, p. 252; 1908, Pt. I, p. 686.

Mountain Mine (also known locally as **Simmons**). M. Johnson, owner, Yountville; E. E. Lillard, et al., lessees, Oakville. This prospect is in Sec. 2, T. 6 N., R. 5 W., M. D. M., west of Yountville and south of the La Joya mine. A little work has been done spasmodically. The present lessees are planning to open it up.

Bibl.: Cal. State Min. Bur., Reports X, p. 362; XIV, p. 291; Chapter rep. bien. period, 1913–1914, p. 119.

Northern Light Prospect. Fr. Josh, owner, Lower Lake. It is about 2½ miles west of Knoxville, and near the Lake County line. Idle.

Bibl.: Cal. State Min. Bur., Report XIV, p. 289; Chapter rep. bien. period, 1913–1914, p. 117; Bull. 27, p. 92.

Oat Hill Mine (Napa Consolidated). E. J. Sittig, 1216 Oxford Street, Berkeley, and R. P. Newcomb, 1052 E. 11th Street, Oakland, owners. E. J. Sittig and Earlbert Newcomb, Middletown, have leases on the dumps for concentration; and Murray Innes, Kohl Building, San Francisco, has taken a lease on the underground portions of the mine. There are 17 claims in the group, all patented, lying at the

Photo No. 16. Dumps of low grade ore at Oat Hill Quicksilver Mine, Napa County, from Eureka, Osceola and Humboldt veins.

junction of Secs. 27, 28, 33 and 34, T. 10 N., R. 6 W., M. D. M. (see Map, Plate V), between James and Bucksnorter creeks, and 9 miles southeast of Middletown. Elevation: 2250′ (bar.) at the office. This mine was for many years one of the important quicksilver producers of California, having been opened up in 1876 and operated continuously up to 1909, when it was closed by the Napa Consolidated company as being worked out—at least, the ore had dropped below a profitable working grade for the price at which quicksilver was then selling. The records show a total output of 152,066 flasks from 1876 to 1917 inclusive.

The older worked ore shoots were on the Mercury and Manzanita veins, the later developments being to the southwest and around on the other side of the ridge, on the Escape, Eureka, Humboldt and Osceola veins. Though the ore was connected with the veins and on their footwall, there was little cinnabar in the siliceous vein matter itself. The values occurred almost entirely as impregnations in the soft, light-gray sandstone. The lenses of ore were all near to the surface, the deepest one on the Eureka reaching only a depth of 400 feet; though the Manzanita vein carried values down to the 750′ level. In places, the stopes broke through to daylight. The largest single lenses were opened upon the Humboldt and Osceola veins, in both cases being stoped for a length of 500 feet. A flow of basalt is a prominent feature of the surface at Oat Hill. During the last two years that the Napa Consolidated Company operated, the territory outside of the zone explored by underground operations was prospected by boring numerous holes to a depth of 200′ to 350′ from the surface, with a Davis-Calyx core drill. During their last year, no underground development was carried on, only the ore then in sight being extracted. It is estimated from the maps of the property that there are over 21 miles of underground workings in the mine. Equipment included two 50-ton Scott furnaces, which were dismantled and cleaned up when the mine was closed.

Since 1913, during the seasons when water has been available, R. P. Newcomb and succeeding lessees concentrated material from the extensive dumps on the property (see Photo No. 16). These operations are described elsewhere herein[1] under the section on metallurgy. Newcomb estimated that there are in excess of 250,000 tons of ore on the dumps which can be economically treated by this method, and that he could handle at a profit material carrying as low as 0.15% quicksilver (3 pounds per ton). Being a friable sandstone with impregnated cinnabar, and having lain out in the weather for some years, it is more or less disintegrated and air-slaked, requiring no crushing; so that it is particularly favorable for low-cost concentration treatment. Since the writer's last visit to Oat Hill, Murray Innes, as lessee, has put on a number of men reopening certain of the old underground workings and exploring for available orebodies that will pay to extract under present conditions. If developments justify it, his intention is to install furnace equipment. Wood costs $5 per cord. The present lessees on the dumps, Sittig & E. Newcomb, plan to carry classification of their table feed to a greater degree than has been done by any of their predecessors. On the trails and roadways about the Oat Hill

[1]See pp. 332–335, *post*.

mine, after a rain, cinnabar can be seen concentrated among the rocks and small crevices of the water courses.

Bibl.: CAL. STATE MIN. BUR., Reports V, p. 96; VIII, 413; X, p. 270; XI, pp. 65, 72; XII, p. 364; XIII, p. 598; XIV, pp. 289–291; Chapter rep. bien. period, 1913–1914, pp. 117–119; Bull. 27, pp. 89–91. U. S. G. S., Mon. XIII, pp. 354–358, 469; Min. Res., 1883, pp. 394–397; 1884, p. 492; 1888, p. 97; 1892, pp. 145, 160; 1902, p. 251; 1906, p. 497; 1907, Pt. I, p. 679; 1908, Pt. I, p. 686; 1909, Pt. I, p. 553; 1910, Pt. I, p. 698; 1911, Pt. I, p. 902. ENG. & MIN. JOUR., Nov. 1, 1913, p. 828.

Palisade Silver Mine (locally called **Grigsby**). R. F. Grigsby, owner, Calistoga. This silver mine is in Sec. 24, T. 9 N., R. 7 W., 3½ miles northeast of Calistoga. It was first opened up in 1876, and was a bullion producer from 1888 to 1893. The vein mineral is quartz carrying antimonial silver sulphide, with which are associated cinnabar and pyrite. The ore was treated by dry crushing, roasting, and pan amalgamation for its silver contents; but no attempts were made to recover the quicksilver present.

Bibl.: CAL. STATE MIN. BUR., Reports V, p. 93; VI, Pt. I, p. 77; VIII, pp. 413–415; X, p. 363; XII, p. 376; XIII, p. 606; XIV, p. 270; Chapter rep. bien. period, 1913–1914, p. 98. U. S. G. S., Mon. XIII, p. 370 .

Patten Claims (see also **James Creek Placers**). Mrs. M. F. Patten, owner, Calistoga. These consist of 600 acres of patented ground on James Creek, adjoining the Oat Hill group. So far, only the placer gravels in the stream bed has been worked; but there is stated to be cinnabar in place in the sandstone on this property, which prospects are as yet undeveloped.

Philadelphia Claims (**James Creek** prospect). This prospect is near (southeast from) the Oat Hill mine, but has been abandoned since the death, about 1911, of the owner.

Bibl.: CAL. STATE MIN. BUR., Report XIV, p. 291; Chapter rep. bien. period, 1913–1914, p. 119; Bull. 27, p. 93.

Summit Mine. Joseph Scheerer, owner, 747 Noe Street, San Francisco. It is in Sec. 19, T. 7 N., R 5 W., M. D. M., 3 miles west of Oakville and south of the La Joya. It was a producer in the early seventies, but was idle for many years until quite recently. In 1916, some development work was done.

Bibl.: CAL. STATE MIN. BUR., Reports XII, p. 365; XIII, p. 599; XIV, p. 291; Chapter rep. bien. period, 1913–1914, p. 119; Bull. 27, p. 92. MIN. RES. W. OF ROCKY MTS., 1874, p. 30.

Twin Peaks Mine. B. A. & A. A. Wilson, and L. D. Fay, owners, Aetna Springs or Calistoga. This group of 5 claims near Oat Hill adjoins the Corona mine on the southeast, and is in Sec. 33, T. 10 N., R. 6 W., and Sec. 4, T. 9 N., R. 6 W., M. D. M., about 9 miles northeast of Calistoga. In two years preceding 1906, it is stated that a total of $40,000 in quicksilver was produced from a lens of ore. As the surplus is stated to have been all paid out in dividends and none used for further development, the mine was closed for lack of funds for development work, when the pocket had been mined out. Except for assessments, the property remained idle until reopened in 1915 by the present owners, then under a lease. The mine is credited with a total output to the end of 1917 of 275 flasks.

The footwall is sandstone and the hanging wall, serpentine. In 1916, a portion of the quicksilver yield was obtained by concentrating material from the dumps with a New Standard table. In September, 1917, they had 4 men at work. Some good ore had been struck on the 200-foot (upper adit) level; and a lower adit (400-foot level) was being driven to cut the vein with depth. Reduction equipment consists of 2 'D' retorts.

Bibl.: Cal. State Min. Bur., Report XIV, p. 291; Chapter rep. bien. period, 1913–1914, p. 119; Bull. 27, p. 92. U. S. G. S., Ann. Rep. XXI, Pt. VI, p. 278; Min. Res., 1902, p. 252; 1907, Pt. I. p. 679; 1911, Pt. I, p. 902; 1915, Pt. I, p. 269.

Whitney Mine, G. B. Whitney, owner, Calistoga. This prospect is in Sec. 21. T. 10 N., R. 5 W., M. D. M., in Snell Valley, 10 miles southeast of Middletown, on agricultural patented land. The property was not visited by the writer but we were shown specimens of the ore, which is a schistose sandstone impregnated with cinnabar. The country rock is said to be sandstone and serpentine. Development consists mainly of a drift and winze, and several prospect holes. A few flasks of quicksilver have been produced, with a retort. The owner states that lack of capital has prevented more extensive development.

Bibl.: Cal. State Min. Bur., Report XIV, p. 292; Chapter rep. bien. period, 1913–1914, p. 120.

NEVADA COUNTY.

The reported occurrence has been noted by Lindgren,[1] of gold amalgam in the Odin drift mine, and of cinnabar in the Manzanita hydraulic mine, near Nevada City. Apparently neither had been definitely identified in place in the quartz veins themselves, though not unlikely, as such occurrences have been found elsewhere in the Sierran 'Gold Belt.'

The same author, with Turner[2] describes an occurrence, in place, a short distance south of the above area in this same county:

> "One of the few occurrences of cinnabar in the Sierra Nevada is found near Nickerson's ranch in the southeastern corner of the Smartsville area [12 mi. south of Grass Valley]. The ore occurs sparingly scattered through a quartzose and dolomitic gangue on the contact of serpentine and quartzite."

Bibl.: Cal. State Min. Bur., Bull. 67, p. 35. Report State Bd. of Agr., Annotated Cat. of Mineral species in Cal., 1866. U. S. G. S., Ann. Rep. 17, Pt. II, pp. 116, 119; Smartsville Folio (No. 18), p. 4.

ORANGE COUNTY.

The occurrence of native mercury associated with small veins of barite has been recorded, 2 miles east of Tustin, in an outlying hill of Tertiary sandstone, partly surrounded by the Santa Ana plain. There has been no commercial development.

Bibl.: Cal. State Min. Bur., Reports XI, p. 118; XV, p. 516; Chapter rep. bien. period, 1915–1916, p. 56; Bull. 67, p. 35.

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[1] Lindgren, Waldemar, The gold-quartz veins of Nevada City and Grass Valley districts, California: U. S. Geol. Surv., Ann. Rept. 17, Part II, pp. 116, 119, 1896.

[2] Lindgren, W., and Turner, H. W., Geologic Atlas of U. S.: U. S. Geol. Surv., Smartsville Folio (No. 18), p. 4, 1895.

SAN BENITO COUNTY.

San Benito County ranks among the oldest and most important quicksilver producing counties in California. It contains the New Idria mine, which stands second only to the New Almaden mine, both in length of continuous operations and in point of total production to date. In fact, since the decline of the latter mine from its former importance, the New Idria for some years past has been the largest single producer of quicksilver in the state.

The total recorded output of the quicksilver mines of San Benito County is shown by the accompanying tabulation:

Quicksilver Production of San Benito County.

Year	Flasks	Value	Year	Flasks	Value
1865	*17,455	$943,617	1892	848	$34,523
1866	6,525	346,673	1893	869	31,936
1867	11,493	527,529	1894	1,005	30,861
1868	12,180	559,062	1895	1,100	36,000
1869	10,315	473,459	1896	1,335	46,725
1870	9,888	567,373	1897	3,605	135,185
1871	8,180	516,158	1898	5,000	190,000
1872	8,171	538,714	1899	4,780	245,000
1873	7,735	621,353	1900	3,990	180,000
1874	6,911	726,899	1901	4,806	242,300
1875	8,432	709,553	1902	7,291	306,081
1876	7,272	319,968	1903	8,180	344,251
	†2,000	139,000	1904	‡8,480	314,000
1877	6,316	235,587	1905	7,764	279,651
1878	5,138	169,040	1906	7,203	262,909
1879	4,425	132,048	1907	7,675	292,878
1880	3,209	99;479	1908	9,600	405,792
1881	2,775	82,778	1909	8,900	440,241
1882	1,953	55,123	1910	10,800	488,700
1883	1,606	46,173	1911	9,775	449,748
1884	1,025	31,263	1912	9,743	409,596
1885	1,144	35,178	1913	9,719	390,995
1886	1,406	49,913	1914	6,633	325,349
1887	1,890	80,088	1915	6,291	475,370
1888	1,320	56,100	1916	11,110	1,032,156
1889	980	44,100	1917	11,150	1,057,770
1890	977	51,293			
1891	792	35,838	Totals	316,159	$16,641,376

*Production of New Idria Mine from 1858-1866: yearly details not obtainable.
†Estimated output of Cerro Bonito, Monterey and Stayton mines, 1870-1877; yearly details concealed under heading of "Various Mines" in early reports.
‡Flasks of 75 pounds since June, 1904: of 76½ pounds previously.

There are three quicksilver districts in the county, all situated in the Diablo Range, which traverses the eastern part of the county in a northwest-southeast direction. The Stayton district is at the northern end at the junction of San Benito, Santa Clara and Merced counties. The New Idria district is in the southeast corner of San Benito County; and the third district, in which are the old Cerro Bonito and Bradford mines is situated between the other two. Only the New Idria district has been active recently, or has ever produced quicksilver to any notable extent, the others having been idle for many years.

NEW IDRIA DISTRICT.

The general geology of this region, with particular reference to the quicksilver deposits, has been described in considerable detail by Becker[1] and Forstner.[2] The most recent geological map of this part of California is that accompanying the report of Anderson and Pack[3] on the oil possibilities of the region and from which we have prepared the map presented herewith (Plate XII), with some minor additions from our own observations.

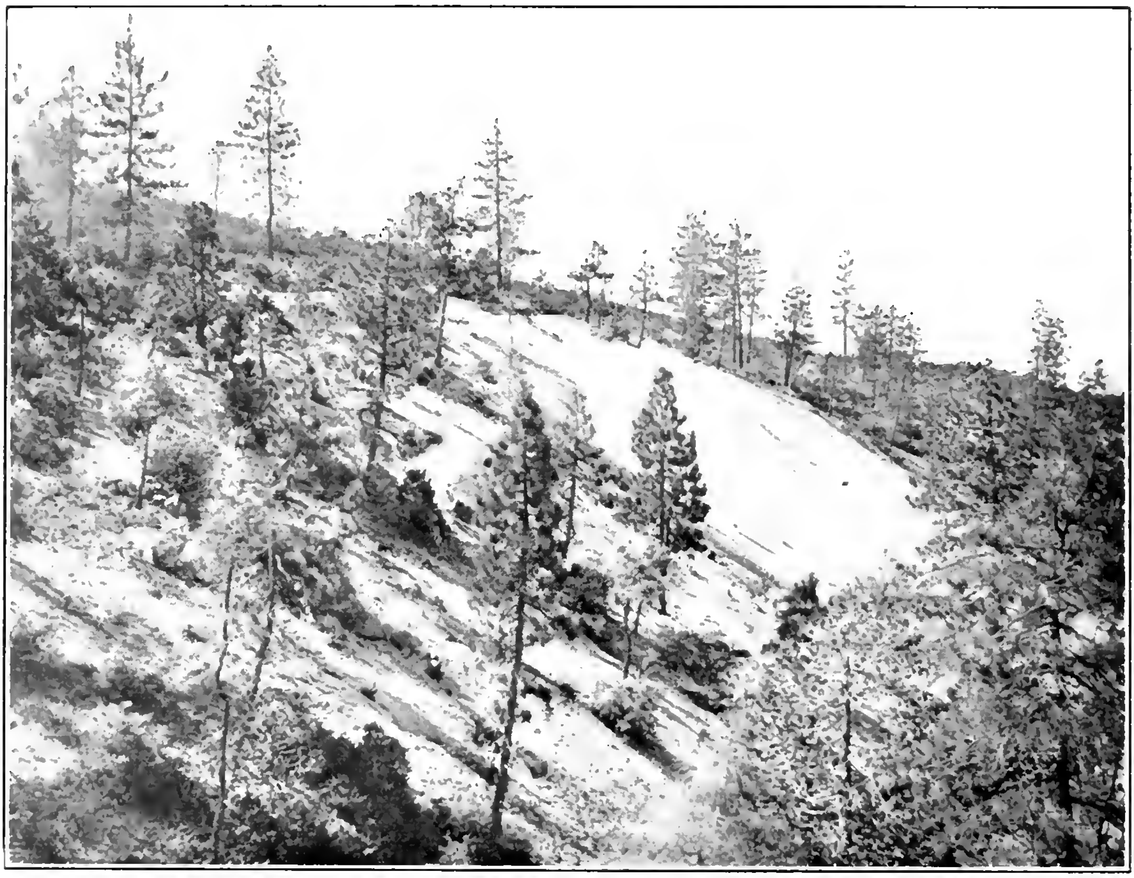
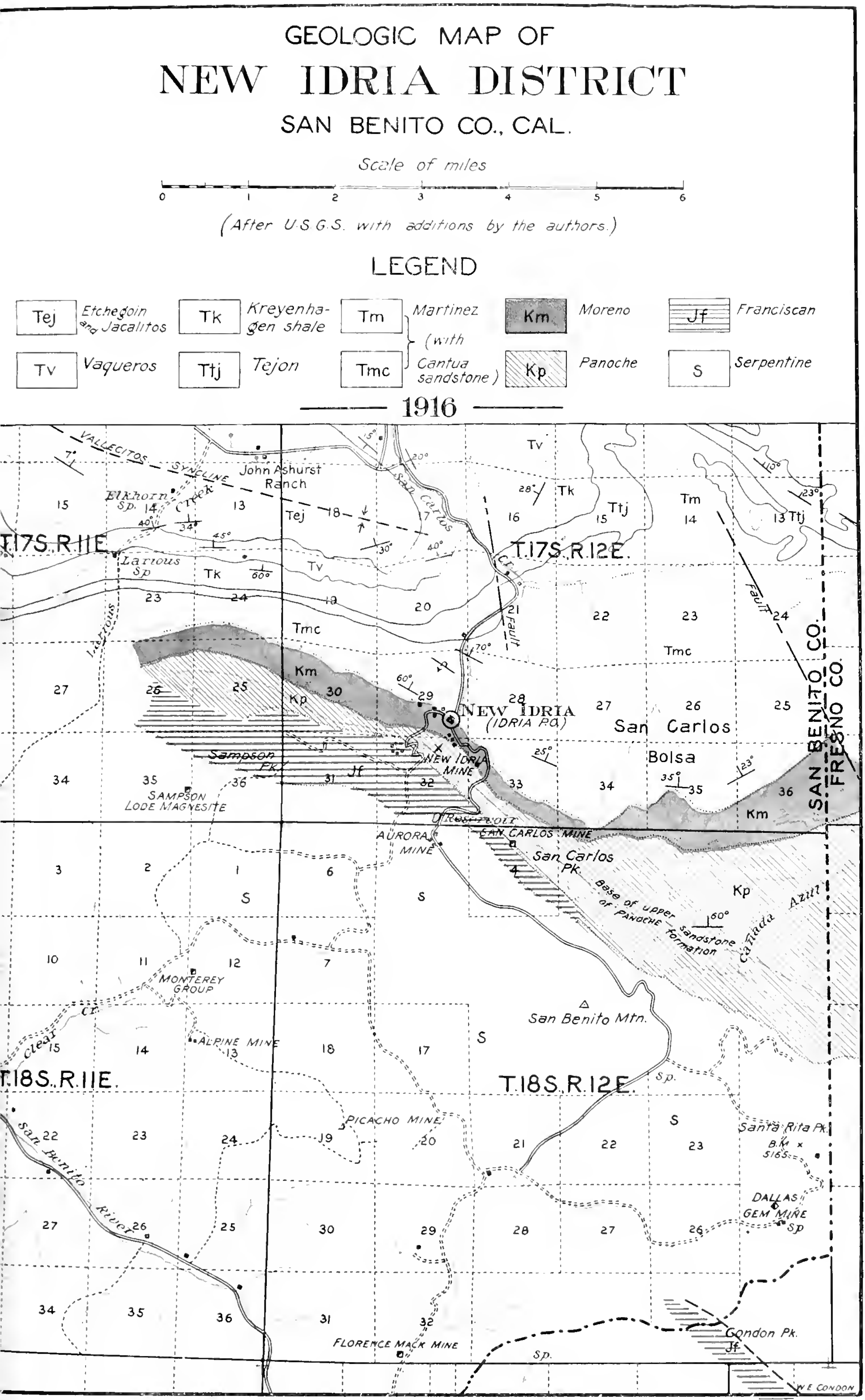


Photo No. 17. Serpentine surface near New Idria, San Benito County, showing characteristic sparseness of timber and brush growth.

The most striking feature of the geology of this district is the large area of serpentine to the south and southeastward from New Idria. Many of the ridges and slopes within this area are characterized by the scarcity of underbrush and the sparseness of the timber growth (see Photo 17). In such places the serpentine is light colored, pale blue and green, and pulverulent. In other portions of this serpentine area where the reddish color of the soil indicates the presence of iron, the underbrush is fairly abundant. This is particularly the case on

[1]Becker, G. F., Geology of the quicksilver deposits of the Pacific Slope: U. S. Geol. Survey., Mon. XIII, pp. 64, 189, 215, 291–309, 465–467, 1888.
[2]Forstner, William, Quicksilver resources of California: Cal. State Min. Bur., Bull. 27, pp. 125–129, 1903.
[3]Anderson, R., & Pack, R. W., Geology and oil resources of the west border of the San Joaquin Valley north of Coalinga, California: U. S. Geol. Surv., Bull. 603, pp. 206, *et seq.*, 1915.


GEOLOGIC MAP OF
NEW IDRIA DISTRICT
SAN BENITO CO., CAL.
Scale of miles
0 1 2 3 4 5 6
(After U.S.G.S. with additions by the authors.)
LEGEND
Tej Etchegoin and Jacalitos
Tv Vaqueros
Tk Kreyenhagen shale
Ttj Tejon
Tm Martinez
Tmc (with Cantua sandstone)
Km Moreno
Kp Panoche
Jf Franciscan
S Serpentine
1916
VALLECITOS SYNCLINE
John Ashurst Ranch
Elkhorn Sp.
Creek
San Carlos Cr.
T.17S.R.11E.
T.17S.R.12E.
Larious Sp.
Larious
Fault
NEW IDRIA (IDRIA P.O.)
NEW IDRIA MINE
San Carlos Bolsa
Sampson Pk.
SAMPSON LODE MAGNESITE
Reservoir
AURORA MINE
SAN CARLOS MINE
San Carlos Pk.
Base of upper sandstone of Panoche formation
Cañada Azul
SAN BENITO CO.
FRESNO CO.
MONTEREY GROUP
Clear Cr.
ALPINE MINE
San Benito Mtn.
T.18S.R.11E.
T.18S.R.12E.
PICACHO MINE
Santa Rita Pk.
B.M. 5165
DALLAS GEM MINE
San Benito River
FLORENCE MACK MINE
Condon Pk.
W. E. CONDON

the western slope of Sampson Peak where the magnesite deposits are being worked. In the gravels of many of the stream beds in this area, chromite float and sands are noticeable. Some commercial shipments have been made of such chromite float gathered together; but thus far no bodies of workable size in place have been reported. Most of the smaller quicksilver properties in the New Idria district are within this serpentine area. The Aurora mine, a mile south of the New Idria mine, is just within the boundary of the serpentine, being not over ¼ mile from the contact.

In contact with the serpentine along its northern edge, is a tongue of Franciscan shale and sandstone, this being covered to the north and east by the overlying Panoche formation, a member of the Chico group of the Upper Cretaceous. This latter formation is covered to the north by succeeding later Cretaceous, Eocene and other Tertiary sedimentaries in turn. The ore bodies of both the New Idria and San Carlos mines, the most important in the district, occur in the altered and highly fractured shale and sandstone of the Franciscan formation near its contact with the overlying Panoche formation. The principal source of the ore in the New Idria mine is the stockworks deposits, where the cinnabar acts as a cementing material binding together the brecciated Franciscan rocks. Cinnabar also occurs here disseminated in the more porous sandstone, as thin films coating fracture surfaces, and as fillings in true fissure veins. The metal now obtained is entirely from cinnabar, but in a portion of the earlier, upper workings a considerable deposit of metacinnabarite was taken out.

The railroad outlets for the district are: via Mendota, 40–45 miles to the northeastward, and via Tres Pinos about 55 miles to the northwest. For the mines at the southern end of the district, near Hernandez, the rail outlet is via either Coalinga or Kings City, each about 40 miles distant by the roads. Round timber for mining is obtainable in the district by contract with the U. S. Forest Service, but not abundant. The New Idria Company for many years used local, round timbers, but is now hauling in sawed timbers by motor trucks from Tres Pinos. That company also, uses oil for fuel, which is brought in via Mendota.

CENTRAL SAN BENITO DISTRICT.

The central San Benito district is not a well-defined district as are the other two, but includes a few scattered mines between the New Idria and Stayton areas. The principal mines are the Cerro Bonito and Bradford which yielded some quicksilver in the 70's, but have had little work done on them since. They are in the Diablo Range, which here consists mainly of rocks of the Franciscan series, in places covered by or adjacent to younger formations. The country is fairly well timbered, both for mining and fuel purposes; and the rail outlet is via Tres Pinos.

STAYTON DISTRICT.

The Stayton district is mainly in San Benito County, but in part extends over the boundary lines into Santa Clara County on the north and into Merced County on the east (see Map, Plate XIII). The mines in this district have been mostly idle for many years, and were not visited by the writer, the following description being quoted from Forstner's[1] report:

"The surface rock of this district is prominently of igneous origin and except in the northwestern part the underlying sedimentaries are almost exclusively found in the bottoms of the deeply-eroded gulches. The post-Tertiary igneous rocks vary greatly in character; from very fine-grained, dark-colored basic, basaltic rocks, to very fine-grained, nearly white acidic rocks. The great majority is, however, a light grayish-colored porphyritic rock, which Whitney classed as trachyte, but which closely answers the asperites described by Becker. There is no doubt that this district has been the locus of repeated igneous eruptions, and that these different igneous rocks represent various stages of magmatic differentiation.

"The sedimentary rocks belong to the metamorphic series, prominently sandstones. * * * Some shales are also exposed, * * * Only at one place in the northwest corner of the district, in the old Comstock property, is an exposure of serpentine noted, and this not over 1000 feet wide, abutting to the west against schist and to the east against a flow of basalt.

"There are no hot springs in the district, but in the western belt, sulphur emanations principally carrying antimonious ores, are very prominent, and the ledge matter and part of the wall rocks in all the metalliferous deposits have been so thoroughly leached by sulphurous waters that determination of their original composition is extremely difficult, if not impossible."

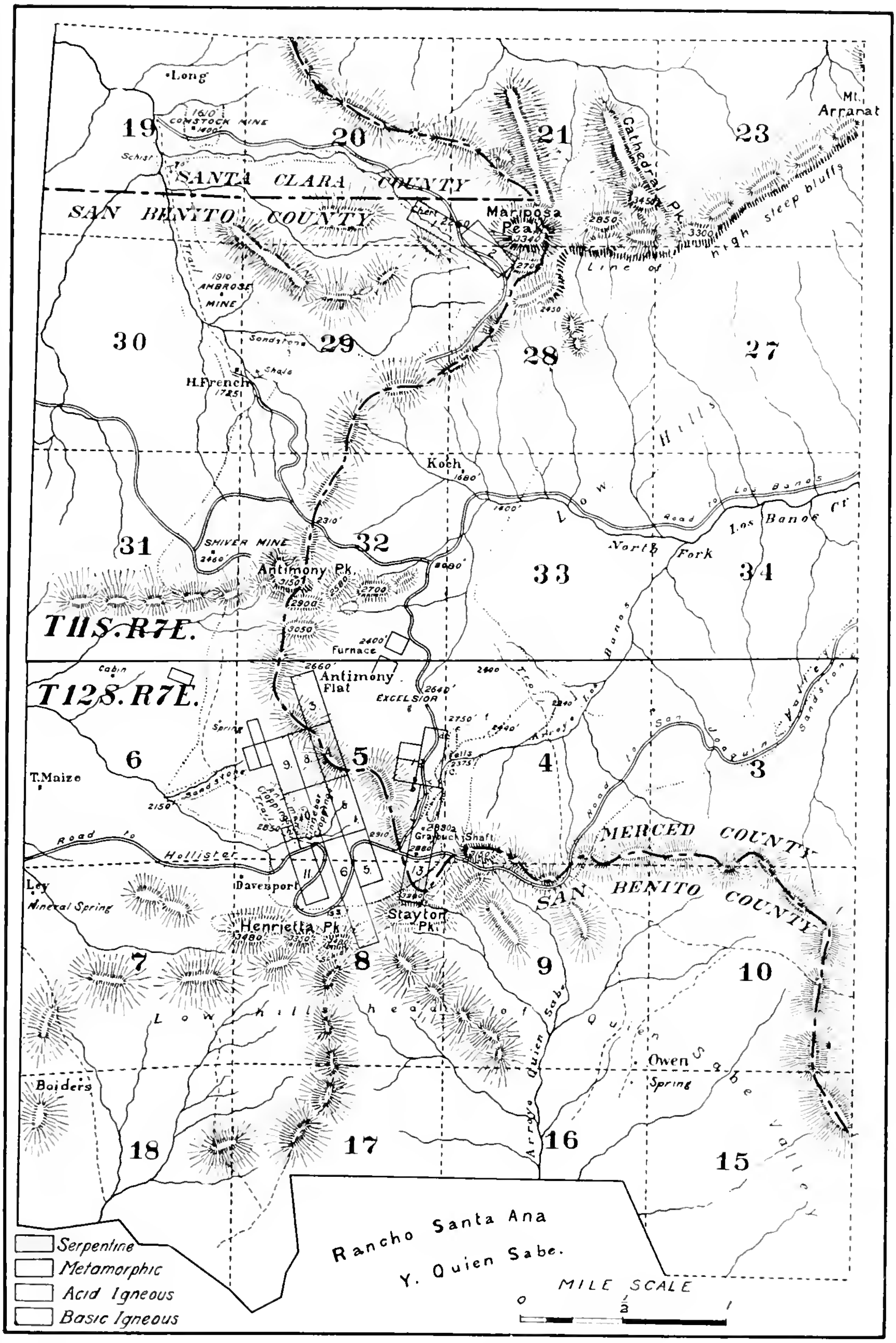
The district is 15 miles from the railroad at Hollister. The vicinity is practically devoid of mining timber, but there is ample wood for fuel. The following claims correspond to the numbers appearing on the map of the district: 1. Santa Cruz; 2. Mariposa; 3. Green Valley; 4. F. Smith; 5. Cold Springs; 6. McLeod; 7. Badger; 8. Fairplay; 9. Santa Clara; 10. Pacific; 11. Last Chance; 12. North Star; 13. Stayton.

Alpine Quicksilver Mining Company (one time called the **Esmeralda Quicksilver Mining Company**). H. B. Leonard, manager, San Benito; D. McPhail, Hollister, Cal., secretary. The company owns 32 full claims in Secs. 13 and 14, T. 18 S., R. 11 E., 6 miles from Hernandez and 40 miles from Coalinga, the nearest railroad point.

These claims occupy the southwestern portion of the zone of highly metamorphosed silicified serpentine which extends from the creek just east of Los Picachos Peak, to the old Clear Creek and Boston mines in Sec. 2, T. 18 S., R. 11 E., M. D. M. They have a total length of about 1½ miles along the strike of the outcrop zone and join the Monterey Group on the northeast. The original discovery was made by Silvester Tirado, who sold the early holdings to the present company about 1910.

They have since made additional locations. The surface outcrop is ochreous and highly silicified, but as one descends into the mine the

[1] *Op. cit.*, pp. 129–131.



Geological Map of Stayton District.

Reprinted from Bulletin No. 27.

serpentine shows less and less alteration. A slip at the discovery point strikes S. 20° E., with a dip of 70° NE. Ore so far mined has been taken out in bunches along the locus of this slip for an inclined depth of 190 feet, along which the slickensided wall can be easily traced. The width of ore at the outcrop was about two feet. No surface work has been done to determine the extent of mineralization along the strike. The older work was carried on through a tunnel 150 feet long from which an inclined raise at an angle of about 45° followed the mineralized fault zone 100 feet to the upper tunnel, which was only a few feet long. Small stopes along the raise yielded some good ore which was treated in 'D' retorts and pipe retorts, giving a nominal output. A small stope was also driven off the lower tunnel and a 15-foot drift from the raise between the levels, but the latter did not uncover ore. Later work has gone on through a new tunnel, which had been connected with the next level above by an inclined raise of 90 feet and which is 230 feet on the incline below the outcrop. In December, 1915, this had been driven 800 feet in an endeavor to cut the 'vein' at depth, but was in serpentine the entire distance. This showed minor fractures filled with silica and calcite, but only small traces of cinnabar. Two crosscuts, driven 45 and 75 feet respectively, off this level, failed to show ore. Work had started on a stope four sets wide off the middle level (the old lower tunnel). This had entered a mineralized lens and had been carried 15 feet without having passed out of ore. The cinnabar made in a chalcedonic gangue varying in color from light to black, and also in the fractured serpentine with a gangue of silica and calcite, in narrow stringers. Hand specimens show bunches of grey and greenish chalcedony carrying cinnabar, associated with lumps of magnesite, through which tiny specks of cinnabar are sprinkled. Considerable native mercury in serpentine was also noted in this stope. This ore was of furnace grade, and in spots rich enough to retort.

The reduction plant formerly used, and still in order, consists of 8 'D' retorts and 2 pipe retorts, with 6 other pipe retorts which had been burnt by using too hot a fire. The new plant, which was completed early in 1916 includes an improved Scott furnace of 20 tons capacity, and four brick condensers. The bricks were burned at a clay bed on the stream four miles from the mine, and heavy work was encountered in hauling them to the furnace site. This plant was operated for several months up to November, 1916, since which it has been closed down, except for a few weeks in the summer of 1917. The total recorded output of the Alpine mine has been 408 flasks to the end of 1917.

This district is handicapped by having roads which become nearly impassable after a rain, and mining development is bound to be retarded by the difficulty and cost of transportation. The furnace is located at an elevation of 3600 feet (U. S. G. S.). The country is entirely serpentine, with the characteristic sparse growth of brush and only scattered pine timber. The company obtains timber from its own land, and pine wood for fuel cut nearby at a cost of $8 to $9 per cord, delivered. A few men are at work on development, and report a new shoot of ore encountered, which promises well.

Bibl.: Cal. State Min. Bur., Report XV, pp. 649–651; Chapter rep. bien. period, 1915–1916, pp. 55–57.

Andy Johnson and **Fourth of July Mines (Flint Group).** Thomas Flint, owner, Hollister; O. A. Austin, et al., lessees, #185 Busch Ave., Hanchett Park, San Jose. This group comprises the old mines known as the Andy Johnson, Fourth of July, and Clear Creek, and consists of 552 acres of patented land in Secs. 2, 11, 12 and 13, T. 18 S., R. 11 E., and Sec. 18, T. 18 S., R. 12 E., M. D. M. The Clear Creek, and Andy Johnson (and the adjacent Monterey Group of the Esmeralda company) occupy the northwestern portion of the prominent zone of ochreous, silicified croppings which strike northwest from the Hernandez (Los Picaches) mine. They lie adjacent to Clear Creek, taking in the hills to an elevation of about 3700 feet (barometric reading) and 600 feet above the creek. The Andy Johnson claim adjoins the recently located Capitola on the southeast, where some very rich surface ore is being retorted. These properties have been idle so long that definite data concerning them is not obtainable. The Andy Johnson, according to Mr. Flint, was worked by an open cut and was noted for the amount of native mercury yielded, as much as a pint being taken at times from one spot. The Clear Creek mine was operated through a tunnel 600 feet long, from which underground operations on rather an extensive scale revealed good ore. All these workings caved in years ago. A furnace for reducing the ore was operated on the bank of Clear Creek near the junction of the Alpine and New Idria roads, but this also has long since fallen to ruin, and definite information concerning the output of mercury from it is not to be had. The mines were closed in the early eighties when the price of quicksilver was so low as to practically prohibit mining. It is believed that workable ore remains in these properties. Most of the ground has not been thoroughly explored, and in view of the showings of ore in other near-by mines on the same series of out-croppings, it appears as though thorough prospecting would be justified on these holdings. Values of $1.50 to $2 per ton, in gold, are reported from assays of samples of the ore. The country is mantled by serpentine in deeply disintegrated and rounded knolls, carrying little vegetation except along the watercourses. A fairly good road reaches the mines from Hernandez, 5 miles distant.

In 1916, the lessees built a Johnson-McKay retort, and made a few flasks of quicksilver. They did some exploratory work and reopened portions of both the Andy Johnson and the Fourth of July mines, up to November, 1917, some ore being taken out and retorted. At present idle.

Bibl.: CAL. STATE MIN. BUR., Report XV, p. 654; Chapter rep. bien. period, 1915–1916, p. 60; Bull. 27, pp. 131, 137, 138. U. S. G. S., Mon. XIII, p. 309. GEOL. SURV. OF CAL., Geol. vol. II, p. 123.

Aurora Group (one time called **Morning Star Mine**), and **Monterey Group** (one time called **Boston**), owned by the Esmeralda Quicksilver Mining Co., Richard Phelan, president; R. W. Gilloghy, secretary; H. T. Hays, engineer; office, 942 Phelan Bldg., San Francisco, Cal. The two groups consist of a total of 38 claims, the Aurora being in Sec. 5, T. 18 S., R. 12 E., M. D. M., and the Monterey Group mainly in Sec. 12, but extending into Secs. 11, 13 and 14, T. 18 S., R. 11 E., 5 miles southeast of Idria, and just north of the Alpine mine. Both groups are within the serpentine area. Only a small amount of development work has been done on the Monterey, which it is stated will be equipped and worked in conjunction with the Aurora. In the latter the principal development is an adit, in between 300′ and 400′ and a raise connecting with the surface, where there are several open cuts. The cinnabar occurs in a vein-filling of chalcedonic silica dark green to white in color. The croppings have a course of S. 15° E. Though said to have been discovered in 1853, it has been worked only at irregular intervals. In 1911 a revolving furnace, similar to a cement kiln (see Photo No. 18), was installed, but owing to mechanical difficulties it was operated only one day. The flue connections leading to the condensers can be seen at the upper end. In October, 1915, the furnace was repaired and refitted, and operated for a few weeks, until severe winter storms damaged the roads from Mendota, cutting off the supply of fuel oil. Operations have not since been resumed except for a short period of prospecting work in the open-cuts in July, 1917. The capacity is stated to be 50 tons per day. According to J. H. Eggers,[1] who superintended the work at that time, the ore was crushed to ½ inch, and passed through the furnace in 9 minutes. This he considers too

[1]Personal conversation with the author.

short a time, as the furnace should be longer and set on a flatter pitch. During these latest operations, ore was quarried from the outcrop.

Bibl.: CAL. STATE MIN. BUR., Report XV, p. 652; Chapter rep. bien. period, 1915–1916, pp. 57–58; Bull. 27, p. 131. MIN. RES. W. OF ROCKY MTS., 1874, p. 381. U. S. G. S., Mon. XIII, pp. 309, 466; Min. Res. 1914, Pt. I, p. 326; 1915, Pt. I, p. 269. GEOL. SURV. OF CAL., Geol. vol. II, p. 120.

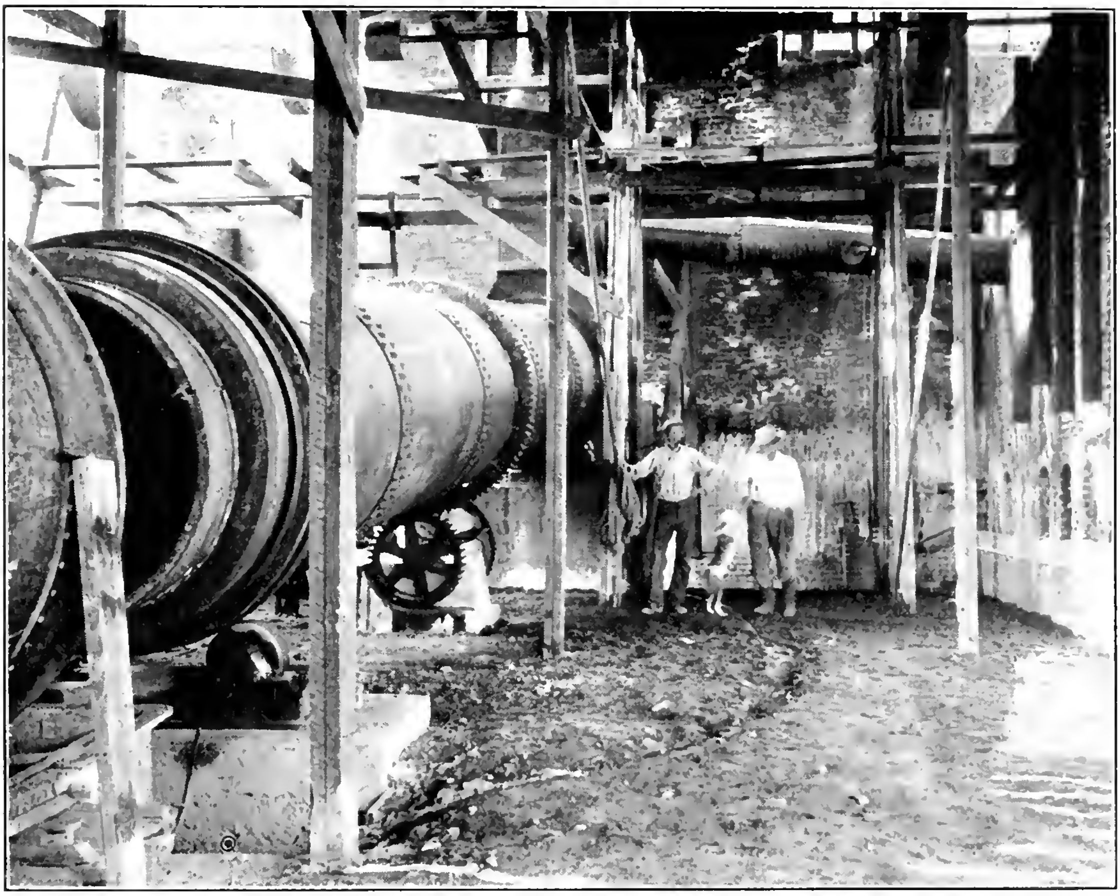


Photo No. 18. Rotary furnace, Aurora Mine, San Benito County.

Benta Group, in Secs. 20 and 29, T. 18 S., R. 12 E., M. D. M., was located in 1913 by M. G. Ramirez and S. Tirado, of Hernandez. There are two claims in the group, which joins the Ramirez or Los Picachos claims on the southwest. The claims are on the same series of highly siliceous croppings which show so prominently on the Ramirez property, but the serpentine appears less silicified. Only the annual assessment work has been done so far. A little cinnabar has been found, occurring in veinlets with silica in the serpentine fractures. It is in the Monterey National Forest, reached only by trail.

Bibl.: CAL. STATE MIN. BUR., Report XV, p. 652; Chapter rep. bien. period, 1915–1916, p. 58.

Bonanza Group. Bonanza Quicksilver Mining Co., owner; S. H. Bauman, president, Hernandez. M. G. Ramirez and Ramon Tirado, of Hernandez, made locations here on two claims, naming them the Bonanza 1 and 2 in the winter of 1913. There is no variation in geology from the other properties near-by, except that these claims are a little away from the line of croppings and exhibit a less highly silicified serpentine. They lie just southwest of the Benta claims, in Sec. 29, T. 18 S., R. 12 E., in the Monterey National Forest and are accessible only by trail, a distance of 2½ miles from the Florence Mack, or 5 miles southeast of the Alpine mine. An adit has been driven in about 60 feet, and is reported to have crosscut a promising looking body of ore. A few men are at present employed on development work.

Bibl.: Cal. State Min. Bur., Report XV, p. 653; Chapter rep. bien. period, 1915–1916, p. 59.

Bradford Mine (Cerro Gordo). J. F. Tatham, lessee, Almaden Road, Los Gatos. It is in Secs. 3, 4, and 9, T. 15 S., R. 8 E., M. D. M., on Tres Pinos Creek about 5 miles each of Emmett, and 18 miles from Tres Pinos. Cinnabar was discovered here in 1859 as an incident to the construction of a road from Tres Pinos to the New Idria mines; and for a number of years various prospecting and development work was done. It is at the contact of a belt of sandstone on the west, and serpentine to the east, both having a northwesterly strike. The western part of the serpentine consists of a highly silicified belt of varying width, in part opaline rock, carrying some cinnabar. Between this belt and the sandstone is a wide belt of black gouge, and at least one other belt of black gouge has been found in tunnel No. 2 in the silicified serpentine. An incline shaft, following the contact of the opalized serpentine with the underlying gouge, was sunk 200 feet. At 160 feet vertically below the collar of the shaft, a tunnel was driven in 535 feet, and connected by a raise to the shaft. No defined orebody was found, but the serpentine is stated to carry some cinnabar throughout. The surrounding country is well timbered. There has been no production in recent years.

Bibl.: Cal. State Min. Bur., Report XV, p. 653; Chapter rep bien. period, 1915–1916, p. 59; Bull. 27, pp. 131–133.

Butts Mine. Wm. Butts, owner, Pine Rock, via Tres Pinos; Geo. Kline, lessee, Pine Rock. Located in Sec. 4, T. 16 S., R. 8 E., M. D. M., 21 miles south of Tres Pinos. The old workings of this mine, which have been abandoned for years, produced only a small amount of mercury. The new workings, which have recently yielded some metal are located about ¼ mile north of the old mine. An open cut and tunnel totalling 75 feet, driven some time ago by Kline, in which it is reported that good ore was found, have caved in. A tunnel and open cut totaling 60 feet have been driven above this caved ground and about 20 feet below the outcrop. This has cut diagonally across a chert and sandstone breccia which carries ore for a width of about 18 inches. Cinnabar and metacinnabarite occur in the cementing material of the breccia with a calcite gangue. The work done is not sufficient to show conclusively that the deposit is in place and there is only one outcrop of the cinnabar-bearing breccia, but the strike of N. 35° W., and dip of about 60° NE. (as closely as they can be measured in the shallow workings) agree with the general run of the country rocks and appear to confirm the supposition that the deposit is in place and not fragmental. The claim is at an elevation of about 2300 feet, with sandstone and shale country rock and metamorphics derived from these sediments.

Reduction is carried on in a 'D' retort. Two men are occasionally employed. In December, 1915, one man produced a flask of mercury in 19 days, working alone and carrying the ore on his back some distance to the retort. Wood for fuel is available, but there is little mining timber near-by.

Bibl.: CAL. STATE MIN. BUR., Report XV, p. 653; Chapter rep. bien. period, 1915–1916, p. 59; Bull. 27, p. 133.

Cannon Mine. A. C. Cannon, formerly owner, Emmett. It is in Sec. 4, T. 15 S., R. 8 E., M. D. M., north of and adjacent to the Bradford mine, being on the same line of croppings. Some development work was done years ago, but nothing recently. The serpentine carries cinnabar, but no shoot of payable ore was found.

Bibl.: CAL. STATE MIN. BUR., Report XV, p. 654; Chapter rep. bien. period, 1915–1916, p. 60; Bull. 27, p. 133.

Cerro Bonito Mine. Cerro Bonito Quicksilver Mining Company, owner; Thos. Flint, president, Hollister; N. C. Briggs, secretary. It is in Sec. 31, T. 15 S., R. 10 E., M. D. M., 30 miles southeast of Tres Pinos and two miles south of Llanada. It was one of the early mines opened in the county. Patented. A Knox and Osborne furnace was in operation here previous to 1874, and production up to 1876 is said to have been about 800 flasks. The mine showed little activity after that until about 1902, when some work rebuilding the furnace and reopening the tunnel was done; but no production since then has been reported. The geology of the vicinity is complicated. Between the property and Panoche Valley is a flow of basalt. The top of Cerro Bonito hill, which rises steeply, is surrounded by two lines of bluffs, one forming the top itself, the other from 200′ to 300′ lower and much more prominent, especially on the north and northwest sides, where in places the bluffs are 100 feet high. These bluffs are of a hard siliceous material, probably a metamorphic breccia recemented by silicification. Some black opaline rock is found through this formation, and occasionally some sandstone. In three places the breccia overlies the regularly-bedded sandstone. The mine was developed by a large amount of surface work and rather extensive underground workings, which are now mostly inaccessible. The geology was described in some detail by Forstner[1] who states that the ore bodies in the two upper series of workings in the breccia, were never connected with those in the underground works of the main, or 'sandstone' tunnel, and appear to be a separate deposit.

"From the fact that in the sandstone tunnel cinnabar is found in the sandstone, it must be concluded that the ore deposition took place through water channels cutting through this sandstone; but the occurrence of the recemented breccia so extensively overlying unaltered and undisturbed sandstone is as yet unexplained. The large bodies of black gouge (attrition products), showing very important movements in the strata resting upon these same sandstone beds, render the explanation all the more difficult. It is hardly conceivable that all this metamorphic material has been moved into its present position by dynamic action finding its center in Cerro Bonito Hill. * * * The cinnabar forms generally in the hard, siliceous brecciated material, which may be considered the gangue rock."

Timber for both mining and fuel purposes is available near-by.

Bibl.: CAL. STATE MIN. BUR., Report XV, p. 654; Chapter rep. bien. period, 1915–1916, p. 60; Bull. 27, pp. 134–137. MIN. RES. W. OF ROCKY MTS., 1875, p. 14.

Don Juan and **Don Miguel** Mines (also known as **San Benito,** and **Cody**). W. A. Breen, manager, Hernandez. This group in Sec. 36, T. 18 S., R. 11 E., and Sec. 31, T. 18 S., R. 12 E., M. D. M., on the San Benito River southwest of Picacho Peak has been idle for many years. It is stated that a company has recently been formed, and 8 men are now at work, reopening and retimbering the old tunnel. It is proposed to build a small furnace the coming spring (1918).

Bibl.: CAL. STATE MIN. BUR., Report XV, p. 654; Chapter rep. bien. period, 1915–1916, p. 60; Bull. 27, p. 137.

Florence Mack Mine. C. P. Smith, owner, King City. In 1915-1916 it was leased to G. W. Warner and S. M. Suffron, Paso Robles, but is at present idle. The holdings consist of 6 full claims, with a total length of 6000 feet, in Sec. 32, T. 18 S., R. 12 E., M. D. M., on Saw Mill Creek, 7 miles from Hernandez and 30 miles from Coalinga, about

[1] *Op. cit.*, pp. 134–137.

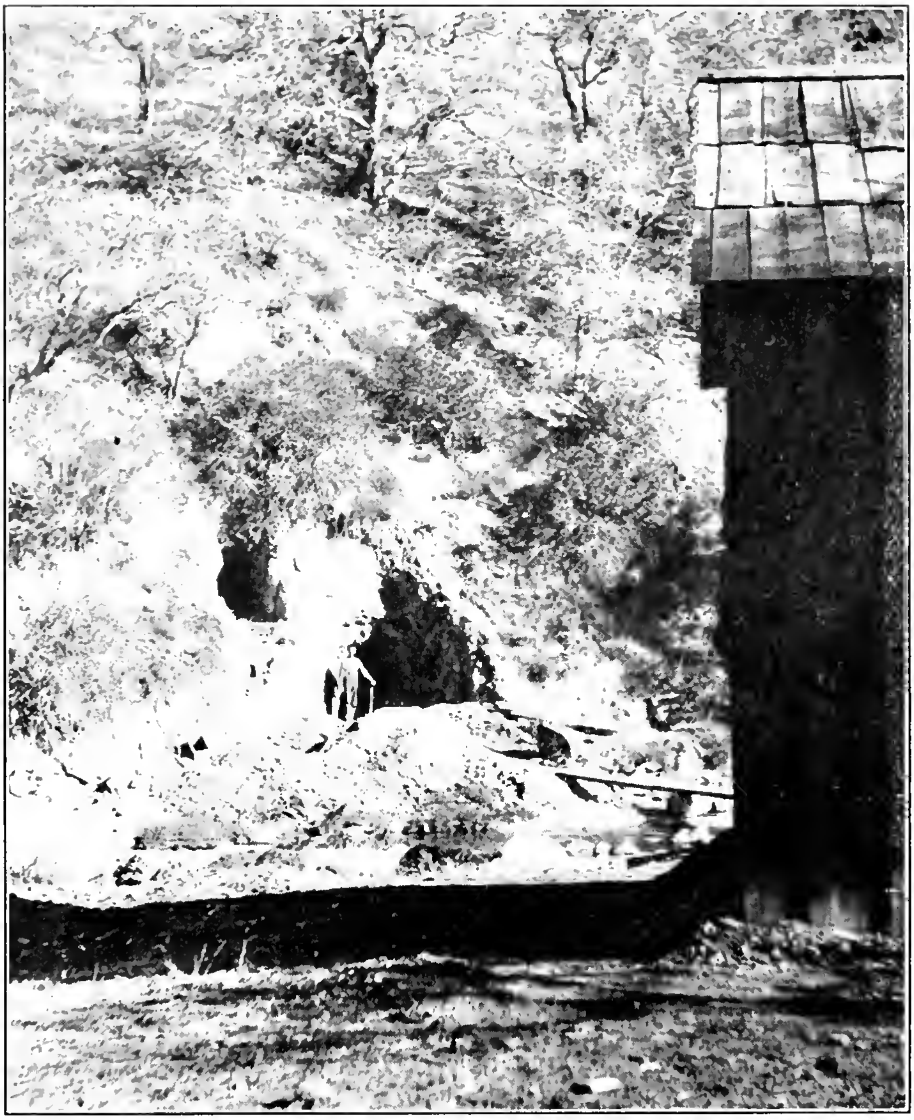


Photo No. 19. Old and new prospect tunnels. Florence Mack Mine. The old (upper) tunnel was a few feet too high and failed to uncover the vein; the lower tunnel showed a fair prospect of cinnabar. Photo by C. A. Logan.

one mile from the main highway joining Hollister and the latter. According to Logan[1]:

"The development of the property was done largely by a Mr. Courtney, of Hanford, who prospected it under bond in 1901 and the following years. The mineralized zone strikes northwest and dips 40° to 45° SW. The tunnels and crosscuts show a stratum of black clay shale or 'mudrock' about two feet wide, carrying cinnabar values near the footwall, which is a fine-grained indurated sandstone or shale. This belt is cut by numerous pyrite stringers, carrying considerable cinnabar. There are three tunnels on each side of the creek, but the work was done mostly on the left or northwest side.

"The lower and chief tunnel on this side enters the hill almost east and west. Near the portal the first crosscut north about 40 feet shows no ore. About 50 feet from the portal this tunnel branches, the chief working running N. 20° W. A crosscut 125 feet long east and west shows stringers of small size, striking north and south and carrying cinnabar. One hundred feet from the portal a crosscut 45 feet long was driven to follow a highly pyritized zone one foot wide striking northwest. Pyrite stringers about 2" wide, nearly solid, occur here, giving out, however, at a length of 6' to 8'. They carry good quantities of cinnabar. Fair ore in the vein was struck in this tunnel at a distance of 151 feet, and was followed to a shaft, 50 feet farther. This

[1]Logan, C. A., Bradley, W. W., et al., Mineral resources of Monterey, et al counties; Cal. State Min. Bur., Rep. 1915 1916, p. 61, 1917.

shaft and the tunnel, at a distance of 50 feet beyond the shaft, were inaccessible and efflorescences on the tunnel sides obscured observation.

"The second tunnel runs N. 20° E., 100 feet. It shows mudrock, 2 feet wide, carrying cinnabar near the footwall. A crosscut 20 feet southwest follows FeS_2 stringers 1" wide carrying cinnabar. The main crosscut runs 120 feet NW.-SE. and at its end is a small hole cut down on the vein; a 20' branch crosscut connects with the raise from the lower tunnel, 60 feet below.

"The upper tunnel is 40 feet above the second and 50 yards west. It is a crosscut tunnel, exposing at the breast the same 2' stratum of black clay shale, but no cinnabar is in evidence.

"There is a large tonnage of low-grade ore on the dump at this mine, which has been lying for some time and should prove susceptible to concentration. A considerable portion of it would make furnace ore. * * * The sedimentary country rocks and the nature of the vein filling distinguish the mine from those 2 miles or more north. It is completely outside the serpentine belt. The old tunnels south of the creek were short and appear to have been driven too high. The vein crosses the creek and has been exposed on the southeast side by a short tunnel driven in 1915; one of the old tunnels, driven in 1906 scarcely 10 feet above and to the left of the new opening, failed completely to uncover ore." (See Photo No. 19.)

In December, 1915, a 12-pipe retort plant, with a daily capacity of 250 lbs. of ore per pipe, was built. It was observed that no water had been provided to cool the exit pipes, and the fire seemed to be too hot for good recovery. The ore is highly pyritiferous and so requires great care to avoid roasting at too high a temperature.

Bibl.: Cal. State Min. Bur., Report XV, pp. 655–657; Chapter rep. bien. period. 1915–1916, pp. 61–63.

French Ranch. H. French, owner, Hollister. This now embraces the old properties formerly known as the **Santa Cruz** and **Mariposa** mines, of the Stayton district, in Secs. 20, 21, 28 and 29, T. 11 S., R. 7 E., M. D. M. Some surface indications of cinnabar here caused prospecting in the seventies, but a little work revealed the fact that the cinnabar did not persist, and stibnite was found to be the principal mineral.

Bibl.: Cal. State Min. Bur., Reports XII, p. 365; XV, p. 657; Chapter rep. bien. period, 1915–1916, p. 63; Bull. 27, p. 147.

Hernandez Quicksilver Mining Company (known also as **Picachos** or **Los Picachos** Mine, and the **Ramirez Consolidated**). M. G. Ramirez, president, San Juan Bautista; A. E. Reynolds, secretary, King City; Silvester Tirado, superintendent, Hernandez. Six claims, 5 of which are patented, form the group. They lie in Secs. 19 and 20, T. 18 S., R. 12 E., M. D. M., and are accessible only by trail, being 5 miles from the Alpine mine and 2 miles north of the Florence Mack mine. The elevation is 4500 feet (U. S. G. S.). Through this property, striking northwest and extending to the northern end of the Flint group, 5 miles distant, is a wide and prominent mineralized zone, revealed on the surface by deeply altered, bold, siliceous outcroppings, stained a rusty color by the iron oxide present. The softer parts of this rock have been weathered out, leaving an altered material composed principally now of silica, showing in different places a great number of phases—chalcedony, quartz, flint, and agate. At the Hernandez this zone of croppings is nearly ½ mile wide, ending abruptly about 1500 feet southeast of the furnace.

The mine was opened in the days of the old quicksilver boom by a tunnel driven northward from the southern slope a distance of 3000 feet, designed to cut the ore exposed in the outcrop at depth. As far as can be learned, this work never led to any appreciable production. In later years operations have been confined to the exploration of the outcrop near the surface in the southeastern part of the holdings, although there are other prospects of cinnabar in the mile of outcrops

Photo No. 20. Characteristic outcrops; Los Picachos Peak, Hernandez Quicksilver Mine, San Benito County, California.

embraced in the claims, which would seem to warrant prospecting. The present company has been in possession since 1904, but work has been desultory and actual progress in development small. For about four years up to 1916, a small yearly production of metal was made in a retort of four pipes. The ore has come from the southern and eastern sides of the outcrop near the surface. Inclined shafts, one of 160 feet and two of 50 feet each, have been driven, besides which some rich ore has been taken from the face of the outcrop. The bluffs at the furnace face southwest and stand up about 100 feet above the furnace, showing cinnabar in many places (see Photo No. 20). The ore being treated in

December, 1915, came partly from an incline about 45 feet deep. This had been sunk on a lens of ore which had a thickness of about 3 feet, width of 40 feet and had been worked out 50 feet along the strike. The shoot strikes N. 35° W., with a dip 50° to 60° NE., and appeared to be about 100 feet long on the strike, judging by the shape of the portion mined. In this lens cinnabar had been deposited in various ways. It occurs with stringers of pyrite, apparently occupying minor fissures; it is also seen as a coating in fracture planes. The most characteristic occurrence, however, is where a layer of cinnabar about 1/8″ thick, in association with pyrite, had been deposited from solution on the main fissure wall; superimposed on this and indicating a second period of deposition was a layer of silica crystals of equal thickness. The ore from this lens had yielded as high as 150 pounds of mercury per ton.

A fine-ore furnace of 4 tons capacity with 2 brick condensers was completed in December, 1915. A few flasks of quicksilver were produced in 1916, but the property has since been idle. The district north and east is sparsely timbered and watered, being mantled by serpentine, but there is a fair growth of timber to the south, outside the serpentine belt. Dry wood for fuel costs $3.00 to $4.00 per cord. In the summer 5 men are employed.

Bibl.: CAL. STATE MIN. BUR., Report XV, p. 658; Chapter rep. bien. period, 1915–1916, pp. 64–65; Bull. 27, p. 145; GEOL. SURV. OF CAL., Geol. vol. II, p. 121, U. S. G. S., Mon. XIII, pp 309, 466.

Lone Star Mine. Geo. Wapple, owner, Hollister; M. T. Dooling and M. Forcade, Tres Pines, lessees. Located in the Rancho Real de las Águilas, 18 miles southeast of Tres Pinos, near Los Muertos Creek. A tunnel said to be 800 feet long has been driven. Rock purporting to come from this mine showed a little cinnabar in altered and iron-stained serpentine, but no ore in commercial amount was reported. There is no reduction equipment. The country rocks are highly altered and silicified sedimentaries.

Bibl.: CAL. STATE MIN. BUR., Report XV, p. 659; Chapter rep. bien. period, 1915–1916, p. 65.

New Idria Quicksilver Mining Company. W. B. Buckminster, vice president and general manager; home office, #70 Kilby St., Boston, Mass.; H. W. Gould, general superintendent, Crocker Bldg., San Francisco; John Mocine, superintendent; Maurice Bowman, assistant superintendent; mine office, Idria, Cal. It is 40 miles south of west from Mendota, and 58 miles southeast from Tres Pinos. The mining property includes the Idria, West Idria group (3 claims), Sulphur Spring, Molino, San Carlos group (6 claims), covering 240 acres in addition to

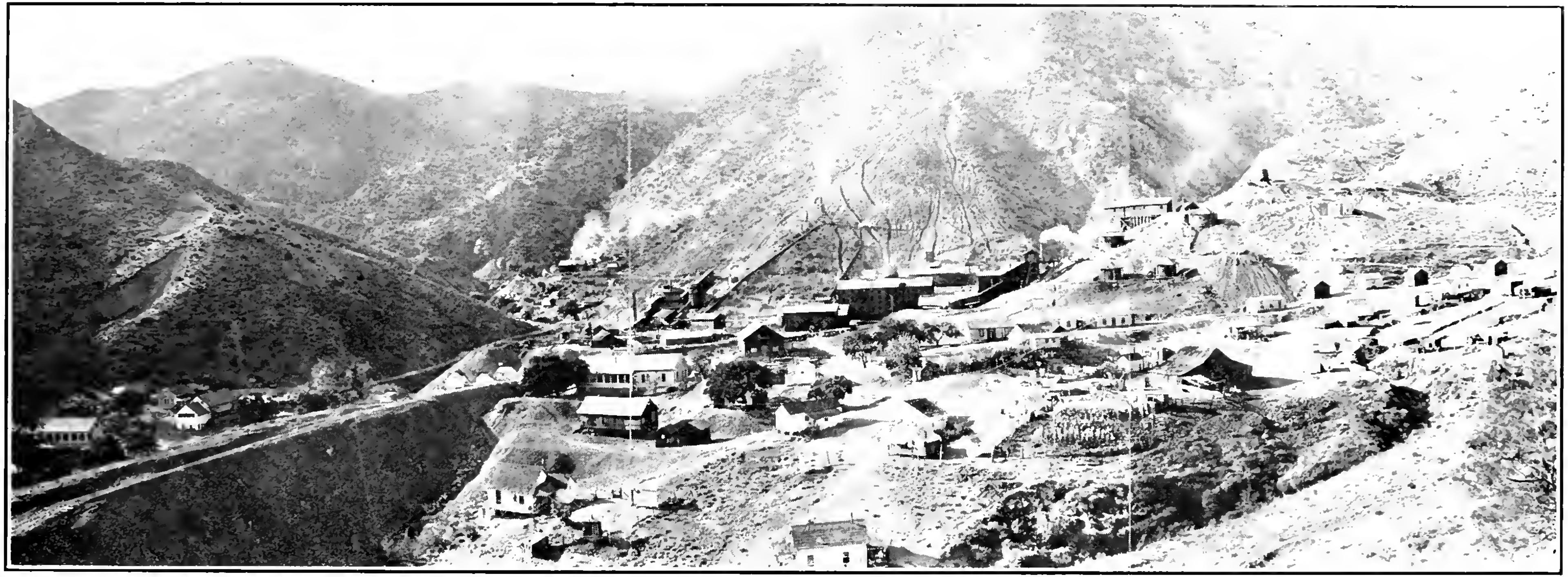


Photo No. 21. Panoramic view of New Idria Mine, plant, and town, San Benito County, looking southerly.

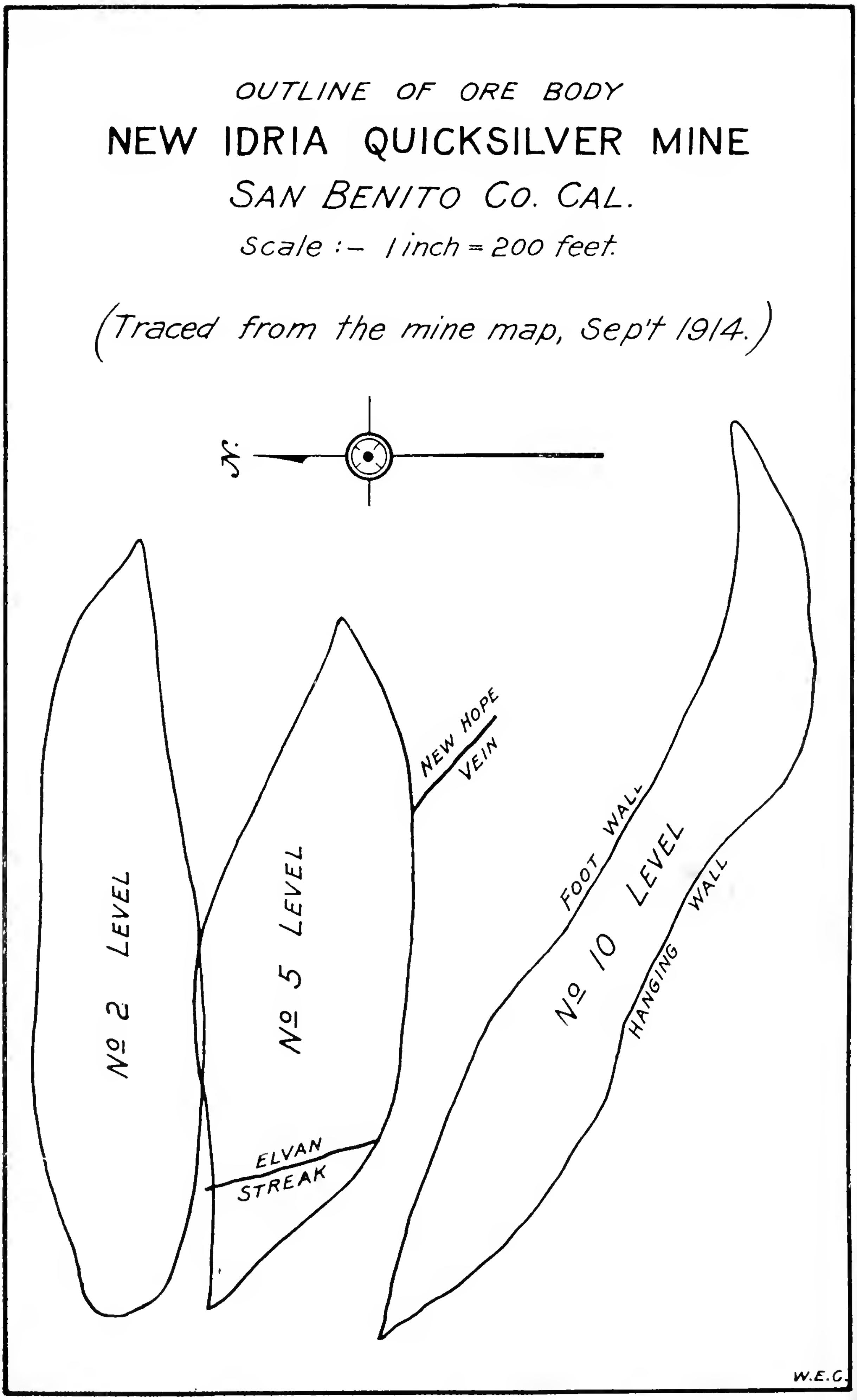
other patented land. The claims are located in Secs. 28, 29, 32, 33, 34, 35, T. 17 S., R. 12 E., and Secs. 3 and 4, T. 18 S., R. 12 E., M. D. M. The elevation at the office is 2500 feet (U. S. G. S.) and 4000 feet at Idria Peak, the summit of the mine hill (see Photo No. 21). Approximately 97% of San Benito County's recorded production of quicksilver has come from the New Idria property, it being credited with a total of 306,475 flasks from 1858 to 1917 (inc.). The mine has been in continuous operation since 1850, and its total yield is exceeded in North America by only that of the New Almaden mine. The present company has been in possession since April, 1895.

There are two main ore areas (so to speak), the New Idria group and the San Carlos group, the latter of which lies over 2 miles to the southeastward of the former. The principal output to date has come from the New Idria though at present ore is also being drawn from the San Carlos mine and transported by aerial tram to the Idria furnaces. For some months during 1915–1916, previous to the installation of the ropeway, ore from the San Carlos was taken out through the 'Molino Tunnel,' then trammed around the hill. The portal of the Molino tunnel is about midway between the two main groups. This adit was driven southeasterly about 4000 feet in length and cut the ore body some distance below the old San Carlos workings. A raise was driven and connections were completed early in 1915. At several places in the Molino adit near cinnabar-bearing veins, pyrite in small crystals was encountered, stated to assay $1.40 per ton in gold. Much of the ground through which this adit passes is soft and very heavy to hold open, for which reason it was superseded by the aerial tramway.

NEW IDRIA MINE.

An idea of the size and shape of the main New Idria ore-body, or rather 'ore-zone,' may be gained from the outline shown on Plate XIV, which was traced from the mine map. On account of the very large number of adits, crosscuts, drifts, levels and intermediate levels, no attempt was made to reproduce them, which would only have complicated the drawing. For similar reasons, the outline of the ore zone was taken at three separated levels, only: the 2d, 5th and 10th. This shows a roughly elliptical shape in the upper levels, narrowing, lengthening eastward, and curving toward a crescent shape in the lower levels. The No. 7 level (not shown) has a distinctly crescent outline. This zone has a general dip to the southeast of about 60° to 65°. It varies up to 235 feet wide between walls and 800 feet long on the No. 5 level, and averages about 120 feet wide, with a length of nearly 1200 feet on the No. 10 level.

The term 'ore zone' is deemed by the writer a better designation in this case than 'ore-body,' because all of the rock within the outlines


OUTLINE OF ORE BODY
NEW IDRIA QUICKSILVER MINE
SAN BENITO CO. CAL.
Scale :- 1 inch = 200 feet.
(Traced from the mine map, Sep't 1914.)
N.
No 2 LEVEL
No 5 LEVEL
NEW HOPE VEIN
ELVAN STREAK
FOOT WALL
No 10 LEVEL
HANGING WALL
W.E.C.

noted is not ore. The ore occurrences are not altogether regular. There are various veins, cross-veins, stock-works and impregnations. The main ore-body within the area is stock-works in sandstone and shale, and in places an impregnated sandstone, somewhat harder than the others. As will be noted from the map (Plate XII), the mine is in the Franciscan metamorphic sandstones and shales and some distance

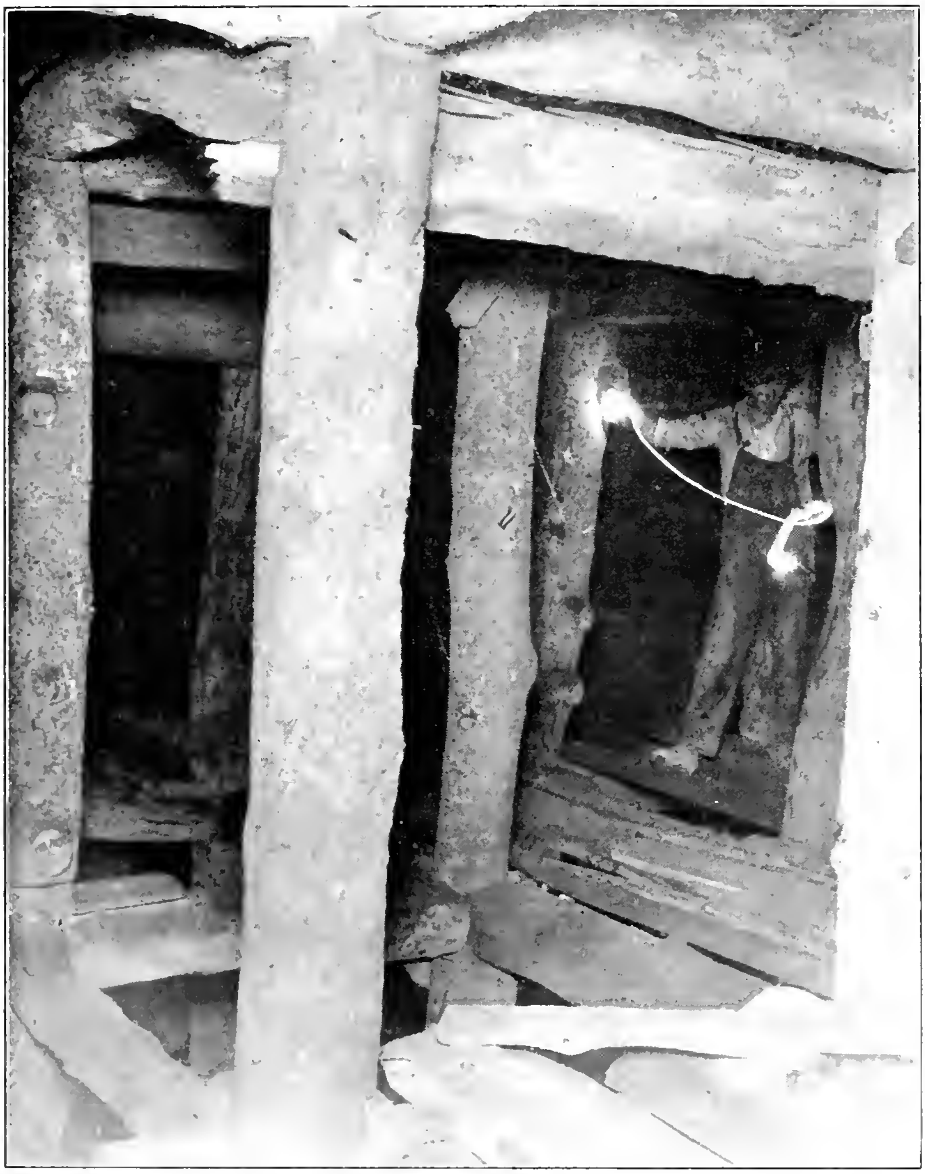


Photo No. 22. Flashlight view in square set stope (30′ wide) between No. 2 and No. 2½ levels, New Idria Mine.

from the contact of the large serpentine area already mentioned. Some of the shale is indurated so that it resembles slate, and was so called in some of the earlier reports. The hanging wall is marked by a black clay 'alta' outside of which is metamorphosed shale, then sandstone and finally serpentine beyond. The footwall is not as distinctly defined as the hanging, the value frequently not showing a sharp stopping off line.

The mine workings are complicated and numerous, due to the irregularity of the ore shoots. Considerable timbering is required, especially in the larger stopes, where the square set system is employed (see Photo No. 22). The stope shown is 5 sets (6 feet each) wide, or 30 feet. Others are up to 50 feet square. The two more important ore shoots developed are at opposite ends of the zone. The 'Bodie shoot' is at the east end, the other being known as the West End shoot and has been an important producer, especially below the No. 5 level. There are two other veins, known as the Elvan Streak and the New Hope, which are quite distinct from the main ore-body. The former cuts across the main zone, while the latter cuts across the hanging wall to the ore-body but stops at the alta. At the time of Becker's visit (1884)[1] development had not yet proceeded to the point that these relations were as evident as they now are. The Elvan streak is described as a "clean-cut fissure, filled with decomposed attrition products which are impregnated with cinnabar." This gouge material is misnamed 'talc' by the miners. At one point associated with this vein was a considerable amount of metacinnabarite, which it is stated, amounted to several tons. The New Hope vein was distinctly of metacinnabarite, in the upper levels, where it was very rich; but it has not been worked in the lower levels. In the main zone pyrite, though not abundant, is associated with the cinnabar, and the gangue minerals are quartz, calcite and gypsum. From the north end of the New Idria to the south end of the San Carlos, the ore-bearing area has been proven for a length of 2½ miles.

As already stated, the mine workings are rather complex, if one attempts to consider them in detail. Development is mainly by adits, with connections by raises and winzes. There are ten main levels, No. 1 to No. 10, and a number of intermediates. The No. 10 tunnel, which is the main haulage way for delivery of ore to the furnaces, is 3175′ in length to the vein, at which point it is 1060′ vertically below the outcrop. There is a total of 15 to 20 miles of underground development in the company's property, including 5000′ in the San Carlos, 5000′ in the Molino, 600′ in the Creek tunnel and over 3 miles of open working tunnels (crosscuts) in the New Idria. The system of mining in use is that of overhand stoping, and timbering with square sets. Pneumatic stopers and drills are employed; and a certain amount of hand-sorting is done within the mine. On the No. 9 level there is a grizzly 22′ long of ½″ bar iron on edge, spaced ½″ apart at the top and 1¼″ at the bottom. At that point there are two chutes, one for fine ore and the other for coarse, leading to No. 10 level, where the cars are loaded and hauled in trains to the furnaces. No. 10 adit is a mile in

[1] U. S. G. S., Mon. XIII, p. 305.

length from the chutes to its portal. Formerly mules were used for motive power, but have been superseded by a 16 h. p. Edison storage-battery locomotive (see Photo No. 23), for underground haulage; while a Ford gasoline motor is used for surface haulage. The hot ore discharged from the furnaces is hauled to the dumps by mule-drawn trains. There is a winze from No. 2 level to No. 9, in which a gasoline hoist operates a skip for tools and timber down to the No. 7. A 25-h. p. distillate engine furnishes the power.

Photo No. 23. Ore trains at New Idria Mine. At left, an electric storage-battery locomotive for underground haulage. At right, gasoline motor for surface haulage.

At the time of the writer's visit in September, 1917, a considerable part of the New Idria ore going to the furnaces was from the old dumps and from quarries being opened up near the top of the hill along the original outcrop workings (see Photo No. 24). The coarse, waste rock is sorted out, and the finer rock and pieces carrying cinnabar sent to the chutes. Material from the dumps between #2 and #5 levels was hauled by mule-train into #5 and dropped down a winze to the chute on #10 level. It was stated that the dump ore cost 85¢ per ton placed in #10 level chute. One shift (day) only was worked here. This outside ore supply will continue to be drawn upon except during winter months, when two shifts will be worked underground. An aerial tramway 3500′ long is being installed between #5 level and the furnace terminal of the San Carlos tram, being of the same type and size of buckets as the San Carlos installation. With this tramway in operation, this surface ore will be moved at even a cheaper cost figure than that quoted above for the underground route. In excavating the upper dumps made from the early outcrop workings at least as early as 1860, much broken, slide material is being encountered, some of it apparently from the original outcrop; as the writer noted many pieces of very high-grade ore containing massive cinnabar. It is intended to quarry off a considerable portion of the top of the hill.

Photo No. 24. New Idria Mine, showing open cuts and dumps being reworked at top of hill. Much of this is to be quarried off. Buildings in center are at portal of No. 2 level.

Within the mine during the summer months, the main gangways will all be kept open, with some stoping and development work carried on. They will stope, largely above the #6 level, for some time yet; but expect to break a larger tonnage of lower grade ore.

At the portal of #2 level there was formerly a steam-driven sawmill of 2000 b. m. ft. daily capacity. Round timbers were used—both pine and cedar—some being cut on land owned by the company and some also at a point 11 miles to the south of Idria, within the Monterey National Forest, under contract with the U. S. Forest Service. At present, sawed timbers, cut to dimensions, from Santa Cruz, are hauled in by motor trucks from the railroad at Tres Pinos. This freighting is contracted at $10 per ton from Tres Pinos to #2 level. Hauling from Mendota costs $9 per ton for miscellaneous freight and $10 per ton for oil, with a drawback for outgoing shipments. The company maintains most of the repair work on the roads, though San Benito County does some work on the Tres Pinos road.

Equipment at #2 level portal includes a timber framer driven by a 9 h. p. distillate engine, which consumes 53 gallons of distillate per month. There is also a saw especially set for cutting wedges. The blacksmith shop, here, is equipped with a Waugh drill sharpener. The #2 adit is the main entry to the mine for timbers and other supplies, from which they are distributed to the levels below by means of the winze and hoist previously mentioned.

The power-house is situated around the hill to the left (see Photo No. 21) of the Scott furnace. There are two semi-Diesel engines, Type Y. Fairbanks-Morse, 75 h. p. and 50 h. p., respectively, direct-connected to a common line shaft, which drive the compressor, also a 60 k. w. generator for lights and furnace blowers. These are also boosted by a water-wheel. The generator is on a short-center drive from the line shaft. In the winter time, this drive is dropped, and water used, and the compressor is run by one of the semi-Diesels. Water-power is obtained from San Carlos Creek, the reservoir being above a series of falls, near the Aurora mine, and giving a head of 975 feet.

SAN CARLOS MINE.

Like the New Idria mine, the San Carlos orebodies are also within the area of Franciscan rocks noted on the map (Plate XII), but apparently nearer the serpentine contact than the former. Most of the ore is in sandstone, which is in part metamorphic. Some of the cinnabar is in seams, and some is disseminated. The sandstone is blocky, and harder than in the New Idria mine. There is a serpentine 'dike' crossing through the workings, which also is mineralized. It is considerably decomposed, and is characterized by an abundance of chlorite, an end product of the weathering of serpentine. There is some fine-grained sandstone, and some 'mud-rock.' At the left of the quarry shown in Photo No. 25 there is a vein of amethyst crystals cutting through the sandstone.

The resumption of San Carlos ore shipments to the New Idria furnaces in September, 1915, is stated to have been the first since 1864. All the work is at present being done above #2 level haulage tunnel which has been driven clear through the ridge, and is 1030′ long. A Ford motor is used for hauling to the aerial tram bin. Raises are driven at various points up under the dumps on the surface. It is intended to quarry off the entire top of the hill down to #2 level. The ore being sent from here to the furnaces in September, 1917, was averaging about 0.7% mercury.

The ore from the San Carlos mine is transported to the reduction works by a Painter aerial tramway, 2 miles long, with a drop of 2130′ between terminals, and its operation is controlled by brakes at the upper end. There are 30 buckets of 1000 lb. capacity, each. Lock-coil steel cables are used, the track rope on the loaded-bucket side being 1 1/8″ diam., on the empty side 7/8″ diam., and the traction or pulling rope 5/8″ diam. An automatic, track oiler is passed over the line once every 5 days, spreading crude fuel-oil on the cable. The buckets are held onto the traction rope by a grip which is attached and detached

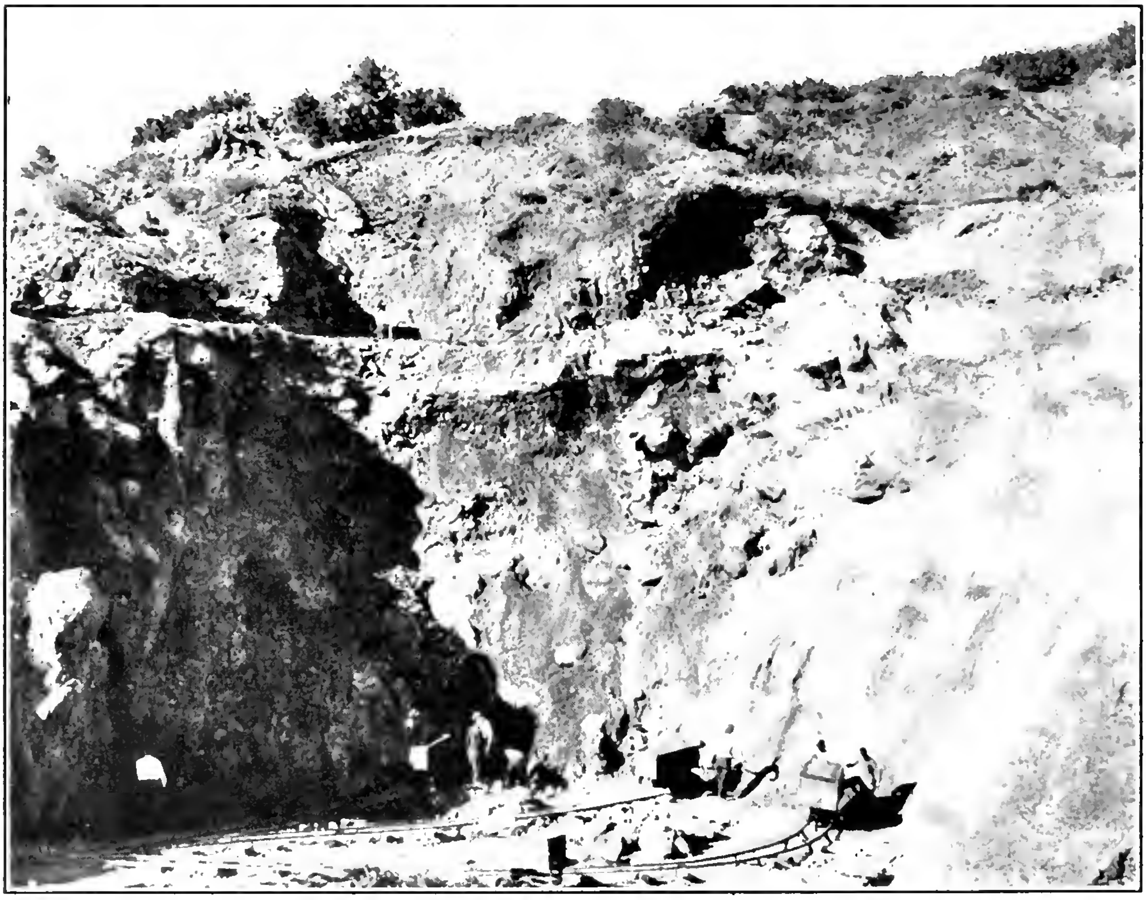


Photo No. 25. San Carlos Mine, open cut above No. 2 level. Recovering dump material and old pillars.

automatically at the terminals. The buckets are dumped by hand. The capacity of the tramway is 20 tons of ore per hour, and it is operated two 8-hour shifts daily.

REDUCTION EQUIPMENT.

The reduction equipment of the New Idria Company has been undergoing rapid and vital changes during the past year, and other important developments are in comtemplation; so that by the time this report comes from the printer, the photographs and flow-sheet reproduced herewith will not in all details truthfully portray the installation and practice as they may exist at that moment. However, these changes are here recounted to show the present status, and to record the history of the developments. At the present writing (April, 1918,) the reduction equipment includes a concentrating mill, two Idria coarse-ore furnaces of 88 tons daily capacity, a 60-ton Scott fine-ore furnace, and a rotary furnace of the cement-kiln type 4′ diam. x 50′ long. In the panoramic view (Photo No. 21), the coarse-ore furnaces are in the large building in the center, the Scott being to the left with the long flue and stack running up the hillside. The aerial tramway terminal is to the right near the water and oil-storage tanks, while the concentrator is between the coarse-ore furnaces and the tram terminal. The new rotary furnace has been installed just this side of the concentrator in a building that has been erected since the photograph was taken.

The New Idria coarse-ore furnace is of a design developed by Mr. B. M. Newcomb, for many years general superintendent of the company, and is described elsewhere herein,[1] with drawing accompanying. The fine-ore furnace ('No. 1') is of the Scott pattern, and was built for 60 tons daily capacity, but it is at present handling about 75 tons of ore and concentrates.

Formerly a small Scott furnace ('No. 4') of 9 tons capacity was used for some years for retreating soot from the condensers, instead of retorting it as is done at most quicksilver mines. This was described by the writer[2] in a recent report. This furnace is one tile (3′) long and 25 tiles high (28′ 1⅛″), wtih a 3″ spacing between the tiles instead of 6″ as in the larger Scott furnaces. Also, the tiles are set on a 50° slope instead of 45°. With each 1 ton of dried soot, 8 tons of fine ore were mixed, before feeding to the furnace. Use of this furnace was discontinued in 1917 because of improvements in the condensing system which reduced the amount of soot formed, and such as was formed was treated in the soot mill described elsewhere herein,[3] in the section under Metallurgy.

Formerly the condensers near the furnaces were of stone, followed by a series of barrel-form chambers of wood. The stone condensers on the Scott furnace have been replaced by three round, vertical, wood-stave chambers (see Photo No. 60, *post*). The stone condensers on the coarse-ore furnaces were replaced by a large, rectangular wooden chamber, prior to the adoption of the round vertical form. The flues and stacks are also of wood-stave construction (see Photo No. 26). The

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[1]See pp. 223–225, *post*.
[2]Bradley, W. W., et al., Mines & mineral resources of Monterey et al. counties: Cal. State Min. Bur., chap. of State Mineralogist's Report, 1915–1916, p. 73, 1917; reprinted in Report XV, p. 667 (in press).
[3]See p. 275, *post*.

New Idria condensing system is described in the section of the bulletin under Metallurgy,[4] as is also the new rotary furnace.[5] The furnaces are fired by crude oil; but in starting up a cold furnace wood is first used before turning on the oil, until the fuel box is heated enough to keep the oil vapor afire. This lessens the danger of back-firing, or the flame going out temporarily and filling the furnace with gas, which

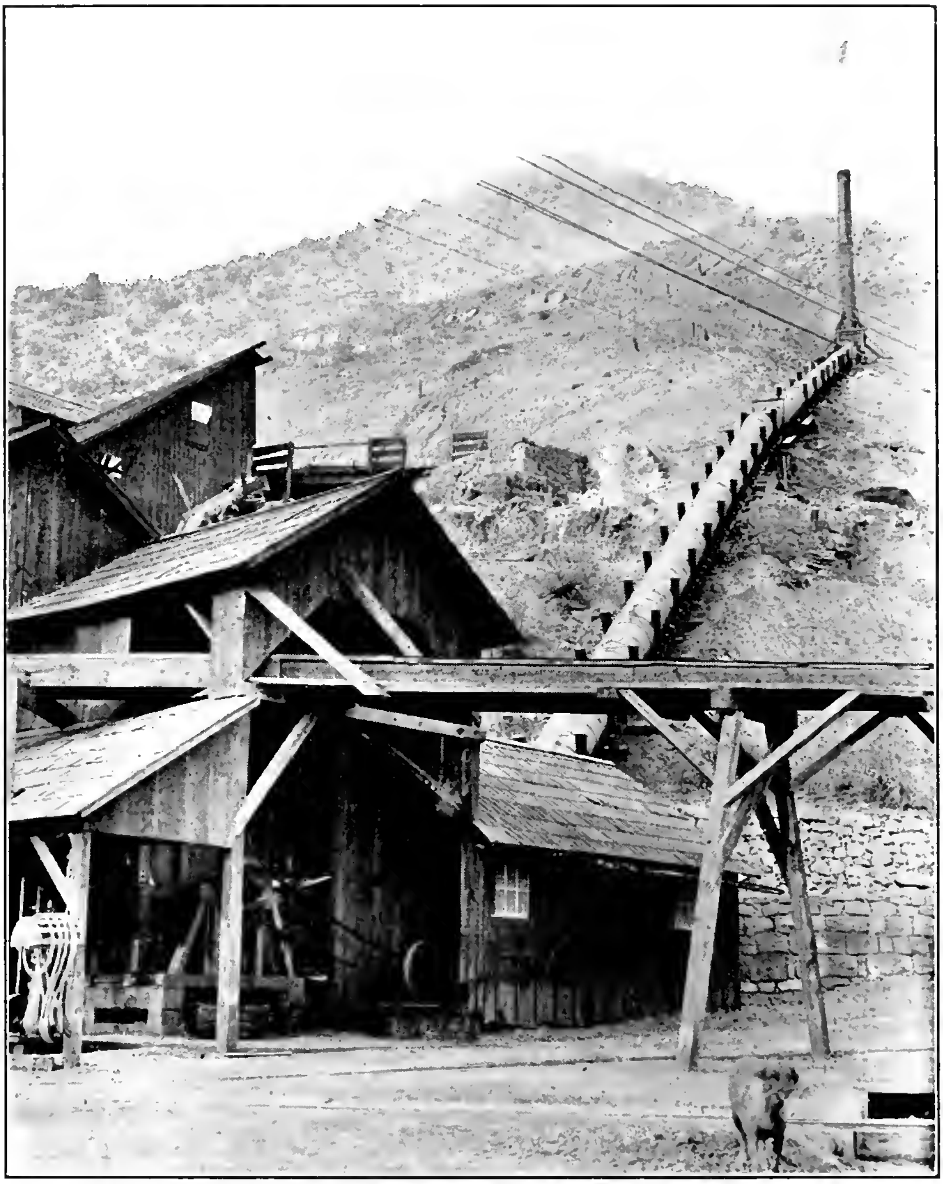

Photo No. 26. Blower and stack from fine-ore furnace, New Idria Mine.

would explode on the oil being re-lighted. Crude oil for fuel in 1917 cost $2.98 per barrel at the mine.

A Brown recording and indicating electric pyrometer installed in the office of the furnace foreman is connected into each of the three older furnaces about half-way up. The following temperatures are maintained: #1 at 600° C; #2 at 500° C; #3 at 450° C.

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[4]See pp. 261–266, *post*.
[5]See pp. 248–250, *post*.

Ore sizing.

Ore brought out through #10 tunnel of the New Adria mine is first taken to the 'screen house' where it is dumped onto a grizzly with 1½″ aperture. The oversize from the grizzly goes to No. 3 coarse-ore furnace. The undersized is elevated to a revolving, wire screen which makes a segregatien into 3 sizes: +7/8″ to 1½″ which goes to No. 2 coarse-ore furnace; —7/8 to +1/8″ which goes to the Scott fine-ore furnace; —1/8″ which goes to the mill for concentration.

Ore from the San Carlos mine is dumped at the tramway terminal onto a grizzly with a 1″ aperture. The oversize is sent to the coarse-ore furnaces. A part of the undersize, up to the mill's capacity, is sent to the concentrators. Most of the balance is sent to the revolving screen in the screen house. Some of the grizzly undersize has been sent direct to No. 1 (Scott) furnace.

Descriptions of the concentrating mill, the soot mill, and the experiments made on flotation with oil, are described in the section of this report on Metallurgy.[6]

The following summary of operations during the years 1914, 1913 and 1912, is taken from a published[7] extract from the annual report of the New Idria company for the year, 1914, and is quoted here to show the status before the present high prices of quicksilver were in vogue:

	1914	1913	1912
Development, feet	12,367	9,182	11,080
Ore treated, tons	62,578	76,993	76,348
Quicksilver recovered, flasks	6,550	9,700	9,600
Average price per flask	$41	----------	----------
Total revenue	$295,361	$363,054	$377,484
Operating expenses	340,371	298,041	303,721
Loss	45,010	*65,013	*73,763
Dividends	10,000	40,000	120,000
Previous surplus	144,600	119,587	165,824
Surplus carried forward	89,590	144,600	119,587

*Profit.

In 1914, up to July, 400 men were employed, when the number was curtailed owing to the low price of quicksilver then prevailing, and one of the coarse-ore furnaces shut down; so that in September when the writer first visited the property, there were 171 in the mine and 53 on top and around the furnaces—a total of 224 men on the payroll. Since then, however, due to the rise in the price of quicksilver, more are being employed, and all of the furnaces are operating; so that when last visited, in September, 1917, there were 295 men on the payroll, though 350 men was considered a full crew. Miners were being paid $3.00 per day; muckers $2.75; furnace men $2.75 and $3.00 with the charge and

[6]See pp. 275, 339–342, *post.*
[7]Min. & Sci. Press., vol. 110, p. 601, Apr. 10, 1915.

draw men working 8-hour shifts. A full crew on the furnaces at that time consisted of 52 men.

Bibl.: CAL. STATE MIN. BUR., Reports I, p. 26; IV, pp. 336, 339; VIII, pp. 483–485; X, p. 515; XI, p. 373; XII, p. 365; XIII, p. 599; XIV, p. 228; XV, pp. 660–668; Chapter rep. bien. period, 1915–1916, pp. 66–75; Bull. 27, pp. 9, 22, 125–129, 138–145, 213, 214, 234, 241, 245; Bull. 67, pp. 33, 35. U. S. G. S., Mon. XIII, pp. 64, 189, 215, 291–308, 465; Min. Res., 1882 to 1915. MIN. RES. W. OF ROCKY MTS., 1868, p. 264; 1869, p. 10; 1870, p. 759; 1871, pp. 58, 528; 1872, p. 523; 1873, pp. 10, 497; 1874, pp. 28, 37; 1875, p. 13. GEOL. SURV. OF CAL., Geol. Vol. I, pp. 57–60; Vol. II, pp. 113–120. TRANS. A. I. M. E., Vol. XXXIII, p. 484.

Niesen Group. John Niesen, owner, Hernandez. Two claims, the Tiger and Buck, in Sec. 31, T. 18 S., R. 12 E., and Sec. 36, T. 18 S., R. 11 E., M. D. M., make up the property, which lies on the headwaters of the San Benito River, 5 miles from Hernandez and about 30 miles from Coalinga. The country rocks are the sedimentary formations, sandstones and shales, lying south of the serpentine area. They have been somewhat indurated by folding. The tunnel on the Tiger claim, which is the only development so far done, was driven 100 feet northeast and 75 feet east and is entirely in an indurated black clay shale, which shows abundant efflorescences of epsomite and some ferrous sulphate. A 2″ streak of gouge at the end of the drift carried a trace of cinnabar, as did also the rock. There was no other evidence of mineralization; no contact had been cut and surface indications were not such as to encourage exploration.

Bibl.: CAL. STATE MIN. BUR., Report XV, p. 669; Chapter rep. bien. period, 1915–1916, p. 75.

Stayton Mine. Stayton Mining Company, owner; John W. Baxter, president, 3015 Hillegass Ave., Berkeley; R. B. Knox, secretary and manager, 819 Pacific Building, San Francisco; E. B. Kendall, superintendent. This group which is the principal property of the Stayton district is in Secs. 5 and 8, T. 12 S., R. 7 E., M. D. M., 15 miles east of Hollister by a good road. The property has been owned by the Stayton company since 1876, and consists of the following patented claims and mines: Stayton, North Star, Pacific, Santa Clara, Fairplay, Green Valley, Cold Spring, Badger Co. No. 2, Last Chance, F. Smith Co., McLeod Co., a total area of 900 acres, and a length of 3000 feet along the lode. Ore was discovered here in 1870, and was first worked for antimony. The timber supply consists of scattered oak, and water is obtained from springs. The total production is stated to have been

800 to 1000 flasks, all before 1880, most of which came from the Gypsy vein and was taken out with a 'D' retort.

The country rocks are basalt and acidic tuff breccias, and are underlain by sandstone. There are six veins, called Grey Buck, Gypsy, Chimney, North Star, Blue Wing, and Pacific. The general strike is approximately N.-S., with dip 60° W. The cinnabar values occur near the footwall with associated fissures extending west into the hanging wall. The associated minerals are quartz, pyrite, and stibnite. The last-named is particularly characteristic of the district, and for which, as above noted, the mine was first worked. The mines are located on both slopes of the main ridge of the Diablo Range, the principal cinnabar deposits being on the east side accompanied by some stibnite; while, the principal deposits on the west side are of stibnite, with some cinnabar veins. In the Stayton group, there are six ore shoots, with average lengths of 40′ and widths averaging 5′. The maximum width of the mineralized zone is 70′, with an average of 35′. The Grey Buck shaft was 250′ deep with levels at 70′, 150′, and 235′, and drifts of 150′, 775′ and 10′ in length respectively. In October, 1917, sinking was in progress in this shaft to open up the vein at the 300′ level, ore then showing at 252′. Preparations were also being made for a furnace. Equipment includes a 20 h. p. Doak distillate engine, Sullivan straight-line WG3-10″x8″ compressor, Murray Bros. direct-connected friction hoist, Water Leyner drills, and Worthington Duplex pump. A total of 10 men were employed, 6 of whom were underground. It is stated that there are 4000 tons of ore on the dump, which will be available for furnacing.

Bibl.: CAL. STATE MIN. BUR., Reports VIII, p. 485; X, p. 515; XI, p. 371; XII, p. 365; XIII, p. 599; XV, p. 670; Chapter rep. bien. period, 1915–1916, p. 76; Bull. 27, pp. 147–149. U. S. G. S., Mon. XIII, p. 380.

Tirado Group. José Tirado, Hernandez, owner. There are two claims, the Capitola and San Domingo, in Sec. 18, T. 18 S., R. 12 E., M. D. M., 2½ miles by trail northeast of the Alpine furnace. The locations were made late in 1914, as the result of discovery of some rich float by Silvester Tirado. The claims follow the strike of the mineralized zone mentioned in describing the Alpine and Picachos mines. The Andy Johnson corners the San Domingo on the southwest and the Monterey claims nearly surround the Tirado group. At only one spot has a cropping of rock been found apparently in place and carrying cinnabar. This is on a steep hillside near the southeast end of the San Domingo, in a stream cut where the loose serpentine has been deeply eroded by a tributary of Clear Creek. The rock here is in part a siliceous breccia which appears to have been recemented by silica deposited from solution which apparently also bore cinnabar, or was followed by deposition of cinnabar in the cavities of the rock mass. The cinnabar is found at times in cavities as drusy coatings or in nearly solid masses 6″ or 8″ thick. Elsewhere the boulders resemble the croppings at Los Picachos. It would seem as if a rather rich ore shoot had been broken up here by the creek branch, which has carved a deep cañon across the strike of the outcrop zone, and concentrated the high-grade material in its stream bed. Several tons of this boulder ore was burned in the 6-pipe retort built in 1915. Development work in a limited way has been carried on, and a small production of quicksilver reported during 1916 and 1917.

Bibl.: CAL. STATE MIN. BUR., Report XV, p. 670; Chapter rep. bien. period, 1915–1916, p. 76.

Wonder Mine. Manuel Gonzales, owner, Idria. This mine is in Sec. 31, T. 17 S., R. 12 E., M. D. M., about 1½ miles west of New Idria, at an elevation of 4000′ (U. S. G. S.). It is within the area of Franciscan rocks noted on the geological map (see Plate XII), and was located in 1908. There are 6 claims in the group, with an area of 120 acres. The cinnabar occurs in a soft, partly serpentinized sandstone, in part as an impregnation and also as seams 1″ to 1½″ in width. Some pyrite accompanies the ore. The strike of the vein is east of south. There are three adits, all being drifts, two of which are on nearly the same level. One is in 195′, another 180′, and the third 80′. There are also 2 or 3 short crosscuts and some small overhand stopes. Wheelbarrows are used to carry the ore to the retort, which is of seven 10-inch pipes set in rather crude walls of mud-plastered rubble masonry. Each pipe treats 100 lbs. of ore daily; and 6 cords of wood are burned per week. The wood is scrub oak and manzanita, cut close to the mine, and costs $1.50 to $2.00 per cord. There were four men at work (three of them being Gonzales' sons), two being underground, one at the retort and one cutting wood. The mine is operated only 7 months each year; and is credited with a total production of 119 flasks of quicksilver to the end of 1917, more than half of which was taken out during 1917.

Bibl.: CAL. STATE MIN. BUR., Report XV, p. 671; Chapter rep. bien. period, 1915–1916, p. 77.

SAN BERNARDINO COUNTY.

The occurrence of cinnabar has been noted in at least four localities in San Bernardino County, but as yet there has been no commercial production reported.

Mercury Group. W. G. Pinkett, J. L. Wedekind, F. L. Madden et al., owners, Danby via Goffs. This group of 14 claims is 9 miles northeast from Danby station, by a good road, and was located in January, 1917. The country rocks are stated to be schist and serpentine. From specimens of the ore examined, it is apparently a breccia which has been re-cemented by deposits from hot springs, which also carried cinnabar. There is considerable reddish iron oxide in some of the material. The veins or mineralized zones, of which there are several, are stated to range from 4′ to 10′ in width, and cut through a series of 'dikes'. The strike is E-W., with dip S. A 20′ shaft has been sunk and a number of superficial prospect holes dug.

Myrickite. This is a local name given to a white, gray and bluish, translucent chalcedony containing bright red inclusions of cinnabar. It is found in the southern end of the Death Valley region, 15 miles northeast of Lead Pipe springs, and 45 miles N. of E. from Johannesburg, on claims owned by F. M. Myrick of Randsburg. Specimens have been mined and cut for jewelry. The chalcedony occurs in bunches and small masses in a lava cap. Some development work was done about 1912 to ascertain its possibilities as a source of quicksilver, but no commercial production has yet been made, so far as the writer is aware.

Bibl.: Cal. State Min. Bur., Bull. 67, pp. 66, 67. U. S. G. S., Min. Res., 1911, Pt. II, p. 1039; 1913, Pt. II, p. 651.

Specimens of **wolframite** from the Jack tungsten claim in the Clark Mountains near Ivanpah, have been found showing cinnabar associated. The mercuric sulphide occurs in the middle of a thin wolframite vein, but was deposited at a later time.

Bibl.: U. S. G. S., Bull. 652, p. 47, and Plate V.

A cinnabar-bearing ledge on City Creek, six miles from San Bernardino, is stated to have been worked prior to 1873, in which year another prospect was located a little over a mile from the first one. The record does not show definitely if any metal was actually reduced.

Bibl.: U. S. G. S., Mon. XIII, p. 383. Min. & Sci. Press., vol. 27, p. 166, 1873.

SAN FRANCISCO COUNTY.

The occurrence of native quicksilver and cinnabar in small quantities in the hills around the Mission was known in the early days, but no commercial deposit ever developed. About 1892, cinnabar was found in stringers and bunches in a siliceous vein enclosed in serpentine on Divisadero street near McAllister street. Cinnabar and globules of the native metal have also been noted on Twin Peaks. None of these have ever yielded quicksilver in commercial amount.

Bibl.: CAL. STATE MIN. BUR., Report XII, p. 366; Bull. 67, pp. 18, 35. U. S. G. S., Min. Res., 1892, p. 160. GEOL. SURV. OF CAL., Geol. vol. I, p. 78.

SAN LUIS OBISPO COUNTY.

As noted in the introductory paragraphs to Chapter 4 herein,[1] there are four quicksilver districts in San Luis Obispo County (see Map, Plate XV): Oceanic, Adelaide, Pine Mountain, and San Carpojaro. They are all adjacent, and somewhat closely grouped in the northwestern part of the county, being located in zones along the ridges and spurs of the Santa Lucia Range, and separated by more or less barren sections of country. These districts are enumerated above in the order of their importance.

Cinnabar from the Sierra Santa Lucia had been used by the Indians for pigment for generations before the miner appeared. In 1861 active search by prospectors began and the first location is said to have been made in 1862. The usual rush of miners followed and many claims were taken up. The county became an important producer in 1876, but, although many properties are mentioned as yielding, the records give the individual outputs of only the largest, so that we have not an exact figure of the county's total. At the properties, too, no systematic data was kept and hardly a person is now to be found who can give first-hand information concerning past operations.

With the exception of the Rinconada group, and the Deer Trail mine, all the mines which have produced quicksilver are located along the Santa Lucia Range from San Carpojaro Creek in the northwest corner of the county, to the middle of T. 27 S., R. 10 E., a distance of about 30 miles. All except the Oceanic and Polar Star are at elevations of over 1000′.

The mines may be roughly grouped into two classes, depending on the character of ore: to the first belong the properties like the Oceanic, which exhibit sedimentary formations impregnated with cinnabar and

[1]See p. 34, *ante*.

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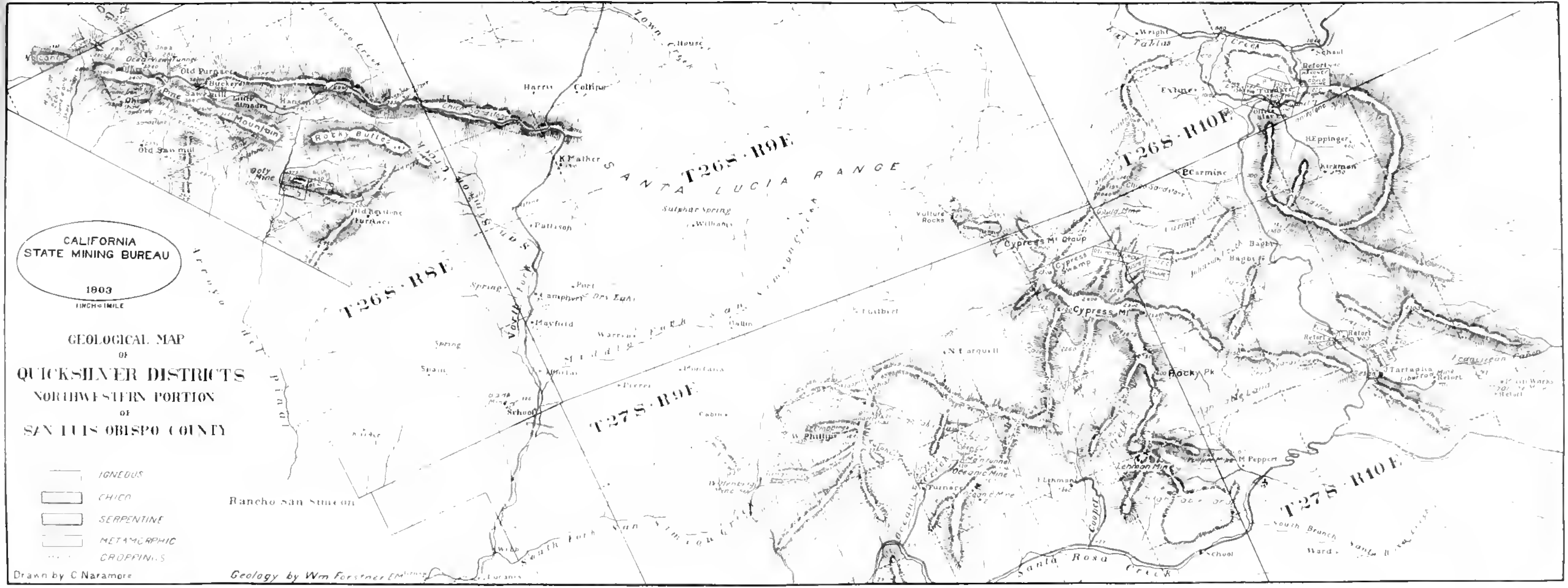

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carrying high percentages of pyrite; the other has ores which are highly silicified metamorphics (including serpentine).

In a recent report, speaking of the character of work done at some of these mines in the past, Logan[2] remarks:

"The nature of the ore occurrences in most of the mines, and the extreme instability of the quicksilver market in the past have no doubt been the chief factors in determining the ruinous policy of exploitation—it can hardly be called mining—which has been followed at a number of the properties visited. The approved method of procedure has been to find a rich pocket of ore, erect a wasteful retorting plant and burn high-grade ore only. The result has not been generally realized, perhaps, until the recent phenomenal rise in the price of mercury. Many owners find now to their chagrin that they have neither high-grade ore bodies rich enough to pay for retorting, nor furnaces to treat the numerous occurrences of low-grade material. Consideration of the costs entailed, and the length of time for which capital would be tied up in erecting and bringing a furnace plant to the producing stage, furnish ample explanation for the lack of activity in mercury mining, in spite of the alluring prices now ruling."

OCEANIC DISTRICT.

The Oceanic district is on the west slope of the main Santa Lucia ridge, and covers the headwaters of the three northern forks of Santa Rosa Creek (Santa Rosa, Cooper, and Oceanic) and the divide between Santa Rosa and San Simeon creeks extending northerly to the south fork of the latter. The geology of this district is complicated, and the rocks belong almost entirely to the Franciscan series, except for an area of overlying, younger formations in the southeastern corner. The most important mine of the district and of the county is the Oceanic.

According to Forstner:[3]

"There are several scattered exposures of rhyolite in this district, which apparently, however, have no relation to the location of the ore deposits. There are very clearly defined lines of croppings, having a northwestern direction; one, starting in the Vulture mine, crosses the divide and runs through a part of Cooper Creek basin; another, starting southwest thereof, crosses the divide between Cooper and Oceanic creeks, on the ground of the Oceanic No. 2 mine, and runs through the Oceanic mine. A third line of croppings lies northeast of the latter, and may be those of a second or back ledge found formerly in the old works of tunnel No. 4 and below in the upper shaft levels of the Oceanic mine. These croppings go some distance farther northwest, but do not reach the divide between Santa Rosa and San Simeon creeks. On this divide a very bold line of croppings starts northward, forming a contiguous line of bluffs about a quarter of a mile long, flanked on both sides by serpentine, which, however, appear not to carry any cinnabar. The principal material of the croppings is a rather light gray, flinty quartz.

"The principal rocks exposed at the surface are, besides the rhyolite above mentioned, sandstone, shales, some chert, and occasionally some serpentine. The sandstone is generally much decomposed, with a brownish or greenish gray color, but not nearly as much silicified as in the Adelaide district. The deep erosions and the fact that the country is continually sliding, lead to the supposition that a large part of the underlying rock is more or less serpentinized, which is confirmed by the fact that in most of the gulches the hard sandstone is found underlaid by shales or serpentine.

"In the Lehman property the younger sandstones are found impregnated with cinnabar in close vicinity to the rocks of the Franciscan series, which would tend to show that the period of ore formation was posterior to that of the deposition of those upper Cretaceous or Eocene rocks. As this deposition was contemporaneous with, or closely following, a strong process of silicification, the highly siliceous character of the ledge matter of most of the mines is readily explained, the Franciscan series having already undergone a prior process of silification."

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[2]Logan, C. A., *et al.* Mines and mineral resources of Monterey *et al.* counties: Cal. State Min. Bur., Report for biennial period, 1915–1916, pp. 104–105, 1917. Reprinted in Report XV, p. 698, 1918.

[3]Forstner, William, Quicksilver resources of California: Cal. State Min. Bur., Bull. 27, p. 151, 1903.

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¹See p. 31, *ante*.

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[3]Forstner, William, Quicksilver resources of California: Cal. State Min. Bur., Bull. 27, p. 151, 1903.

ADELAIDE DISTRICT.

The Adelaide district is on the eastern slope of the Santa Lucia range, to the northeast of the Oceanic district, and covers the headwaters of Las Tablas and El Paso de Robles creeks.

"[1]The rocks of this district belong prominently to the Franciscan or metamorphic series, principally sandstones, with occasionally some shales, and in a few places exposures of chert beds. One wide body of serpentine is found at Cypress Mountain, extending southward past the headwaters of Santa Rosa Creek. The whole belt has a northwest trend, and a narrower and shorter belt of serpentine lies west thereof. In the northern part of the district, on the main ridge, north of Cypress Mountain, is an exposure of rhyolite, belonging to the scattered exposures above mentioned; it has a northern trend, but is of relatively small dimensions.

"The territory comprising this district must at one time have been covered by the Chico series. It is bounded on the east and northeast by the Chico sandstone, and in places larger and smaller patches of the same are found on the top of the ridges, the Franciscan rocks being exposed lower down the hillside or in the cañons. At the contact, the Chico sandstones are so much broken up and contorted that it is impossible to give any idea as to the strike and dip of the beds.

"A line of croppings which can readily be followed runs in a northwesterly direction through this district; though more or less parallel to the direction of the main ridge of the Santa Lucia range, this line is clearly independent thereof. These croppings, starting from the southern part of the district in the Madrone property, run continuously through the La Libertad, Josephine, Alice, Modoc, and Elizabeth mines. Then they become much less prominent and only show occasionally in the ridge between Johnson and Carmine creeks and farther north toward the Cypress Mountain group. The Karl and Mahoney mines are situated on a belt entirely disconnected from these croppings.

* * * "The cinnabar is often accompanied by sensible amounts of iron sulphides, which by their oxidation near the surface give an ochery yellow color to the ore. As a rule, the ore carries more iron sulphides as the cinnabar contents increase. The ore bodies are contiguous to more or less extensive strata of dark-gray to black-colored clays, mixed with bowlders of lighter gray-colored sandstones. They are of the same nature as that of the black clays, generally associated with quicksilver deposits—'alta,' only here they are almost invariably indurated. Their outcrops frequently accompany those of the ore bodies; they are of a light-gray color, having the appearance of a disintegrated sandstone, traversed by a network of narrow seams of an ochreous yellow color; in places small inclusions of serpentine are found. This material, while contigueus to the ore deposits, is always barren of cinnabar."

A large amount of work has been done in this district, especially between 1867 and 1872. Except in the Klau mine, sufficient development work has not been done to enable one to judge as to the character of the ore bodies in depth.

PINE MOUNTAIN DISTRICT.

The Pine Mountain District is several miles to the northwest of the Oceanic district, around Pine Mountain, and covering the headwaters of Arroyo del Pinal and the north fork of San Simeon Creek. The district is characterized by considerable exposures of rhyolite, which appear in a series of knolls. These outcrops are not continuous, but are separated by short exposures of Franciscan formations. To the west lies a wide belt of serpentine, but on the east, serpentine shows only at the Pine Mountain group. Near Rocky Butte, the Chico sandstone lies close to the igneous rocks.

SAN CARPOJARO DISTRICT.

The San Carpojaro district (not shown on Plate XV) is to the northwest of the Pine Mountain district, in the extreme northwestern corner of San Luis Obispo County and extending over the line into Monterey County. Between San Carpojaro Creek and the ocean, the formation is prominently of a highly silicified Franciscan sandstone.

[1]Forstner, *op. cit.* p. 150.

To the east of the creek and forming the backbone of the main ridge is a wide belt of serpentine, along which, on its western line, runs a belt of croppings in which cinnabar has been found on the northern watershed of Salmon Creek. In the basin forming the headwaters of the west fork of San Carpojaro Creek is a minor, parallel belt of serpentine to the west of which are the croppings in which the Dutro mine is found.

Timber and transportation.

Timber is rather scattered and scarce in these districts, except around Cypress Mountain between the Oceanic and Adelaide districts, and in the Pine Mountain district. The Oceanic mine, at the present time, obtains its mine timbers and fuel mainly from Pine Mountain. The transportation outlet for the districts on the west slope is via steamer at San Simeon and Cayucos, 12 to 19 miles; and for the Adelaide district, to the railroad at Paso Robles, 16 to 20 miles distant on the east.

Production.

The total recorded production of the quicksilver mines of San Luis Obispo County is shown by the following tabulation. There are no figures available for the years previous to 1876, though some small properties are known to have been in operation. Their output was combined in the published data with that of other small mines of the state under the heading 'Various Mines'.

Quicksilver Production of San Luis Obispo County.

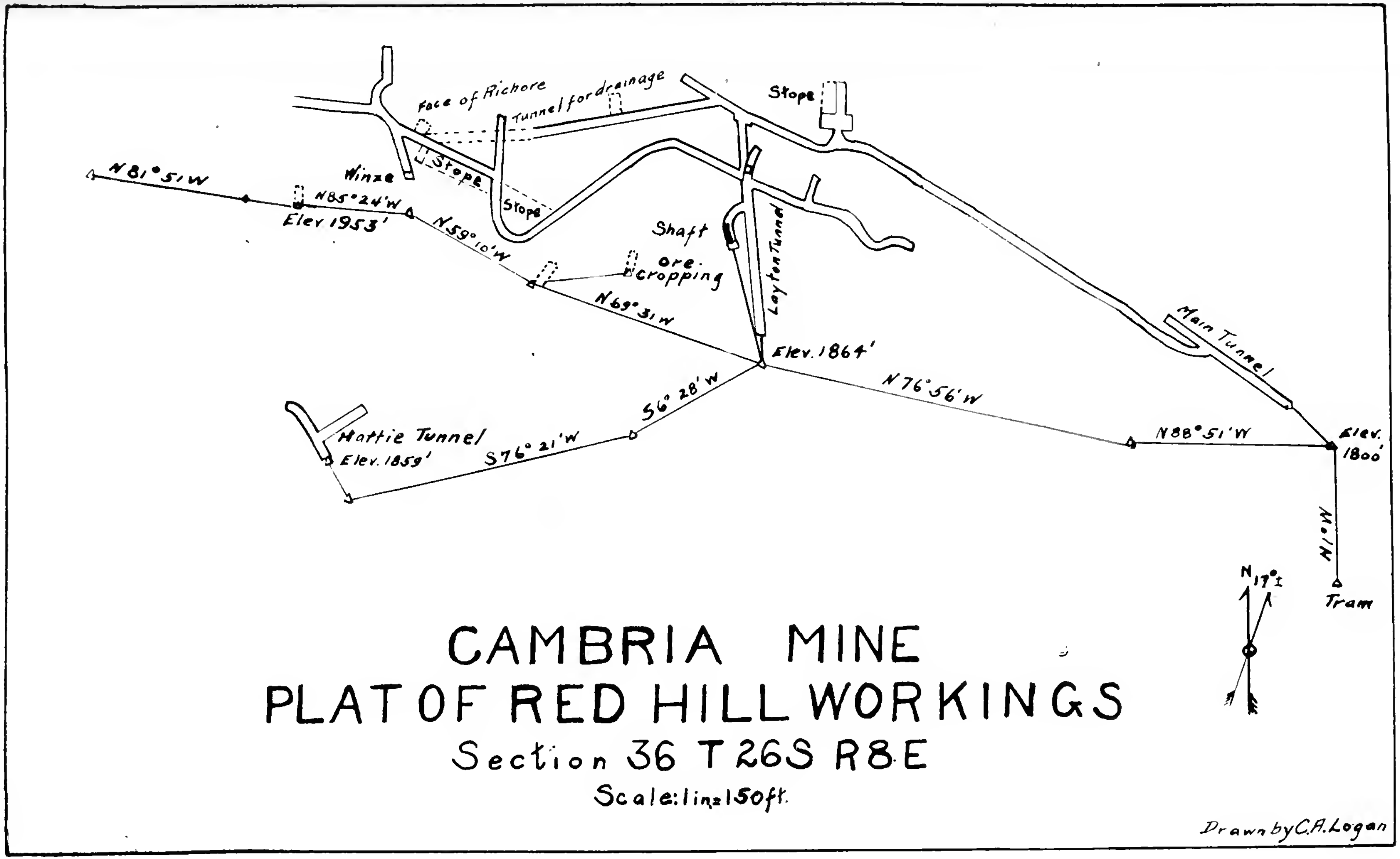
Year	Flasks	Value	Year	Flasks	Value
1876	6,428	$282,832	1905	3,733	$133,748
1877	3,310	123,463	1906	3,511	128,152
1878	2,151	70,768	1907	2,509	95,743
1879	779	2,358	1908	867	36,648
1880			1909	317	15,510
1894			1910	563	25,476
1895	20	800	1911	569	26,180
1896	101	3,400	1912	666	27,998
1897	101	3,939	1913	1,160	46,667
1898	384	11,660	1914	1,266	62,097
1899	394	17,700	1915	1,473	125,542
1900	515	23,886	1916	1,227	114,724
1901	840	41,513	1917	1,565	151,034
1902	3,312	147,215			
1903	4,577	183,580	Totals	47,084	$2,079,199
1904	4,746	176,616			

Benton Ranch Deposit. (Lehman Mine.). This property, formerly known as the Lehman, is in Sec. 13, T. 27 S., R. 9 E., 12 miles from Cambria. It is on the continuation of the 'mudrock' zone which has proven so productive in the Oceanic mine. Some development work has been done, principally in the form of a tunnel in nearly 800′ from which short drifts have been run and which are stated to show promising prospects. There is no reduction equipment as yet.

Bibl.: CAL. STATE MIN. BUR., Report XV, p. 711; Chapter rep. bien. period, 1915–1916, p. 117; Bull. 27, p. 161.

Cambria Mine (formerly the **Bank Mine**). Cambria Quicksilver Co., owner; H. R. Gage, president, 1259 St. Andrews Place, Los Angeles; E. W. Carson, agent, Cambria; located in Sec. 36, T. 26 S., R. 8 E., M. D. M., 13 miles north of Cambria by road and 11 miles from San Simeon, the steamer shipping point. The holdings consist of mineral rights on 360 acres. This mine was first exploited in 1903 by E. S. Rigdon and made a notable output of quicksilver between 1905 and 1908. It is credited with a total of 4135 flasks to date. The surface showings were quite poor but exploration underground revealed an ore-body of considerable size, and quite rich. The present owners obtained the property in 1905, but they carried development work for a year before erecting a reduction plant. A tunnel 800′ long was driven to use in handling the ore and from this a cut 200′ long was driven into the ore-body which proved to be very flat and to consist of a zone of brecciated serpentine about 40′ thick, dipping northeast. When the company had carried development work underground to the point where they were convinced of the value of the ore body, they erected a furnace. During the 18 months ensuing, operations were very satisfactory. An ore body 180′ long, 40′ wide and 150′ in height was worked out by stoping and yielded 3927 flasks. The ore averaged 0.38% mercury (7.6 lb. per ton). Square setting was used but notwithstanding this the cost of production per flask was very low, being stated as $26.03.

The ore carried little or no iron sulphide and gave little trouble in the furnace. Early in 1908 the ore gave out, the body apparently being cut off either from faulting or sliding. Operations were suspended till the fall of 1915, when prospecting began on a series of croppings north of and slightly higher than the old mine. There are 3 deposits, more or less parallel but not overlapping, being in a sort of stepped relation extending northerly and separated by spaces of ½ and 1/8 mile respectively. Up to December, 1915, about 1400′ of new drifts had been driven on two levels and crosscuts totaling over 400′ as well as about 300′ of raises and winzes. All this was done by hand drilling, and was at times in heavy ground. The main croppings, which show on the surface for 700′ have been followed underground for half that distance. Superficially a rather flinty and ochreous cropping, the appearance underground is that of an intensely brecciated serpentine carrying small stringers of rich ore in a siliceous gangue,


CAMBRIA MINE
PLAT OF RED HILL WORKINGS
Section 36 T 26 S R 8 E
Scale: 1 in = 150 ft.
Drawn by C.A. Logan
Main Tunnel
Layton Tunnel
Hattie Tunnel
Elev. 1859'
Elev. 1864'
Elev. 1800'
Elev 1953'
Face of Richore
Tunnel for drainage
Stope
Stope
Stope
Winze
Shaft
ore cropping
N 81° 51' W
N 85° 24' W
N 59° 10' W
N 69° 31' W
N 76° 56' W
N 88° 51' W
S 76° 21' W
S 6° 28' W
N 1° W
Tram
N 17° E

and coatings of cinnabar on the serpentine fragments. The mineralized zone as revealed at that time was about 20′ in average width, with a dip of about 40° N. and strike of a few degrees N. of W. Throughout its width prominent streaks of dark clay selvage occur, and in places form an 'alta,' but the country rock is serpentine on both sides. As above noted, the ground is heavy, and carries a good deal of

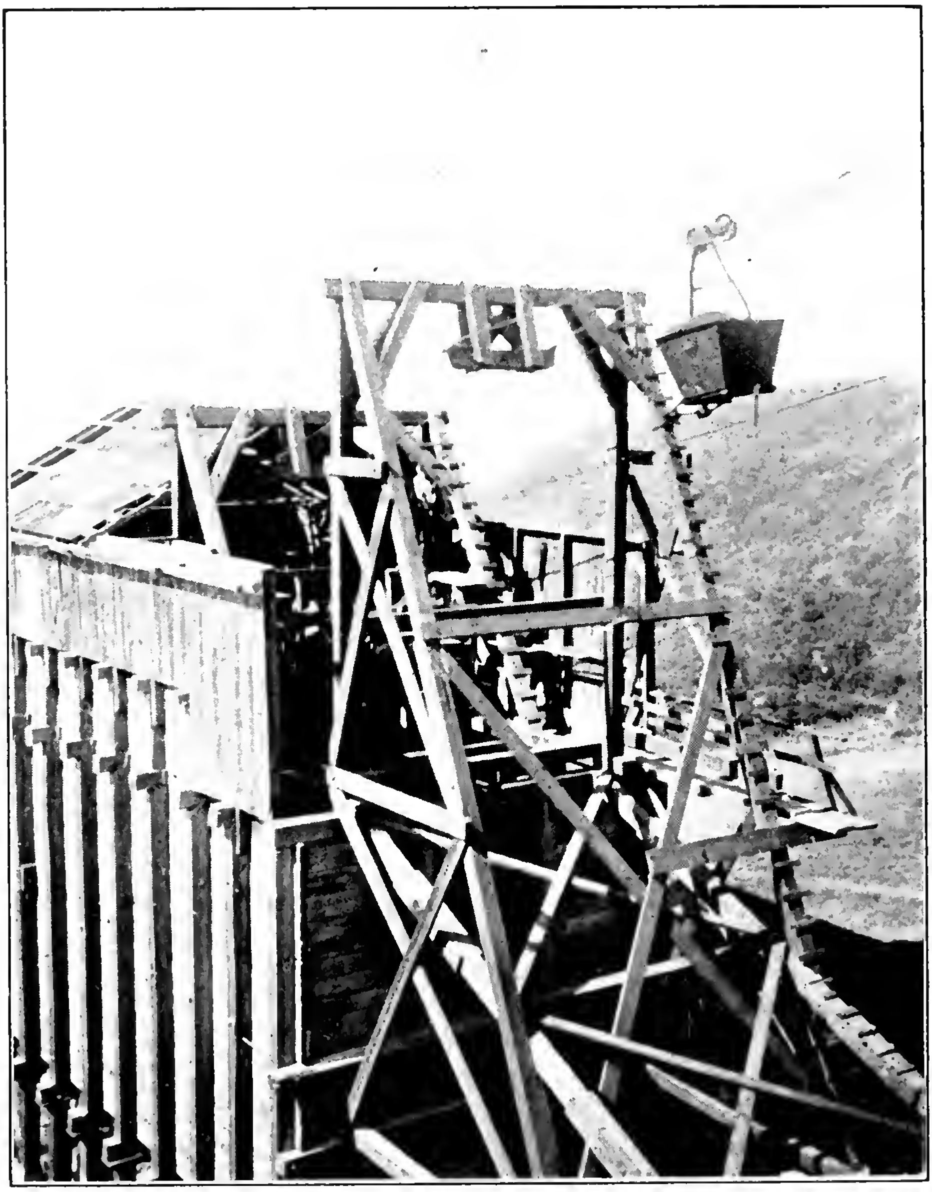


Photo No. 27. Detail of tramway and ore-bin, Cambria Mine, San Luis Obispo County. Photo by E. W. Carson.

water in places. Square setting with round timbers is employed and close lagging is needed at times.

The furnace was put in operation in the summer of 1915 on surface ore of low grade from the croppings, but considerable difficulty resulted, as the rock was a clayey, highly altered serpentine, carrying considerable water. In October, the reduction of ore from the underground workings began, and production continued up to August, 1916.

Since that date, the property has been idle; but it is reported that there are prospects of a reopening this spring (1918).

The reduction equipment includes a 50-ton Scott furnace built in 1906 at a cost of $30,000, with 8 brick condensers, one 'D' retort, an 8″x12″ Hercules-Blake crusher, and a 40 h. p. Fairbanks-Morse compressor. From mine to crusher the ore is hand-trammed in one-ton cars. Storage equipment consists of two bins with a total capacity of 1500 tons. To carry the ore from crusher to storage bins, a Broderick and Bascom two-bucket tramway system was installed in 1915, at a cost of $6,000 (see Photo No. 27). This handles the ore for a distance of 3000′ at the rate of 6½ tons an hour and dumps into the upper ore bin from which it is trammed to a lower bin and to the furnace. When operated in 1915–1916, the ore was roasted 24 hours at a somewhat higher temperature than usual. The furnace and condensers are in excellent condition; the air is excluded as much as practicable from the furnace and the formation of excessive amount of soot is avoided. Labor was cheap; miners were paid $2.50 and muckers $2.00 per day. Total cost of mining including overhead, in 1907, was $1.66 per ton; but it must be borne in mind that the cost of square-set timbering contributes largely to this item. A considerable increase in the cost of timber is noticeable in 8 years. In 1907, lagging cost $8 to $12 per thousand; but in 1915, $20. Timber which was then obtainable for 3½¢ to 5¢ a running foot, increased to 6¢. These advances and other slight increases in transportation brought the 1915 mining cost to about $2.00 per ton. Treatment cost $0.82 per ton. Oakwood cost $6.00 per cord delivered, and the furnace burns 1½ cords per day. The retort burns ¼ cord per day for about 7 days per month when the furnace is working steadily. Other general expense, aside from superintendent's salary, was 20¢ per ton, making a total operating cost for the 1907 period of $2.68 per ton, and for 1915 of $3.00 per ton. Transportation to or from San Simeon, the shipping point, was $5.00 per ton.

Power for the tram and the rock crusher is furnished by an Otto gas engine of 12½ h. p. burning distillate. The cost per horsepower-hour was stated at 1½¢. The rock crusher requires two-thirds of the power generated. The total crew last employed was 34, distributed as follows: 22 underground, 4 on top at the mine, and 8 at the furnace.

Bibl.: CAL. STATE MIN BUR., Report XV, pp. 700–705; Chapter rep. bien. period, 1915–1916, pp. 106–111; Bull. 27, p. 154.

Capitola Mine and **Santa Monica Claim.** Felipe M. Villegas, Wm. Lane and Chas. Pemberton, owners, Klau. This group is in Sec. 33, T. 26 S., R. 10 E., M. D. M., adjoining the Klau mine on the east and south, about 15 miles west from Paso Robles. In the Capitola, ore was struck at 190′ in the lower tunnel and followed for 70′, being stoped out two sets wide for 25 in length, in 1913. Some work was done by lessees in 1915–1916, but this tunnel is now caved. The total output has been 24 flasks. The formations are the same as in the Klau mine, of which the Capitola is an extension being sandstone and serpentine with considerable clay (probably an attrition product). In addition to some cinnabar, the clay carries considerable pyrite in crystals as large as ½″ on an edge and often in aggregates of several inches in diameter where the crystals are intergrown. The outcrop is highly ochreous and does not show any cinnabar to the naked eye, but is stated to pan 0.25% quicksilver. The strike is northwest. The reduction plant consists of a 24″ 'D' retort with capacity of 1000 pounds of ore per day, and two concrete-covered condensers 4′x4′x6′. In February, 1918, development work had been resumed.

The Santa Monica claim was located by Villegas in 1917, on a parallel vein on the south side of the Klau mine, but on the opposite side of the creek. When visited by the writer in September, 15′ of tunnel had been driven. The formations and ore shown are similar to those on the adjoining properties.

Bibl.: CAL. STATE MIN. BUR., Report XV, p. 705; Chapter rep. bien. period, 1915–1916, p. 111.

Claus Group. C. P. and Cecelia Claus, owners, Santa Margarita. This group of 4 claims is in Sec. 28, T. 30 S., R. 14 E., M. D. M., 11 miles southeast of Santa Margarita and adjacent to the Rinconada Group. Claim No. 1 covers the old Pedro mine which has been prospected considerably, and Claim No. 4 has a 75′ tunnel which shows a promise of ore. The geology of this district is covered in the description of the Rinconada group, where developments justify further work. Assessment work is maintained and in 1915 some ore was taken from near the surface and hauled to the pipe retorts on the Rinconada claims.

Bibl.: CAL. STATE MIN. BUR., Report XV, p. 706; Chapter rep. bien. period, 1915–1916, p. 112; Bull. 27, p. 166.

Cypress Mountain Group. W. S. Forrington, owner, Paso Robles. There have been no new developments recently at this property, although assessment work is maintained from year to year. The claims are in Secs. 1 and 2 of T. 27 S., R. 9 E., M. D. M., about sixteen miles from Cambria. All the work done in recent years has been of a superficial and desultory nature, and the old workings are mostly caved. Elevation, 2900 feet.

Bibl.: Cal. State Min. Bur., Report XV, p. 706; Chapter rep. bien. period 1915–1916, p. 112; Bull. 27, p. 156.

Deer Trail Mine. H. H. Carpenter, John W. Adams, Wm. Arebalo, owners, San Luis Obispo. This group consisting of two claims and a millsite, is on Holt Cañon, in Sec. 29 (?), T. 32 S., R. 16 E., M. D. M., about 7 miles east of Huasna post office, and 20 miles from the Pacific Coast Railroad at Arroyo Grande. Like the Rinconada mine, from which it is distant about 15 miles southeasterly, the Deer Trail mine is in a locality entirely separate from the main producing quicksilver section of San Luis Obispo County which is in the northwestern corner. The Deer Trail group was located in 1915, and in 1916 a 12-pipe retort was built, which in 3 months in the late summer is stated to have produced 70 flasks of quicksilver. The deposit is at the top of a sugar-loaf butte. At the surface, the ore shoot was 26″ wide, but it split up into several seams over a width of 4′ at 30′ depth, being worked by underhand stoping. Following that, an adit was driven from below, and connected with the stope. The mine was not visited by the writer, but samples of the ore were submitted. The rock is weathered and ochreous, and appears to be a metamorphic sandstone, with the cinnabar occurring crystallized in botryoidal aggregates and vugs in a vein breccia. It is accompanied by coarsely crystalline calcite. The property was idle during 1917, owing to disagreement among the owners.

Doty Group. Doty Bros., owners, Cambria. The holdings comprise 5 unpatented claims in Sec. 14, T. 26 S., R. 8 E., M. D. M., north of Cambria, including the Quien Sabe group which has been consolidated with the Doty claims. There are several tunnels, one of which is 200′ long and has been driven in a black clay gouge. They have been working on and off for about 12 years. In September, 1917, some caved ground was being reopened. There is no reduction equipment.

Bibl.: Cal. State Min. Bur., Report XV, pp. 706, 719; Chapter rep. bien. period, 1915–1916, pp. 112, 125; Bull. 27, pp. 156, 165.

Elizabeth and Winona Group. Mrs. J. W. Bagby, W. C. Bagby et al., owners, Paso Robles. It comprises two locations in Sec. 17, T. 27 S., R. 10 E., M. D. M., 13 miles from Cambria. The claims lie between the Little Bonanza and La Libertad properties, and exhibit similar croppings to those of the former. The work has been superficial, and for several years was entirely suspended. Some prospecting has been done the past two years. There was a small production years ago but the 10-pipe retort is no longer usable.

Bibl.: Cal. State Min. Bur., Report XV, p. 707; Chapter rep. bien. period, 1915–1916, p. 113; Bull. No. 27, p. 157.

Josephine Group (also known locally as the **Tartaglia Group**; also **George Mine**). Joe Tartaglia, owner, Klau post office. It consists of two claims in Sec. 29, T. 27 S., R. 10 E., M. D. M., 20 miles west of Paso Robles, elevation about 1900′. The original discovery was made in 1862. A furnace was built, and the dump indicates considerable ore was burned, but the plant has long since gone to pieces, and there are no segregated records of the output. The works are all superficial, the ore being similar to that of the Little Bonanza nearby. There is one tunnel in 150 feet, opening up a vein 12′ wide. A small amount of development work is being done to cover the annual assessment.

Bibl.: Cal. State Min. Bur., Report XV, p. 720; Chapter rep. bien. period, 1915–1916, p. 126; Bull. 27, p. 157.

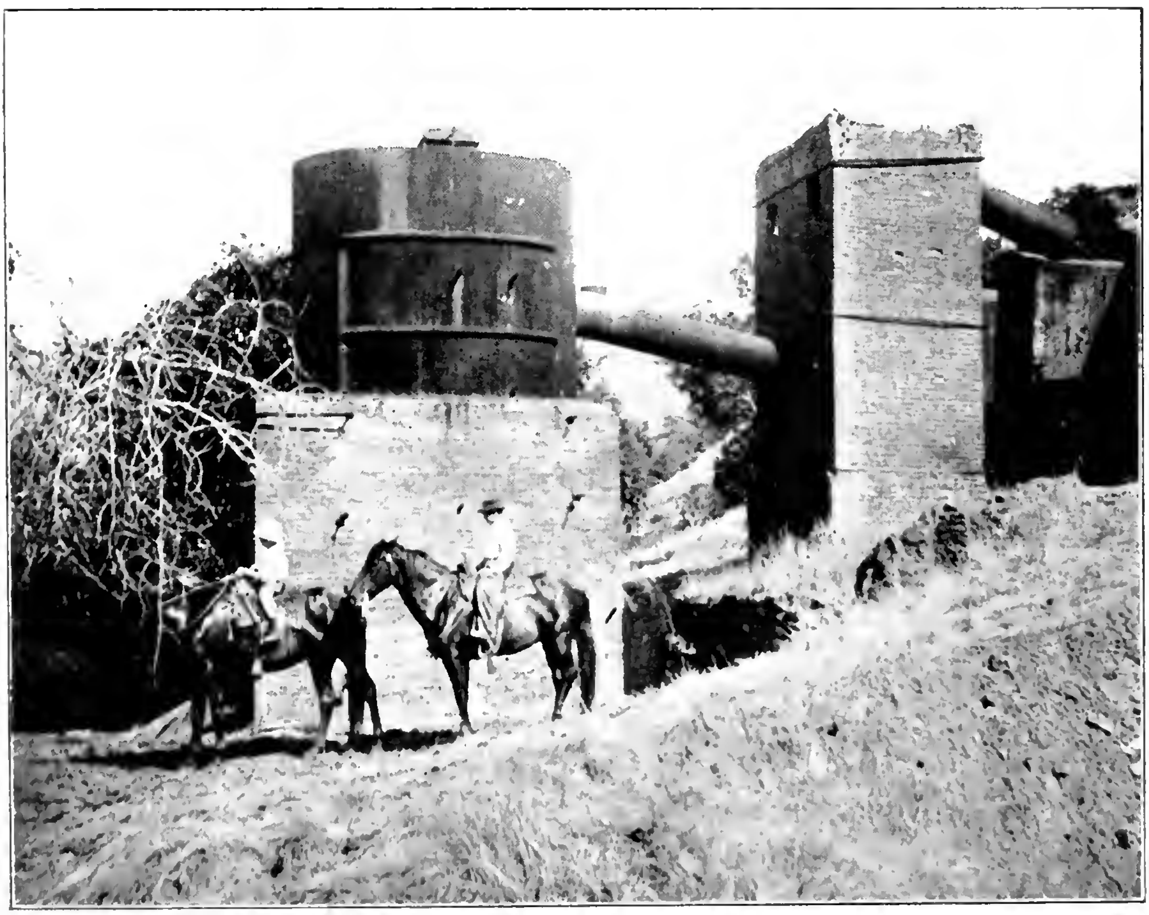


Photo No. 28. Old coarse-ore quicksilver furnace, erected 1873, at Keystone Mine, San Luis Obispo County Photo by E. W. Carson.

Keystone Mine. Phelan Bros., owners, Cambria. It is on patented land on the flank of Rocky Butte, in Sec. 13, T. 26 S., R. 8 E., M. D. M., 16 miles east of San Simeon by road. This property was located in the early seventies and has been credited in former reports with considerable production. The furnace and condensers, shown in the photograph (No. 28), were completed late in 1874 and the mine produced about 60 flasks of quicksilver in 1875, according to the best information obtainable, and which seems to be the only production of which there is record. The furnace is of the old coarse-ore type of 5 tons capacity and there are 6 of the sheet-iron condensers. The whole plant is quite an interesting relic, as most of such equipment has long since disappeared. The underground workings consisted of a tunnel said to have been about 300′ long with a winze sunk from it to a depth of 50′, but both have been inaccessible for years. It is stated that the winze was in good ore when work was abandoned. The outcrop shows cinnabar in highly altered serpentine, with a black clay 'alta' and a serpentine footwall, striking E., and dipping 40° N. In 1916 and 1917, some work was done by the owners, intermittently, in driving a tunnel on the level of the old main tunnel to reach the reputed rich ore in the winze. In September, they still had 40′–50′ to drive before reaching the old stopes.

Bibl.: CAL. STATE MIN. BUR., Reports X, p. 581; XV, pp. 113–114; Chapter rep. bien. period, 1915–1916, p. 113. MIN. RES. W. OF ROCKY MTS., 1875, p. 14.

Kismet Group. Three claims in Sec. 7, T. 27 S., R. 10 E., M. D. M., in the Adelaide district. Idle.

Bibl.: CAL. STATE MIN. BUR., Report XV, p. 114; Chapter rep. bien. period, 1915–1916, p. 114; Bull. 27, p. 159.

Klau Mine (originally called **Sunderland; Santa Cruz**; also known as the **Karl**, or **Sierra Morena**). Owners: Antone Luchessa, San Luis Obispo, E. Bianchini and Wm. Bagby, Paso Robles. The group includes 3 claims and a mill site as well as the mineral rights on certain adjacent land, being in Sec. 33, T. 26 S., R. 10 E., M. D. M., at an elevation of 1400′ on the eastern side of the Sierra Santa Lucia, 16 miles west of Paso Robles. The original location was made in 1868 and it was among the list of producing quicksilver properties in 1874, though no segregated record of output is available till 1876, when the mine yielded 1590 flasks of mercury with a furnace of only 15 tons daily capacity. The recorded production from 1876 to 1879 was 1777 flasks. No further output is shown till 1895, although development work was going on for several years previous, the failure to strike ore being due to ill-advised mining methods, according to local report. Intermittent work was done without much production till 1901. In the following year the Klau was the fourth largest producer in the state and the chief mine of the county in point of output with a yield of approximately 3300 flasks, as the Oceanic furnace was not started till the fall of the year. Work continued, with an 8-tile, 60-ton Scott furnace and 8 condensers till 1908, in which year the only output was made from cleaning out old condensers. Another period of inactivity ensued, and in 1911 the wooden structure over the furnace and con-

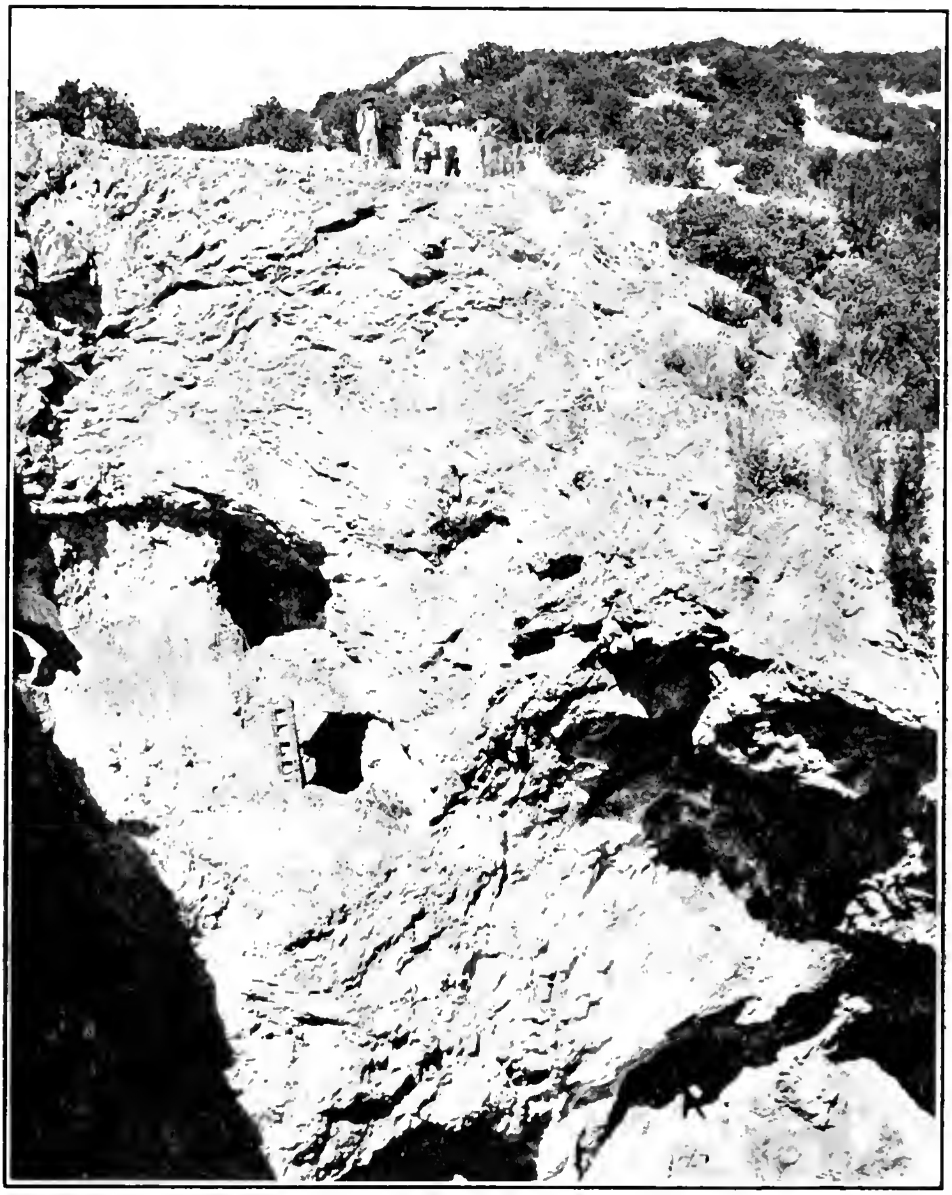


Photo No. 28a. Klau Mine, San Luis Obispo County. Old stopes and drifts exposed by later, open-cut operations. Looking northeast across the strike of the ore zone.

densers was burned (see Photo No. 56, *post*). The recorded production of the Klau mine totals 14,213 flasks, to the end of 1917.

There appears to be a mineralized zone 200′–300′ wide running through the property N. of W., within which the ore shoots are segregated along two principal lines or 'veins'. Large opencuts and extensive underground workings have been made. The geology of the mine was described in considerable detail by Forstner,[1] who states that there were two main ledges developed, running nearly parallel N. 50° W., dipping NE., but approaching each other on the dip. The more southwesterly ledge is locally called the serpentine ledge. Its footwall is a belt of serpentine from 20′–40′ wide, rather siliceous in places, to chalcedonic in character. This serpentine does not appear at the surface, but is capped to a depth of 20′–30′ by the croppings of the gouge accompanying the ore deposit. The ledge matter of this orebody is loose, coarsely-granular quartz, carrying iron and mercury sulphides. In this loose quartz are found boulders of very hard chalcedonic quartz and of a laminated, somewhat calcareous material. Some of the boulders carry visible amounts of cinnabar and pyrite; others are entirely barren, and their relation to the surrounding country rock is not clear. The hanging-wall of this 'ledge,' which forms also the footwall of the second ledge above mentioned, is a slightly metamorphosed sandstone. This parallel ledge forms in what appears to be a brecciated zone of country rock, probably of quartzose character, but having some clay in it, probably an attrition product. This ore contains considerable pyrite and some free sulphur. Both these ledges are developed by the 60° inclined shaft sunk, it is stated, to a depth of 800′, but a large amount of drifting and crosscutting failed to reveal workable ore on the lower levels. These workings became so extensive that a raise to the surface for ventilation was required, and in the course of driving it the best orebody found in the mine was uncovered. These old workings are now largely caved, and inaccessible. In some of the later operations, large open cuts were made (see Photo No. 28A). The cinnabar is crystalline, occurring in part as stringers, in part disseminated, and on fracture faces. In some of the old workings, particularly in the 'serpentine ledge,' there are abundant efflorescences of epsomite and iron salts.

At the southeast end, the ore zone either becomes wider or it splits and the Capitola mine is on one branch and the Mahoney mine on the other.

In 1915, a lessee did some superficial work, confining himself to searching for small, high-grade pockets along the outcrop. He was successful in finding several such, from which the broken ore was hand-sorted, and the richer material hauled on a sled to the retort. This method of handling brought his cost per ton to about \$6, but the grade of the resulting ore was such as to yield a net profit as high as \$28 per ton, some of the rock giving 1.5% mercury. Considerable work was done by the owners in 1916 and 1917, mostly in reclaiming ore from around the old stopes and open cuts, and about 30 flasks of quick-

[1]Forstner, William, Quicksilver Resources of California: Cal. State Min. Bur., Bull. 27, pp. 157–159, 1903.

silver per month were produced in the first half of 1917, with 2 banks of 12-pipe Johnson-McKay retorts (see Photo No. 44, *post*). At the south end, a new adit was started in the footwall side of the ore zone. At the time of the writer's visit in September, 1917, the retorts were idle, but some ore was being accumulated from the operations of two men who were taking out hand-sorted ore from the upper edge of old #5 stope at the east end. They expected soon to resume retorting. Wood for fuel, mostly live oak, is abundant nearby. Formerly it cost $3.50 to $4.00 per cord delivered; but this has increased to $4.50, being $2.00 for cutting and $2.50 for hauling.

Bibl.: CAL. STATE MIN. BUR., Reports IV, p. 336 (table); X, p. 580; XII, p. 366; XIII, p. 600; XV, pp. 709–711; Chapter rep. bien. period, 1915–1916, pp. 115–117; Bull. 27, p. 157. U. S. G. S., Mon. XIII, p. 382; Min. Res. 1902; 1906, p. 492; 1908, 1910; 1912, p. 943. MIN. RES. W. OF ROCKY MTS., 1875, p. 14; 1876, p. 20. MIN. & SCI. PRESS, Nov. 12, 1904.

La Libertad Mine. G. A. Trafton, manager, Watsonville. This mine is in the Adelaide district, in Sec. 21, T. 27 S., R. 10 E., M. D. M., about 20 miles west of Paso Robles, at an elevation of 1900′. In 1915–1916 it was operated under lease by the Belt Quicksilver Mining Company, which has since dissolved, the mine being at present idle. Considerable work has been done, development having been carried on mainly through 3 tunnels; and some fair orebodies were stoped out. The company's report of March 1, 1915, states that there were 1000′ of drifts, raises and stopes. The work underground revealed an irregular ore body dipping at different angles, which had a width of 20′ to 25′ and has been worked by stopes of 40′ to 60′ in length. New work was being done in driving a crosscut off the lowest drift, which showed some ore. The cinnabar is in the form of small crystals with silica in a highly metamorphosed rock which has been classed as serpentine, and which shows a rather soft clayey texture. The ore is near the contact with a dark clay footwall which carries sandstone in small rounded boulders and shows calcite stringers, as well as the characteristic epsomite efflorescences. The reduction equipment consists of a 12-pipe retort, in good order.

Bibl.: CAL. STATE MIN. BUR., Report XV, p. 700; Chapter rep. bien. period, 1915–1916, p. 106; Bull. 27, p. 159.

Little Bonanza Mine (originally **Josephine**; later **Alice** and **Modoc**). Mrs. Forbes (an eastern estate), owner; R. W. Putnam, agent, San Luis Obispo, Cal. This the first quicksilver mine worked in San Luis Obispo County, consists of 2 patented claims in Sec. 17, T. 27 S., R. 10 E., M. D. M., about 20 miles east of Paso Robles, and near the summit of the Santa Lucia divide; elevation 2000′. In 1915 and 1916, it was operated under lease by E. S. Rigdon & E. Bianchini of Cambria, who produced a fair amount of metal with a 12-pipe retort; but the property was idle when visited by the writer in September, 1917.

The original discovery is said to have been made in 1862 by Mexicans. The temporary closing of the New Almaden Mine prompted the purchase of this property by Messrs. Barron & Company. Considerable money was spent in development and an 8-ton furnace was put up. An adverse report on the property by its superintendent, and the reopening of the New Almaden, led to the abandonment of the Josephine. In later work, several bodies of ore were taken out by stoping; two in particular showing a thickness of 10′. The ore shoot has been stoped out for about 200′ along the strike, which is S. of W., with dip S., about 30° at the surface, but steeper in the lower tunnel. It appears to be cut off by a cross slip near the lower level which is down about 200′ on the dip of the vein, but the displacement may not be great. The stopes are up to 20′ wide. Much of the work done, however, has taken the form of gouging out rich bunches. These stopes have broken through to the surface. In the upper workings, there were 2 parallel shoots stoped out, leaving a pillar of 15′–20′ between. The ore is in the form of a network of cinnabar veinlets, and cinnabar on fracture faces, in a silicified, altered serpentine. On the footwall there is a gouge with brecciated masses. The hanging wall is serpentine. There has been no stoping, as yet, on the lowest level.

Bibl.: CAL. STATE MIN. BUR., Reports X, p. 580; XV, p. 711; Chapter rep. bien. period, 1915–1916, p. 117; Bull. 27, p. 154. MIN. RES. W. OF ROCKY MTS., 1875, p. 14.

Madrone Mine. John Carmine, owner, Cayucos. This is in Sec. 22, T. 27 S., R. 10 E., adjacent to La Libertad mine. It was worked about 1900 and considerable mercury recovered by retorting, but no depth was attained in any of the operations. The croppings are similar to those in the Little Bonanza, and La Libertad. Some small rich bunches of ore are present both in the characteristic siliceous gangue and in a softer ochreous material, and the wall rocks are similar to those in the two properties above mentioned.

In addition to the mineral found in place, there are several bodies of material scattered over the property where free mercury can be panned out. It is found in the loose soil and is probably the weathered product of a one-time outcrop. Samples of this, taken from several places by Mr. Merrifield, the former superintendent, gave from 1½ to

2½ pounds of mercury per ton in the retort. There would seem to be justification for more extensive work on this property.

Bibl.: CAL. STATE MIN. BUR., Report XV, p. 712; Chapter rep. bien. period, 1915–1916, p. 118; Bull. 27, p. 161.

Mahoney Mine (also called **Gould**; also **Buena Vista**). Miss Mary I. O'Toole, owner, San José. It is in Sec. 33, T. 26 S., R. 10 E., M. D. M., 14 miles west of Paso Robles; elevation 1140′. It is on the extension of the Klau ore zone, to the southeast. There is a tunnel said to be in 400′, but it was inaccessible when visited by the writer. No work has been done for some years.

Bibl.: CAL. STATE MIN. BUR., Report XV, p. 712; Chapter rep. bien. period, 1915–1916, p. 118; Bull. 27, p. 161.

Marquart Ranch Prospect. John Marquart, owner, Cambria. There are cinnabar-bearing croppings on the Marquart ranch, 2 miles northeast of the Oceanic mine. Undeveloped.

North Star Mine (Santa Maria). In San Carpojaro district, in Sec. 13, T. 25 S., R. 6 E., M. D. M., southeast of the Polar Star mine. Idle for years.

Bibl.: CAL. STATE MIN. BUR., Report XV, p. 712; Chapter rep. bien. period, 1915–1916, p. 118; Bull. 27, p. 162.

Oceanic Mine. Murray Innes, owner, 217 Kohl Building, San Francisco; Ellard W. Carson, manager, Cambria. It is 5 miles easterly from Cambria and comprises three patented claims containing 60 acres, also the mineral rights on 400 acres of adjoining land. The property is in Secs. 15 and 21, T. 27 S., R. 9 E., on Santa Rosa Creek. The patent for the three original claims was granted in 1865, being signed by President Lincoln. The mine has had an interesting and instructive history. In 1875 it was taken hold of by a corporation who began developments on a very ambitious scale. A large force of men were hired and 600 acres of timber land purchased. Seven tunnels were driven and a body of good ore opened up. A Louis Janin furnace was built in 1875. The first recorded production occurred in 1876, when the yield was 2358 flasks. The metal at that time was worth about $1.50 per pound and the quicksilver mining industry was at the highest pitch of prosperity which it has ever enjoyed previous to the present war-boom. During the period of 1876–1879 inclusive, the Oceanic produced 7391 flasks. Sharp declines in price, however, brought quicksilver to less than 40¢ a pound in 1882 and left only 6 mines in the state which could produce without loss. The Oceanic had practically closed down three years before, and remained idle till 1902, when a new company assumed ownership and erected a 50-ton Scott furnace.

Production was resumed soon after, and was maintained more steadily than at any other property in the county. In 1906 the Oceanic was one of the six chief producers in California and in 1908 it is also mentioned as one of the nine leaders, in spite of the depressed condition of the industry. In 1909–1910 the mine was operated by lessees and in the latter year was the only producing quicksilver property in the

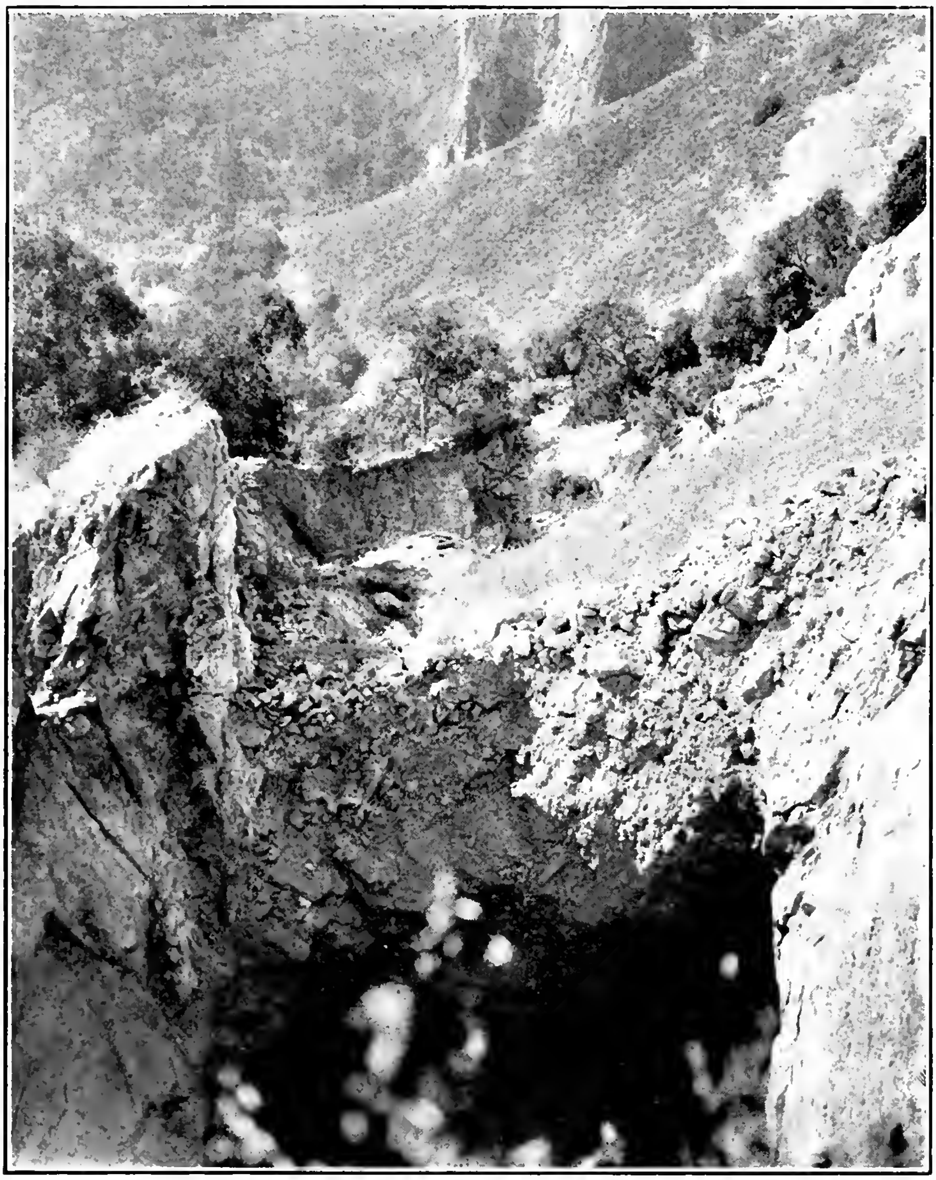


Photo No. 29. Open cuts at Oceanic Mine, looking northwest along strike of ore zone. In foreground, top of stope caved through to surface.

county. About this time the coarser sandstone ore gave out. The rock on the hanging wall side of the old vein (and easterly on the strike) proved, on exploitation, to be a finer-grained material, carrying cinnabar in much smaller percentage than the old ore. It was erroneously named a shale 'mudrock.' In 1912, the present owner took control of the property, rebuilt the furnace, and made a small production that year, besides developing a very large orebody of this low grade material. In 1916, Edward A. Clark, et al., of New York, took a bond on the property, built a 300-ton concentrating mill,[1] a new aerial tramway of greater capacity than the old one, and a second 50-ton Scott furnace. They gave up their bond early in 1917, and the property with improvements reverted to Innes. The total recorded output of the Oceanic mine to the end of 1917 has been 23,251 flasks of quicksilver.

Mine.

The ore is a dark-gray, fine-grained sandstone, which contains enough calcite to cause marked slaking on exposure. Petroleum is also associated. There is considerable pyrite, and the cinnabar values are

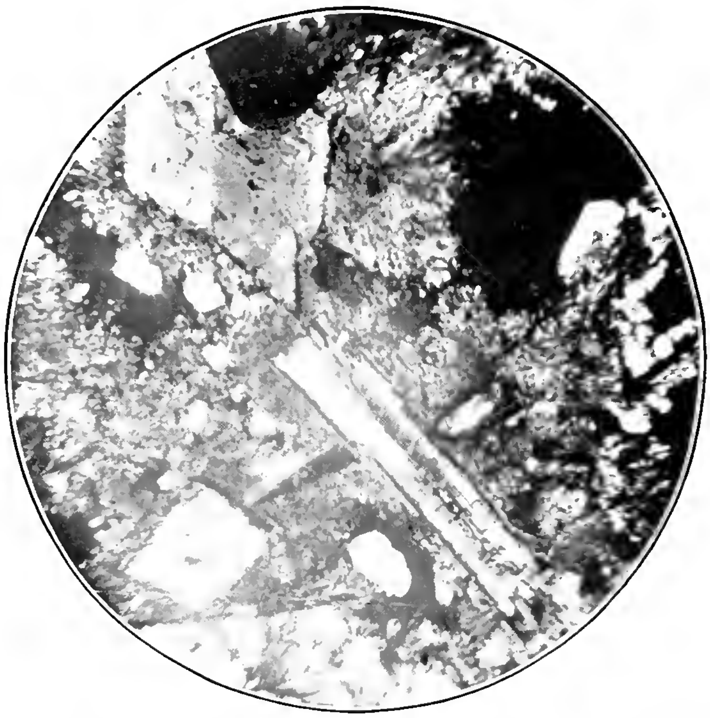
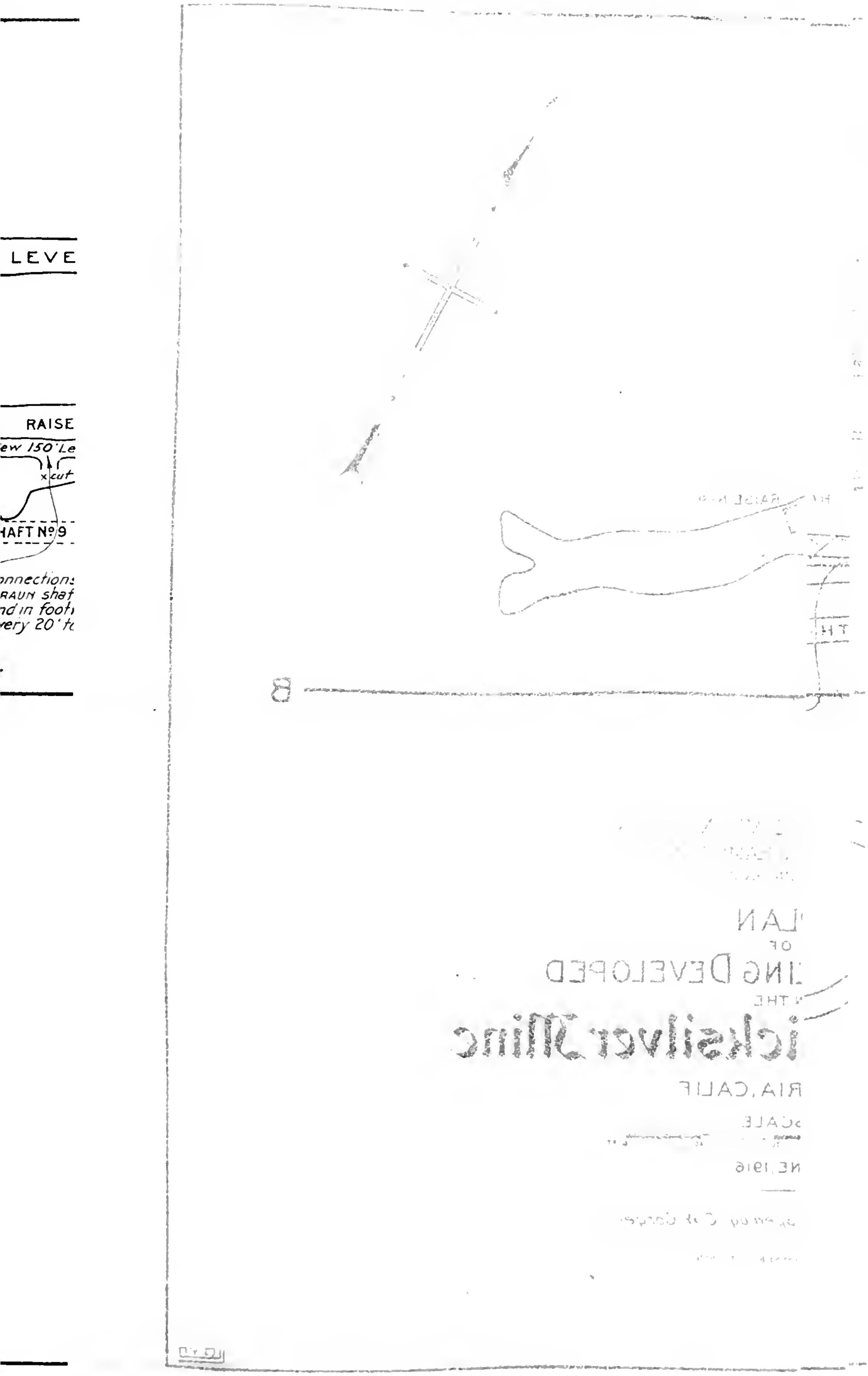


Photo No. 30. Micro-photograph of diorite-gabbro at the Oceanic Mine. ×60 diam. magnification. Photo by S. A. Tibbetts.

so finely disseminated as to be largely invisible underground, but if specimens are taken from any part of the ore block, reduced on a buckboard and panned, a surprising prospect is obtained. There are also occasional crystalline accumulations of cinnabar on fracture faces. This ore is quite uniform in value. The ore strikes NW-SE. (see Plate XVII), and the dip is nearly vertical though in places it reverses itself, being mainly NE. (see Photo. No. 29). It is from 15′ to 60′ wide, being 40′ wide at the top of the hill. The hanging-wall is serpentine and the footwall, shale. On the southwest side, and more or less parallel to the orebody, is a body of igneous rock of the diorite-gabbro series (see Photo No. 30). The sample from which the thin-

[1]See description, p 339, *post*.



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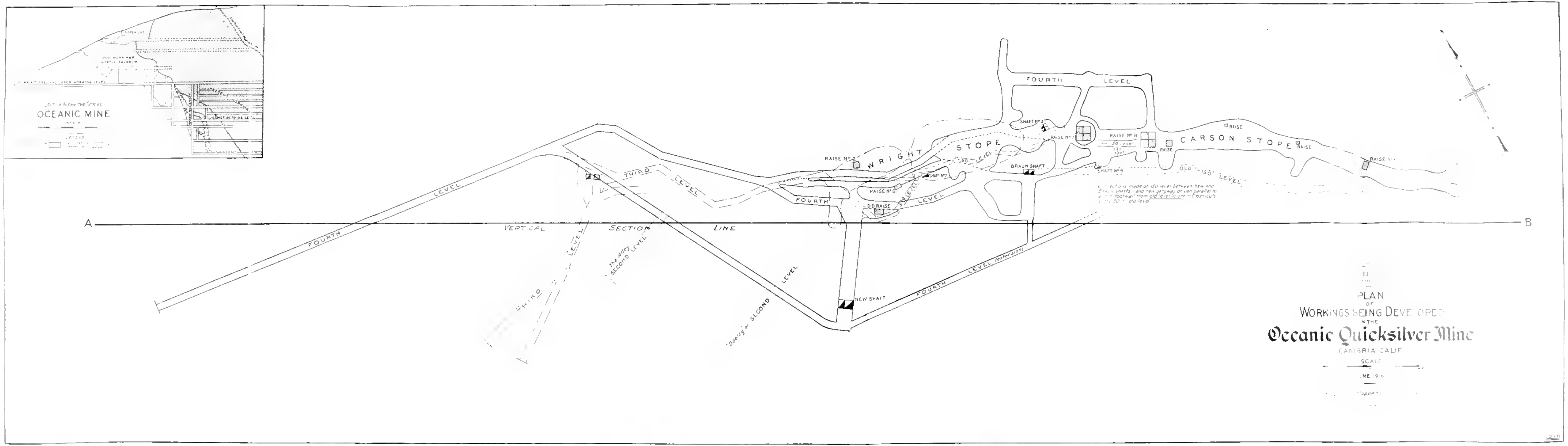
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WRIGHT STOPE
CARSON STOPE
RAISE Nº 2
RAISE Nº 6
RAISE Nº 8
RAISE
SHAFT Nº 3
SHAFT Nº 9
BRAUN SHAFT
D.D. RAISE
THIRD LEVEL
A
B
VERTICAL SECTION LINE
FOURTH LEVEL
THIRD LEVEL
The Alley SECOND LEVEL
"Dooley" or SECOND LEVEL
NEW SHAFT
FOURTH LEVEL (extension)
PLAN
OF
WORKINGS BEING DEVELOPED
IN THE
Oceanic Quicksilver Mine
CAMBRIA CALIF
SCALE

section was cut was obtained by the writer on the 250-foot level (i.e. 150′ below No. 4 tunnel). There is an exposure of the same or another body of similar rock on the road between the mine and the furnaces (see Photo 31). It has not been opened up sufficiently underground, nor did the writer have sufficient time for field study to ascertain if this diorite-gabbro has had any connection with the mineralization of the orebodies.

The immediate walls of the orebodies are composed of harder sandstones than the ore itself: that on the northerly side being gray, and that on the southerly side being darker and more compact ('barren mudrock'). The actual ore boundary is merely a slip, in the sandstone, and very difficult to follow. In the earlier-worked 'sand' orebody, the north wall was well defined, being an 'alta' of black clay slate, but it

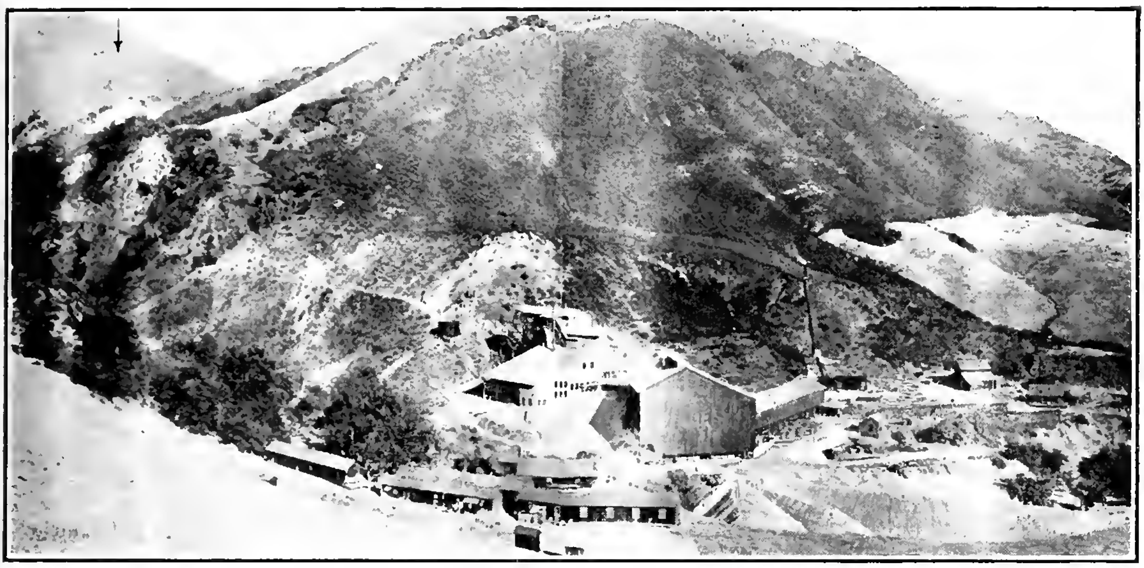
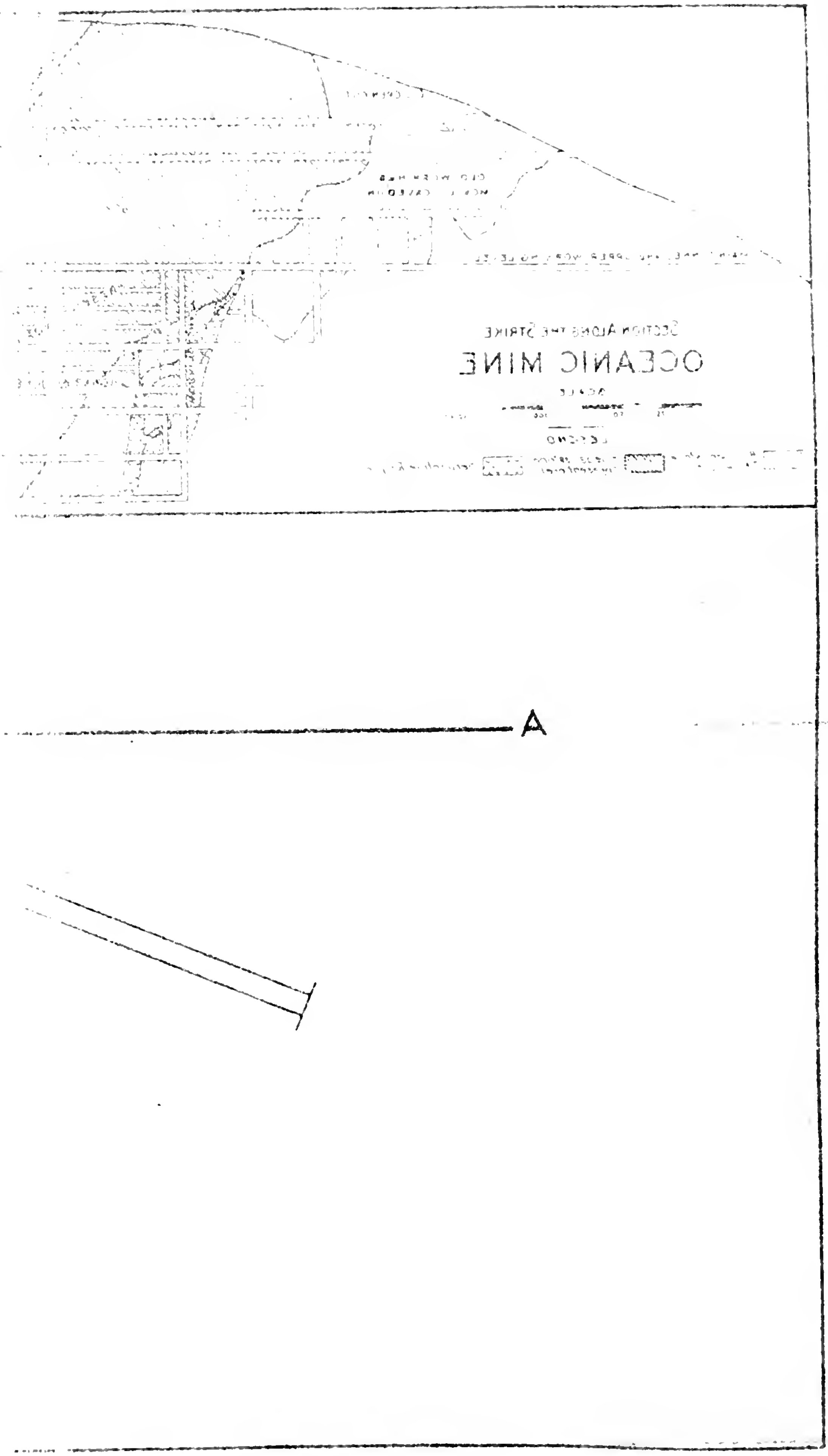


Photo No. 31. Plant of Oceanic Mine, San Luis Obispo County. The light streak below the arrow is the line of the open cuts.

ran out to a point at the west end as the 'sand rock' ran out. The best ore was obtained next to this alta. At the westerly end of the property, these formations can be traced across the cañon of Santa Rosa Creek, but no ore values have been found there.

The methods of mining used are a caving system and that known as sublevel slicing. As used at the Oceanic, two main or working levels were driven 150′ vertically apart along the strike of the orebody for 300′. These are well timbered. At vertical intervals of 25′ between the two main levels, sublevels are driven. Mining begins on the far end of the block, where a raise has been cut through. The angle of drilling is such that the ore can fall freely to the lower level, and at the same time permit easy handling of the machines. Holes are driven above and below on a slice and the two rounds of shots break through it, and so on through the block. There are several adits, but the prin-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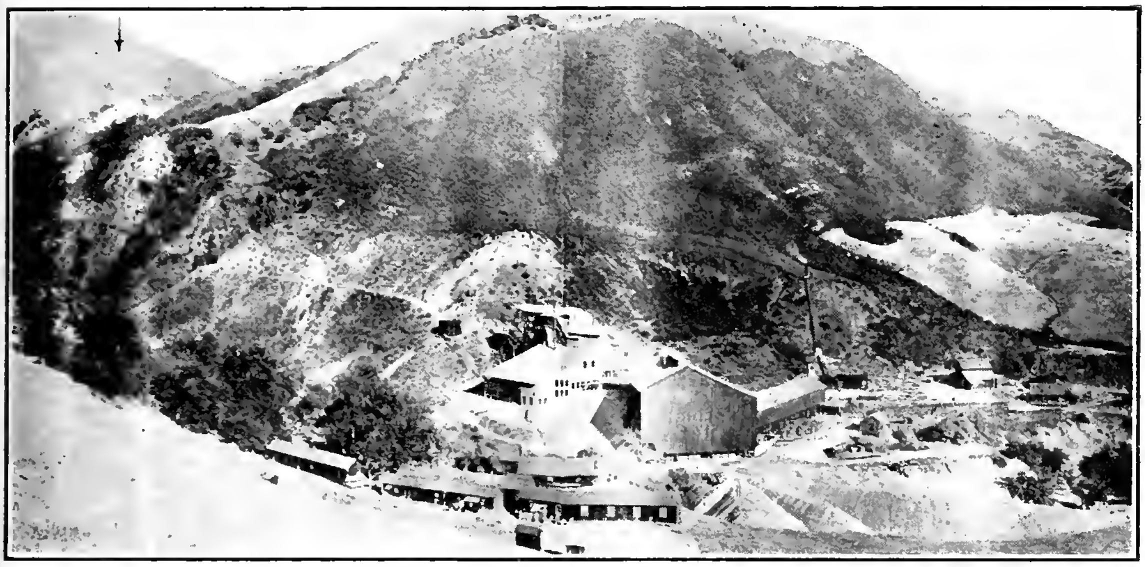

Photo No. 31. Plant of Oceanic Mine, San Luis Obispo County. The light streak below the arrow is the line of the open cuts.

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During the Clark operations in 1916–1917, the ground began caving on them and got beyond control, so that it became impossible to use the Braun shaft. The 'New Shaft' (winze) was sunk by the present manager and connections made on the 150′ level with the Braun workings. Then a new gangway was driven in the north wall and parallel to the old 150′ drift which was in ore, and from this crosscuts were being driven every 20′ to the old level. Through these crosscuts and new gangway the caved ore was being reclaimed, when visited by the writer in September, 1917. The material simply required shoveling into the cars and tramming to the shaft, only occasionally having to bulldoze a chunk too large for handling. This caved ore was being delivered on the 150′ level to the hoist at a cost of 30¢ per ton; and on the No. 4 tunnel level it was being delivered to the chute at the same figure. Hoisting and tramming to the crusher, costs about 15¢ per ton. The hoist is on No. 4 tunnel level. The total operating cost on this ore, exclusive of overhead charges and development, was approximately $1.50 per ton. In one portion of the mine, called the 'Wright stope', this caving of the orebody had extended through to the surface (see Plate XVII, and Photo 29). In 1917, up to September, approximately 2400′ of development work, mostly not in ore, was done at a cost of $2–$4 per foot, to make available this large tonnage of caved ore. When visited by the writer, one shift only (day) was required in the mine to keep the two 50-ton furnaces going. Square-set stoping costs $1.50 to $2.00 per ton of ore extracted. The machine drills used are principally Ingersoll-Rand jack hammers.

On the No. 4 tunnel level, in the north-wall side about 50′ NE. from the Braun shaft, a new cinnabar occurrence of a different type from the main orebody was cut in the course of driving the new gangway to get back of the caved ground. The cinnabar and associated minerals have crystallized in open fractures in a hard siliceous material, possibly chert or a highly silicified serpentine. An interesting sequence of deposition is shown. First pyrite was precipitated, followed in order by calcite, coarse crystals of cinnabar, and finally scattered euhedral transparent crystals of calcite. This occurrence will be further prospected to determine its extent, and its possible relation to the main orebodies.

At the portal of No. 4 tunnel are located the blacksmith shop, compressor, crushers, and tramway loading terminal. The rock breakers are set at 3″ and 2½″ openings. The ore is transported to the furnace bins one-half mile by a Painter aerial tramway, having twenty 10-cu. ft. buckets, and a capacity to deliver 20 tons per hour. It has a chain drive, but the difference in elevation between terminals is such that occasionally some power is developed and the brakes have to be used. The old aerial tram, a Hallidie, having 1½ cu. ft. buckets and a capacity of 50 tons per day, is still retained in repair for use in case of emergency. The buckets on the new tram are dumped by hand (see Photo No. 32). The ore bins at the discharge terminals of the two trams have a combined capacity of 1500 tons.

Reduction equipment.

There are two '50-ton' Scott fine-ore furnaces, the second one having been built in 1916. It is stated that the first furnace, which was built in 1902, cost $30,000, the brick having been made at the mine. The

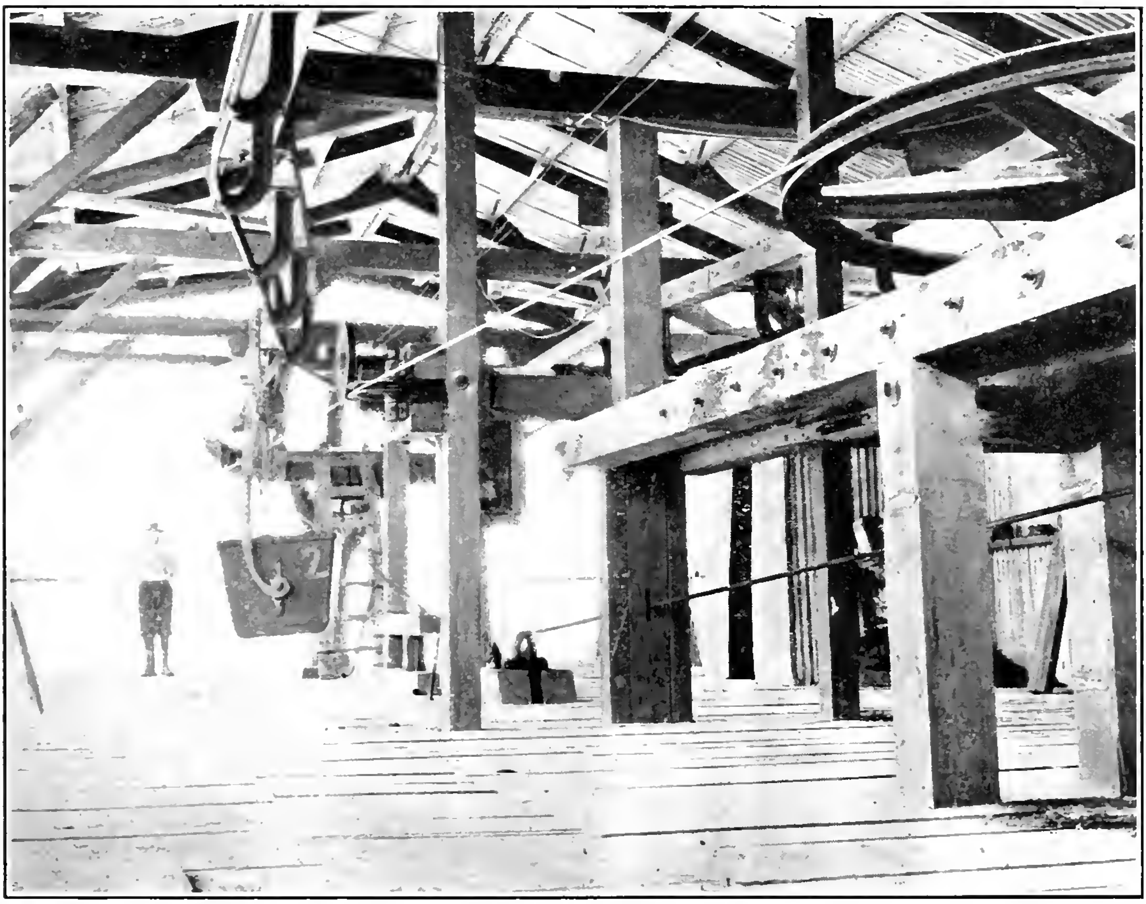

Photo No. 32. Tramway unloading terminal at Oceanic Mine.

second one cost $50,000, the brick being shipped from San Francisco. A careful check recently made on the tonnage, with an average moisture allowance shows these two furnaces to be handling an average total of 90 tons of ore daily. A heads sample of the ore is taken from each bucket at the tramway loading terminal, and the tailings sample is taken from the car at the furnace discharge. These samples are quartered down weekly and sent to an assayer in San Francisco. A portable screen with 2″ square opening is laid on top of the furnace-charging ore car while filling it at the ore-bin chutes. The coarser pieces are rejected. The furnaces have a special fume trap, which is described in the section of this report on Metallurgy.[1]

The first condensing chamber on each furnace is of brick. On the older furnace, #2, #3 and #4 chambers are of wood, the following three being of brick. On the new furnace, the brick chamber is followed by two large wooden condensers, each 16′ wide x 40′ long x 23′ high.

These condensers are constructed of 1″ tongue and groove redwood or pine, with a 1½″ floor; not painted; and held together with wooden pins instead of nails. There is an air-inlet hole in #1 condensing chamber. The old brick condensers show considerable efflorescence of salts on the outside. This is said to show a noticeable increase when wet ore is being roasted. There is a dead-end, wooden condensing chamber about 20′x20′x16′, connected to the series on No. 1 furnace, but it seems to collect very little mercury. It was built as an experiment.

Soot is treated in 'D' retorts, being charged in large sheet-iron pans or 'boats.' There are two 'D' chambers set in brick work with a single fire-box under their center. They obtain 40% of the total quicksilver yield from the soot. The retorts are operated 3 weeks of each month. No extra labor is required, as the Scott furnace shift-men also keep the retorts going. Repairs are slight, and 10 cords of wood per month are consumed as fuel.

In 1915–1916, wet concentration of the Oceanic low-grade ores was tried, but has now been discontinued. A detailed description of those operations is given elsewhere herein,[2] as is also a discussion of furnace operation costs.[3]

Power for the mine and crusher plants is furnished by distillate engines, at a cost of $25 per h. p.-year in 1915, but this has doubtless increased somewhat since. In that year, labor underground and at the furnace was paid $2.50 per day, and 2 foremen, $4.50 each. In September, 1917, muckers were being paid $2.75 and miners $3.25 per day. A total of 57 men was employed, including 27 underground, 13 on top, and 17 at the furnaces.

Bibl.: Cal. State Min. Bur., Reports IV, p. 336 (table); VIII, p. 531; X, p. 580; XII, p. 366; XIII, p. 600; XV, pp. 712–718; Chapter rep. bien. period, 1915–1916, pp. 118–124; Bull. 27, pp. 151, 162, 243. U. S. G. S., Mon. XIII, p. 382. Min. Res. W. of Rocky Mts., 1875, p. 14; 1876, p. 20. A. I. M. E., Bull., Feb., 1915, pp. 497–504; also Trans. vol. LI, pp. 110–119. Eng. & Min. Jour., vol. 102, p. 512, Sept. 16, 1916.

Pine Mountain Group. Mrs. Phoebe A. Hearst, owner, San Francisco. This group of 22 mining claims and several tracts of timber

[1]See p. 241, *post.*
[2]See p. 338, *post.*
[3]See p. 244, *post.*

land on and around Pine Mountain, in Secs. 3, 10, and 11, T. 26 S., R. 8 E., M. D. M., includes the Buckeye, Little Almaden, Pine Mountain, and Ocean View prospects, 11 miles east of San Simeon. The principal workings are on the east side of the body of rhyolite forming Pine Mountain, which is the most southerly of three eruptive cones, close together, but not connected and of slightly varying material, lying along the backbone of the main ridge. The country rocks are of the Franciscan series. There has been no work done on these claims for years: and the holdings are now occupied by the cattle ranges of the Hearst estate.

Bibl.: CAL. STATE MIN. BUR., Reports VIII, p. 531; X, pp. 580, 581: XV, p. 718; Chapter rep. bien. period, 1915–1916, p. 124; Bull. 27, pp. 163–165.

Polar Star Mine (also called **Santa Clara, or Black Hawk**). This group of two claims, relocated in 1915, by A. L. Carpenter of San Luis Obispo, is in Sec. 13, T. 25 S., R. 6 E., M. D. M., in the cañon of San Carpojaro Creek, 3 miles above its mouth and 15 miles north of San Simeon. It has been worked sporadically since 1870 by various owners, the earlier operations being confined to retorting float material. Between 1890 and 1900, E. S. Rigdon and others, tried hydraulicking in an attempt to expose a vein. This has not yet been uncovered, although the surface dirt for several hundred feet up the steep hillside is said to carry cinnabar to the extent of 0.1%. Logan[1] states that he

"found no ore in place, but in the creek bed in the center of the claims he found a boulder of over a ton in weight which shows prospects of cinnabar, and some pieces of the ore which were left by the last operators contain good amounts of the sulphide. The rock in which the cinnabar makes its appearance is extremely hard, being apparently a highly metamorphosed and silicified sandstone. The large boulder no doubt came from either hillside nearby."

Bibl.: CAL. STATE MIN. BUR., Reports X, p. 581; XII, p. 366; XV, p. 718; Chapter rep. bien. period, 1915–1916, p. 124; Bull. 27, p. 165.

Rinconada Mine (also called **San José Valley Mine**). Mrs. Theresa L. Bell, owner, San José; C. B. Claus, lessee, Santa Margarita. This group of 4 patented claims, named San José, Rincon, Tres Amigos, and Livermore, is in Secs. 21 and 28, T. 30 S., R. 14 E., M. D. M., 11 miles southeast of Santa Margarita. It is, as noted in the introduction to San Luis Obispo County, quite apart from the main quicksilver district of this county which is in the northwestern part.

The property was located in 1872 and in 1876 was equipped with a furnace of the old sheet-iron type, with 5 sheet-iron condensers. The designer attempted to keep the mercury vapor separated from the fuel

[1] Logan, C. A., et al., Mines and mineral resources of Monterey et al. counties: Cal. State Min. Bur., chapters of State Mineralogist's report, 1915–1916, p. 125, 1917.

smoke, but the only definite result achieved appears to have been the salivation of the furnace employees. It is said that little if any quicksilver was recovered, and the plant was abandoned in 1883. In 1897, two benches of 10-pipe retorts were put up; some rich ore treated and a small production made, but no definite figures of which are now obtainable. The upper tunnel, said to be 75′ long, is now caved and inaccessible. Two intermediate adits were driven 40′ and 25′ respectively, and there is a lower adit 400′ long as well as several shorter ones and open cuts.

The country rock is largely serpentine, but some shale exposures are found in the bed of a creek about a quarter of a mile west of the main workings. The mine is in a basin formed by a bend of the mountain ridge. Through this basin runs a line of outcrops showing boldly in places. The face of the lowest adit is at the contact of the serpentine and sandstone. The ore thus far worked is stated to have occurred in small rich bunches, at times nearly solid cinnabar. Pyrite, calcite, dolomite, quartz and organic matter accompany the ore. It is to some extent disseminated, but usually occupies cracks in the rocks, which it often only partly fills. A former employee at the retort says that some ore gave 5 flasks from 2½ tons and in a few cases as much as 65 to 80 pounds were obtained from a single charge in one pipe. Some samples which have been assayed carried a little silver and iron sulphide with $2.60 per ton in gold, besides the quicksilver. A little ore was mined in 1915 and hauled to the retort on a sled. The capacity of the retorts is 3½ tons per day. Fuel is easily obtainable nearby, but timbers for mining are scarce.

Bibl.: CAL. STATE MIN. BUR., Reports X, p. 581; XII, p. 366; XIII, p 531; XV, p. 719; Chapter rep. bien. period, 1915-1916, p. 125; Bull. 27, p. 166. U. S. G. S., Mon. XIII, p. 381.

Sunset View Mine. In San Carpojaro district, in Secs. 13 and 18, T. 25 S., R. 6 E., M. D. M., southeast of the North Star mine. Idle for years.

Bibl.: CAL. STATE MIN. BUR., Report XV, p. 720; Chapter rep. bien. period, 1915–1916, p. 126; Bull. 27, p. 167.

Vulture Mine. Mark Rickles, owner, Cambria. It is on Vulture Mountain, in Sec. 24, T. 27 S., R. 9 E., M. D. M., 10 miles east of Cambria. The development has been insufficient to uncover any ore, although there are prospects of cinnabar. Only a little superficial and desultory work has been performed. It is located on an outcrop of black, flinty, siliceous rock, more or less charged with cinnabar, in a belt of serpentine.

Bibl.: CAL. STATE MIN. BUR., Report XV, p. 720; Chapter rep. bien. period, 1915–1916, p. 126; Bull. 27, p. 167.

Warren Ranch, adjoining the Oceanic Mine. W. W. Warren, owner. Float ore occurs over an area ¼ mile wide down a steep hillside from near the summit. Murray Innes, of the Oceanic Mine, drove a 60′ tunnel into the hill in an effort to find an orebody in place. Wm. Spargo also drove two tunnels totaling about 200′, but no deposit of any value was uncovered in either instance.

Bibl.: CAL. STATE MIN. BUR., Report XV, p. 720; Chapter rep. bien. period, 1915–1916, p. 126.

William Tell Mine in Sec. 32, T. 26 S., R. 10 E., M. D. M., west of the Klau mine, shows no new development in recent years.

Bibl.: CAL. STATE MIN. BUR., Report XV, p. 720; Chapter rep. bien. period, 1915–1916, p. 126; Bull. 27, p. 168.

Wittenberg Mine in Sec. 8, T. 27 S., R. 9 E., M. D. M., near the Oceanic mine, has been idle for a number of years.

Bibl.: CAL. STATE MIN. BUR., Report XV, p. 720; Chapter rep. bien. period, 1915–1916, p. 126; Bull. 27, p. 168.

SAN MATEO COUNTY.

Cinnabar was early noted on the Corte de Madera Rancho near Searsville in San Mateo County, west of Palo Alto. Some prospecting was done about 1863, but nothing of commercial value was found. About 1910, minute yellow crystals of the mercury oxychloride, eglestonite (Hg_4Cl_2O), were identified by Rogers,[1] about 5 miles west of Palo Alto in seams and cavities in a similar siliceous material to that so common in the serpentine of the cinnabar districts. The crystals showed on analysis 88.0% Hg. and 7.4% Cl, and were associated with cinnabar, mercury, calomel, dolomite, magnesite, opal and quartz. This is evidently the same locality as the first-mentioned, above.

Bibl.: CAL. STATE MIN. BUR., Bull. 67, p. 61. GEOL. SURV. OF CAL. Geol. vol. I, p. 71, 1865. AMER. JOUR. SCI., vol. 32, p. 48.

[1]Rogers, A. F., Eglestonite from San Mateo County; Amer. Jour. Sci., vol. 32, p. 48, 1911.

SANTA BARBARA COUNTY.

Quicksilver was discovered in Santa Barbara County at the Los Prietos mines in 1860. Seven years later cinnabar was found in Acachuma Cañon in the San Rafael Mountains. At both of these localities it has been mined intermittently for many years; but no segregated records of the production of Santa Barbara County previous to 1893 are available. The recent increases in the price of this metal has stimulated interest in the old mines and renewed activity in their development.

The available published records show the following quicksilver yield in this county:

Quicksilver Production of Santa Barbara County.

Year	Flasks	Value	Year	Flasks	Value
1893			1912		
1904			1913		
1905	52	$2,070	1914		
1906			1915	*	*
1907	60	2,289	1916	*	*
1908			1917	*31	*$4,196
1909					
1910	70	3,225	Totals	263	$14,081
1911	50	2,301			

*Combined to conceal outputs of single producers.

Acachuma Mine (probably same as the **Eagle Mine,** mentioned in some of earlier reports). In 1915, C. Woods of Santa Ynez was owner; present address, not known to the writer. It was one time worked by the Red Rock Quicksilver Mining Company, and is in Sec. 2, T. 7 N., R. 29 W., S. B. M., 12 miles east of Los Olivos at the head of Acachuma Creek. Development consists of several tunnels totaling 2000 ft. The orebody is mineralized serpentine and shales striking N. 40° W. and dipping 50° E. This is said to average 30 ft. in width. The ore was treated in a 12-pipe retort, 2 miles below the mine, on Acachuma Creek. A good wagon road runs from Los Olivos to the retort. This mine has been worked mostly by tributers. Idle.

Bibl.: Cal. State Min. Bur., Reports VIII, p. 537; XV, p. 746; Chapter rep. bien. period, 1915–1916, p. 153; Bull. 27, p. 196; Reg. of Mines, Sta. Barbara Co., 1906. U. S. G. S., Mon. XIII, p. 382.

Los Prietos Mines (includes the **Milburn-McAvoy** and **Snow** groups). F. M. Townsend, owner, 912 Higgins Building, Los Angeles. The original Los Prietos group apparently covered quite an extensive area, being situated within the old Rancho Los Prietos y Najalayegua grant. A few years ago, after lengthy litigation regarding titles, the United

States government purchased the grant and restored the land to the public domain. Following this, several mineral locations were made on portions of the ground containing old quicksilver workings. Among these were the claims of the Snow and Milburn-McAvoy (also called Santa Ynez Quicksilver Company) groups, taken over by the present owner in 1916. The property was not visited by the writer, but by Messrs. Huguenin and Tucker of the State Mining Bureau staff, and from whose notes the data herewith are compiled.

These mines are 8 miles in an air line directly north of Santa Barbara, in that portion of the Santa Ynez Mountains north of the river. They are in Secs. 9, 10, 11, 12, T. 5 N., R. 27 W., S. B. M. The group is located on a belt of mineralized serpentine, that extends along the range for several miles. Strike N. 50° W., dip southward. The width

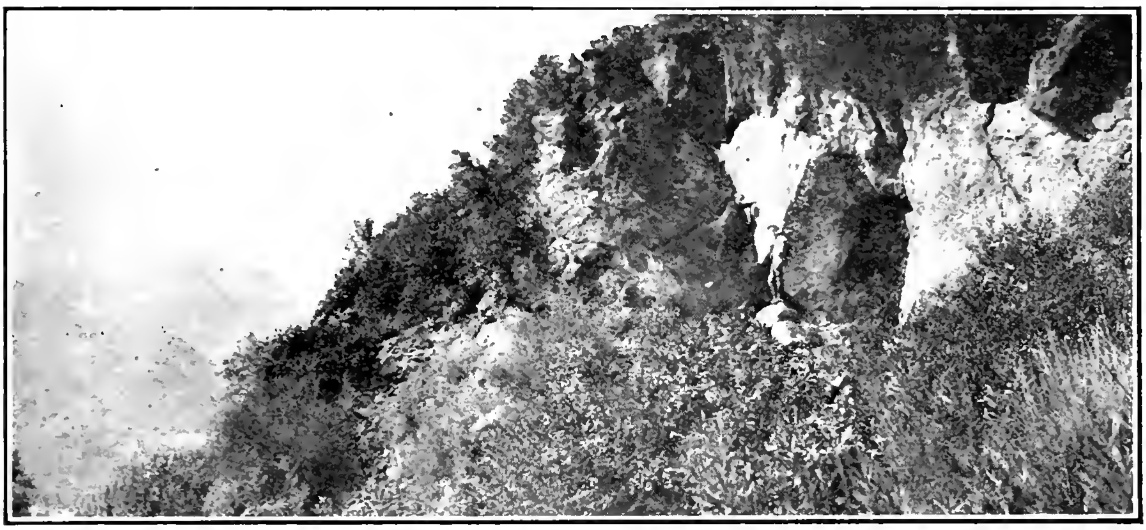

Photo No. 33. Open cut at Milburn-McAvoy (Los Prietos) Mine, Santa Barbara County, showing 'orebody' 65 feet wide. Photo by Carl Milburn.

of the orebody varies from 40′ to 200′, being a well-defined ledge. The ore, cinnabar, is disseminated through the ledge matter, and is in general low grade, said to average about 0.25% throughout. Occasionally rich pockets or shoots are encountered in which the ore will run up to 13%.

The footwall is serpentine, and the hanging-wall sandstone. The ledge can be traced for 3 miles. Considerable calcite is associated. This deposit was discovered in 1860 by José Moraga, but was not worked to any extent until 1874, when the price of quicksilver rose. A large furnace (now in ruins) was erected on the Santa Ynez River below the mine, and over 200 men were employed. Operations ceased in 1876 due to a decline in the price of quicksilver and prolonged litigation over the title to the property. Reopened in 1877 but has not since been worked on a large production basis. The property is somewhat inaccessible, being reached by trail over the Santa Ynez Mountains 13 miles from Santa Barbara, or by wagon road, 40 miles. It can also be reached via the Santa Barbara Water Tunnel, being two miles east of the north portal.

The old workings are somewhat extensive, and scattered over about 3 miles in length of the ledge. Most of them are caved, as the ground is soft. By driving a tunnel above high-water mark of the Santa Ynez River, 600 feet of backs can be gained. Power can be obtained from the Southern California Edison Co., by extending a line from the north portal of the Water Tunnel. In 1917, development work was confined to drifting from an old tunnel on the lower, or Snow, mine at the west end of the group. Five men were employed. A 12-pipe retort has been built. Recent advises (March, 1918), are to the effect that owing to heavy rains in February they have been compelled to shut down until the water subsides sufficiently in the river to enable them to get supplies across; also that some of their workings have caved. It is proposed to drive a lower adit, as suggested above.

Bibl.: Cal. State Min. Bur., Reports VIII, p. 537; X, p. 596; XII, p. 366; XV, pp. 746–748; Chapter rep. bien. period. 1915–1916, pp. 152–153; Bull. 27, p. 196. U. S. G. S., Mon. XIII, p. 382.

Mercur Claim. F. E. Willson, Goodwill mine, via San Luis Obispo, and O. W. Boeseke, Santa Barbara, owners. This claim was located in March, 1916, in T. 5 N., R. 27 W., S. B. M., adjoining the Milburn-McAvoy group, and therefore, on a portion of the old Los Prietos area. It is at the junction of Camuesa Creek and Santa Ynez River, 20 miles by road to Los Olivos and 10 miles by a good trail to Montecito. The vein is a fault or contact breccia between sandstone and serpentine and carries cinnabar in sandstone and shale. It is 20′–30′ wide, with strike N. 80° W., and dip 60° N. A 30′ shaft has been sunk, from which they have drifted 30′. Equipment includes an 11 h. p. gasoline engine, Braun 'rapid grinding mill,' jig, canvas tables, and a 2-pipe retort. Willson states that a small concentrating mill of 6 tons daily capacity was built in the summer of 1916 to test the ore; but owing to the hardness of the ore requiring fine grinding to release the cinnabar, extraction by concentration was found too expensive. A 2-pipe retort was later installed for further testing of the ore. A 4-ton run with this furnace on ore from a width of 6 feet on the footwall side of the vein yielded one flask (75 pounds) of quicksilver.

Santa Rosa Mine. D. D. Davis and Chas. R. Clark, owners, Los Olivos. This property is 18 miles by road northeast of Los Olivos, in Sec. 3, T. 7 N., R. 29 W., S. B. M., adjoining the Acachuma mine of which it is a continuation. The country rocks are serpentine and shale.

The vein is crosscut near the portal of No. 1 tunnel, where it shows 7′–8′ in width. No. 2 tunnel, 25′ lower than No. 1 is in 90′ and will be driven another 50′. There is no reduction equipment as yet.

Bibl.: Cal. State Min. Bur., Report XV, p. 748; Chapter rep. bien. period, 1915–1916, p. 154.

Steward Mine adjoins the Acachuma mine. Some development work was done here over 12 years ago, but no quicksilver produced. Abandoned.

Bibl.: Cal. State Min. Bur., Report XV, p. 748; Chapter rep. bien. period, 1915–1916, p. 154; Reg. of Mines, Santa Barbara Co., 1906.

SANTA CLARA COUNTY.

The first known occurrence of quicksilver within the area of the United States, was that found at the New Almaden mine in Santa Clara County in 1824 by Antonio Suñol and Louis Chaboya. Though some occurrences had apparently been earlier noted in Mexico, the New Almaden was the first producing quicksilver mine in North America. Suñol and Chaboya built a mill nearby and endeavored to extract silver from the cinnabar. Late in 1845, the ore was shown to Andreas Castillero,[1] a Mexican officer, who identified it as cinnabar, and under whose direction development work was immediately begun. Gun barrels were utilized as their first retorts. The output was small, however, until after California became part of the United States, since which time more than a million flasks have been produced in this county, as may be noted from the tabulation herewith, the greater portion of which came from the New Almaden mine.[2]

The quicksilver deposits of Santa Clara County are confined, with one exception, to what is known as the New Almaden district (see Plate XVIII). This district lies east of south from San José, extending from the northeasterly foothills of the Gabilan Range on the west to the low foothills that lie between Coyote and Dry Creeks on the east. It also embraces the Santa Teresa Hills, a low spur ridge which lies between and in general parallel to the other two. The principal deposits are 8 to 13 miles from San José, on the ridge which forms the southwestern boundary of the Santa Clara Valley at this place, having a general NW-SE direction, and locally called the New Almaden Ridge.

The geology of this district and particularly of the New Almaden ridge and its orebodies has been described in considerable detail by various writers, especially by Becker[3] and by Forstner,[4] the latter of whom says:

"The three ridges in which the deposits occur are to a great extent formed by serpentine, especially the two first named. The serpentine is associated with metamorphic sandstone and jaspilites. Large bodies of croppings can be found in each of these ridges, having also a general northwestern trend, but not coinciding with the backbone of the ridges.

"In the New Almaden ridge the most extensive orebodies have been found in and close to Mine Hill, the highest peak of the ridge, lying in its southeastern part. From this point going northwestward the croppings, while not continuous, can be traced along the ridge into the territory of the Guadalupe mine, a distance of about 3½ mines. At the surface the serpentine shows in large detached bodies surrounded by the sandstones and shales of the Franciscan series and having a general northwestern trend. This general direction of the serpentine exposures is important in connection with its occurrence underground, proven in the New Almaden mine. The line of ore croppings runs from Mine Hill to the American shaft, passing about 600 feet southwest of the Randol shaft. The underground workings in this territory have shown

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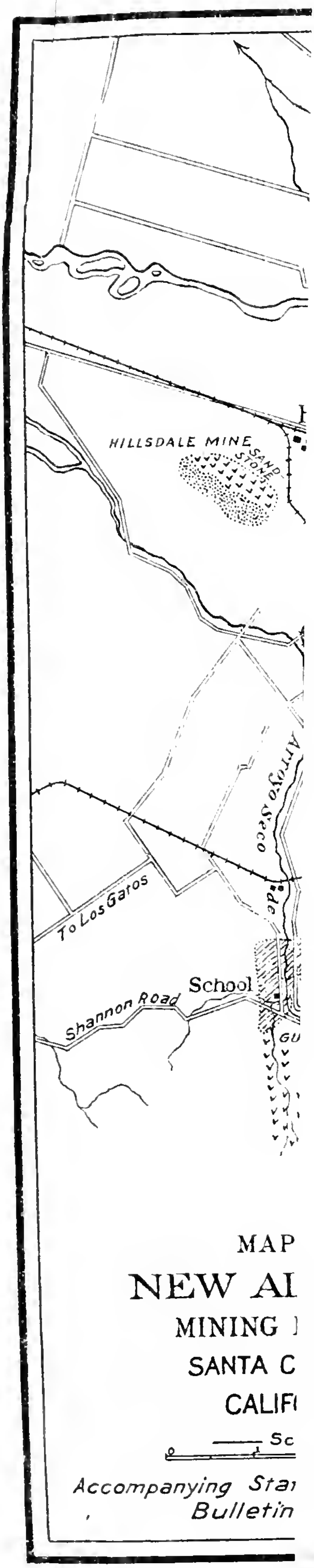
[1]Black's Supreme Court Reporter: The United States vs. Andreas Castillero: vol. 2, 1862. Also U. S. G. S., Mon. XIII, pp. 8–10, 1888.

[2]A portion of the data herewith relating to the quicksilver mines of this county is taken from the manuscript of a report on the "Mines and Mineral Resources of Santa Clara, et al. counties" by Emile Huguenin: Cal. State Min. Bur., biennial period, 1917–1918, in preparation. This has been supplemented by later observations of the present author with particular reference to plant equipment.

[3]Becker, G. F., Geology of the quicksilver deposits of the Pacific Slope: U. S. Geol. Surv., Mon. XIII, pp. 310–330, 467, 1888.

[4]Forstner, Wm., Quicksilver resources of California: Cal. State Min. Bur., Bull. 27, pp. 168–171, 1903.


HILLSDALE MINE
SAND STONE
Arroyo Seco
To Los Gatos
School
Shannon Road
MAP
NEW AL
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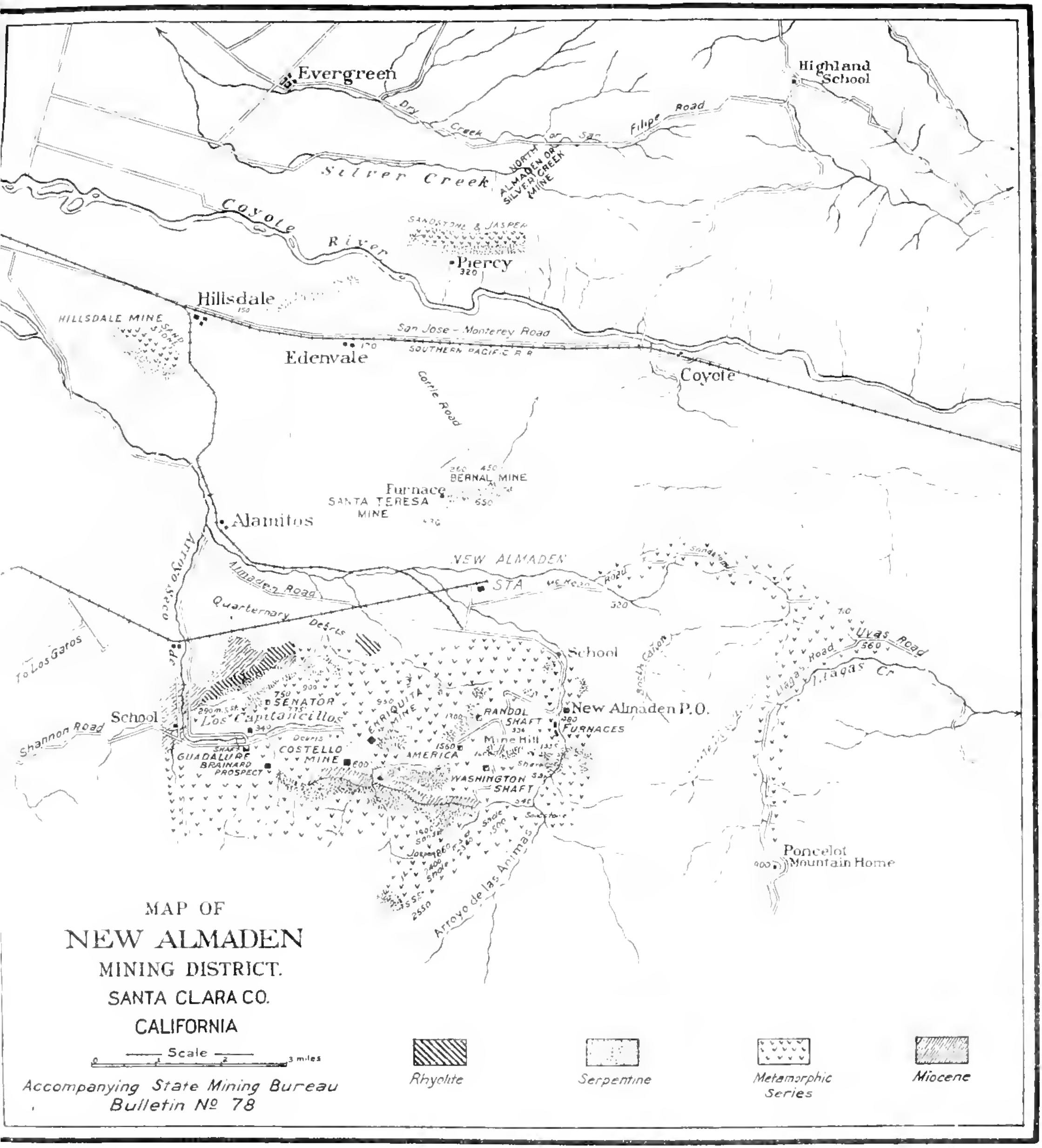

Evergreen
Highland School
Dry Creek or San Filipe Road
Silver Creek
NORTH ALMADEN OR SILVER CREEK MINE
Coyote River
SANDSTONE & JASPER
Piercy
Hillsdale
HILLSDALE MINE
SANDSTONE
San Jose - Monterey Road
SOUTHERN PACIFIC R.R.
Edenvale
Coyote
Cottle Road
BERNAL MINE
Furnace
SANTA TERESA MINE
Alamitos
Arroyo Seco
NEW ALMADEN STA
Almaden Road
Quarternary Debris
To Los Gatos
School
Uvas Road
Llagas Road
Llagas Cr
SENATOR
Los Capitancillos
ENRIQUITA MINE
RANDOL SHAFT
New Almaden P.O.
FURNACES
Shannon Road
School
GUADALUPE SHAFT
BRAINARD PROSPECT
COSTELLO MINE
AMERICA
Mine Hill
WASHINGTON SHAFT
Arroyo de las Animas
Poncelot Mountain Home
MAP OF
NEW ALMADEN
MINING DISTRICT.
SANTA CLARA CO.
CALIFORNIA
Scale
3 miles
Accompanying State Mining Bureau
Bulletin № 78
Rhyolite
Serpentine
Metamorphic Series
Miocene

that the fissures wherein the orebodies have formed have invariably a serpentine footwall; hence the serpentine must be considered to occur underground in a continuous body through this entire territory and to be in places covered by overlying sandstones and shales. Southwest of Capitancillos Creek lies another parallel exposure of serpentine, contiguous to which the outcrops of the Costello mines are found. The Santa Teresa and Bernal mines are located in the serpentine of the Santa Teresa hills, and the North Almaden or Silver Creek mine close to those of the most northern ridge. In the latter a great part of the serpentine is very highly altered by silicification, as also the sandstones, a great portion of the rocks being jaspilites. The western slope of the adjoining Mount Diablo range is nearly exclusively formed of shales.

"In this district the occurrence of cinnabar-carrying orebodies is clearly closely allied to that of serpentine, and as the New Almaden was the first extensively worked quicksilver mine in California, this association explains the reason why, for a considerable lapse of time, cinnabar ores were, in the opinion of most quicksilver miners, considered related to this rock formation. The croppings consist of a more or less weathered material having usually an ochreous color from the oxidation products of the iron sulphides, and traversed by a network of quartz seams, from a knife blade to quarter of an inch wide. Overlying the ore bodies is almost invariably found a body of clay, generally black, and containing more or less inclusions of a dark-gray sandstone. As this clay overlies the ore bodies it has received the name of 'alta' (Spanish for 'high' or 'upper'). At the surface this 'alta' crops as a light-gray material, resembling disintegrated sandstone, traversed by a network of very thin, yellowish-brown seams, often very much like a bunch of very fine roots. In places the same material can be found in the New Almaden mine several hundred feet below the surface, forming part of the 'alta.' * * * The rocks of the Franciscan series in this region show a great amount of silicification. The chert beds are, however, almost entirely unrepresented.

"To the west of the New Almaden ridge a belt of bedded sandstone is exposed. The beds are from 3 to 5 feet thick and interbedded with thinner beds of shale. * * * The country west of the New Almaden ridge and south of Capitancillos Creek, belonging to the Gabilan mountain system, consists almost exclusively of the sandstones and shales of the Franciscan series with occasionally some jaspilites. * * * West of the serpentine belt which lies west of the New Almaden ridge, south of Costello's house, a small exposure of glaucophane schist was found. A body of rhyolite lies in the northern part of the New Almaden ridge, having a nearly east and west strike and being about two miles long."

The alta, or so-called clay referred to above, is not a substance of definite composition, though it is usually a dark or black mass, readily distinguishable even in hand specimens from the country rock. It is simply an attrition product of the country rock and varies in composition with the material from which it has been produced. Its black color is in part due to the presence of manganese.

With reference to the age of the formations in the New Almaden district, Becker[5] summarizes his observations in the following:

"Upon highly metamorphosed rocks lie Miocene sandstones, which were sharply folded at the Post-Miocene upheaval. They are not conformable with the lower series and contain pebbles from these older beds. In the older rocks near New Almaden Mr. Gabb found *Aucella*, proving the presence of the Knoxville series.

"In this district is the only mass of rhyolite thus far found in the Coast Ranges. It forms a dike nearly parallel to the line connecting the New Almaden and the Guadalupe. It is almost continuous, and I have followed it for a distance of several miles. It is certainly Post-Miocene and probably Post-Pliocene.

"The New Almaden is a very extensive mine * * *. The ore is cinnabar, with occasional traces of native quicksilver, accompanied by pyrite and marcasite, with rare crystals of chalcopyrite. The gangue is quartz, calcite, dolomite, and magnesite. These materials were deposited in shattered masses of pseudodiabase, pseudodiorite, serpentine, and sandstone. * * *

"The other mines of the district contain similar ores in similar rocks. The Guadalupe was the most productive. * * *

"All the deposits of the district appear to occur along a rather simple fissure system. The main fissure is nearly parallel to the rhyolite dike at the Guadalupe. It follows the direction of the hills, the axis of which curves gradually away from the dike for a certain distance. Passing through or near the San Antonio and Enriquita, it seems to break across the ridge at the America and enters the Almaden on the strike of its two great fissures. It is near this fissure that new orebodies are most likely to be found. The Washington seems to be on a branch of the main fissure.

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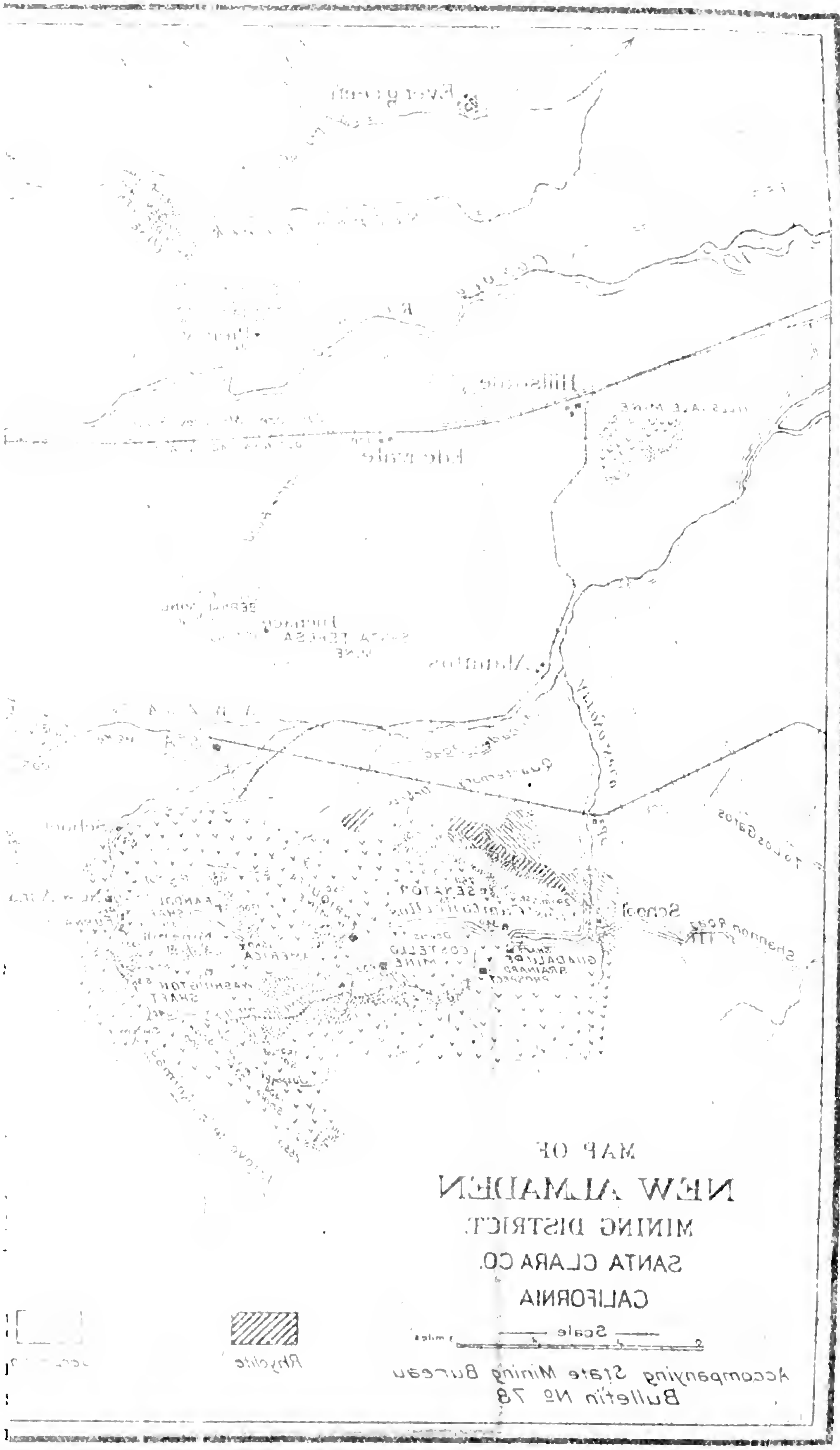
[5] *Op. cit.*, p. 467.


MAP OF
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To Los Gatos
Shannon Road

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"This was probably formed at the time of the rhyolite eruption, to which also I ascribe the genesis of the ore."

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[5]*Op. cit.*, p. 467.

Also:[6]

"This dike not only proves the former existence of volcanic activity in this district, but emphasizes a fundamental structural axis. The character of the metamorphic rocks shows that the line along which compression and upheaval took place in the early Cretaceous was about west by north, east by south. The folding of the Tertiary rocks shows that compression was repeated in the same direction at the close of the Miocene. The position of the rhyolite dike proves that the dislocation which opened a passage for this lava again followed a similar course."

Also:[7]

"Ore deposition followed the eruption of lava. The minerals deposited and the manner of their deposition are such as in the more northerly quicksilver districts were induced by volcanic springs. Though there are now no indubitable remnants of the volcanic activity which certainly prevailed here since the beginning of the Pliocene, the analogies of the deposit, together with the presence of lava of approximately the same age as the ore, make any theory of deposition excepting from hot sulphur springs improbable."

There have been but two mines of consequence developed in this district, the New Almaden and Guadalupe, though there are a number of small properties which have at times produced a few flasks of quicksilver. The total recorded output of quicksilver from this county is given in the following tabulation:

Quicksilver Production of Santa Clara County.

Year	Flasks	Value	Year	Flasks	Value
1850	7,723	$768,052	1885	21,400	$658,050
1851	27,779	1,859,248	1886	18,000	639,000
1852	15,901	927,505	1887	20,000	847,600
1853	22,284	1,235,648	1888	18,000	765,000
1854	30,004	1,663,722	1889	13,100	589,500
1855	29,142	1,560,554	1890	12,000	630,000
1856	27,138	1,401,678	1891	8,200	371,105
1857	28,204	1,374,381	1892	5,563	226,470
1858	25,761	1,232,149	1893	6,614	243,064
1859	1,294	81,690	1894	7,235	222,169
1860	7,061	378,117	1895	7,050	253,800
1861	34,429	1,447,739	1896	6,222	211,570
1862	39,671	1,442,041	1897	4,700	169,200
1863	32,803	1,380,350	1898	5,875	235,000
1864	42,489	1,950,245	1899	4,435	186,270
1865	47,194	2,166,205	1900	5,145	241,073
1866	35,150	1,867,519	1901	5,220	236,608
1867	24,461	1,122,760	1902	5,869	254,260
1868	25,628	1,176,325	1903	5,603	233,130
1869	16,898	775,618	1904	†3,889	148,103
1870	14,423	827,592	1905	2,693	95,968
1871	18,568	1,171,611	1906	2,592	94,608
1872	18,574	1,224,584	1907	2,518	96,086
1873	11,042	887,004	1908	2,460	103,984
1874	9,084	995,455	1909	3,747	158,490
	*20,000	*1,098,000	1910	4,038	182,719
1875	16,980	1,428,867	1911	7,533	346,593
1876	27,930	1,228,920	1912	8,695	365,538
1877	30,237	1,127,840	1913	3,709	149,213
1878	24,924	820,000	1914	2,407	118,063
1879	36,054	1,076,212	1915	4,386	376,319
1880	30,135	934,185	1916	4,016	375,496
1881	31,288	933,321	1917	5,921	639,594
1882	29,208	824,542			
1883	29,084	836,165	Totals	1,127,380	$52,299,517
1884	20,000	610,000			

*Estimated production of Guadalupe Mine previous to 1875.
†Flasks of 75 pounds since June, 1904; of 76½ pounds previously.
[6] *Idem*, p. 314.
[7] *Idem*, p. 328.

Bernal Mine. Mrs. Ygnacio Bernal, owner, Edenvale. It is 10 miles southeast of San José, on the east slope of the Santa Teresa hills, at an elevation of about 450 feet. A tunnel, over 200′ long, was driven along a clay gouge and serpentine contact, many years ago; but failed to encounter any important orebody, so it was abandoned. No work has been done in recent years.

Bibl.: CAL. STATE MIN. BUR., Bull. 27, p. 171; Chapter rep. bien. period, 1917–1918, in prep.

Bowie Prospect, New Almaden district. Circle B. Mining Company, owner. Prospect only. Idle.

Brainard Prospect. This is on patented property owned by Mrs. M. D. Brainard et al. of San José, situated south of the Guadalupe mine, and west of the northern end of the New Almaden lands. There is an old adit in which it is stated some cinnabar-bearing material was cut, but there has been no work done in recent years.

Comstock Mine. T. H. French, owner. Lone Tree via Hollister. It is in the extreme southeastern corner of Santa Clara County, in Sec. 19, T. 11 S., R. 7 E., M. D. M., and in the Stayton district most of which lies in San Benito and is described herein under that county. The Comstock mine is located on the only surface exposure of serpentine found in the Stayton district. Abandoned some years ago.

Bibl.: CAL. STATE MIN. BUR., Report XII, p. 367; Bull. 27, p. 172: Chapter rep. bien. period, 1917–1918, in prep. MIN. RES. W. OF ROCKY MTS., 1875, p. 14.

Costello Mine. M. Costello, owner, New Almaden. It is about 1½ miles by road southeast of the Guadalupe mine, on the hillside above Los Capitancillos Creek at an elevation of about 1000′. It is a prospect only and no ore was found in place. It has been idle for a number of years.

Bibl.: CAL. STATE MIN. BUR., Bull. 27, p. 172; Chapter rep. bien. period, 1917–1918.

Guadalupe Mine. New Guadalupe Mining Co., owner; Hugh C. Davey, president; John L. Stubbs, vice-president; Chas. W. Aby, treasurer; Route A, Los Gatos. This property, covering a territory of 2500 acres, is situated 10 miles south of San José on the west slope of New Almaden Ridge, and adjoins the land of the New Almaden company on the northwest. The mine was discovered in the early 50's and is said to have produced 20,000 flasks of quicksilver up to 1875, when it became the property of the Guadalupe Mining Company. This company erected furnaces and made many surface improvements. In 1886 the mine was shut down due to litigation, remaining idle until 1900

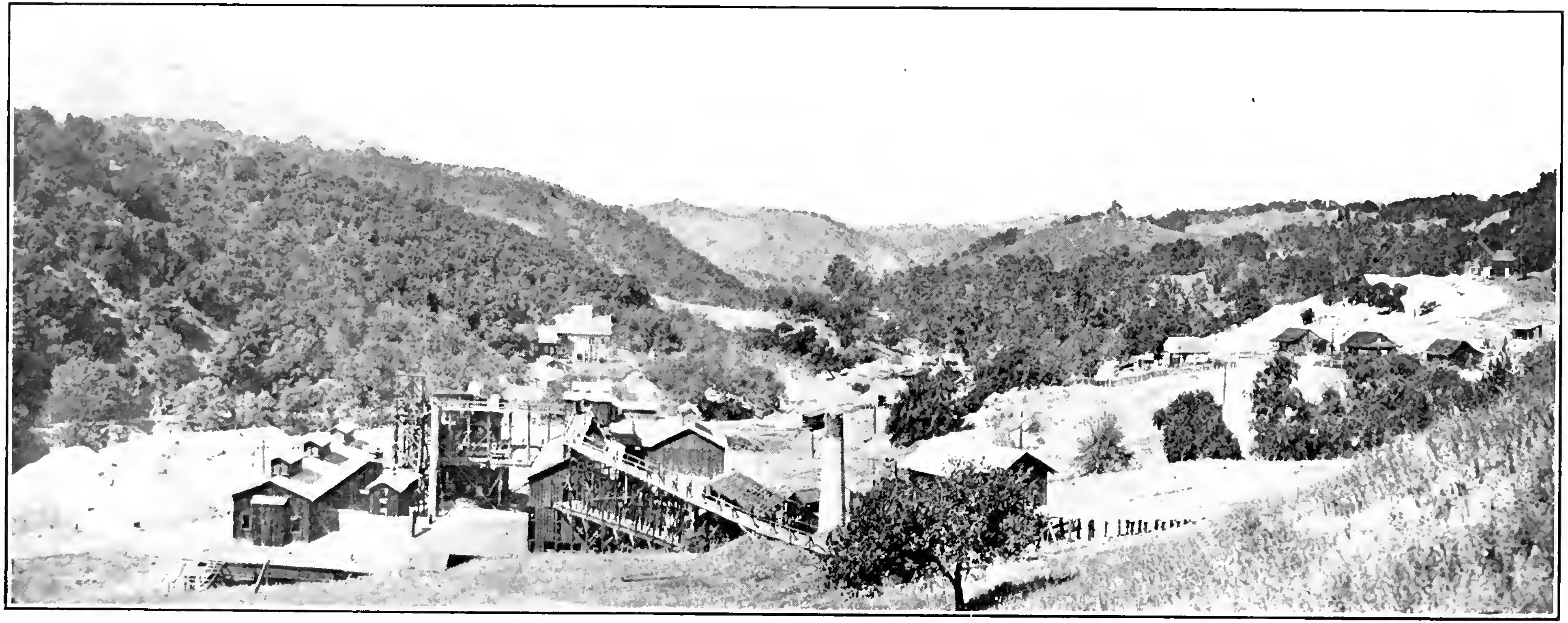

Photo No. 34.—Guadalupe Mine, Santa Clara County. Furnaces in foreground; old vertical-shaft house in middle distance; main working incline shaft at extreme right.

when H. C. Davey, one of the present owners, organized the Century Mining Company. The old furnaces were remodeled, the mine unwatered, and operations resumed, since which time it has been an important and continuous producer. The total recorded output has been 105,772 flasks to the end of 1917.

The mine was first worked by a vertical shaft, 625′ deep, sunk on the south side of, and near the bottom of Capitancillos or Guadalupe Creek. It was very difficult to keep the surface water out of this shaft during the wet seasons, and it was finally abandoned. A 700-foot incline, which is now the main working shaft, was then sunk on the opposite side of the creek on the dip of the vein (see Photo No. 34). It has 3 compartments down to 180′ on the incline (where it connects with No. 1 Tunnel, whose portal is just above the creek bed), and 2 compartments below that. There are many miles of underground workings in the Guadalupe. Several shallow shafts and drifts have been driven on different outcrops about the property, but mining is now confined to the main workings.

From the plan of the old workings, it appears that the orebody developed by the vertical shaft on the south side of the creek had a northwest strike and southwest dip. The second level, 300′ below the collar of the vertical shaft, connects with the incline shaft on the opposite bank of the creek. From the sixth level (625′) of the vertical shaft an incline winze was sunk from which the seventh, eighth and ninth levels were driven; but ore was developed only on the seventh and eighth levels. The ore of the Guadalupe mine is similar in appearance to that of the north-end New Almaden ground, being in part at least a silicified serpentine with cinnabar. There is some associated pyrite. When visited by the writer in September, 1917, the bed of the creek was being replaced by a concrete flume, 740′ long and 55′ wide, with side walls 9′ high, to carry the stream over the portions of the old mine beneath. There is a 1′ high cross-wall every 100′ to hold the gravel and protect the flume floor from excessive wear. With this improvement in service, it is intended to un-water and again open up the old workings. Electric power will be used.

Equipment includes electric hoists, air compressors and machine drills. The reduction plant consists of 2 coarse-ore furnaces of 18 tons capacity each, and 2 fine-ore furnaces of 30 tons capacity each, all oil-burning, and modeled after the Davey patents. The ore is broken to cobble size and sorted by hand in the mine, the waste being partly used to fill old stopes. At the surface, the ore is screened, and then trammed by mule-drawn trains to the fine and coarse-ore furnaces respectively. The fine ore is passed through a rotary drier, 29′ long x 28″ diam., lined with one row of fire-brick, and driven by a 3 h. p. electric motor at 2 r. p. m. The discharge is directly into the feed end of the fine-ore furnace, in a sealed compartment to prevent escape of any mercury vapors that might be present.

A concentrating plant of 50 tons daily capacity was built, and started operating in February, 1917, handling material from the old mine dumps. Crushing is done in a ball mill with 20-mesh screen. After classification, the fine pulp goes to a Deister table, and the sand to two Wiltleys. The plant is driven by a 25 h. p. semi-Diesel oil engine. The concentrates are said to assay 8%–10% mercury, and are reduced in the fine-ore furnaces. In September, 1917, there were 75 men employed, 25 of whom were underground.

Bibl.: Cal. State Min. Bur., Reports, VIII, p. 542; XIII, p. 600; Bull. 27, p. 173; Chapter rep. bien. period, 1917–1918 in prep. Min. Res. W. of Rocky Mts., 1875, p. 13; 1876; p. 20. U. S. G. S., Mon. XIII, p. 326.

Hillsdale or **San Juan Bautista Mine** (one time called **Chapman**; also **Chaboya**). Elizabeth Kohrs, owner, Hillsdale via San Jose, R. F. D. It is about 2 miles southeast of San José on the east slope of the San Juan Bautista Hills, and within one-half mile of a street-car line. These hills, an isolated group, composed of metamorphic rocks, largely serpentine, rise to a height of only a few hundred feet above the valley, and are a northward continuation of the Santa Teresa Range.

The mine is said to have been discovered in 1847 and worked to 1861 by Mexicans, subsequently becoming the property of a Mr. Chapman who worked it up to 1874. In the spring of 1871, production was at the rate of 30–40 flasks of quicksilver per month.[1] It lay idle from 1874 until 1892, when it was reopened by R. H. Harper of San José, and worked spasmodically in a small way up to 1907. In 1915, under the name of New Discovery Quicksilver Company, a lease and bond was taken and a few flasks of quicksilver produced; but little work was done underground, and the lease forfeited. R. H. Harper was recently reported to be negotiating for the purchase of the property. There are said to be over 4,000 feet of underground workings, but most of the tunnels are now inaccessible, being caved. The reduction plant consists of two 12-pipe retorts, evidently built in later years, as they are in good condition.

Bibl.: Cal. State Min. Bur., Report XIII, p. 600; Bull. 27, p. 174; Rep. bien. period, 1917–1918, in prep. Geol. Surv. of Cal., Geol. vol. 2, pp. 112–113.

New Almaden Mine (originally **Chaboya**; then **Santa Clara**). The Quicksilver Mining Company, owner; New Almaden Company, Inc.,

[1]Goodyear, W. A., Report on examination of quicksilver mines in California: Geol. Surv. of Cal., Geol. vol. 2, pp. 112–113, 1882.

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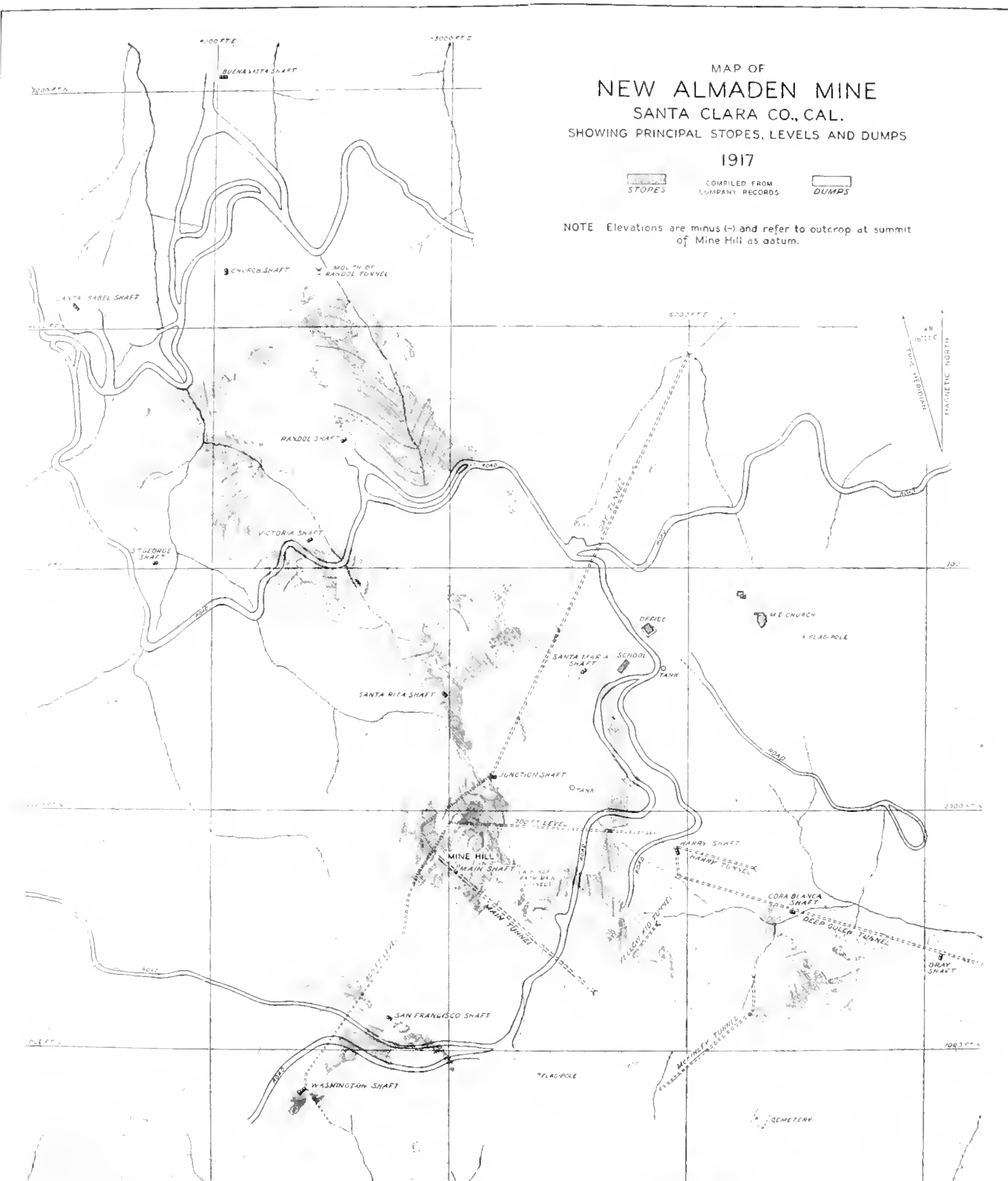
[1]Forstner, Wm., Quicksilver resources of California: Cal. State Min. Bur., Bull. 27, p. 175, 1903.



Accompanying Bulletin No 78, California State Mining Bureau.

lessee; Geo. H. Sexton, president, 45 Broadway, New York; Chas. A. Frank, secretary and treasurer; Edmund Juessen, general manager, 57 Post Street, San Francisco. This property, covering over 8000 acres, lies from 8 to 13 miles east of south from San Jose′ along the New Almaden Ridge, and was at one time second only in production to the famous Almaden mine in Spain, after which it was named. This property is the oldest known quicksilver mine in the United States, being first worked in 1824 by Antonio Suñol and Luis Chaboya. In 1845, Andreas Castillero, a Mexican army officer, 'denounced' (located) it under the name of Santa Clara. After the admission of California into the Union, Castillero and associates leased the mine to Barron Forbes & Co., who changed the name to New Almaden. It has been worked continuously since 1845, but the greatest surface improvements were made after it became the property of The Quicksilver Mining Company in 1864.

Many important practices and appliances in the metallurgy of quicksilver had their beginning here, including the development of the Hütt-ner-Scott fine-ore furnace in 1875–1876. The present operating company took over the property under a lease and bond in 1915. The total production has been 1,021,183 flasks of quicksilver, to the end of 1917, surpassed by only one mine in the world (Almaden Mine, Spain) during the period in which New Almaden has been operating. Published records show that this total, however, has been exceeded by the Idria mine, Austria, and the Santa Barbara mine, Huancavelica, Peru, the bulk of whose production was made prior to 1850; in fact, Huancavelica has yielded but little quicksilver since 1800.

GEOLOGY AND MINE WORKINGS.

The New Almaden property really contains three mines, all of which are located on the same mineral belt: the great New Almaden mine proper, the Enriquita, and the Senator or El Senador as the Mexicans named it (also referred to as the North Line Mine). A distance of nearly 4 miles separates the first and the last-named. The workings of the main New Almaden mine, cover a territory of about 2½ square miles, which is exclusive of the Enriquita and Senator; and their greatest depth is 2450 feet below the top of Mine Hill, which is the datum point for all underground workings. The elevation of Mine Hill is 1600′ above sea-level. In this territory 18 shafts have been sunk, and there are nearly 100 miles of underground excavations, much of which is at present inaccessible. Forstner states[1] that in 1903, the Victoria shaft, a short distance to the southwest of the Randol shaft, and the Harry shaft, on the southeast slope of Mine Hill (see Plate XIX) were the

[1]Forstner, Wm., Quicksilver resources of California: Cal. State Min. Bur., Bull. 27, p. 175, 1903.

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[1]Goodyear, W. A., Report on examination of quicksilver ... California: Geol. Surv. of Cal., Geol. vol. 2, pp. 112-113, 1882.

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[1]Forstner, Wm., Quicksilver resources of California: Cal. State Min. Bur., Bull. 27, p. 175, 1903.

only two shafts then in operation. The deepest workings then being followed were on the 1000′ level, as below 1300′ the mine was filled with water. Since that time, most of the work has been done through the Harry shaft and the Day tunnel, and more recently at the Senator mine.

Geology.

The geology of the New Almaden mine has been studied and described in considerable detail by a number of authors, the most important of whom was Becker. He states:[2]

"The ores * * * are composed of the usual association of minerals: cinnabar (sometimes accompanied by a little native mercury), pyrite, quartz, calcite, and dolomite, and more or less closely associated masses of bituminous matter. Accompanying the deposits is a small amount of chalcedony or opal, usually black in color, but this substance is much less abundant here than in the greater part of the northern mines. Dolomite is more prevalent as a gangue mineral here than in most quicksilver districts * * *.

"The rocks associated with cinnabar in this district include every variety of the metamorphic series. Where the rock happens to be a permeable sandstone, impregnations have resulted. Elsewhere the ore seems to occur exclusively in crevices in the rock * * * I was unable to perceive any indication that ore had been deposited by substitution or that the rock had influenced the deposition of ore by its chemical properties. Ore is found with nearly equal frequency in contact with various rocks and the existence of fissures appears to have been the necessary and sufficient condition for the deposition of cinnabar and gangue minerals. * * *

"The ore in the New Almaden mine seems never to occur except close to evidences of faulting. This evidence consists in the presence of layers of attrition products, so-called clays, full of slickensides and of fragments of rocks more or less rounded by attrition. These layers of clay usually occur on the hanging side of deposits and are known to the miners as altas, the Spanish term for hanging-walls. The clays are impermeable to solutions and the ore usually forms on their lower side, as if the cinnabar had ascended and been arrested by the altas. * * *

"While the evidence of the existence of a fissure system is, if possible, more abundant in the New Almaden mine than in most quicksilver deposits of the Pacific Slope, the deposits themselves are of various types. The commonest is the reticulated mass, or stockworks, consisting of irregular bodies of broken rock into which solutions of cinnabar and gangue minerals have filtered, cementing the fragments together with ore. Where the disturbance has been less extensive and irregular, clean-cut fissures may sometimes be seen filled with ore, and these can only be classified as veins, though they are not persistent. * * *

"Certain features must be common to the ore bodies taken singly and to the ore-bearing ground as a whole. It would be impossible to suppose that each stockwork has an independent fissure system, and a mere glance at the mine map shows that a connection between them exists. It is also a historical fact that the thin seams of ore * * * have led from one ore chamber to another. * * *

"The distribution of serpentine, the average strike of the metamorphic strata, the compression of the Miocene beds, the position of the rhyolite dike, and the trend of the range, in short the whole structural geology of the region shows that the fundamental axis of disturbance must have a direction which is approximately northwest and southeast."

Also:[3]

"Considered in detail, the ore bodies are stockworks; but they are arranged along definite fissures and the deposits as a whole have a vein-like character and answer to the 'chambered veins' defined in a subsequent paragraph. The workings have developed two main fissures. One of these dips from the surface at a high angle and in a nearly straight line. The other strikes in nearly the same direction as the first, dips steeply from the surface, then flattens and approaches the first fissure rapidly, again becomes very steep, and in the lowest workings almost coincides with the first. In vertical cross-section the two fissures form a figure resembling a V. The great ore bodies are distributed along these two fissures, making irregularly into the walls. The wedge between the fissures also contains ore bodies."

Mine Hill Workings.

The surface and workings of the New Almaden mine have been minutely surveyed and the data carefully preserved by the officers of the Quicksilver Mining Company in the form of a large, detailed,

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[2]Becker, G. F., Quicksilver deposits of the Pacific Slope: U. S. Geol. Surv., Mon. XIII, pp. 314 et seq. 1888.

[3]*Op. cit.*, p. 467.

colored map which hangs in a specially-constructed fireproof draughting room, adjoining the office at the Hacienda. An excellent reproduction of this map, up to the date of its publication, 1888, accompanies Becker's report.[4] The map herewith (Plate XIX) was compiled from the company's records and is reproduced herewith by courtesy of Mr. Edmund Juessen, general manager. The principal dumps are shown in brown with the surface contour lines. The principal orebodies extracted since Becker's publication of the map, are indicated by: 1. The N-S line of stopes to the west of and nearest the Harry shaft. 2. The line of stopes lying approximately at right angles across the northwestern end of the older stopes, and extending southwesterly from the 'mouth of Randol tunnel.' 3. Portions of the stopes south of the Cora Blanca shaft.

The ore deposits are limited on their hanging-wall side by the alta, which being an impermeable layer prevented the passage of water circulation. According to Forstner,[5] the footwall side is persistently serpentine, from which it is concluded that the serpentine, or rather the intrusive peridotite which has altered to serpentine, is the cause of the fracturing of the other rock strata.

"The fracturing has taken place on both sides of the serpentine, which apparently can not be considered otherwise than as an intrusive body having uplifted the rocks of the Franciscan series.

"The ore bodies form principally in those parts of the zones where the dip of the 'alta' is very flat * * *. The contact of the alta with the underlying vein filling, and where this is missing with the serpentine, is very tortuous in both directions, vertically and horizontally, so that in the gangways, which * * * follow this contact, it is an exception to find a straight line of any length. The stopes are locally called 'labores.' The material which fills the zones of fracturing and wherein in places cinnabar forms, is generally rather hard and siliceous, traversed by a network of seams of quartz and dolomite, showing repeated fissuring and filling containing some inclusions of serpentine, the cinnabar forming principally in connection with the seams. In places the vein-filling has more of an ochreous character, the matrix being more or less leached out, leaving only the network of seams intact. * * *

"The general character of the vein-filling indicates that, as in most of the other quicksilver deposits in the State, the deposition of cinnabar has been associated with the process of silicification, which characterizes the alteration of the rocks of the Franciscan series.

"The general direction of the seams in the vein-filling is not parallel to the line of contact with the alta. * * * In the upper workings the part nearest to the alta is seldom the richest, the cinnabar forming more plentifully at from 5′ to 8′ below the alta, while in the lower workings the richest ore is invariably close to the alta.

"The contact between the alta and the vein-filling is very sharply marked, but there is a gradual change of the above-described vein-filling into the material of the serpentine foot-wall, the vein material gradually carrying more serpentine, until it has entirely changed into the latter. The hanging-wall is a shale, judging from surface exposures. Underground, no crosscut through the alta to the hanging-wall was seen."

Recent work.

When visited by the writer in September, 1917, some ore was being broken in stopes connected with the Day tunnel, and which it was intended to burn in the coarse-ore furnaces at the Hacienda. Plans were being made to drive a connection on the 800′ level, from the Santa Rosa drift near the main shaft, to Deep Gulch tunnel. This will permit of tramming around the hill to the Hacienda furnaces, a distance of about ½ mile, or about one-half that now traveled for delivery from

[4]*Op. cit.*, Atlas Sheet IX.
[5]*Op. cit.*, p. 178.

the Day tunnel. Equipment at the mouth of the Day Tunnel includes an Ingersoll-Rand duplex compressor, 16″x14″ and 10″x 14″, driven by a 100 h. p. electric motor.

Senator workings.

The principal ore extraction of recent months has been from the Senator workings, which are, as already stated in a preceding paragraph, nearly 4 miles distant from Mine Hill. This ground adjoins that of the Guadalupe mine, they being on opposite sides of the same ridge. A new 'shaft' (winze) is being sunk, on a 60° incline, starting at 1300′ in from the portal of the main adit. The collar of the old winze is at 1150′ in. An electric hoist with 75 h. p. motor is used. The tunnel level is designated as the 260′ level, and levels down to #5 have been established in the winze, with sinking nearing #6 level. Only a little sorting is done in the stopes underground. The ore going to the furnaces is stated to vary from 0.2% to 1.0% mercury. The formations and orebodies in the Senator and Enriquita mines are in general similar to those at the southern end of the New Almaden belt, but no bonanza shoots have been found like the massive cinnabar bodies worked in the upper levels of Mine Hill. The Enriquita mine was opened up in 1859, and up to January 1, 1865, had yielded 10,571 flasks of quicksilver. It has not been worked in recent years.

REDUCTION EQUIPMENT.

A study of the development of practices and appliances in the metallurgy of quicksilver during the past 60 years shows the intimate relations of such developments to the history of operations at New Almaden. In the earlier operations, the intermittent form of furnace was utilized. These furnaces and their *modus operandi* are described in detail by Goodyear[6] who observed them working in 1871 at New Almaden, Knoxville, and New Idria. The most important item for which credit is due to the staff of the New Almaden mine was the development in 1875–1876, of the Hüttner-Scott fine-ore furnace (now generally referred to as the Scott), by H. J. Hüttner, Robert Scott, and J. B. Randol. This furnace is described in detail elsewhere herein[7] under the section on Metallurgy.

For some years, the furnace equipment at the Hacienda (the name given to the community grouped about the reduction plant) included two Exeli coarse-ore furnaces of 12 tons capacity each; two Scott furnaces for 'granzita' (medium ore) of 36 tons and 18 tons capacity, respectively; and two Scott furnaces for 'tierras' (fine ore) of 36 tons and 24 tons capacity. When visited by the writer in September, 1917,

[6]Goodyear, W. A., Examination of the quicksilver mines of California: Geol. Surv. of Cal., Geol., vol. II, pp. 106, 119, 131–132, 1882.
[7]See pp. 231 *et seq.*, *post.*

these were all being torn down, except the Exelis, and treated for their absorbed quicksilver. The soil and gravel under the site of the old intermittent furnaces and of the Scotts was being excavated to bedrock, a depth of 30 feet, and run through a washing plant for recovery of the

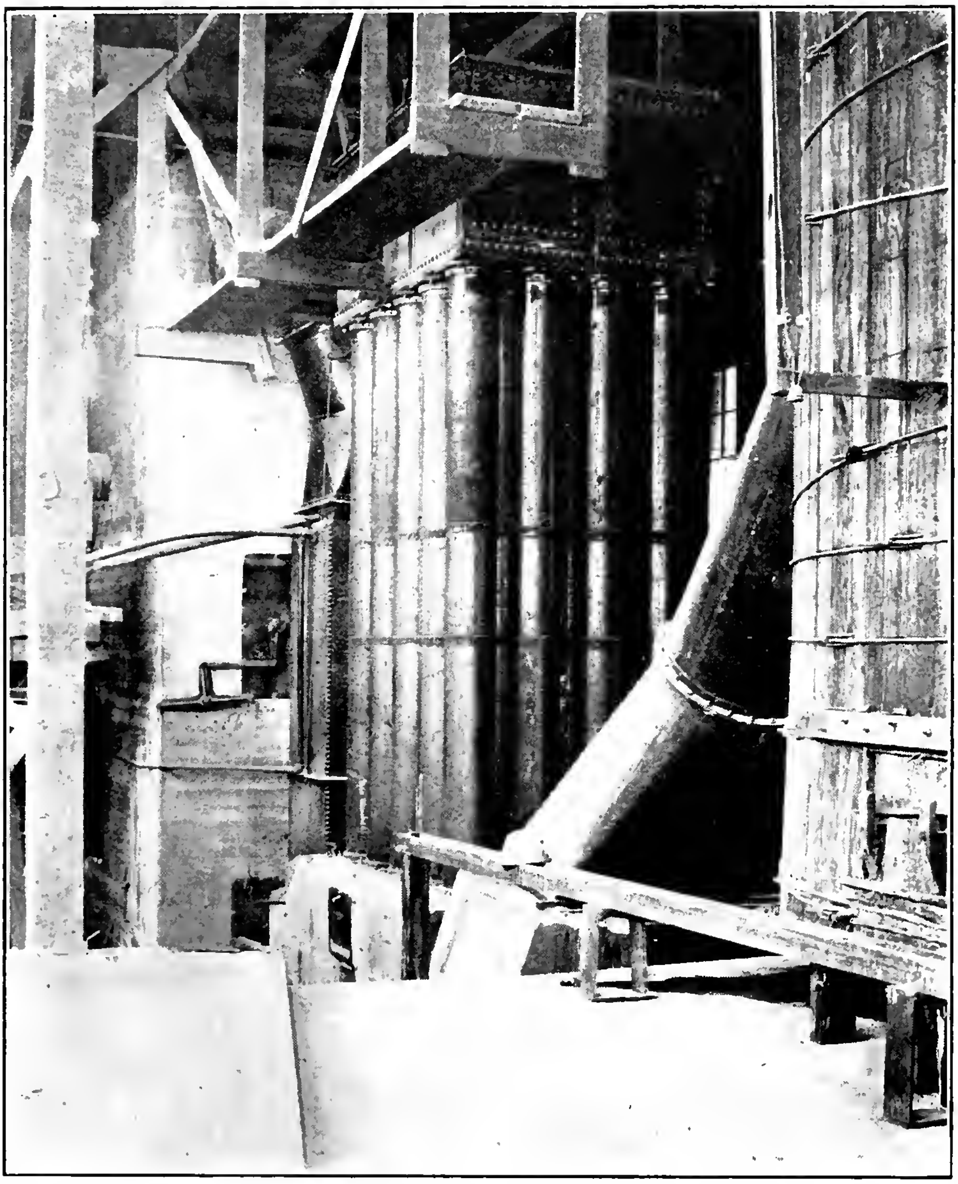

Photo No. 35. Cottrell Dust Precipitator, or 'Hot Treater' (concrete chamber at left), and Condensers connected with Herreschoff Furnace, at Senator Mine of New Almaden Company, Santa Clara County.

metallic quicksilver contained.[8] An important yield of metal is being obtained from this material.

At the Senator mine, in 1917, a Herreschoff multiple-hearth furnace, mechanically rabbled, was handling the ore. A 90-ton Scott furnace

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[8]See p. 344, *post*.

has since been erected and is now (April, 1918) in operation.* As the Herreschoff furnace does not work economically on material coarser than 3/4", the ore after preliminary breaking in a gyratory crusher, is passed over a shaking screen of 3/4" mesh, and the oversize re-crushed in a jaw breaker. A bucket elevator is included in the equipment, and electric power is used. The operation of the Herreschoff furnace is described herein under the section on Metallurgy.[9] Following the furnace is a Cottrell electric fume-precipitator (called the 'hot treater') to throw down the dust particles before they can reach the condensers.

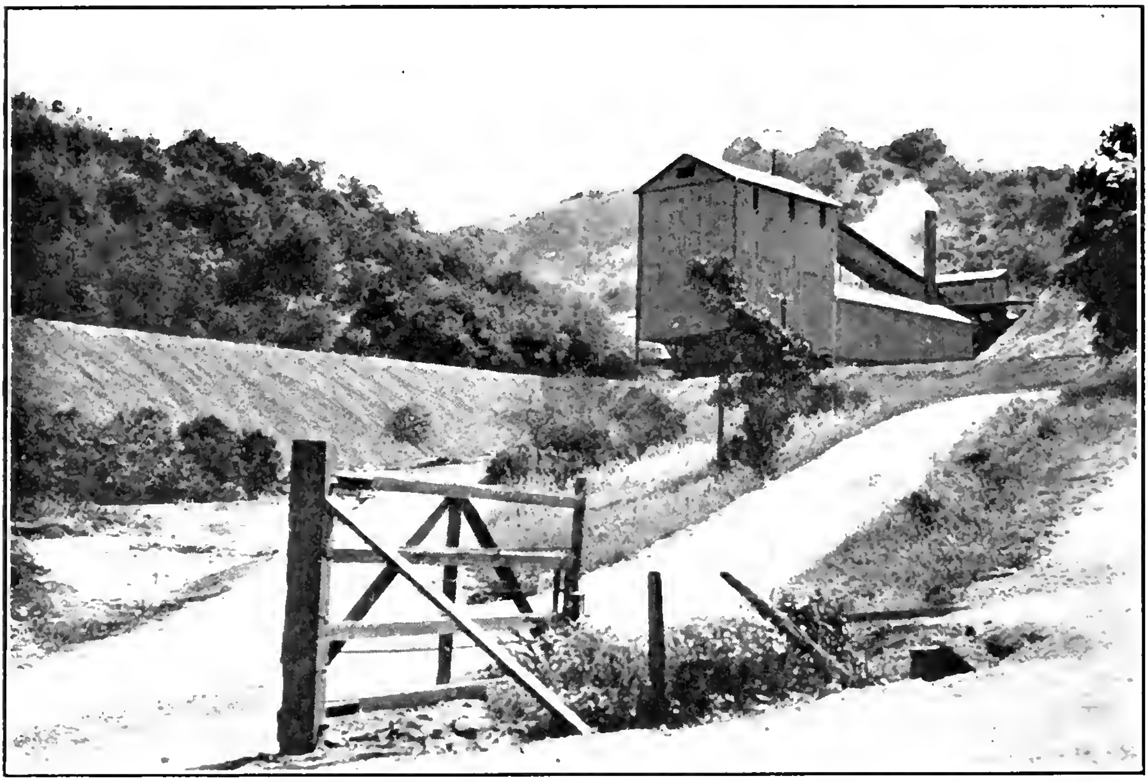


Photo No. 35a. New 90-ton Scott furnace at Senator Mine of New Almaden Company.

The first condenser consists of 20 iron pipes 12" diam. x 12' long (see Photo No. 35) an arrangement patented by Landers[10] in 1916, then manager of the New Almaden company. Condensers #2, #3, and #4 are redwood-stave tanks. 12' diam. x 16' high. No. 2 can be seen at the right of the photograph. These tanks are cleaned out once a week.

*Since the above copy was prepared, the writer has visited (June 10/18) this new plant which is a double, Scott fine-ore furnace built with 4 fireboxes, and is handling a minimum of 75 tons per day, though it has treated up to 96 tons per 24 hours. It is thus the largest Scott furnace at present in operation. The ore is crushed to pass a 2-inch ring; and is transported from the crusher bins, by an inclined belt-conveyor, discharging directly into the top of the furnace. (See Photo No. 35 A.) The side walls of the furnace are built up several feet above the level of the throat, thus giving an auxiliary ore-bin and providing an automatic furnace-feed.

There are eight new condensing chambers connected with this furnace, arranged in a double row. The first chamber in each row is of concrete, and the other three are of tongue and groove redwood, built rectangular. A 3-foot redwood-stave flue was being put in to connect the last of this series of condensers to the first circular wooden condenser of the Herreschoff series. Crude oil is used for fuel.

[9]See pp. 250–253, *post*.

[10]Landers, W. H., The smelting of mercury ores: Eng. & Min. Jour., vol. 102, p. 634, Oct. 7, 1916.

Between the condensers and the outlet stack is a second Cottrell fume-precipitator (called the 'cold treater') to throw down any remaining mercury 'mist' that may still be in the gas flow. It is stated that a little quicksilver is obtained in this cold treater. For the Cottrell electric precipitators, the incoming line current of 440 volts is transformed up to 50,000 volts for the 'hot treater', and to 100,000 volts for the 'cold treater'.

During 1916 and a part of 1917, concentration plants including flotation units were in operation at the Day tunnel and at the Senator mine, but both had been dismantled just previous to the writer's visit in September, 1917. These plants are described in detail elsewhere herein,[11] in the section under Metallurgy.

There is little or no mining timber available in the vicinity of these mines. Sawed timber is brought in by the railroad from outside points. Fuel oil is used at the furnaces. In September, 1917, a total of 105 men were employed, including 60 underground, and 6 at the Senator furnace plant.

Bibl.: Note—The New Almaden mine and plant have been described by so many writers, that only the principal references are here given. Others will be found in the Bibliography in Part III, of this bulletin.
Cal. State Min. Bur., Reports I, pp. 26, 27; IV, pp. 336 et al; VIII, pp. 541–542; X, pp. 604–606; XI, pp. 374–375; XII, pp. 367–370; XIII, pp. 600–601; Bull. 27, pp. 174–186; Chapter rep. bien. period 1917–1918, in prep. U. S. G. S., Mon. XIII, pp. 8, 310–330, 467; Bull. 78, pp. 80–83; Min. Res. 1883–1915 inc. Min. Res. W. of Rocky Mts., 1867, pp. 170–178; 1874, pp. 33, 380, 540; 1875, p. 13; 1876, pp. 4–18, 20. Min. & Sci. Press, vol. 84, pp. 393–404, 1902; vol. 87, p. 201, 1903; vol. 100, pp. 15–16, 446–447; Feb. 16, 1916, pp. 282–284. Eng. & Min. Jour., vol. 34, pp. 185–186, 334, 1882; vol. 91, p. 85, 1911; vol. 102, p. 630, 1916. Geol. Surv. of Cal., Geol. vol. I, p. 68; vol. II, pp. 91–110, 122.

Santa Teresa Mine. Enos Fontis, of Edenvale, owner. This property is 8 miles southeast of San José on the east slope of the Santa Teresa hills. It was developed by the Santa Teresa Quicksilver Mining Company, of which R. H. Harper of San José was superintendent. A 40-ton Scott furnace was erected, and several tunnels driven into the hill to cut the vein. The country rock is serpentine, and the ledge matter an alteration product of serpentine through silicification, carrying a low percentage of cinnabar. After working a few years, without

[11]See pp. 343–344, *post*.

encountering any orebodies of sufficient size or richness to warrant their further exploitation, the mine was abandoned; and is still idle.

Bibl.: Cal. State Min. Bur., Bull. 27, p. 186; Chapter rep. bien. period, 1917–1918, in prep.

Silver Creek Mine (North Almaden). A. R. Bradford et al., owners, 770 E. St. John St., San Jose. This property, formerly known as the North Almaden mine, is 12 miles by road southeast of San José, on the east side of Silver Creek. A large body of serpentine containing cinnabar was found in Silver Creek gulch, overlying Knoxville gravels. This detached body was evidently due to a great landslide which is plainly visible about the works. It was approximately 1000′ in length, 300′ wide, 60′ in thickness, and was exhausted in a few years, producing about $60,000 worth of quicksilver. Occasional prospecting has been carried on since, but no important ledge has been found in place. The property is equipped with a 20-ton Scott furnace and a pipe retort.

Bibl.: Cal. State Min. Bur., Reports XII, p. 367; XIII, p. 600; Bul. 27, pp. 187, 235, 238; Chapter rep. bien. period, 1917–1918, in prep.

Wright Mine. Mrs. A. Rodgers, owner, San Francisco. It is 3 miles south of the New Almaden Hacienda, on Llagas Creek, and is said to have produced some high-grade ore many years ago. It is hardly more than a prospect, and has had but little deevlopment work done on it. Idle.

Bibl.: Cal. State Min. Bur., Reports XII, p. 370; XIII, p. 600; Bull. 27, p. 187; Chapter rep. bien. period, 1917–1918, in prep.

SHASTA COUNTY.

Clover Creek Mine (formerly **Clover Creek Cinnabar Company**). N. B. Frisbie and F. P. Primm, owners, Redding. It is on patented ground in Secs. 4 and 5, T. 32 N., R. 1 W., M. D. M., 30 miles northeast of Redding, and was discovered about 1898. A mineralized zone containing cinnabar is reported, 100′ wide, striking northwest and dipping 30°, having been treated for one-quarter mile in length. Developments consist of several shallow shafts the deepest of which is 50′, and some drifts. No commercial production of quicksilver has as yet been reported. There is plenty of wood and water at hand. The owner states that the property has been twice bonded to St. Louis parties; but that they spent most of their money on salaries and office rent instead of mine development.

Bibl.: Cal. State Min. Bur., Bull. 27, p. 196.

SISKIYOU COUNTY.

Several occurrences of cinnabar have been noted in the northern part of Siskiyou County in the vicinity of Oak Bar on the Klamath River, northwest from Yreka. Some development work has been done at intervals, and the records indicate a small commercial production of quicksilver some years ago. There is prospect of further output the coming season, 1918, in at least one property. Cinnabar is often found in the sluice boxes of the hydraulic mines of this district.

Minnehaha Mine (also known as **Barton-Lange Mine**). H. J. Barton, owner, Oak Bar. It is in Sec. 15, T. 46 N., R. 10 W., M. D. M., on the Klamath River near the mouth of Horse Creek, about 5 miles west of Oak Bar. Patented, 20 acres. Discovered in 1878. The cinnabar mineralized zone is in an area of metamorphic rocks stated to be in contact with granite. The development work done so far has all been superficial, consisting of open-cuts and ground sluicing. About 1916 some cinnabar concentrate was obtained by ground sluicing, about enough it is stated to yield 4 flasks of quicksilver, but it has not yet been treated as there is no reduction equipment at the property. Small amounts of the translucent red, cinnabar crystals obtained here by sluicing with pole riffles were formerly sold to the Chinese for medicinal purposes.

Bibl.: Cal. State Min. Bur., Reports XIII, p. 602; XIV, p. 870; Bull. 27, p. 196; Chapter rep. bien. period 1913–1914, p. 126.

Mt. Shasta Cinnabar Mine (also referred to as the **Cowgill Mine**; formerly owned by the **Ivanhoe Quicksilver Mining Company**). Mercury Company of America, owner; Eugene C. Belknap, manager, Yreka. This group of claims is in Sec. 34, T. 48 N., R. 9 W., M. D. M., on the west fork of Beaver Creek, 10 miles in an air-line northwest of Gottville, and adjoining Garretson Springs. It is 12 miles by trail, or 24 miles by a steep, difficult wagon-road from Gottville, and about 3 miles south of the California-Oregon state line. Gottville is 20 miles by a good county road down the Klamath River from the Southern Pacific railroad at Hornbrook. Locations have been made by this company on other quicksilver prospects in nearby sections, and an option taken on the Herzog-Morgan claims in Secs. 24 and 25, T. 47 N., R. 8 W., on Empire Creek. Some work was done years ago on this property by the Siskiyou Quicksilver Mining Company, who built a 10-ton furnace, and are stated to have produced a few flasks of quicksilver. The present owners have recently completed a 12-pipe Johnson-McKay retort.

The cinnabar, which is coarsely crystalline, occurs in a wide mineralized zone with sandstone and metamorphic rocks some of which are schistose. Belknap states that screen tests made on the surface soil in this mineralized zone showed that after passing through a ¼″ screen, 72.3% of the material will pass a 20-mesh screen and assays 0.013% mercury. Owing to the fact that apparently such a large percentage of low-grade material can be gotten rid of by simply screening, the values being mainly in the particles coarser than 20-mesh, it is proposed to adopt such a method of ore dressing. A scraper and cable equipment will be installed for excavating the ore, which will be passed through a revolving screen with a stream of water, as it will be simpler to carry the tailings away in a launder than to transport it dry. The oversize, or concentrate, will then be dried and retorted. It is expected by this method to test out the ground. The soil occurs up to a depth of 60 feet. There is plenty of water at hand both for power and milling purposes.

Bibl.: CAL. STATE MIN. BUR., Reports XII, p. 370; XIII, p. 602; XIV, p. 870; Bull. 27, p. 196; Chapter rep. bien. period, 1913–1914, p. 126.

SOLANO COUNTY.

The quicksilver mines of Solano County are situated on the prominent ridge known as Sulphur Springs Mountain from five to seven miles northeast of Vallejo. This ridge trends northwest, and has been the locus of volcanic or other igneous activity and consequent metamorphism. The Vallejo hot sulphur springs are on the western side of this ridge, about midway, being a mile and a half south of the St. John's mine, and about a mile northwest from the Brownlie and Hastings properties. The St. John's mine is at the northern end of the ridge, the culminating point of which is Mt. St. John, elevation 1110′ (U. S. G. S.). The Brownlie and Hastings workings are on opposite sides of the ridge, about three miles southeast from the St. John's mine which has been the only important producer of quicksilver in Solano County.

The recorded production of quicksilver in Solano County is shown in the accompanying tabulation:

Quicksilver Production of Solano County.

Year	Flasks	Value	Year	Flasks	Value
1873	1,800	$144,594	1906	528	$19,272
1874	1,900	199,842	1907	640	24,422
1875	2,100	176,715	1908	764	33,294
1876	1,683	74,052	1909	-----	-----
1877	1,463	54,570	1910	-----	-----
1878	802	26,386	1911	-----	-----
1879	1,290	38,507	1912	-----	-----
1880	492	15,252	1913	-----	-----
1881	-----	-----	1914	320	15,680
1901	-----	-----	1915	466	35,000
1902	42	1,890	1916	660	61,710
1903	100	4,100	1917	554	52,765
1904	*377	15,080			
1905	542	18,518	Totals	16,523	$1,011,649

*Flasks of 75 pounds since June, 1904; of 76½ pounds previously.

Brownlie Mine. John Brownlie Estate, owner, Vallejo. It is on patented ground, on the western side of Sulphur Springs Mountain, about ½ mile due west from the Hastings mine, and 4 miles north of east from Vallejo. It is in Sec. 10, T. 3 N., R. 3 W., M. D. M.; elevation 600′ (U. S. G. S.). Some work was done on this property in the '70's, but it consisted only of shallow, surface cuts. An option has recently been given by the owners to parties who may soon start exploration work.

Bibl.: Cal. State Min. Bur., Reports VIII, p. 631; XIII, p. 599.

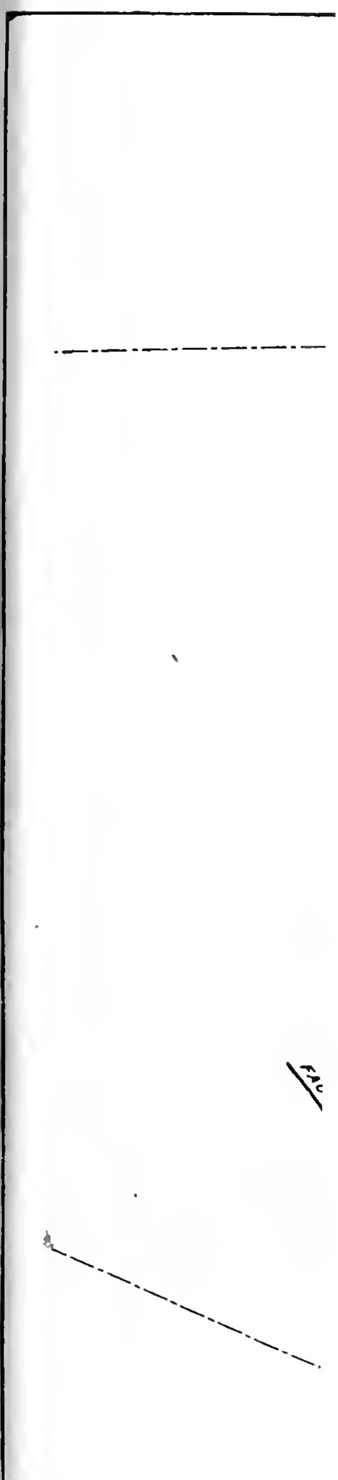
Hastings Mine. Hastings Estate, owner; Chas. Wendell Hunt, agent; White Investment Company, lessee, G. A. Newhall et al., Newhall Building, #206 California St., San Francisco; John Andrews, superintendent at the mine. It is in Sec. 11, T. 3 N., R. 3 W., M. D. M., on the eastern side of Sulphur Springs Mountain, 7 miles by road north of Benicia, and 4½ miles in an air-line, north of east from Vallejo. The lease covers the mineral rights on 600 acres of the Suscol Rancho, also known as the D. N. Hastings Sulphur Spring Valley Ranch. The property was originally operated in the '70's by a series of shallow surface cuts, and 'coyote holes'. Some work is reported to have been done about 1904–1905, but apparently no production of metal was then made. A small yield was reported in 1916. In February, 1917, the mine was reopened by A. G. Kullberg, et al., under lease; and a fair output of quicksilver made, the lease being transferred to the present operators in November.

The mineralization occurs in a brecciated zone about 40′–60′ wide, striking W. of N., and dipping 70°–80° W. There is an igneous mass (dike?) on the hanging-wall side, which resembles the granular, meta-andesite dikes of the St. John's mine and which were formerly described as 'metamorphic sandstone.' The ore occurs in the fractures of the brecciated rocks. An indurated shale or chert, and opaline material were noted. Both cinnabar and metacinnabarite are present, being mainly crystalline, with little or no pyrite apparent. The main tunnel cuts the vein at 950′ in, and continues another 150′ to the igneous formation noted above. This gives a depth of 112′ below the outcrop. It is stated that on the surface some ore has also been found on the other (west) side of this igneous rock. In fact, the Brownlie mine is on the west side of it, ½ mile distant. There is another adit, 20′ above the main level. There is one stope 30′ high x 15′ long x 10′ wide, and another 40′x20′x20′, besides other smaller ones. The mine car dumps into a small ore-bin with a grizzly, at the portal of the main adit, from which point the ore is hauled in a dump cart, about 200 yards down the hill to the furnaces.

Reduction equipment consists of a small, Neate coarse-ore furnace of about 6 tons capacity, and a bank of 3 retorts similar to a large 'D' retort but having a rectangular cross-section, instead of an arched top. They have a capacity of 1½ tons each per day. They are arranged to use oil, but when visited by the writer (March, 1918), were being fired by coke, because of inability to get oil for a time. The Neate coarse-ore furnace is not now utilized. There are 4 brick condensers, with 3 chambers, each. The ore being treated was yielding 1.72% mercury. There were 9 men employed.

Bibl.: CAL. STATE MIN. BUR., Report XIII, p. 599.

St. John's Mine (originally referred to as the **Vallejo**). St. John's Mines Company, owner; Clifford G. Dennis, president and manager, Vallejo; C. F. Colmar, secretary, Mechanics Institute Building, San



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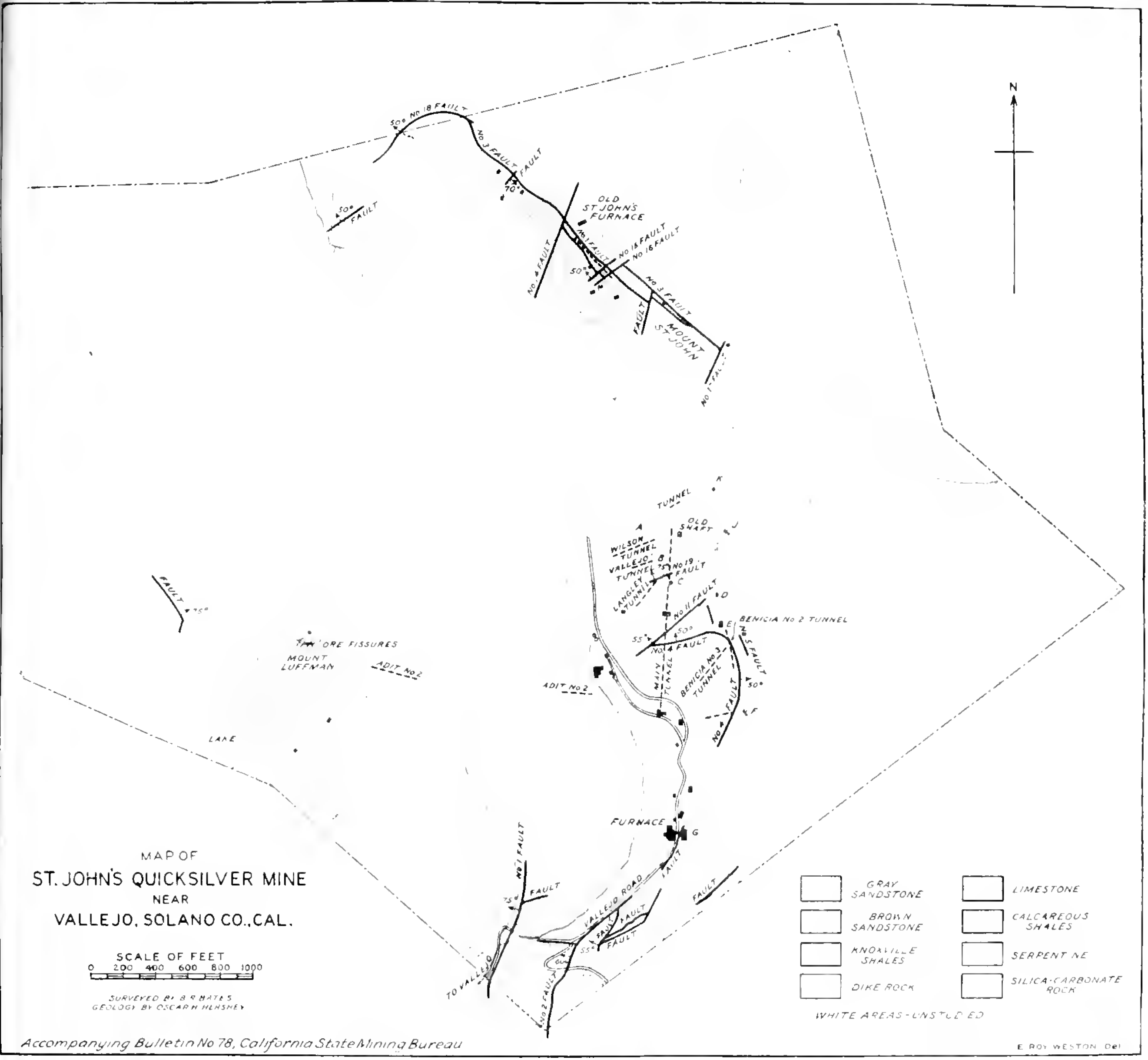

Accompanying Bulletin No 78, California State Mining Bureau

E. ROY WESTON, Del.

Francisco. It is in Sec. 33, T. 4 N., R. 3 W., M. D. M., 6 miles northeast from Vallejo, with an excellent oiled road to within 1 mile of the furnaces. The mine is at the northern end of the Sulphur Springs Mountain ridge. Cinnabar was first found here in 1852 by John Neate, who carried on prospecting in a small way for a number of years. Commercial production of quicksilver began in July, 1873, with the mine's discoverer as superintendent, who first built here the Neate coarse-ore furnace. This first producing period continued to 1880, yielding a total of 11,530 flasks in the seven years. The St. John's Consolidated Quicksilver Mining Company reopened the mine in 1899 and continued production up to 1909, following which only a small amount of development work and occasional retimbering to keep the mine open was done until the present operators took over the property in 1914. The total recorded production of the St. John's mine has been 16,453 flasks of quicksilver to the end of 1917.

GEOLOGY.

A detailed study of the geology of the St. John's orebodies and adjacent formations was made in 1916 by Oscar H. Hershey, from whose report[1] most of the following geological data are abstracted, and the accompanying maps. (Plates XX and XXI) reproduced. The rocks consist primarily of a series of sedimentary beds and igneous intrusions therein. The intrusive rocks have been highly altered, at least near the surface, and only remotely indicate their original condition. The sediments are Lower Cretaceous in age and appear to be divisible into two series, the earlier of which may possibly be Franciscan, but because of not yet being definitely identified as such is here designated the 'Lower Series'. The upper series is of Knoxville formations.

The Lower Series: The summit of Mt. St. John and the rugged ridge extending thence northwest to the old St. John's furnace has extensive outcrops of rather hard rocks consisting basally of a light-gray, rather heavy-bedded sandstone, succeeded by shaly and calcareous layers of dark-gray color. These rocks strike northwest and near the summit of the mountain dip southwest 50°, but they straighten to nearly vertical toward the northwest. The sandstone may be 80 feet thick and the shaly division several hundred feet. Beyond a fault of small throw as shown on the map, the sandstone appears to have been cut out and only the shaly belt outcrops. The shaly division seems to become more calcareous toward the northwest and at a point about 500 feet northwest of the old furnace, it appears as a considerable body of light-gray impure limestone. This limestone is traversed by a network of quartz

[1]An unpublished private report made for the St. John's company, and kindly loaned with accompanying maps to the present author by courtesy of the manager, Mr. Clifford G. Dennis, with permission to publish.

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seams. Throughout a larger part of the formation the quartz was very abundant, and has given rise, through the decay of the limestone, to rough outcrops of very porous flinty quartz. This quartz-skeleton country has been locally called 'carbonate rock', and most of it on this property is associated with serpentine. In the particular area now under discussion, the main body of which is about 1000′ long and 300′–400′ wide, some serpentine was recognized and a fine-grained granular rock that represents a basic intrusion different from that which altered to serpentine; but, the main body is a great mass of skeletal quartz with interstices either filled with fine-grained, calcite-like limestone, or is leached and iron-stained. The structure and hence thickness are not clear. Probably most of it has a rather low, southerly dip, and the maximum thickness may be not over 100′ or 150′.

The attitude of the 'Lower Series' in relation to that of the rocks surrounding the area indicates that it is bordered on the northeast by a fault of considerable throw and on the southeast by a fault of great throw. The northwest limit is probably a fault, but the southwest limit has sufficient irregularity as to suggest that it is the line of original contact between the Lower Series and the overlying Knoxville series, a contact that probably represents a non-conformity.

Knoxville Series: This series consists predominantly of a great thickness, probably many hundreds of feet, of dark-olive, to nearly black soft shale, which is evenly and thinly laminated. The lower portion of it is characterized by the presence of many lentils, usually not over 2′ or 3′ in length and 2″ to 6″ thick of fine-grained compact limestone of brownish-gray color. These weather out into hard boulders that accumulate along the gulleys. The limestone lentils may be seen at various places on the 100′, 160′, and 260′ levels. They are of no economic significance but aid in the determination of the structure. At a higher horizon, thin beds of brown, fine-grained, soft, impure sandstone appear in the shales. Particular attention was given to a study of the attitude of the Knoxville rocks, because of an opinion then held at the mine that the ore occurs chiefly where faults are intersecting certain sandstone beds. The mine workings, so far as studied, are in a fairly uniform block of Knoxville formation dipping northeast at an average angle of 35°, though locally somewhat disturbed especially along the faults.

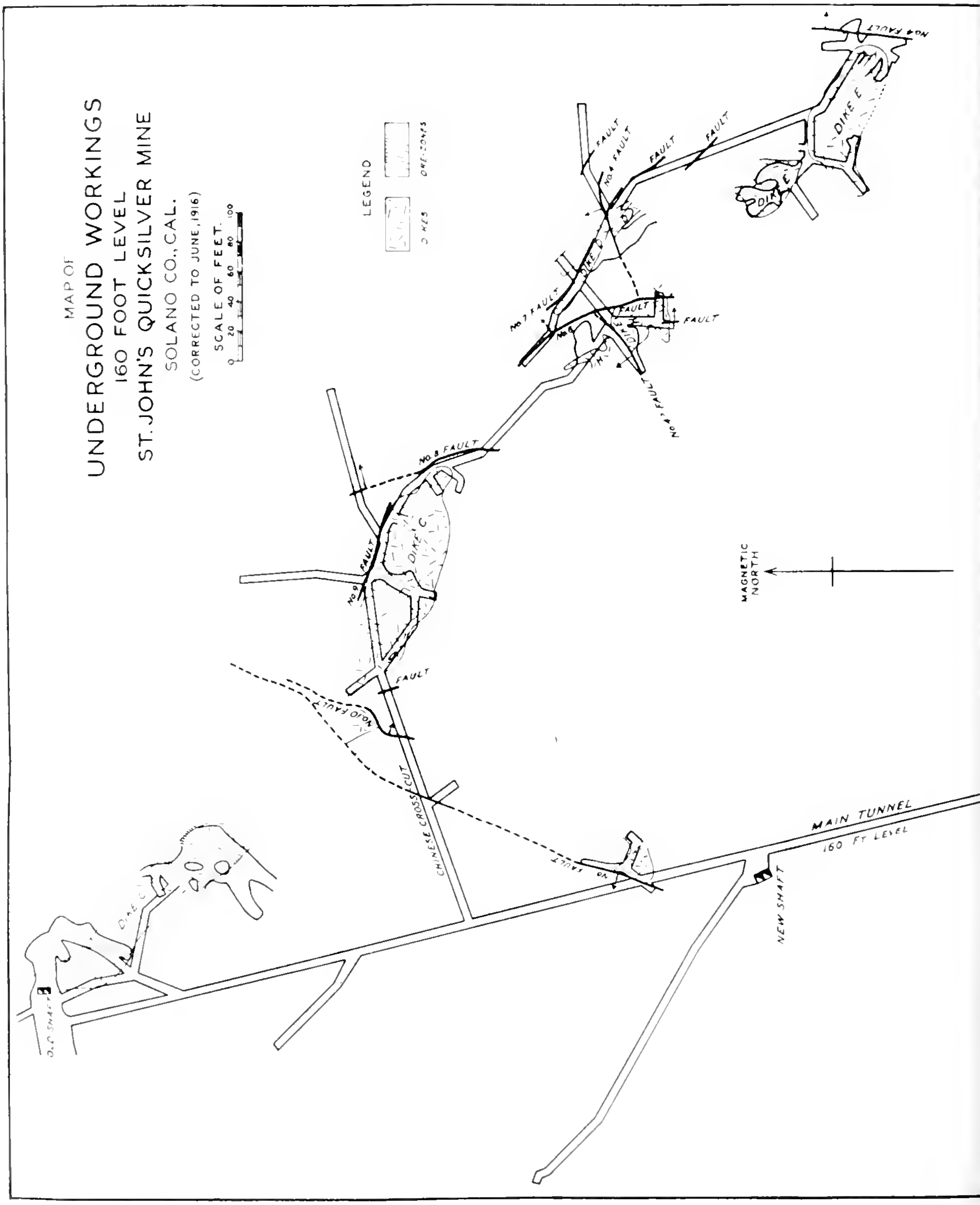
Serpentine: The sedimentary series were intruded by peridotite, which was subsequently altered to serpentine. The serpentine areas were doubtless at one time co-extensive with what has been mapped as serpentine and 'silica-carbonate' rock, except a portion northwest of the old St. John's furnace discussed above.

'Silica-Carbonate Rock': A large part of the serpentine has been altered to an aggregate of carbonates of iron, magnesia, and lime traversed by small veins of chalcedony, opal, and quartz. This weathers into a skeleton of rusty quartz. Except on Mt. Luffman, none of the quicksilver deposits of the property occur in this material, but there is an area extending southwest from the new furnace, in which conditions appear to be favorable for the formation of ore in this phase of rock.

Dike Rock: The important rock from an economic standpoint, is a certain type of intrusive that occurs in many relatively small bodies in the easternmost one-third of the property. The rock has been highly altered and at present appears to be largely a fine-grained aggregate of silica and carbonates. In outcrop it is a pinkish-brown, fine-grained rock consisting of white, fine-grained replacement quartz abounding in small porous areas stained brown by limonite. There are some black manganese stains and traces of a carbonate, probably calcite. Underground it is whiter and more compact, and has frequently very fine-grained pyrite disseminated. This is the rock that in former published accounts was designated as a metamorphic sandstone. On the 350-foot level it has been found apparently much less altered than above, and by examination of thin-sections has been identified as a 'meta-andesite'. It is a light-gray crystalline rock, having somewhat the appearance of a very compact, fine-grained sandstone, resembling some of the Franciscan metamorphic sandstones. "The important fact is that it is an intrusive rock that was injected into Knoxville shales in bodies that are generally more or less elongated in a north to northwest direction, forming short blunt dikes, though a few are rounded or irregular chimneys to which the term dike can only be applied by courtesy. Some of them tend to follow the bedding on the dip, but most of them cut the bedding planes at high angles. Where the borders are not faults, the contacts are typically intricate intrusive contacts, with angular fragments of the shale in the dikes. Furthermore, the shales near the contact have been altered to a hard, black, siliceous shaly material. No further evidence is needed to prove that these bodies are intrusive. These dike-like masses show no tendency to pinch with depth, but rather the opposite." To facilitate correlation of these dikes from level to level, they have been designated by letters, on the map. At least 11 of these dikes have been identified, the most important ones from the standpoint of associated orebodies thus far developed, being dikes C, D, and E.

Faults: The rocks of the area are traversed in various directions by many faults, most of them of small displacement. To facilitate their correlation from level to level, the more important ones are designated on the map by numbers. At least 20 of these have been so designated.

PLATE XXI.


MAP OF
UNDERGROUND WORKINGS
160 FOOT LEVEL
ST. JOHN'S QUICKSILVER MINE
SOLANO CO., CAL.
(CORRECTED TO JUNE, 1916)
SCALE OF FEET
0 20 40 60 80 100
LEGEND
DIKES
ORE-ZONES
MAGNETIC NORTH
MAIN TUNNEL
160 FT LEVEL
NEW SHAFT
OLD SHAFT
CHINESE CROSSCUT
DIKE C
DIKE D
DIKE E
No. 4 FAULT
No. 7 FAULT
No. 8 FAULT
No. 9 FAULT
No. 10 FAULT
FAULT

One of the most important is No. 4 fault. Most of them have northeast courses and dip northwest; though a few swing by east to south, dipping east finally. Another group that tends to strike N. to W. of N. and dip eastward, faults the first group. There are a few practically vertical faults, but they do not seem to form a definite system.

Orebodies: The orebodies have formed invariably (the Mt. Luffman and old St. John's deposits excepted) in the dikes, or the hardened shale along the borders of the dikes, or in the fault breccias near the dikes. The faulting of the rocks formed fissures along which hot water ascended and deposited quartz, calcite, cinnabar, and pyrite or mar-

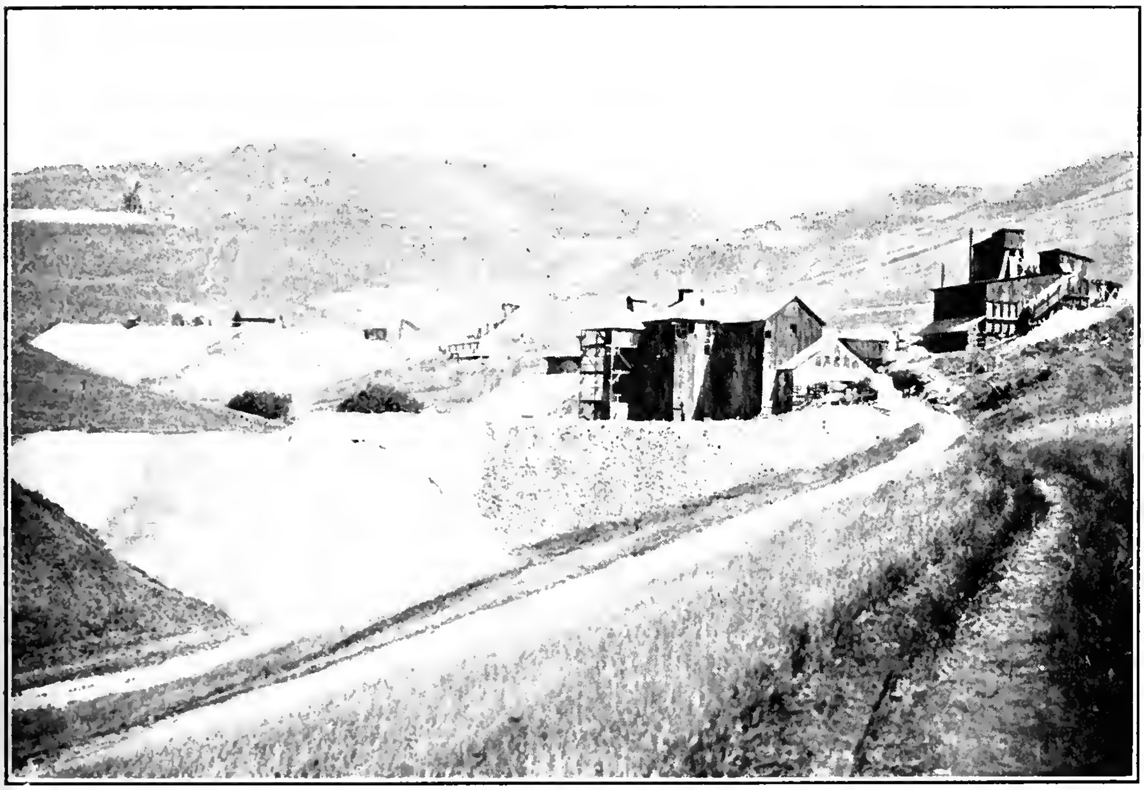
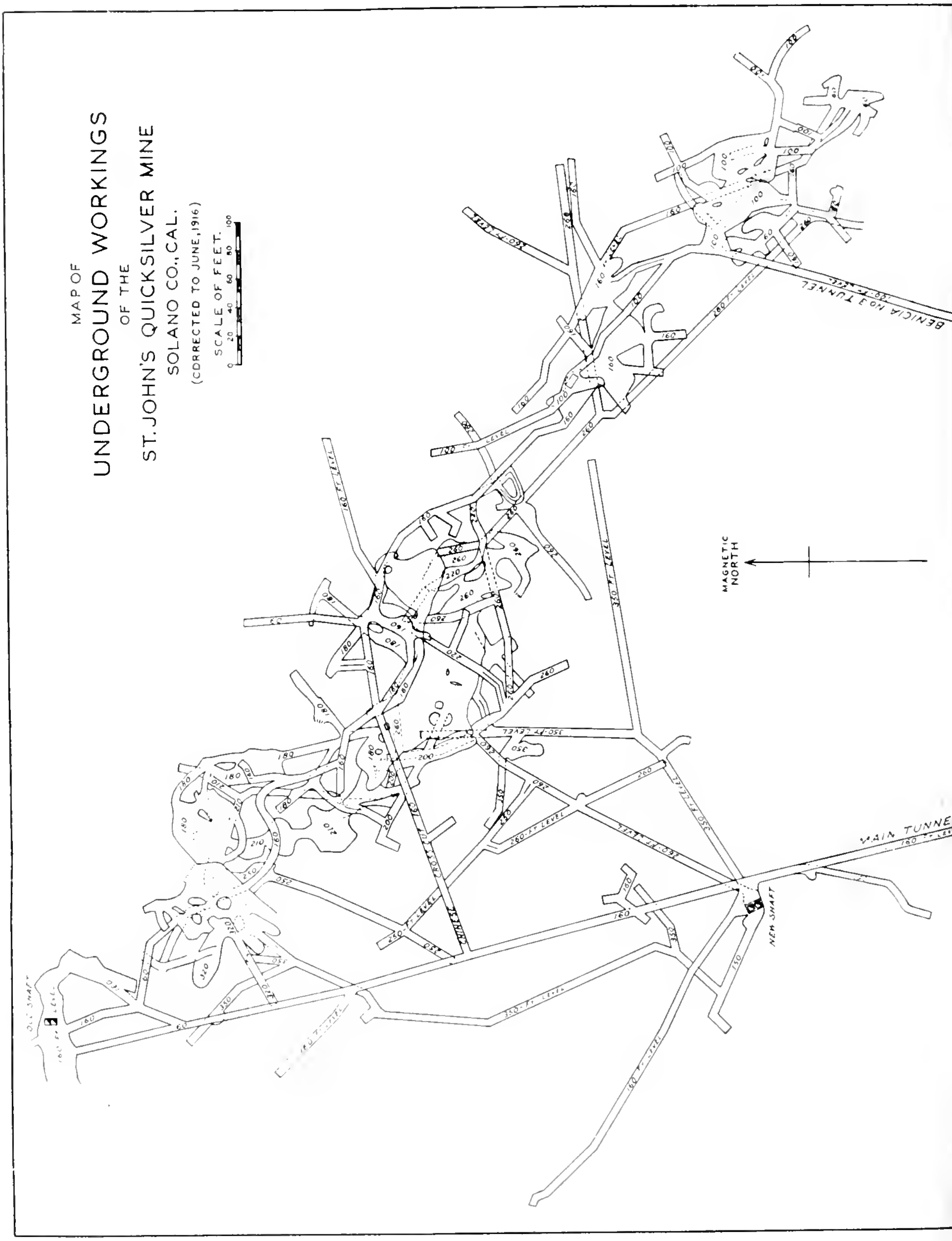


Photo No. 36. St. John's Mine, near Vallejo, Solano County. Mt. St. John in the left distance.

casite. A thick, dark-brown mineral oil which burns readily when a candle is applied to it, is found in the jointages and fissures in and near the orebodies.

"In the soft shales the fault movements made strong gouges and there were no open fractures and hence there is no ore. Where the faults cut the harder dike rock, there was more or less brecciation and open fractures were formed in great numbers. Thus the rôle played by the dikes was a purely mechanical one. Much of the richest ore occurs in the fault breccias on the border of the dikes. By far the commonest form of occurrence is in connection with thin seams that extended across the larger dikes from wall to wall. A group of parallel seams in places produces a sheeted zone. These fractures

PLATE XXII.


MAP OF
UNDERGROUND WORKINGS
OF THE
ST. JOHN'S QUICKSILVER MINE
SOLANO CO., CAL.
(CORRECTED TO JUNE, 1916)
SCALE OF FEET.
MAGNETIC NORTH
MAIN TUNNEL
BENICIA NO 3 TUNNEL
NEW SHAFT

often have no apparent direct connection with the faults, but they were doubtless the result of stresses set up in the dikes by neighboring fault movements. Another favorable site for ore is in certain portions of the hardened shale on the borders of the dikes that were more or less brecciated by the general fault movement, though not necessarily adjacent to any known fault gouge.

"Thus the undisturbed contacts between the dikes and shales are invariably barren. Large sections of the dikes are barren because they are not sheeted or brecciated. Long stretches of the faults are barren because there is too much soft gouge. But almost invariably where the proper combination of a dike and a fault is encountered there is more or less cinnabar and usually some commercial ore."

In the deposit on Mt. Luffman, pockets of high-grade ore were mined from the silica-carbonate rock. In the old St. John's mine on Mt. St. John, cinnabar seems to have occurred in hard shales near faults, and where structural conditions may enable the ore-shoots to extend to considerable depth.

Mine workings.

From the foregoing, and an examination of the map (Plate XX), it is seen that there are three principal ore-bearing localities in the area of the property: The earliest workings on Mt. St. John's; the smaller workings on Mt. Luffman; and the present main workings which are to the eastward of a line between the other two. The main working level is an adit above the furnace level. It connects with the shaft at the 160′ level and is in over 1100′. The shaft is down 400′, reaching a depth of 650′ vertical, below the outcrop. There are 3 main levels from the shaft (see Plate XXII) and 5 intermediates. It is proposed to further prospect the deposits on Mt. Luffman and Mt. St. John.

REDUCTION EQUIPMENT.

The ore is trammed from the main adit, around the hill to the crusher and drier building above the furnaces. (See Photo No. 36.) Below the grizzly is a shaking screen with 1¾″ openings. The oversize goes to the coarse-ore bin, and the through material is elevated to the fine-ore bin from which it is fed automatically into the ore drier. There is an automatic ore-sampler attached to the bucket elevator; and the furnace tailings are sampled by hand. The ore drier (see Photo No. 57, *post*) is of a design developed by Mr. Dennis, built of steel plates and channel bars, and fired by crude oil. It is 26′ long, with the fire-box at the lower end. The space underneath is divided into three flues longitudinally, the flames going up the two outer passages, then back down the center one to the stack. From the drier, the fine ore is trammed to the 18-ton Scott furnace, which was built by the present operators in 1915. Crude oil is used for fuel, the burner having an air atomizer. There are also two 10-ton Neate coarse-ore furnaces, but they have not been kept in continuous operation since the new, Scott furnace has been in service. Coke is used in these Neate furnaces.

The furnace temperatures are watched by means of a Brown electric pyrometer,—E. F. 8; Resist. 554.3 ohms,—having a 6-point switch. There are six points of observation, the first three being in the Scott furnace: 1. Fire-box; 2. Top of first arch; 3. Furnace discharge; 4. Coarse-ore furnace; 5. Halfway point in condenser line; 6. Stack. It is intended to change #4 to the end of #2 condenser. At first, a recording pyrometer was used on the Scott, but it was found that sometimes the furnace man neglected to look at the record and the fire went up or down without attention. With the present apparatus it is necessary for the shift man, hourly, to make the contacts with the switch and write down the temperatures on a tabulated sheet. By this system, close regulation of the temperatures is obtained. A 25 h. p. Fairbanks-Morse, type Y, semi-Diesel oil engine furnishes power for the blower and air compressor. In addition to the brick chambers, a series of flues and T's of brown, glazed sewer-pipe is used for condensers. Dennis considers that these clay pipes give greater radiation than wood, brick or stone. In September, 1917, it was stated that the cost of producing each flask of quicksilver was $15 more than that in September, 1916, which in turn was at least 33% greater than the cost in 1914. This is due to the increased cost of materials and labor, and to lower labor efficiency. There are 25 men employed.

Bibl.: Cal. State Min. Bur., Reports I, p. 26; VIII, p. 631; X, p. 661; XIII, p. 599; Bull. 20, p. 19; XIV, p. 311–312; Bull. 27, pp. 93–97; Chapter rep. bien. period 1913–1914, pp. 139–140. U. S. G. S. Mon. XIII, p. 378; An. Rep. XXI, Pt. VI, p. 278; Min. Res. 1907, 1908, 1909, 1910, 1911, 1912. Min. Res. W. of Rocky Mts., 1873, p. 10; 1874, pp. 30, 31; 1875, pp. 14, 178; 1876, p. 20. Min. & Sci. Press., Vol. 109, p. 585.

SONOMA COUNTY.

The Sonoma County quicksilver deposits, particularly those of the Pine Flat district, are among the oldest known in the state. They vary in character from the ordinary, mainly cinnabar-bearing ores, and the less common meta-cinnabarite, to the purely native mercury type as in the Rattlesnake and the Socrates. This last named group is found in the Pine Flat district, southeast of The Geysers; and has proven so far the most difficult to handle both from a mining and a metallurgical standpoint.

Prospecting and exploitation of the Pine Flat belt of deposits began in the early sixties and in 1861 some 33,000 feet of claims had been located on it.[1] Among the claims being worked in that year were the Cincinnati, Dead Broke, Pittsburg, Pioneer (later renamed Socrates), and Denver. Though small amounts of quicksilver were produced by a retort from the Pioneer's native mercury ore, the result was not profitable from a pecuniary standpoint. The first definitely recorded output of quicksilver in the county was from the Sonoma mine in the same district in 1873.[2]

With the exception of the Great Eastern lode which is isolated from the other quicksilver deposits of this section of the state, the quicksilver mines of Sonoma County are located at the western end of what is known as the Mayacmas District (see Plate V, *ante*), the general geology of which is described in a preceding section[3] of the present report. The Cloverdale is the westernmost mine on this belt. The ore-bearing zone, which strikes southeast in the Cloverdale turns abruptly to the south at the Squaw and Buckeye claims, crossing to the opposite side of Big Sulphur Creek; then turning again runs south of east through the Esperanza mine, passing to the south of The Geysers and continuing southeasterly through the Socrates mine in the Pine Flat section. In the Cloverdale, the dip is northeast at about 70°, east at the Buckeye, and southwest at the Socrates. While native mercury is a characteristic in the southeastern part of this zone, none is found in it north of Big Sulphur Creek.

As will be noted from the table of production, there have been two principal periods of activity in the yield of quicksilver from Sonoma County mines previous to the present one, 1874 to 1883 and 1888 to 1906. From 1882 to 1894, the Great Eastern mine was the only pro-

[1]Whitney, J. D., Geol. Surv. of Cal., Geology, Vol. I, p. 89, 1865.
[2]Raymond, R. W., Min. Res. West of the Rocky Mts., 1874, p. 30.
[3]See pp. 30–32, *ante*.

ducer. The recorded production, to the end of 1917 has been as follows:

Quicksilver Production of Sonoma County.

Year	Flasks	Value	Year	Flasks	Value
1873	50	$4,017	1897	1,538	$59,982
1874	1,700	178,806	1898	1,704	63,048
1875	1,218	102,495	1899	2,119	105,950
1876	3,897	171,468	1900	2,209	99,500
1877	3,609	134,616	1901	2,130	95,850
1878	3,255	106,890	1902	1,440	64,685
1879	2,977	88,923	1903	2,404	98,676
1880	1,145	44,795	1904	*2,700	102,829
1881	1,273	37,974	1905	2,584	97,041
1882	2,124	59,960	1906	2,070	75,555
1883	1,669	47,984	1907	560	21,369
1884	332	10,126	1908	590	24,939
1885	446	13,715	1909	344	14,226
1886	735	26,093	1910	260	11,765
1887	689	29,196	1911	94	4,325
1888	1,151	48,918	1912	646	27,158
1889	1,345	60,525	1913	12	483
1890	1,046	54,915	1914	13	638
1891	1,660	75,115	1915	159	21,793
1892	1,630	66,357	1916	1,039	97,146
1893	1,445	53,104	1917	2,592	244,810
1894	1,368	41,998			
1895	1,813	70,707	Totals	65,210	$2,897,615
1896	1,126	37,150			

*Flasks of 75 pounds since June, 1904; previously 76½ pounds.

Almaden, Incandescent and Tunnel Site Group. These prospects near the Socrates mine have been abandoned several years. A 10-pipe retort was built.

Bibl.: Cal. State Min. Bur., Report XIV, p. 343; Bull. 27, p. 97; Chapter rep. bien. period 1913–1914, p. 171.

Altamont Copper Group. Quicksilver has been reported on these copper claims north of Camp Meeker, but no definite vein or orebody has been found.

Bibl.: Cal. State Min. Bur., Report XIV, p. 343; Chapter rep. bien. period 1913–1914, p. 171.

Bacon Consolidated Group. On Pine Mountain. Abandoned.

Bibl.: Cal. State Min. Bur., Report XIV, p. 343; Bull. 27, p. 97; Chapter rep. bien. period, 1913–1914, p. 171.

Boston Group. C. P. Gerald, owner, Pine Flat. These prospects about a mile east of the Pine Flat schoolhouse have been idle for several years past. It is stated that a homestead has been filed on the land.

Bibl.: Cal. State Min. Bur., Report XIV, p. 343; Bull. 27, p. 97; Chapter rep. bien. period, 1913–1914, p. 171.

Buckeye Claim (Mt. Vernon). C. A. Baumeister and George Hemenway, owners, Cloverdale. It is in Secs. 3 and 4, T. 11 N., R. 9 W., M. D. M., 14 miles east of Cloverdale; elevation 2100 feet (bar.). This was formerly the Mt. Vernon claim of the Cloverdale group, which it adjoins, and was relocated by the present owners in 1910. Subsequent court proceedings confirmed their title to the ground. The ore-bearing zone is stated to be 100 feet wide and is made up of chert, impregnated sandstone, and stockworks, carrying cinnabar. Only the necessary annual assessment work has been done recently. It is being developed on three levels by an open-cut and two adits, the lowest of which will give 200′ of backs. There is a shaft of 50′, and a tunnel of 300′, which were driven by the original locators. There are 200 tons of ore said to average 5% mercury, broken in the open-cut. There is no reduction equipment.

Bibl.: CAL. STATE MIN. BUR., Report XIV, p. 344; Bull. 27, p. 99; Chapter rep. bien. period, 1913–1914, p. 172.

Cinnabar King Group. Cinnabar Mining Company, owner; Eli Bush, treasurer, Healdsburg. This group of 5 patented claims in Sec. 11, T. 10 N., R. 8 W., M. D. M., has been idle for several years past. The occurrence of ozocerite has been noted in this mine, associated with quicksilver.

Bibl.: CAL. STATE MIN. BUR., Reports XI, p. 461; XII, p. 371; XIII, p. 602; XIV, p. 344; Bull. 27, p. 98; Chapter rep. bien. period, 1913–1914, p. 172. U. S. G. S., Min. Res. 1910, Pt. I, p. 701.

Cloverdale Mine. Western Mercury Company, owner; Andrew Rocca, Jr., president and superintendent, Cloverdale. This group consists of the Cloverdale, patented, with 5 other claims and a millsite. The mine has had a somewhat intermittent history, having first been opened up in 1872, and the furnace built in 1875. It has been operated by the present company since 1915, control of which has recently passed to the above-named official and associates. The total recorded production of quicksilver by this property to the end of 1917 has been 6738 flasks. The mine is in Sec. 4, T. 11 N., R. 9 W., M. D. M., 12 miles east from Cloverdale, on the ridge between Big Sulphur and Squaw creeks, at their junction, the mine workings and reduction plant being on the slope toward the former. The topography is very steep (see Photo No. 37), the elevation being 1000′ at the furnace and 2200′ (bar.) at the top of the ridge.

The orebody is characterized by ledges of thinly stratified chert, enclosed by sandstone. These ledges have generally a northwest strike and northeast dip. The chert strata vary from ½″ to 3″ in thickness.

The cinnabar forms as 'face metal' and incrustations in the fissures of the more compact chert beds, and as richer seams and bunches in the crushed portions. The chert is highly siliceous. The deposit has been opened up at several levels by both open-cuts and adits. It is stated that at present sufficient ore is blocked out to operate the 20-ton furnace for several years. As a whole the underground workings are not very extensive, the major portion of the output having come from the open-

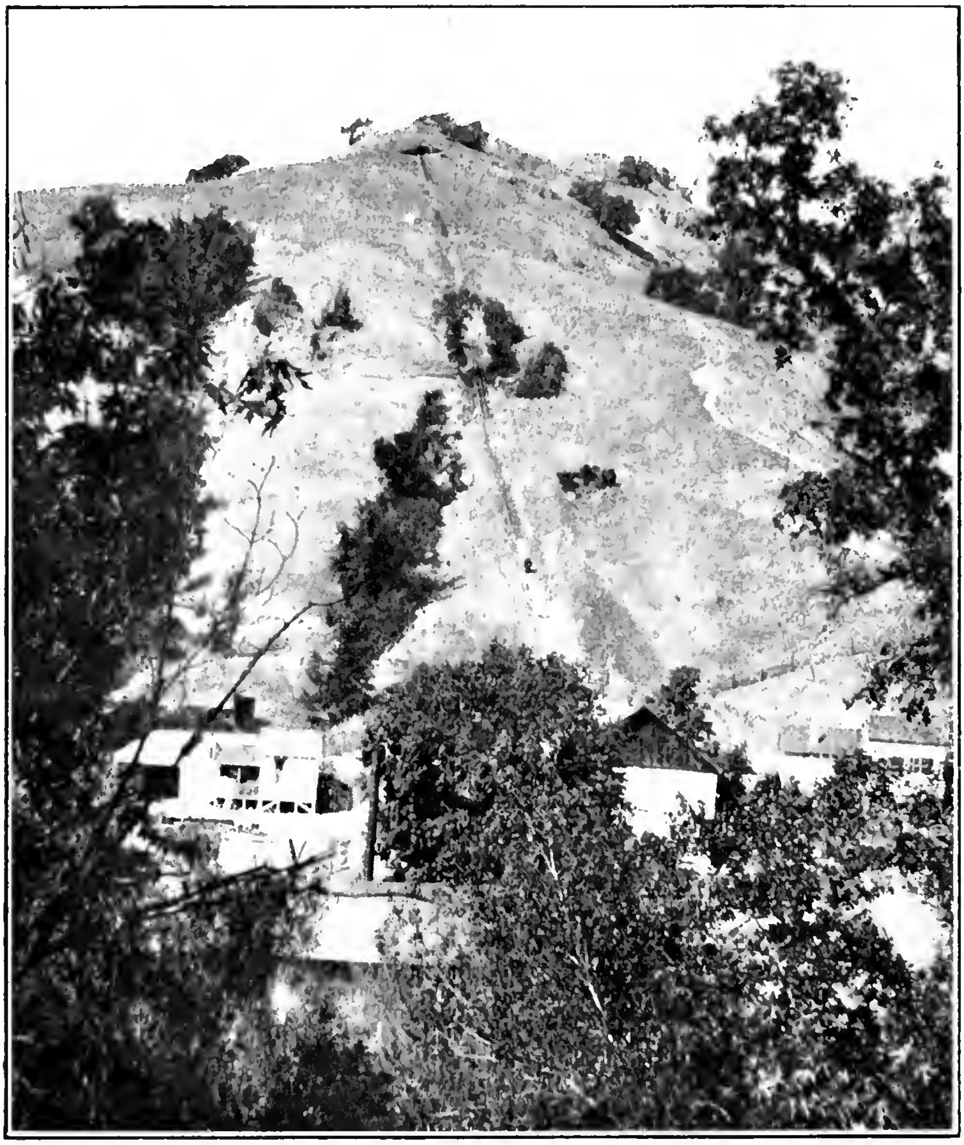


Photo. No. 37. Cloverdale Mine, Sonoma County, showing gravity tram to furnace ore-bins. Photo by Emile Huguenin.

cuts. With topography decidedly in their favor, the ore is handled a surprisingly unnecessary number of times between the mine and the furnace.

The latter is a modified Livermore furnace, of 20 tons capacity, which is essentially a tile furnace with inclined reverberatory hearth.[1] The products of fuel combustion pass directly over the ore layer.

[1]See pp. 226, 229, 230, *post*; also Photo No. 47.

Crude oil is now used for fuel instead of wood, as formerly, the oil being fed by 4 Ray electric burners. (See Photo No. 48, *post.*) The condensers are in part Knox & Osborne iron chambers, to which were added in 1917, three redwood, rectangular boxes, approximately 5'x8'x15', each having 3 compartments. An experimental concentration plant set up on the Squaw Creek side was in operation for a short time early in 1916. Some success is said to have attended their experiments, but for certain financial reasons a larger plant was not built.

Bibl.: Cal. State Min. Bur., Reports X, p. 675; XIV, p. 344, Bull. 27, pp. 98–102, 215; Chapter rep. bien. period, 1913–1914, p. 172. U. S. G. S., An. Rep. XXI, Pt. VI, p. 278; Min. Res. 1902, p. 253; 1907, Pt. I, p. 554; 1910, Pt. I, p. 701; 1911, Pt. I, p. 904; 1912, Pt. I, p. 944; 1915, Pt. I, p. 271. Min. Res. W of Rocky Mts., 1875, pp. 14, 177; 1876, p. 20.

Culver-Baer Mine. Culver-Baer Mining Company, owners; C. E. Humbert, president; J. P. Menihan, secretary; home office, Cloverdale. The holdings of this company now include, besides the Culver-Baer group, proper, the Black Bear, Clyde, Kentucky and Missouri. There are 9 patented claims: Clyde, Culver-Baer #1 and #2, Sunnyside, Brush, Republic, Safe Deposit, Acomax and Hatteras (the last 2 being formerly the Missouri); but the Black Bear and 3 others are unpatented. Besides 169 acres of patented ground, there are 2000 acres of grazing and timber lands in connection. These claims are at the head of Devil's Den, a branch of Little Sulphur Creek, in Sec. 23, T. 11 N., R. 9 W., 20 miles south of east from Cloverdale. The Culver-Baer group proper includes the old Geyser and Oakland mines, of early days, which were producers for several years previous to 1880. In 1875 the Oakland mine was producing 100 flasks per month with six retorts. The property is credited with a total production to the end of 1917 of 8922 flasks.

The topography is rugged; elevation 2200 feet (bar.) at the stable. The ledge is characterized by a bold outcrop of silicified sandstone with abundant yellow ochre, and is traceable on the surface for a mile in length. The vein-filling is mostly quartz with some lime and chalcedony. The ore carries cinnabar, meta-cinnabarite and some native mercury. The ledge averages 100 feet in width but only 35 feet on the footwall is stoped. It strikes northwest, dips northeast on an average of 60° and has been drifted on, all told, for a length of 1200 feet. The hanging-wall is serpentine.

The three main levels are the upper tunnel of 700 feet in length, the lower tunnel in 2000 feet, and 300 feet below, and an intermediate level which does not come to the surface. These two tunnels are connected by a raise from the 1200′ point in the lower one. In 1914–1915 a new raise was driven starting at 1960′ in the lower tunnel. More recently a crosscut started at 550′ in the lowest level, had been driven 130′ north up to September, 1917, and was then opening up a body of furnace-grade ore. One stope from the No. 1 raise is 25′ wide by 90′ long and has 400′ of backs.

The equipment includes an air compressor driven by a 32 h. p. Fairbanks-Morse gasoline engine; also Cleveland stopers and an 8″x10″ jaw crusher. There is a 16-ton Knox-Osborne coarse-ore furnace, a 24-ton, Scott fine-ore furnace and a retort. A small steam engine drives the furnace blower. Bricks for furnace work were burned from clay near the mine. The cost of wood cutting has increased to $2.50 per cord, from $1.50 formerly paid.

Bibl.: CAL. STATE MIN. BUR., Reports IV, p. 336 (table); V, p. 96; XI, p. 461; XII, p. 371; XIII, pp. 602, 603; XIV, p. 345–346; Chapter rep. bien. period, 1913–1914, pp. 173–174; Bull. 27, pp. 102–105, 113, 215. U. S. G. S. Mon. XIII, p. 377; Min. Res. 1902, p. 253; 1907, Pt. I, p. 680; 1908, Pt. I, p. 690; 1909, Pt. I, p. 554; 1910, Pt. I, p. 701; 1911, Pt. I, p. 904; 1912, Pt. I, p. 944; 1915, Pt. I, p. 371. MIN. RES. W. OF ROCKY MTS., 1875, pp. 14, 175, 177, 493. TRANS. A. I. M. E., vol. III, pp. 276, 304.

Double Star Prospect. It is near Pine Flat. Abandoned. No ore was found after considerable development.

Bibl.: CAL. STATE MIN. BUR., Report XIV, p. 346; Chapter rep. bien period, 1913–1914, p. 174; Bull. 27, p. 105.

Esperanza Mine (formerly **Bright Hope**). Dr. Geo. T. Pomeroy, president, Delger Block, Oakland. This prospect is on an 80-acre piece of land held under an agricultural patent. It is on the Geysers road 15 miles east of Cloverdale, and 2 miles above the Cloverdale mine on the opposite side of Big Sulphur Creek; elevation 1475 feet (bar.). There are two crosscut tunnels on the stage-road level, one in 180′ and the other 450′. The latter attains a depth of 100′ below the surface, and has drifts of 75′ west and 60′ east, also a 50′ winze. The main adit, #2 level, is below the road, and when visited by the writer in September, 1917, had been driven 350′ and was just breaking into the contact, showing cinnabar apparently without native quicksilver. The country rocks are sandstone and serpentine. The ore occurs partly in a contact ledge and partly as an impregnation in the sandstone. Both cinnabar and native quicksilver are present in the upper levels at least, with quartz as the principal gangue mineral, mixed with some serpentine. No ore has been taken out as yet except that in the course of development. The native metal seems to occur principally in brecciated areas in the contact zone.

In 1916, a Livingston, continuous-feed-retort furnace was built and a small amount of ore run through it, but it was not successful. This furnace is described elsewhere herein,[1] under the section of Metallurgy. Late in 1917, a few flasks of quicksilver were produced with a small retort.

Bibl.: CAL. STATE MIN. BUR., Report XIV, p. 343; Chapter rep. bien. period, 1913–1914, p. 171.

Eureka Mine (originally **Flagstaff**). Eureka Quicksilver Mining Company, owner; James B. Barber, president, #1421 High St., Oakland; W. B. Hodges, secretary. This group of 4 claims and 3 mill-sites, part of which is patented, is in the Pine Flat district, in Sec. 22, T. 11 N., R. 8 W., M. D. M., about 20 miles by road northeast from Healdsburg and the same distance northwest from Calistoga. It is northwest of and adjoints the Socrates. Outside of a small amount of prospecting work done as assessments to hold the unpatented claims, the property has been mostly idle for some years. In 1916–1917, it is stated some further prospecting was done, but only low-grade ore found. A few flasks of quicksilver were produced in 1904, and a few also in 1916 with a retort.

The orebody is on the contact between a serpentine hanging-wall and sandstone footwall, being in part altered and gouge material from both. Values occur as cinnabar, meta-cinnabarite and native mercury, about 50% being native. There is one tunnel in about 1000′, giving 300′ backs, and several other shorter ones above. The lowest tunnel has drifts of 250′ and 100′, respectively. Another adit has been started at a still lower level. There is a 10-ton, modified Livermore-Fitzgerald furnace, a gasoline engine, and a small compressor included in the equipment.

Bibl.: CAL. STATE MIN. BUR., Report XIV, p. 346; Chapter rep. bien. period, 1913–1914, p. 176; Bull. 27, pp. 106–108. U. S. G. S., Mon. XIII, p. 376. MIN. RES. W. OF ROCKY MTS., 1875, pp. 14, 176.

Great Eastern Mine. Great Eastern Quicksilver Mining Company, owner; George Roeth, president, 450 Mountain Ave., Oakland. This mine is in Sec. 16, T. 8 N., R. 10 W., M. D. M., 4 miles northeast of Guerneville by a good road; elevation 360 feet (bar.). Production of quicksilver began here with an output of 412 flasks in 1875; and the mine is credited with a total output to date of 42,092 flasks, or nearly two-thirds of the total output of Sonoma County to the end of 1917.

[1]See p. 217, *post*.

This includes the yield of the Mt. Jackson mine adjoining, as the two were operated in conjunction for a number of years, and their individual figures are not separable. As noted in a foregoing paragraph, from 1882 to 1894, the Great Eastern mine was the only quicksilver producer in Sonoma County.

This Great Eastern-Mt. Jackson lode is peculiar because of its isolation from other workable quicksilver deposits and from any known eruptives. It resembles somewhat the Culver-Baer ledge with its bold, ochreous outcrop between a serpentine hanging-wall and sandstone footwall. (Seen at left of Photo No. 38.) The strike is north of west and dips north at 50° to 60°, being steeper at the surface. The Great

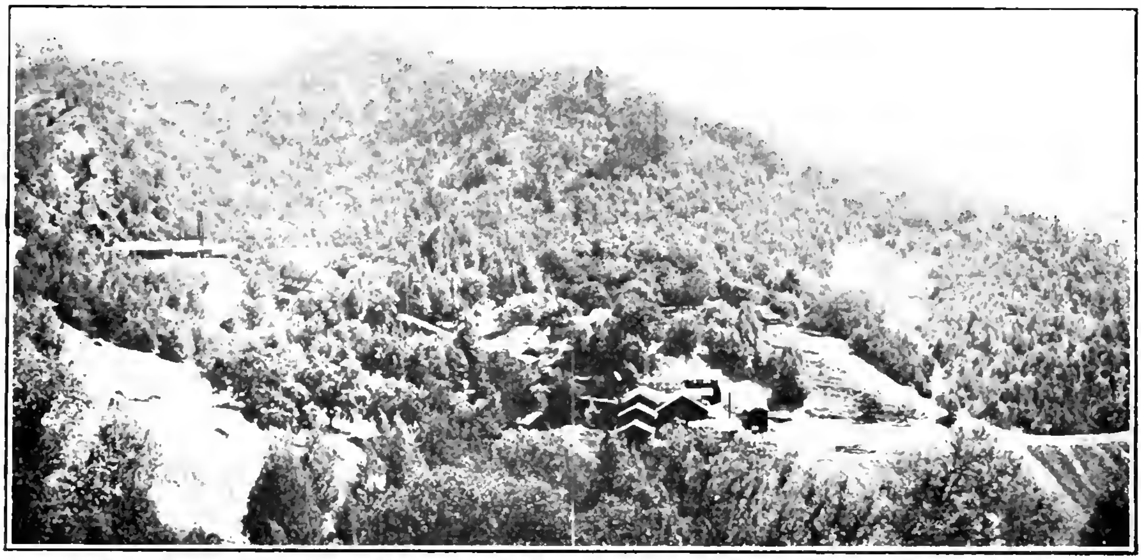


Photo No. 38. Great Eastern Mine, near Guerneville, Sonoma County. Ledge outcrop at left; furnaces in center; furnace dump at right.

Eastern vertical shaft sunk in the sandstone footwall is down 550′, with two winzes of 160′ each sunk from the 500′ level. There is also a 400′ drift on the 500′ level. The collar of the shaft is about 200′ below the upper outcrop, and at that level there is a tunnel in 1100′, with connecting drifts and stopes in the ledge above. From the shaft there are levels at 150′, 220′, 360′ and 500′, respectively.

The ore shoot is enclosed within the ledge of opalized rock which was originally probably mostly serpentine. Becker[1] considers that this silicification "preceded the deposition of ore, though somewhat closely connected with it." Occasionally a little pyrite accompanies the cinnabar. The ledge filling is characterized by numerous cross-fissures, at a flat angle, filled with quartz stringers, like the 'ladder veins' described by Lindgren.[2] The ore forms principally in relatively softer zones in this material. Accompanying the ore, frequently in stringers

[1]Becker, G. F., Geology of the quicksilver deposits of the Pacific Slope: U. S. Geol. Surv., Mon. XIII, p. 364, 1888.
[2]Lindgren, Waldemar, Mineral Deposits: pp. 133, 146, 1913.

parallel to the above-mentioned quartz partings, is a brittle black bitumen, which may possibly be grahamite, as its properties correspond in part at least to that bitumen. It is partly soluble (even in fragments not powdered) in ether; completely soluble in chloroform; distinctly soluble in California kerosene; apparently insoluble in Pennsylvania petrolic ether of 88° Baumé; and is broken up by, but only slightly soluble in carbon tetrachloride. It deflagrates, and only partly melts in a candle flame. This bitumen is usually associated with good ore values.

For several years previous to 1905 (in which year it expired), the Great Eastern Company had a lease on the Mt. Jackson ground adjoining and worked it through the Great Eastern levels. The earthquake of April 18, 1906, shook from the outcrop cliff near-by a large rock which rolled into the shaft, killing three men coming up in the cage. It also partially wrecked the shaft. The damage to the shaft has been repaired, but the lower levels have not been operated since, being at present filled with water. Ore reduction was resumed in May, 1915. Only the upper portions of the mine, above the hoist level, are being worked. The ore is broken in stopes and open-cuts and dropped through chutes to the main adit level. There is an abundant water supply from several springs on the property. The hoist was operated by a wood-burning steam plant. The crusher plant adjoins the hoist and a gravity tram conveys the ore to the furnaces. After screening through the grizzly, the wet fine ore is hauled in wheelbarrows and spread out on a level 'patio' in the sun to dry. After drying, it is returned to the ore-bins by the same route. There is too much handling of the ore by manual labor before it gets to the furnace.

When visited by the writer in September, 1917, the old Knox & Osborne 14-ton coarse-ore furnace was being partly torn down to be rebuilt as a Scott fine-ore furnace of about 30 tons capacity. Their #1 Scott fine-ore furnace has a capacity of 18 tons. There are two 'D' retorts, 18″ and 24″ respectively; but they are not much used now, as there is very little soot to handle since the use of oil fuel instead of wood, and the construction of the new concrete condensers. The 18-ton furnace was using 100 gal. of 23° B. fuel oil per 24 hours at a cost of slightly over 3¢ per gallon. A Hauck crude-oil burner is used, with compressed air for atomizing. On the retort, a 'Rotary Oil Burner' is used, driven by a small water-wheel. With this, it requires 30 hours to heat up the retort, after which the consumption of oil is 100 gal. per 48 hours.

Condensers on No. 1 Scott furnace: No. 1 is a 2-chamber, brick condenser, 10′ x 12′ x 22′; No. 2 is a 2-chamber, concrete unit, 16′ x 10′ x 22′; No. 3 is a 4-chamber, concrete unit, 16′ x 8′ x 22′. These concrete condensers cost about $600 apiece. They are built with a 6″ wall, reinforced with wire and painted on the inside with 'neat cement' to fill the pores. In the cleaning-up, these walls are simply hosed down with a stream of water. The old brick condensers which these replaced, yielded 8 flasks of quicksilver. They were set in cement mortar.

In September, 1917, the ordinary quicksilver flasks were costing $2 apiece. Roeth had had some cast of stove-iron, to his own pattern, at a foundry in Oakland at a cost of approximately 75¢ apiece, weight 18 pounds. At that time, some of these had made three trips to San Francisco without damage.

Bibl.: Cal. State Min. Bur., Reports IV, p. 336 (table); V, p. 95; VIII, p. 633; XI, p. 460; XII, 371; XIII, p. 602; XIV, p. 347; Chapter rep. bien. period, 1913–1914, p. 175; Bull. 27, pp. 108–112, 226, 239, 246. U. S. G. S., Mon. XIII, pp. 362–364; An. Rep. XX, Pt. VI, p. 271; Min. Res. 1883, pp. 394, 396, 397; 1902, pp. 251, 253; 1907, Pt. I, p. 680; 1908, Pt. I, p. 690; 1915, Pt. I, p. 271. Min. Res. W. of Rocky Mts., 1875, p. 14; 1876, p. 20. Min. & Sci. Press, vol. 89, p. 391.

Great Northern Group. In Sec. 2, T. 10 N., R. 8 W., M. D. M., near Pine Flat. Abandoned.

Bibl.: Cal. State Min. Bur., Report XIV, p. 348; Chapter rep. bien. period, 1913–1914, p. 176; Bull. 27, p. 112.

Hurley Prospect. In Secs 4 and 5, T. 10 N., R. 8 W., M. D. M., near the Sonoma mine. Abandoned.

Bibl.: Cal. State Min. Bur., Report XIV, p. 348; Chapter rep. bien. period, 1913–1914, p. 176; Bull. 27, p. 112.

Lookout Group. In Sec. 32, T. 11 N., R. 8 W., M. D. M., near the Eureka group. Abandoned.

Bibl.: Cal. State Min. Bur., Report XIV, p. 348; Chapter rep. bien. period, 1913–1914, p. 176; Bull. 27, p. 113.

Lucky Stone Group. In Sec. 4, T. 10 N., R. 8 W., M. D. M., near Pine Flat. Abandoned.

Bibl.: Cal. State Min. Bur., Report XIV, p. 348; Chapter rep. bien. period, 1913–1914, p. 176; Bull. 27, p. 113.

Maricoma Prospect (Santa Rita). In Sec. 36, T. 10 N., R. 8 W., M. D. M., near Pine Flat. Abandoned.

Mt. Jackson Mine. Mt. Jackson Quicksilver Mining Company, owner; O. T. Hassett, president, Geyserville, R. F. D. This mine adjoins the Great Eastern mine near Guerneville on the northwest, but has no plant of its own, having been worked through the Great Eastern levels for a number of years by the Great Eastern company under lease. The Mt. Jackson mine has been idle since 1905, but recent press reports (March, 1918) state that an option has been given to J. H. Kendall, 64 Regent St., Oakland, who is reopening one of the upper tunnels.

Bibl.: Cal. State Min. Bur., Reports VIII, p. 633; XII, p. 371; XIII, p. 602; XIV, p. 349; Chapter rep. bien. period, 1913–1914, p. 177; Bull. 27, pp. 108–112.

Napa Prospect. In Sec. 11, T. 10 N., R. 8 W., M. D. M., near Pine Flat. Abandoned.

Bibl.: Cal. State Min. Bur., Report XIV, p. 349; Chapter rep. bien. period, 1913–1914, p. 177; Bull. 27, p. 113.

New Sonoma Mine (formerly **Sonoma Consolidated Group,** including **Crown Point** and **Hope**). T. Gale Perkins et al., owners, Pine Flat postoffice, or #1822 Pacific St., San Francisco. This group of 7 claims is in Secs. 4 and 5, T. 10 N., R. 8 W., M. D. M., in the Pine Flat district, about 16 miles northeast of Healdsburg. About 1910, this property was bought by the Culver-Baer company, particularly for its surface equipment including a Scott furnace, which was transferred to the Culver-Baer mine 5 miles to the northwest. Under the impression that the claims were patented the Culver-Baer company did no work on the mine for several years, following which the ground was relocated by the present owners, as they found it to be unpatented. The last previous operations were by the Crown Point company. Production began with an output of 50 flasks of quicksilver in 1873. The early production was from rich surface pockets. There is an adjacent serpentine belt, striking N. 48° W.

Perkins states that he has found the orebody at 5 separate levels and points in a zone striking southeast, but swinging around to the south and dipping easterly. He has driven 9 crosscut adits up to 110′ in length, until each one cut the orebody, to prove its continuity. He now proposes to drive a lower adit of 1100′ in length. There is considerable native quicksilver with the cinnabar, particularly in the ore near the surface. It is proposed to concentrate the soft, surface material. Some ore taken out in the course of development was retorted in 1917. The reduction equipment is a 'D' retort of 1000 lb. capacity, being 12″ high x 32″ wide x 9′ 2″ long. A water spray is used in the condenser-pipe, similar to that at the Oat Hill mine described elsewhere herein;[1] but Perkins states that he obviates loss of floured quicksilver floating away, by syphoning the flow to successive settlers.

Bibl.: CAL. STATE MIN. BUR., Reports XIII, p. 503; XIV, p. 350; Chapter rep. bien. period, 1913–1914, p. 178; Bull. 27, pp. 102, 112. U. S. G. S., Mon. XIII, p. 377; Min. Res. 1902, p. 253. MIN. RES. W. OF ROCKY MTS., 1874, p. 30; 1875, p. 14. TRANS. A. I. M. E., vol. III, p. 290.

Occidental and Healdsburg Group. In Sec. 10, T. 10 N., R. 8 W., M. D. M., near Pine Flat. Abandoned.

Bibl.: CAL. STATE MIN. BUR., Report XIV, p. 349; Chapter rep. bien. period, 1913–1914, p. 177; Bull. 27, p. 114.

Old Chapman Prospect. In Secs. 25 and 30, T. 10 N., R. 8 W., M. D. M., at the mouth of Sausal Creek cañon, on Deer Creek. On the south side of Deer Creek a line of croppings, course about N. 15° W., runs down the slope toward the creek, but the underground workings have not disclosed any continuation of ore in depth. Abandoned.

Bibl.: CAL. STATE MIN. BUR., Report XIV, p. 349; Chapter rep. bien. period, 1913–1914; Bull. 27, p. 114.

Pacific Group (**Crystal** or **Red Cloud**; also known locally as the **Abbey**). Wm. Jacobs, owner, Pine Flat. This group consists of patented claims in Secs. 5 and 6, T. 10 N., R. 8 W., M. D. M., near the New Sonoma group in the Pine Flat section. Only a small amount of prospecting work has been done for several years past. There is no reduction equipment.

Bibl.: CAL. STATE MIN. BUR., Reports XIII, p. 603; XIV, p. 349; Chapter rep. bien. period, 1913–1914, p. 177; Bull. 27, p. 114. U. S. G. S., Min. Res., 1902, p. 253.

Rattlesnake Mine. G. W. Wheeler and Frank G. Kiessig, owners, Pine Flat; R. A. Sallee, lessee, Pine Flat. This group of 3 claims and 2 mill-sites is in Sec. 31, T. 11 N., R. 8 W., M. D. M., on the road between the Culver-Baer mine and Pine Flat. This mine is credited with a production of 65 flasks in 1875, entirely from native quicksilver, with which was associated an oily bitumen. Not only was the metal entirely in the native state, but it is claimed that there was considerable mercurial vapor in the underground workings. The mine was idle and inaccessible for many years, until reopened by the present owners in 1916. A few flasks of quicksilver have since been recovered by washing and retorting. When visited by the writer in September, 1917,

[1] See p. 211

the lessee was trying a revolving screen and sluice boxes for washing the material.

Judging from the surface, the country rock consists of altered sedimentaries, with occasional small occurrences of serpentine. The native metal occurs in a black, brecciated mass and gouge. No definite walls have been found. There are two adits, each in about 200′, the upper one being at the road level, and the other 60′ below, near the portal of which the retort is located. The furnace consists of 3 pipes of 300 lb. capacity, each. Like the Socrates mine, the difficulty here is to handle the native metal economically. If the underground situation can be handled successfully and safely, it would seem that the ore-dressing end might be solved by concentrating tables or by hydraulic settlers. The ore is rather wet and requires drying if it is to be furnaced. If collected direct by concentration, however, the native metal would not need to be put through a furnace. Only such cinnabar as would appear in the concentrates would need to be roasted.

Bibl.: CAL. STATE MIN. BUR., Reports IV, p. 336 (table); XIII, p. 603; XIV, p. 349; Chapter rep. bien. period, 1913–1914, p. 177; Bull. 27, p. 115. U. S. G. S., Mon. XIII, p. 377. MIN. RES. W. OF ROCKY MTS., 1874, p. 37; 1875, pp. 14, 176. TRANS. A. I. M. E., vol. III, p. 273.

Socrates Mine (originally **Pioneer**; includes **Pontiac Group**; also **Mercury Group**). Socrates Consolidated Mining Company, owner; Wm. H. Jordan, attorney, Monadnock Building, San Francisco; U. S. Mines Development Corporation, lessee; Paul Messchaert, president; B. G. Holt, secretary; office, 514 Sheldon Bldg., San Francisco. This group is at the junction of Secs. 32 and 33, T. 11 N., R. 8 W., and Secs. 4 and 5, T. 10 N., R. 8 W., M. D. M., in the Pine Flat district, on the divide between Big Sulphur and Little Sulphur creeks, 6 miles southeast from The Geysers. Elevation 3,000′ at mine; 2500′ at furnace. The Pioneer claim of this group was the first quicksilver claim located in Sonoma County. The Socrates, proper, is patented, besides which there are 53 other claims mostly unpatented. In 1904, the adjacent property of the Mercury Mining Company was taken over by the Socrates Company. It is about equidistant, 20 miles, from Healdsburg and from Middletown, being on the road between the two which passes through Pine Flat. Owing to the difficulty of handling the native metal which makes up the major portion of the values here, the mine was idle for many years. The occurrence of tiemannite, the selenide of mercury, has also been noted in the Socrates mine. The recorded production for the years 1900–1917, inclusive, totals approximately 3,500 flasks of quicksilver; there being no segregated figures of the early-day output, which is reported to have been about 1000 flasks.

In 1903, a White-Howell rotary roaster was installed and operated for several months on the Socrates ore. The surface plant was destroyed by a forest fire in the fall of 1907. During 1908–1910, the Socrates Development Company, operating the property under bond, made a fair output of quicksilver, employing a Huntington mill and a Woodbury concentrator. The concentrates were retorted. The present operators reopened the mine in 1916, and have built a 40-ton Scott furnace. (See Photo No. 39.) They have cut down the length of the

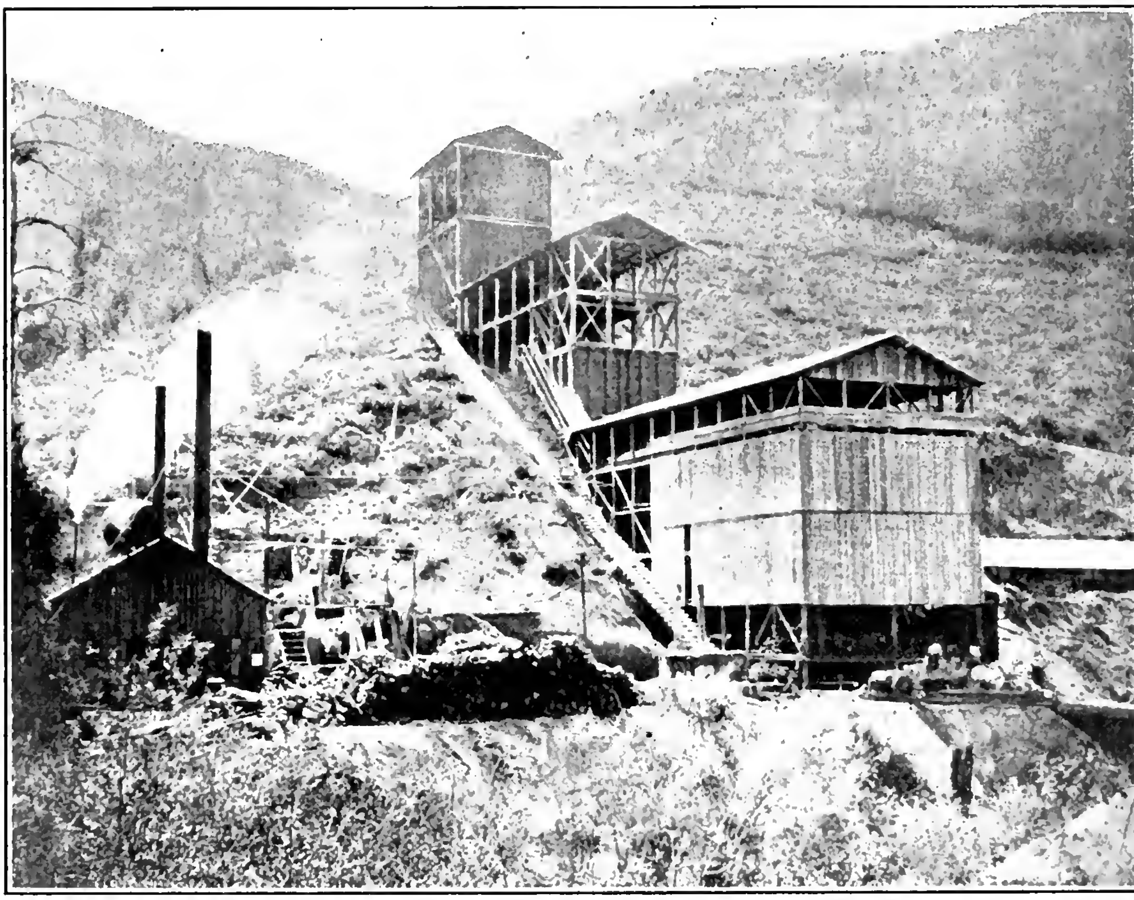


Photo No. 39. Socrates Mine surface plant, Sonoma County. The mine is on the ridge at the left.

White-Howell kiln and reinstalled it as an ore-drier above the Scott furnace.[1]

The country rocks are sandstone and serpentine. The ore occurs in a ledge of soft opaline rocks, considerably fractured, but in the upper levels it is also in sandstone. The strike is about N. 20° W. In the upper levels, the footwall consists of sandstone and shales slightly swelling, and there is a heavy hanging wall of black gouge. A 'horse' of black serpentine runs through the middle of the ledge matter. In the lowest level, the dip appears to have reversed, so that the black gouge is on the footwall, and the hanging-wall is a hard serpentine. There the dip is nearly vertical. In the upper levels, the quicksilver

[1]See Photo No. 51, *post*.

was nearly all in the native form; but in the lowest level when visited by the writer, a considerable proportion of cinnabar was showing in the ore. The values occur both disseminated and in veinlets. Some pyrite or marcasite and calcite are associated. Chlorite, an end product of the alteration of serpentine, is also abundantly present. The ore shoots are from 18″ to 5′ in width, in an ore zone of 60′ maximum width and 30′ average.

There are 3 main adits (#1, #2, and #3) and 2 others, (#3½ and #4) and the vein has been opened up for a length of 750′. A depth of 400′ below the top of the hill has been reached. Many of the old workings are inaccessible. Square-set timbering is used. There is a fair local supply of oak, pine and 'fir.' A single-rope aerial tram, 1875′ long, steam-driven, transports the ore to the furnace bins. Equipment also includes a compressor, Water-Leyner jack-hammer drills, and an air-driven hoist.

Reduction equipment includes the rotary ore-drier and the 40-ton Scott above mentioned, also 2–18″ 'D' retorts. When visited by the writer in September, 1917, the surface plant was being rearranged and development work carried forward underground. A small amount of sorted ore was being put through one retort. They had added 16′ onto the top of the dust-chamber of the Scott furnace, and were covering it with a sheet-iron top to be used as a final drier before the ore is charged to the furnace. From the tramway bin, the ore was to pass through the rotary drier to another bin, thence by a belt conveyor to the sheet-iron drier. In February, 1918, a total of 70 men were employed, 32 of whom were in the mine. At the present writing (April, 1918), we are informed that operations are shut down.

Bibl.: Cal. State Min. Bur., Report XIV, p. 350; Chapter rep. bien. period, 1913–1914, p. 178; Bull. 27, pp. 115–116. U. S. G. S., Mon. XIII, p. 376; Min. Res. 1902, p. 253; 1906, pp. 493, 497; 1907, Pt. I, p. 680; 1908; Pt. I, p. 690; 1909, Pt. I, p. 554; 1910, Pt. I, p. 701; 1915, Pt. I, p. 271. Geol. Surv. of Cal., Geol., Vol. I, pp. 88–91. Min. Res. W. of Rocky Mts., 1875, pp. 14, 176, 177. Min. & Sci. Press, Vol. XC, p. 22, Jan. 14, 1905.

Squaw and **Big Chief Claims.** L. D. Kissack and John June, Cloverdale, owners. These claims are in Sec. 4, T. 11 N., R. 9 W., M. D. M., adjoining the Cloverdale mine, 12 miles east from Cloverdale; elevation 2200 feet (bar.). The ore is similar to that of the Cloverdale. A tunnel and a short incline from it have been driven in about 60 feet.

and a small amount of high grade ore sorted from the material taken out. Assessment work, only, is maintained.

Bibl.: Cal. State Min. Bur., Report XIV, p. 351; Chapter rep. bien. period, 1913–1914, p. 179.

Walker Prospect. On patented ground in Sec. 7, T. 8 N., R. 10 W., M. D. M., near Guerneville, owned by the Meeker Estate of Camp Meeker. A few stringers carrying cinnabar are said to have been found, but nothing of consequence developed.

Bibl.: Cal. State Min. Bur., Report XIV, p. 351; Chapter rep. bien. period, 1913–1914, p. 179; Bull. 27, p. 116.

Wall Spring Prospect. H. C. Wall, Hilton, owner. In Sec. 30, T. 8 N., R. 9 W., M. D. M., near Hilton. Idle.

Bibl.: Cal. State Min. Bur., Report XIV, p. 351; Chapter rep. bien. period, 1913–1914, p. 179; Bull. 27, p. 117.

STANISLAUS COUNTY.

There is an extensive area of Franciscan rocks following along the trend of the Diablo Range, from the cañon of Corral Hollow Creek at Tesla, southeasterly for at least 75 miles. The Stayton quicksilver district at the junction of Merced, San Benito and Santa Clara counties is at the southern end of this belt. Within this belt in western Stanislaus County, and on the eastern slope of the range, are several quicksilver prospects, from some of which metal has been produced. These are east of and near the Red Mountain magnesite district. There are four groups on the upper branches of Orestimba Creek, and one group on Deer Park Creek or the north branch of Arroyo del Puerto. The total output of the district appears to have been slightly in excess of 200 flasks of quicksilver.

Adobe Valley Mine (formerly **Stanislaus**). E. P. Newhall, owner, Box 354, Livermore. This consists of 320 acres of patented land in Secs. 23 and 24, T. 6 S., R. 5 E., M. D. M., east of the Phoenix mine, 21 miles from Patterson. The Patterson & Western Railroad, recently built up the Arroyo del Puerto, passes about two miles from this property. This prospect was opened up in 1884, and a small amount of quicksilver produced up to 1888, since which time, it appears to have been idle.

The country rock is a gray sandstone. The ore occurs in 3 veins which have a northerly strike, and are cut by a 2-compartment vertical shaft sunk to a depth of 180′. The upper vein, with dip of 45° was opened up by a series of open-cuts, short tunnels, and an incline shaft 70′ deep. The vertical shaft cut the first vein at a depth of 40′, at which level a drift was run 30′ N., then a crosscut to the hanging-wall, showing the orebody 4′–5′ wide. At the 75′ level, the second (?) vein was cut, and a drift run 100′ N. This may be a spur from the lower vein, as it dips at a very flat angle; and is irregular in shape and size.

At 100′ depth, the third orebody was cut, showing cinnabar in a fine-grained dark sandstone, with associated pyrite. The shaft is closed below 120′ in depth. It is stated that at 170′ a crosscut was driven westerly, which cut the vein at 70′ showing a width of 15′. This lower orebody shows cinnabar disseminated in the sandstone, as well as occurring along the fracture zones. There is considerable black clay gouge on the hanging-wall.

There is no reduction equipment at present on the property.

Bibl.: Cal. State Min. Bur., Reports X, p. 680; XIV, p. 632; Chapter rep. bien. period, 1913–1914, p. 206; Bull. 27, p. 189.

Crocker-Winship Prospect. M. I. Crocker and K. D. Winship, owners, San Francisco. There are some quicksilver prospects on Sec. 31, T. 5 S., R. 5 E., M. D. M., on which it is stated some work was done about 1913, under a lease, by the Mt. Boardman Quicksilver Company.

Gigax Claims. A. B. Gigax, of Patterson, is reported to have recently located claims on a quicksilver prospect on Mt. Boardman in the northwestern corner of the county, near the Newhall claims.

International Mine. In Sec. 3, T. 8 S., R. 6 E., M. D. M., on the south fork of Orestimba Creek, southeast of the Phoenix mine. The prospect was worked for a short time, prior to 1880, and some metal produced with a small furnace and retorts; but it has been idle since.

Bibl.: Cal. State Min. Bur., Report X, p. 680.

Newhall Mine (formerly **Deer Park**). E. P. Newhall Quicksilver Mining Company, owner; E. P. Newhall, president, Box 354, Livermore; Chester M. Beck, secretary, Mills Building, San Francisco. This group of 7 claims is on Deer Park Creek in Sec. 32, T. 5 S., R. 5 E., M. D. M., 22 miles from Patterson via the Arroyo del Puerto. There are several croppings which show cinnabar in sandstone and in serpentine. Some development work has been done, principally by a tunnel; but no metal has as yet been produced, and there is no reduction equipment. Some work was done on these prospects in 1913 under a lease by a company known as the Mt. Boardman Quicksilver Company, who are stated to have also had a lease on adjoining land in Sec. 31 owned by K. D. Winship and M. I. Crocker of San Francisco.

Bibl.: Cal. State Min. Bur., Reports X, p. 681; XIV, p. 632; Chapter rep. bien. period, 1913–1914, p. 206.

Phoenix Mines (includes the former **Summit, Grayson,** and **Orestimba** mines; also referred to as the **Hayward**). Alvinza Hayward Estate and Mrs. Emma Rose, New York, owners; E. S. McCurdy, manager, 576 Mills Building, San Francisco. The Summit-Grayson group is in Secs. 20, 21, 28, and 29, and the Orestimba group in Secs. 25, 35, and 36, all in T. 6 S., R. 5 E., M. D. M., 39 miles southeast of Livermore by a good road. It is also 24 miles south of west from Patterson, but the road is poor. Elevation 2150′ (bar.). Oak timber is available, and the water supply is from springs.

There are 7 patented claims, 4 millsites, 6 unpatented claims and 160 acres of timber land in the Summit-Grayson group; and 2300 acres of patented land in the Orestimba group. This property was first worked in the 70's by a Mr. Waterford, and sold to Hayward about 1901. The furnace was built in 1902–1903. The mine was reopened in September, 1915, and operated during the high prices prevailing for quicksilver during that winter, closing down in June, 1916, because of the decline in market price of quicksilver, the low grade of the ore, and the need of a larger equipment and more extensive development to handle such low-grade ore. The total production to date has been nearly 200 flasks.

The country rocks are sandstone and serpentine. The cinnabar is disseminated with infiltrated silica in an altered weathered sandstone; also in serpentine. The Summit-Grayson group is opened up mainly by 3 crosscut tunnels, connected by raises and winzes, which show 3 zones of mineralization; Summit vein, strike N. 15° E., dip 60° SE.; a belt of sandstone, with northwesterly strike, crossing the Summit vein; the Grayson vein, with a northwesterly strike and northeasterly dip.

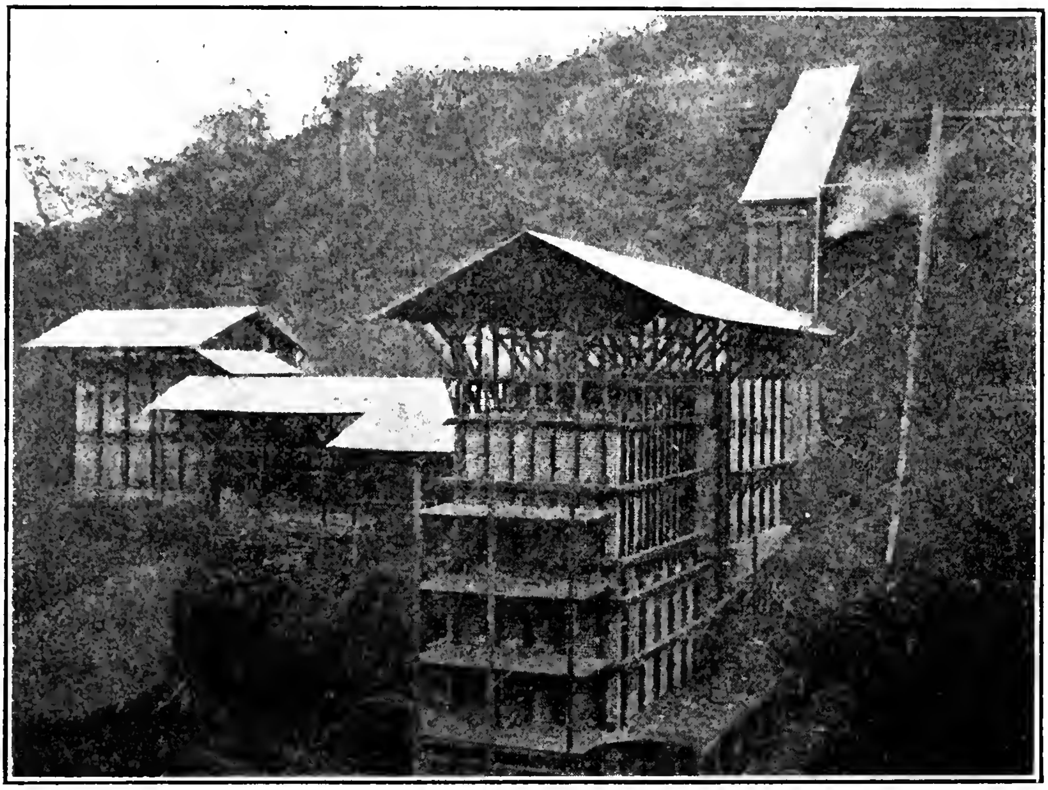


Photo No. 40. Fifty-ton Scott furnace and condensers at Phoenix Mines, Stanislaus County. Photo by F. L. Lowell.

The gangue contains calcite. The principal development is on the Summit vein, which has an average width of 10′. The grade of the ore averages 0.25%–0.30% mercury. The lowest adit is the main haulage level. No. 2 level is 100′ below No. 1, and #3 is 110′ below No. 2. Ore was extracted by overhand stopes. Only a small amount of work has been done on the Orestimba group, where the country rock appears to be a silicified shale.

When last operated equipment included a 12″x7½″x12″ Chicago Pneumatic compresor and machine drills, and haulage was by mule-train; but the movable equipment has now been taken away. There is a 50-ton Scott furnace (see Photo No. 40).

Bibl.: Cal. State Min. Bur., Reports X, pp. 680, 681; XIII, p. 603; XIV, pp. 632, 633; Chapter rep. bien. period, 1913–1914, pp. 206, 207; Bull. 27, pp. 188, 189. U. S. G. S., Min. Res., 1915, Pt. I, p. 271.

TRINITY COUNTY.

Surface indications of quicksilver ores are found in several places throughout Trinity County, but active mining for this metal has only been carried on in the northeastern part of the county, between Crow Creek, a tributary to the east fork of the Trinity River, and the north fork of the east fork of Trinity River. On the surface the country rock is principally serpentine, usually very hard. Chromite and chrysotile asbestos are found in these serpentine areas. There are exposures of metamorphic rocks, principally sandstones, west of the quicksilver zone, on the slope toward the North Fork. The material in which the quicksilver orebodies form is a very much altered rock, probably originally igneous, as it appears to have been porphyritic. The principal commercial output of quicksilver has come from the Altoona mine, with some also from the Integral mine.

The recorded production for the county is shown by the following tabulation:

Quicksilver Production of Trinity County.

Year	Flasks	Value	Year	Flasks	Value
Altoona before 1875			1902	240	$10,251
(estimated)*	1,000	$88,000	1903	266	116,000
1875†	1,500	126,425	1904	102	3,864
1876*	1,979	87,076	1905	389	13,917
1877	1,317	49,129	1906	166	6,059
1878	1,534	50,469	1907	98	3,739
1879	1,919	57,282	1908	90	3,804
1880	245	7,595	1909	197	7,915
1881	------	------	1910	133	5,622
1890‡	240	12,600	1911	44	2,624
1891	------	------	1912	18	758
1895	3,926	137,410	1913	4	161
1896	4,205	139,035	1914	------	------
1897	838	29,330	1915	------	------
1898	4,032	151,200	1916	§	§
1899	3,076	123,624	1917	§12	§2,136
1900	2,294	105,982			
1901	1,302	58,668	Totals	31,166	$1,100,075

*Cal. State Min. Bur. Rep. IV, p. 336 (table).
†Min. Res. W. of Rocky Mtns. 1876, p. 19.
‡Cal. State Min. Bur. Rep. X, p. 716.
§Figures for 1916 and 1917 combined to conceal output of a single operator

The actual total is known to be in excess of that here given, as there are no segregated figures, except for the Altoona mine, available for the years previous to 1894. The figures for 1876–1880, inclusive, are those of the Altoona only, the output of other properties for that period being concealed in the early records under the heading 'other mines'. It will be noted from the above tabulation that there have been two principal periods of activity in the Trinity County quicksilver mines: 1875 to 1879 and 1895 to 1901. Since 1910, the yield has been insignificant.

Altoona Mine. Altoona Quicksilver Mining Company, owner; J. Frowenfeld, president; Chas. Allenberg, secretary; office, 333

Kearny St., San Francisco; Pratt Bros. and Teal, lessees, Carrville. This group of three claims, Trinity, Altoona, and Central, located in 1871, is in Sec. 22, T. 38 N., R. 6 W., M. D. M., 15 miles northeast of Carrville and 16 miles by trail northwest of Castella. Elevation 4625′ (U. S. G. S.). Chromite operators in this vicinity are now building a road which will permit of auto-truck transportation to within 2 miles of the Altoona mine. The first recovery of cinnabar in this district was by washing the gravels in the ravines below the Altoona ground, with rockers. The present company acquired the property in 1875, began development of the orebodies and erected a furnace, which was kept in operation until 1880, when they closed down on account of litigation. They reopened in 1894, continuing until 1911, since which time only a few flasks occasionally have been reduced from surface gouging or clean-up around the furnace plant, and from the old dumps. The present lessees propose to reopen the property to a commercial scale of operations. The main workings are at present filled with water. The total production to date of the Altoona mine has been approximately 29,000 flasks of quicksilver, though the published records appear to be somewhat contradictory in this respect.

There are four veins, three coming together at the lowest level, forming a mineralized zone 400′ long, and from 4′ to 50′ wide. The ore appears to be a contact deposit between serpentine and 'porphyry'. The footwall is serpentine. The workings consist of a vertical shaft 450′ deep, with 5 levels. In the lowest level, a winze, 152′ deep was sunk, from which 2 levels were driven. There are 7 levels in all, covering a territory of 1600′ in a northwest and 1120′ in a northeast direction, within which 4 different veins were worked to a depth of 600′. The mine makes considerable water, and was shut down in 1902, when fire destroyed part of the reduction plant, which has since been repaired. The reduction plant includes a Knox & Osborne fine-ore furnace, and a retort. Water supply is obtained from Crow Creek, between the east and north forks of Trinity River. There is abundant pine and fir timber in the vicinity.

Bibl.: CAL. STATE MIN. BUR., Reports IV, p. 336 (table); VIII, p. 643; X, p. 716; XI, pp. 481, 482; XII, p. 371; XIII, pp. 603–604; XIV, p. 923; Chapter rep. bien. period, 1913–1914, p. 179; Bull. 27, pp. 192, 219. U. S. G. S., Mon. XIII, p. 366. MIN. RES. W. OF ROCKY MTS., 1875, p. 20; 1876, p. 19.

Carr Prospect. G. Carr, owner, Carrville. This consists of one claim in Sec. 22, T. 38 N., R. 6 W., M. D. M., near Carrville. A little cinnabar ore has been exposed by open cuts.

Bibl.: CAL. STATE MIN. BUR., Report XIV, p. 924; Chapter rep. bien. period, 1913–1914, p. 180; Bull. 27, p. 193.

Integral Mine. Integral Quicksilver Mining Company, owner; Wm. J. Simpson, president, 91 Park Row, New York, N. Y.; Frank A. Mahon, manager, Castella, California. This group consists of 46 claims and several sections of timber land in Secs. 14, 15, 21, 22, 23, 27, and 28, T. 38 N., R. 6 W., M. D. M., near the Altoona mine, 16 miles by trail northwest from Castella. The mine workings are at the junction of Secs. 15, 22, and 23, on the west side of Crow Creek. The property was a small producer a few years ago, but has been idle recently.

The ore occurs in lenses in or at the contact of serpentine.[1] "In this serpentine lies a body of highly altered rock, probably an altered feldspar-porphyry, as far as ascertained in the form of an irregular lens with a northwesterly dip." No large bodies are exposed in the workings, which consist of a shaft 180′ deep, 5 levels, a winze 120′ deep, connecting the lower level with a tunnel 2760′ long; also a few hundred feet of drifts. A considerable amount of surface work has been done. Reduction equipment consists of a 24-ton Knox & Osborne furnace. Only assessment work has been maintained in recent years.

Bibl.: Cal. State Min. Bur., Reports, XII, p. 373; XIII, p. 604; XIV, p. 924; Chapter rep. bien. period, 1913–1914, p. 180; Bull. No. 27, pp. 193–195.

Overland Group. A. E. Yocom of Denny, writes (May 2, 1918) that he has located two claims on quicksilver prospects in the northwestern corner of Trinity County, on a branch of New River. Samples sent to the State Mining Bureau show cinnabar with iron oxide. The ground was located in 1886, for gold, and a 75′ tunnel driven, then abandoned. Yocom has cleaned out 40′ of this adit. He states that there is "an iron dike," striking northwest, along which for at least 900′ cinnabar can be panned out. "In one place, I have crosscut on the surface by trench 3′ deep for 50′, and the dirt all pans cinnabar." Samples of this material sent to an assayer in San Francisco showed 0.39% and 0.46% mercury. In places in the cut, the cinnabar is shown in fine stringers. "One wall is granite, the other an altered diorite." Plenty of wood and water are at hand. It is 40 miles from the State Highway, but there is a good pack trail.

Trinity Group. Reischling Bros., owners. In Secs. 21 and 22, T. 38 N., R. 6 W., M. D. M., near the Carr prospect, near Carrville. Idle.

Bibl.: Cal. State Min. Bur., Report XIV, p. 924;: Chapter, rep. bien. period, 1913–1914, p. 180; Bull. 27, p. 195.

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[1]Forstner, William, Quicksilver resources of California: Cal. State Min. Bur., Bull. 27, p. 194, 1903.

TUOLUMNE COUNTY.

The rare telluride of mercury, coloradoite, has been noted[1] in the Norwegian mine at Tuttletown on the Mother Lode gold belt near the northern boundary of Tuolumne County. It was associated with tellurides of gold and silver, but not in commercial quantities.

In the southern part of this county, also within the 'Gold Belt', two occurrences of cinnabar have also been recorded,[2] neither of which have thus far proven of economic value:

"An interesting set of veins occurs on the steep slope of the ridge east of Horseshoe Bend. The country rock is 'greenstone,' an augitic tuff so indurated as to form a hard rock. There are two nearly parallel quartz veins from 1 to 3 feet in width, which strike about N. 40° W. and dip 35° NE. The lower of these, called the Cabinet, contains chalcopyrite and a dark mineral which is apparently bornite. The upper vein is called the Lookout and like the Cabinet, is somewhat auriferous. Cutting both these white quartz veins at nearly right angles is a third vein, with approximately vertical dip, known as the Crystal. This vein contains cinnabar, mostly in small grains and crystals, but occasionally in crystals two-tenths of an inch in diameter. Cinnabar is also found at Marsh's Flat in the form of distinct stains in a decomposed fine-grained augitic tuff. It is not likely that either of these deposits of quicksilver ore will prove of economic value."

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[1]Lindgren, W., Geologic Atlas of U. S.: U. S. Geol. Surv., Mother Lode Folio (No. 63), p. 9, 1900.

[2]Turner, H. W., and Ransome, F. L., Geologic Atlas of U. S.: U. S. Geol. Surv., Sonora Folio (No. 41), p. 5, 1897.

YOLO COUNTY.

The quicksilver mines of Yolo County are in its northwestern corner, southwest of Rumsey and near the Napa County line. Geologically they are a part of the Knoxville district[1] which extends over the county lines into southeastern Lake County, as well as into Yolo. The best-known mine of the Yolo County group is the Reed which was an important producer in the early 70's. The Ruby (now January) was also a producer in former years, and has recently been reopened, and equipped with a concentrating mill.

The recorded output of quicksilver in Yolo County has been as follows:

Quicksilver Production of Yolo County.

Year	Flasks	Value	Year	Flasks	Value
1873	995	$79,928	1881	----------	----------
1874	3,000	315,540	1914	15	$736
1875	----------	----------	1915	*	*
1876	965	42,460	1916	----------	----------
1877	1,516	56,547	1917	*27	*2,101
1878	1,640	53,956			
1879	1,110	33,134	Totals	9,690	$597,484
1880	422	13,082			

*Combined to conceal outputs of single operators.

January Mine (formerly **Harrison**; also known as **Ruby,** and **New England).** Marvin W. and Mrs. Madge Harrison, owners, Georgetown; under lease and bond to January Jones, Stanford Hotel, San Francisco, and the General Mines Company, of Reno, Nevada. It is in Secs. 26 and 35, T. 12 N, R. 5 W., south of west from Rumsey. There is a good auto road from Napa, 50 miles, or from Winters. The New England claim is in Sec. 26, and the Harrison claim in Sec. 35. The principal development of value has been in the latter, which apparently covers the same ground designated by Becker[2] as the Grizzly claim. Both are in serpentine, the mineralization being accompanied by silicification, forming a very hard black opaline material. The cinnabar is crystalline and occurs in seams in the silica.

The vein is 8′–15′ wide, striking E. and dipping S. It is being developed by two adits, the upper one of which cuts the vein at 50′ and has exposed the vein for 150′ E., and 100′ W. The lower tunnel is 160′ vertically below the upper, cutting the vein at 360′, which is being drifted on both east and west. In July, 1917,[3] a raise was being driven to connect the two adits.

[1]See p. 33, *ante*.

[2]Becker, G. F., Geology of quicksilver deposits of the Pacific Slope: U. S. G. S., Mon. XIII, p. 283, 1888.

[3]The mine was visited by Mr. Emile Huguenin, field assistant of the State Mining Bureau, from whose notes, the description herewith is in part written.

A concentration mill of 150 tons daily capacity has been built by the lessees, which at the present writing (April, 1918) is stated to be in operation. The equipment consists of coarse crushers, a ball-mill, Wilfley sand tables and Deister slime tables. The concentrates are reduced in 2 'D' retorts having a capacity of 450 pounds, each, per charge, being recharged every 8 hours. Pending the completion of the mill, and the advent of the rainy season to increase the water supply, some sorted ore from the underground development work was retorted during the latter part of 1917.

Bibl.: CAL. STATE MIN. BUR., Reports XII, p. 363; XIII, p. 598; XIV, p. 369; Chapter rep. bien. period, 1913–1914, p. 197; Bull. 27, p. 117. U. S. G. S., Mon. XIII, p. 283.

Reed Mine (originally **California**). A. H. Breed, owner, Oakland Bank Bldg., Oakland. This mine at the junction of Secs. 23, 24, 25 and 26, T. 12 N., R. 5 W., M. D. M., south of west from Rumsey, was in its early history known as the California. It is first mentioned as operating in 1870, and appears in the producing list in 1873, with an output of 995 flasks of quicksilver. The J. B. Randol table[4] credits the mine with a production of 5,653 flasks between 1876 and 1880. The mine has not been operated since that time, and the buildings have been destroyed by fire, but a small output was made in 1914 and 1915 by burning brick and mortar from the old furnaces, in a 'D' retort. The ore carried is principally metacinnabarite. The property was owned for many years as part of a cattle range.

The Reed mine is close to the line of contact of an area of serpentine with unaltered, fossiliferous rocks, the orebodies being contained in an opaline material. The ore was followed from the surface to the 300-foot level, the deepest in the mine. The trend of the deposit was the same as that of the strata in this vicinity, nearly parallel to the course of the creek, the dip being 30° SW, or somewhat less than the average dip of the disturbed strata nearby. Pyrite accompanied the cinnabar in a quartzose gangue; also some bitumen was present.

Bibl.: CAL. STATE MIN. BUR., Reports IV, pp. 261, 289, 336 (table); V, p. 95; VI, Pt. I, p. 122; X, pp. 358, 793; XI, p. 68; XIII, p. 604; XIV, p. 369; Chapter rep. bien. period, 1913–1914, p. 197; Bull. 27, p. 117. U. S. G. S., Mon. XIII, pp. 281, 282, 283. GEOL. SURV. OF CAL., Geol. Vol. II, p. 133. MIN. RES. W. OF ROCKY MTS., 1873, p. 10; 1874, p. 30; 1875, pp. 14, 174, 493.

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[4]Report of State Mineralogist, Vol. IV, p. 336.

PART II.

METALLURGY.

INTRODUCTION and ACKNOWLEDGMENTS.

In the summer of 1913, preparatory to a field trip through the counties north of San Francisco Bay, for the California State Mining Bureau, the writer made a cursory review of literature descriptive of the quicksilver districts of California, and of the metallurgy of quicksilver. At that time the question came to my mind:—probably induced by personal experiences with handling auriferous sulphide ores—"Why hasn't some one tried concentration on quicksilver ores?" This thought was entirely independent of the subsequent discovery that some comparatively inconspicuous cases existed.

Later, after consultation with Mr. Fletcher Hamilton, State Mineralogist, and Prof. Andrew C. Lawson, Dean of the College of Mining, University of California, the writer was authorized to conduct a series of experiments along these lines, in co-operation between the two departments. Ore samples were obtained from mines in several different localities, and the experimental work has been carried out in the metallurgical laboratory and mill at the University. This work has spread over a period of about two and a half years, interspersed with the writer's other duties as a member of the technical staff of the State Mining Bureau, and which have included field trips to practically all of the operating quicksilver mines of the State.

Appreciation and acknowledgment is here expressed of the latitude of action accorded under the authorization of Mr. Fletcher Hamilton, State Mineralogist, and for assistance and suggestions from Professors A. C. Lawson, E. A. Hersam, and W. A. Morley of the College of Mining, Dr. L. H. Duschak of the U. S. Bureau of Mines, also from Messrs. B. M. Newcomb, R. P. Newcomb, H. W. Gould, H. G. S. Anderson, and S. E. Woodworth. We wish especially, also, to thank the following mine managers, operators, or owners who so kindly furnished the ore samples which made possible the mill and laboratory tests: Messrs. Clifford G. Dennis, A. A. Gibson, Ellard W. Carson, Louis Patriquin, W. G. Adamson, R. H. Broughton, G. T. Ruddock, J. E. Miller, C. G. White, R. L. Beals.

CHAPTER 1.

METALLURGY OF MERCURY OR QUICKSILVER.

Historically, quicksilver was known at least four centuries before the Christian Era. Hoover,[1] in his classic, the translation of Agricola's *De Re Metallica*, in an historical footnote on the metallurgy of quicksilver, says:

"The earliest mention of quicksilver appears to have been by Aristotle (*Meteorologica* IV, 8, 11), who speaks of it as fluid silver (*argyros chytos*). * * * Dioscorides (V, 70) appears to be the first to describe the recovery of quicksilver by distillation." Theophrastus and Pliny are also quoted.

Agricola describes the methods in vogue in 1554,[2] and accompanies his description with wood-cut illustrations.

In this section of the present report it is intended to describe the metallurgical methods and plant equipment utilized in the later-day, modern practice up to the time of the present agitation and to discuss some of the improvements proposed and being tried out as to furnace operation.

Of interest and opportune, at this time besides the author's experiments on concentration, is the investigation of the metallurgy of quicksilver being conducted by the U. S. Bureau of Mines through its Berkeley (Calif.,) Experiment Station under the direction of Dr. L. H. Duschak. Through co-operation with certain of the California quicksilver producers data are being gathered on furnace and condenser operations with a view to discovering and if possible finding means for reducing any existing sources of metal loss. By permission of the Director of the U. S. Bureau of Mines, Mr. Van H. Manning, and with the consent of the management of the co-operating companies[3] some statements from Dr. Duschak relative to their results to date are included in this paper.

Recently a correspondent in one of the technical journals[4] writing re quicksilver, remarked that the "Production of the metal is retarded, it is believed, by ignorance of its technology." One is tempted to reply that there is no such thing as quicksilver technology. At least, the 'ignorance' is due to a LACK of available technology. There is in English very little original literature on the subject; there being somewhat more in German and French, relative to the European practices.

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[1]Agricola, Georgius, De re metallica, 1st Latin edition of 1554, translated by H. C. Hoover & L. H. Hoover, 1912, p. 432.
[2]*Op. cit.*, pp. 426–432.
[3]The U. S. Bureau of Mines is glad to avail itself of this opportunity to express its appreciation of the liberal way in which the quicksilver operators, especially Mr. H. W. Gould of the New Idria Quicksilver Mining Co. and Sulphur Bank Association and Mr. Murray Innes of the Oceanic Quicksilver Mining Co., have placed their records and facilities for experimental work at their plants at its disposal.
[4]Eng. & Min. Jour., Vol. 104, p. 490, Sept. 15, 1917.

The best, original and most detailed works on this subject in English are the two papers of S. B. Christy[5] on furnaces and condensers, respectively, at New Almaden, California.

Is it not out-of-place at this point to remark that many experiments of various operators have been conducted, absolutely unaccompanied by any thought or attempt at technical control. This often results in the hasty adoption of some method or piece of apparatus, which a careful control would have shown to be useless or inefficient; or it may result in the hasty rejecting of what might ultimately prove to be a really economic feature.

PROPERTIES OF MERCURY OR QUICKSILVER.

To assist to a better understanding of the subsequent discussion, the properties and some of the reactions characteristic of this element, are here summarized:

Mercury is the only metal which is fluid at ordinary temperatures. According to various authorities it solidifies at —39.4° C.[6] "It contracts upon solidification, and forms a white, very ductile and malleable mass, which is readily cut with a knife." Sp. gr., fluid, at 0° C. is 13.59; solid, 14.19. "Its electrical conductivity according to Matthiesen at 22.8° C. is 1.63, silver at 0° being taken as 100. * * * Mercury is volatile to a slight extent at ordinary temperatures, and according to Merget even below —44° C. This may be proved by suspending gold leaf above a vessel containing mercury, when it will become coated at ordinary temperatures with a white layer of amalgam. The boiling point of mercury, according to Dulong and Petit is 360° C; according to Regnault, 357.25° C. It is converted into a colorless vapour, the density of which is given as between 6.7 and 7.03. The rapidity with which mercury volatilizes on boiling depends to a great extent upon its purity. It is mainly diminished by lead and zinc, and on the contrary increased by platinum. * * * Platinum increases the rapidity of evaporation if digested for one or two days with mercury at a temperature of 50° to 80° C. Iridium, gold, silver, copper, nickel, cadmium and arsenic have no influence upon the rapidity of evaporation.

* * * * * * *

"Pure mercury is unchanged in air at the ordinary temperature, neither is it affected by long-continued agitation with air, oxygen, nitrous oxide, nitric oxide, or carbon dioxide. In damp air, however, it gradually becomes coated with a thin film of mercurous oxide (Hg_2O). Impure mercury becomes coated with a film of oxide even in dry air. If mercury is heated for a considerable time up to 350° C. in the air, it oxidizes to mercuric oxide (HgO), which, according to Pelouze, is crystalline. This gradually decomposes in the sunlight into mercury and oxygen."

Mercury is soluble in concentrated boiling H_2SO_4, but not in dilute. Insoluble in HCl; solution in HNO_3, even dilute; Soluble in aqua regia, forming $HgCl_2$.

* * * * * * *

"Sulphide of mercury (HgS) * * * can be produced as an amorphous black mass by rubbing together flowers of sulphur and mercury and by gently heating the mixture of the two bodies. If this mass is heated to its melting point, mercuric sulphide volitilizes and may be condensed in the form of a brownish red crystalline sublimate. This on grinding becomes scarlet and forms artificial cinnabar. When gently heated, air being excluded, it is readily reconverted into black amorphous mercuric sulphide, but if heated more strongly, it again sublimes as red sulphide. Native cinnabar begins to darken at 200° C., and to volatilize; at 350° it volatilizes to a very great extent, but for its complete volatilization a low red heat 500° to 600° C., is required. With excess of air, it burns at 350° C. with a blue flame of sulphur, forming sulphur dioxide, metallic mercury separating out and volatilizing. The red sulphide of mercury darkens under the action of light,[7] and after a considerable time it becomes black in consequence of the separation of free mercury.[8] * * * When heated with other metals which possess a greater affinity for sulphur than mercury, for example with iron, tin or antimony, the mercury is liberated in the form of vapour, whilst the sulphur combines with the respective metals. * * * (This is made use of in the distillation assay; as also the following:—W. W. B.). When mercuric sulphide is heated with lime the mercury separates out and volatilizes, sulphide and sulphate of calcium being produced, as shown by the following equation:

$$4HgS+4CaO=4Hg+3CaS+CaSO_4.$$

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[5] Christy, S. B., Quicksilver Reduction at New Almaden; Trans. Am. Inst. Min. Eng., Vol. XIII, pp. 547–584, 1884. Quicksilver Condensation at New Almaden; Trans. Am. Inst. Min. Eng., Vol. XIV, pp. 206–264, 1885.

[6] Schnabel and Louis: Handbook of Metallurgy, Vol. II, 2d ed. 1907, pp. 329–443.

[7] *e.g.*—certain Oat Hill specimens which the writer has—W. W. B.

[8] See Am. Jour. Sci.—Vol. XXXIV, pp. 341–396 for a further study of these reactions.

"The Extraction of Mercury in the Dry Way.

"* * * Two methods are used upon a large scale. The one depends upon the fact that at a high temperature the oxygen of the air combines with the sulphur of mercuric sulphide, forming sulphur dioxide, whilst the mercury is free in accordance with the equation: $HgS+2O=Hg+SO_2$. The other depends upon heating the mercuric sulphide with lime, when the sulphur combines with the calcium forming calcium sulphide and sulphate, whilst the mercury is liberated as shown by the equation (see preceding paragraph).

"Instead of lime, iron may be employed: $HgS+Fe=FeS+Hg$.

"In every case, the above chemical reactions take place at temperatures higher than the boiling point of mercury, so that the latter is separated in the gaseous form, and has to be condensed. * * *

"As * * * in the extraction of zinc, a metal which is also obtained by a distillation process, the condensation of the zinc vapors, which are also diluted by other gases, forms the most difficult portion of the extraction. At a definite degree of dilution the zinc can no longer be obtained at all in the liquid state, but separates out in the pulverulent condition, a considerable quantity of which afterwards remains in the gases escaping from the condensers. The same occurs in the extraction of mercury, in which the condensation of the metal forms the most difficult portion of the process, in consequence of the dilution of its vapours by the above-named gases (SO_2, N,O, and products of fuel combustion), of the high temperature to which the metal has been heated, and of the rapidity with which the current of gas has to pass through the condensing appliances. Nevertheless, the condensation of mercury vapours is more easily effected than that of zinc vapours, because the latter owing to to the low solidifying point of mercury (—39° C.), can not separate out in the form of dust, but, when sufficiently cooled, necessarily forms a liquid, and because mercury can be precipitated without great difficulty, on account of its high specific gravity, even from gases in which it occurs in a high state of dilution. It is, however, unavoidable that comparatively small [?] quantities of mercury—a metal that is volatile at very low temperatures, should escape without being condensed. Even under the best conditions of working, the conversion of some mercury into 'Stupp' (mercurial *soot*) is unavoidable. Thus at the works at Monte Amiata [Italy] only 20% to 30% of the mercury is got in the form of the metal—the rest is converted into 'Stupp.' The soot, which consists of a mixture of finely divided mercury, mercurial compounds and sooty products of the dry distillation of the fuel and the bituminous constituents of the ores, together with its other mineral constituents, forms a deposit in the condensers. It contains up to 80% of mercury. Its formation is due, according to Patera, to the sulphates, formed when cinnabar is heated, and the chlorides, which were either contained in the ores or produced by the chlorides present in the ash, together with soot, tar, and ammonia derived from organic matters, which substances envelop the particles of mercury as they condense, and prevent them from uniting. The greater portion of the mercury is recovered from the soot by processes to be described later on." * * *

OUTLINE OF METALLURGY.

The metallurgy of quicksilver, in outline, is without doubt the simplest of the reduction methods in use for gaining any of the commercially valuable metals from their ores. It is a simple distillation by applying heat, followed by condensation in a cooled, confined space. Crushing of the ore is not even required, in the case of the coarse-ore furnaces. However, though so simple in outline, there are qualifying conditions which render its practical application somewhat difficult as to details. The old-time operators have been so well satisfied and contented with the simplicity of the process, and with the consequent assurance that "the furnace gets it all" (as one of them expressed himself to the writer, in answer to "What percentage of extraction are you getting?"), that they have complacently sat back and quite refused to consider any further improvements possible. Since H. J. Hüttner and Robert Scott evolved their improved Hüttner-Scott fine-ore tile furnace at the New Almaden Mine, in 1875, that furnace has been considered the last word in quicksilver metallurgy, until quite recently. Nor does the writer intend to convey the idea by that statement that the Scott furnace is not still and likely to be for some time yet, individually the most important reducing agent in the metallurgy of quicksilver. One very surprising feature of this complacent attitude, as it appears particularly to one familiar with metallurgical practices in the reduction of gold, silver, copper, etc., is the absolute lack of any sampling and assaying at the quicksilver mines. So far as observed, up to at least early in 1916, there was not a single quicksilver mine in California which possessed or utilized an assay office. This, too, though the distillation assay for mercury is quite accurate and simple of manipulation. There had been a short-lived attempt or two at assaying in years gone by at both the New Almaden and New Idria mines. The various assaying methods are discussed in detail in a subsequent section.

The older forms of furnaces and their methods of operation are described by Crookes & Röhrig,[9] and by Egleston,[10] and the European plants in certain of the German, French and Italian references noted under Bibliography. It is not the intention, here, to take up those earlier types, but only these which have been in use in California in comparatively recent years.

There are two main types of quicksilver furnaces: The closed retort, and the vertical, continuous-feed type; the last-named being divided into two main varieties—the coarse-ore without interior tiles, and the fine-ore with interior tile baffles or shelves.

RETORTS.

Retorts are made in two forms: pipe retorts and 'D' retorts, the differences being merely of shape and size. The former consist of circular, iron pipes, 8 inches to 11 inches in diameter, arranged in 'banks' or groups up to 12 pipes. The latter are larger in capacity and have a cross-section like the letter D, but with the straight side laid horizontally, thus:  The essential difference between the retort and shaft furnace types is that in the former the products of combustion of the fuel are kept outside of the space occupied by the ore and not allowed to mix with the distillation products from the ore; while in the latter, the heated gases and vapors from the fuel combustion pass up through the interstices between the pieces of ore, and mingle with the vapors being driven from the ore itself. This latter condition makes condensation of the mercurial vapor a much more difficult problem than the relatively simple condensing of retort vapors.

A good form of pipe retort was that formerly used by Mr. G. V. Northey for reducing concentrates at the Manzanita Mine, Colusa County, and described by Forstner,[11] the illustration herewith (Plate XXIII) being reproduced from his report.

[9]Crookes & Röhrig, A Practical Treatise on Metallurgy, 1868, pp. 501–531.
[10]Egleston, T., Metallurgy of Silver, Gold and Mercury in the United States, Vol. II, 1890, pp. 799–901.
[11]Forstner, William, Quicksilver Resources of California: Cal. State Mining Bur. Bull. 27, p. 201, 1903.

PLATE XXIII.

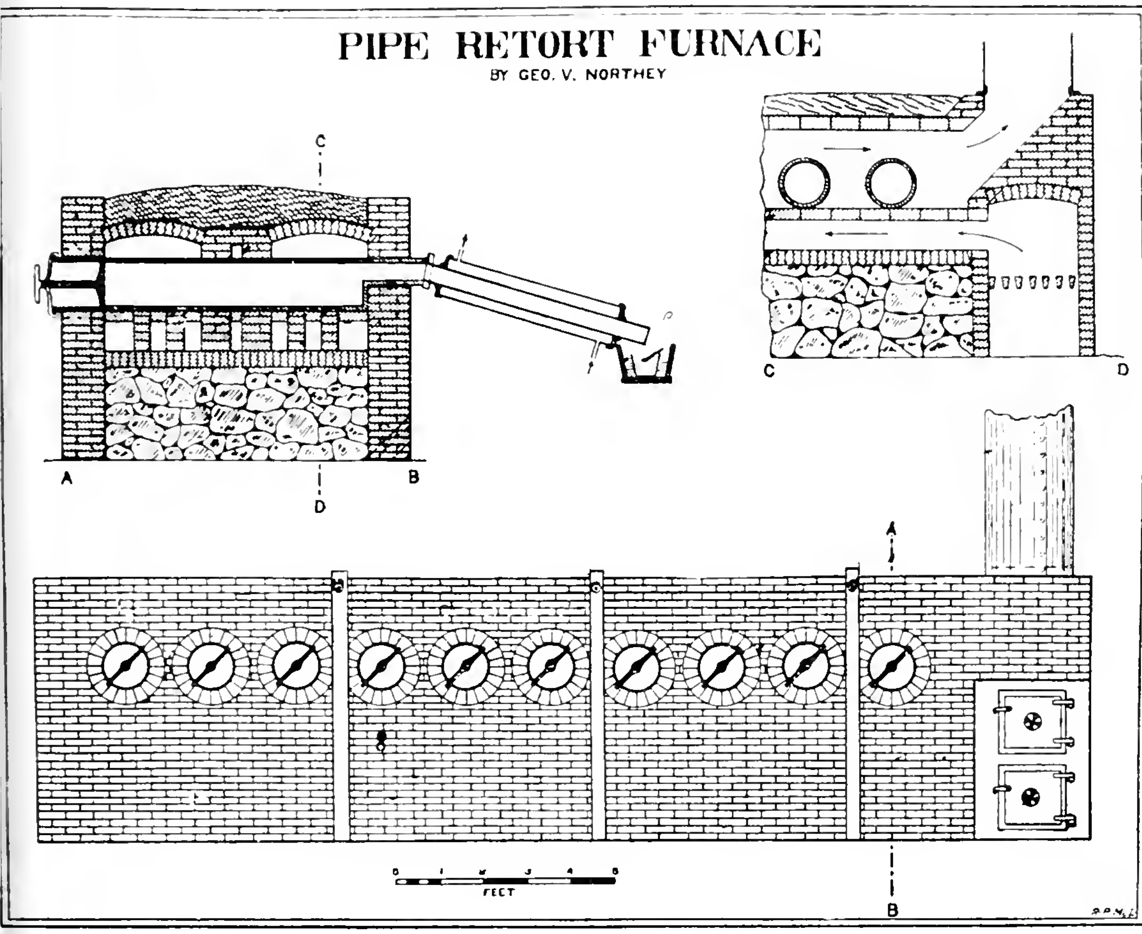
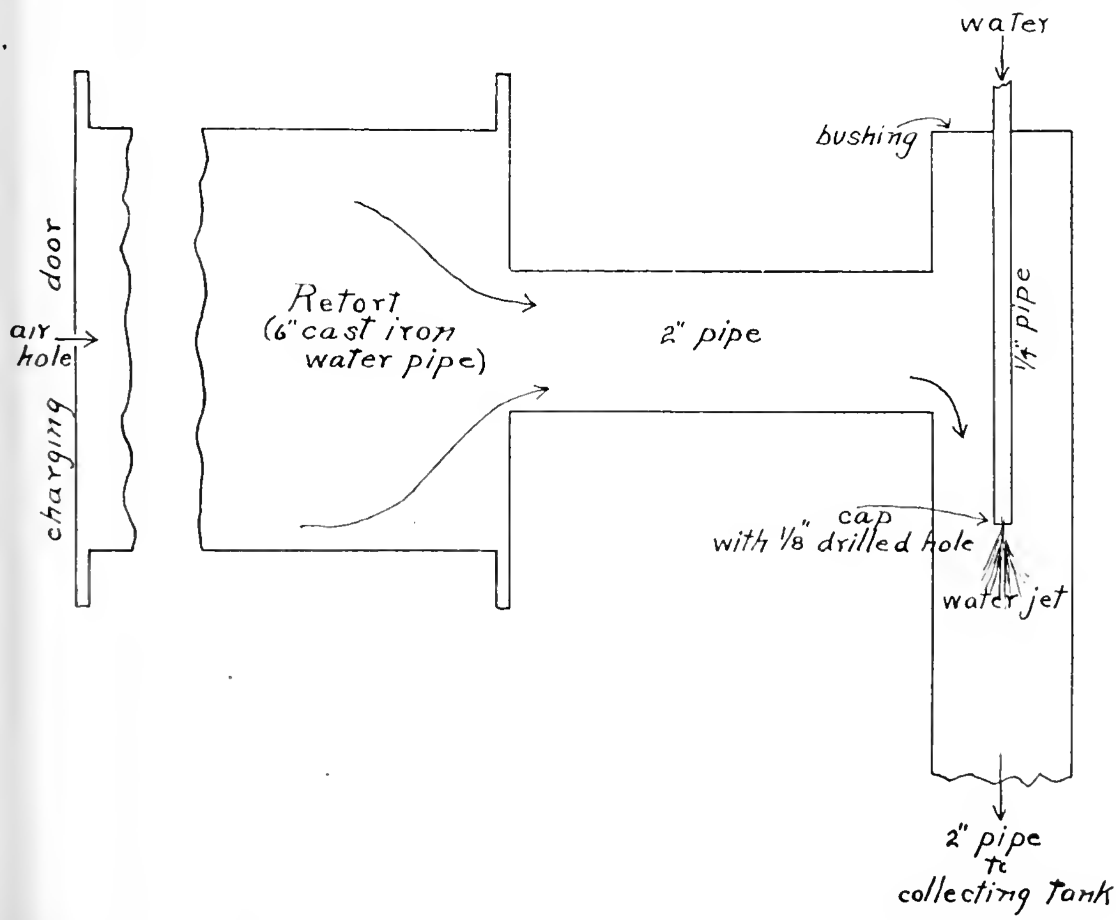


PLATE XXIV.



Plan of water-jet condenser for quicksilver retort at Oat Hill mine, Napa County.

"By using arches around the pipe spaces, each retort can be taken out separately without interfering with the working of the others. Each retort has a separate mercury outlet, allowing opportunity to judge about its workings, and the water circulation through each water jacket can be regulated separately. The firebox is placed to the side of the first retort, instead of under it, enabling the easy discharging and charging of this retort. By placing the door of the retort inside the wall, cooling of the space against the door and consequent accumulation of mercury at that point are prevented. The charge is from 75 to 80 pounds of concentrates per shift, with the necessary lime, against 150 pounds of raw ore. Two furnace men are required—one per shift.

"The expenses of this plant are about $25 per day for labor, [12]fuel, repairs, etc. The 10-pipe retort, with suitable ore, can handle the total product of the concentrating mill, running day and night, concentrating from 20 to 24 tons. The total cost of the plant, not including the mill building, is approximately:

25 h.p. engine	$1,000
Rock crusher	250
5-foot Huntington mill	1,500
5 bumping tables	1,000
Concentrating table	500
1 elevator	100
Fittings, pipe, etc.	150
Contingent expenses	500
	$5,000
1 pipe retort, with building and drier	2,000
	$7,000

"This plant in three months turned out 330 flasks of mercury."

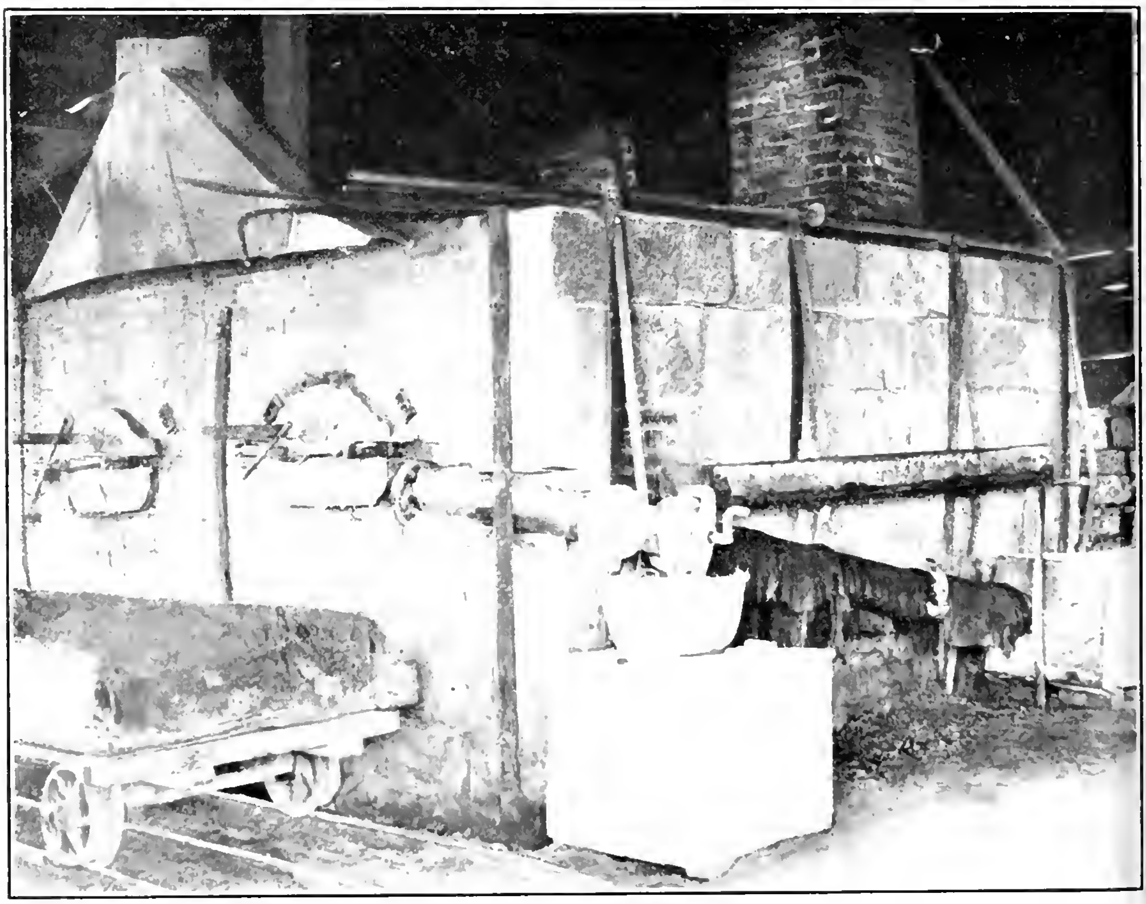


Photo No. 41. 'D' retorts at Aetna Mine, Napa County. The 'T' of 1" pipe at retort door is the inlet for air circulation. Water-wheel and fan are at right, just out of picture.

The 10-inch pipe retorts are usually 9 feet in length, and the 12-inch, 7 feet in length, the capacity thus varying from 4.9 to 5.5 cu. ft. In the usual practice the retort is not completely filled with ore, so that a

[12]That was in 1903.

supply of free oxygen will be present to unite with the sulphur driven off and prevent its reuniting with the vaporized mercury.

In some instances an air circulation has been provided, particularly in handling concentrates. This was done with a water jet by R. P. Newcomb at Oat Hill, Napa County, the arrangement being described by the writer[13] in a recent report on the mines of that county (see Plate XXIV). Another arrangement for accomplishing the same purpose is that adopted with the 'D' retorts at the Ætna Mine, Napa County. (See Photo No. 41.) A 1-inch iron pipe is fitted into the

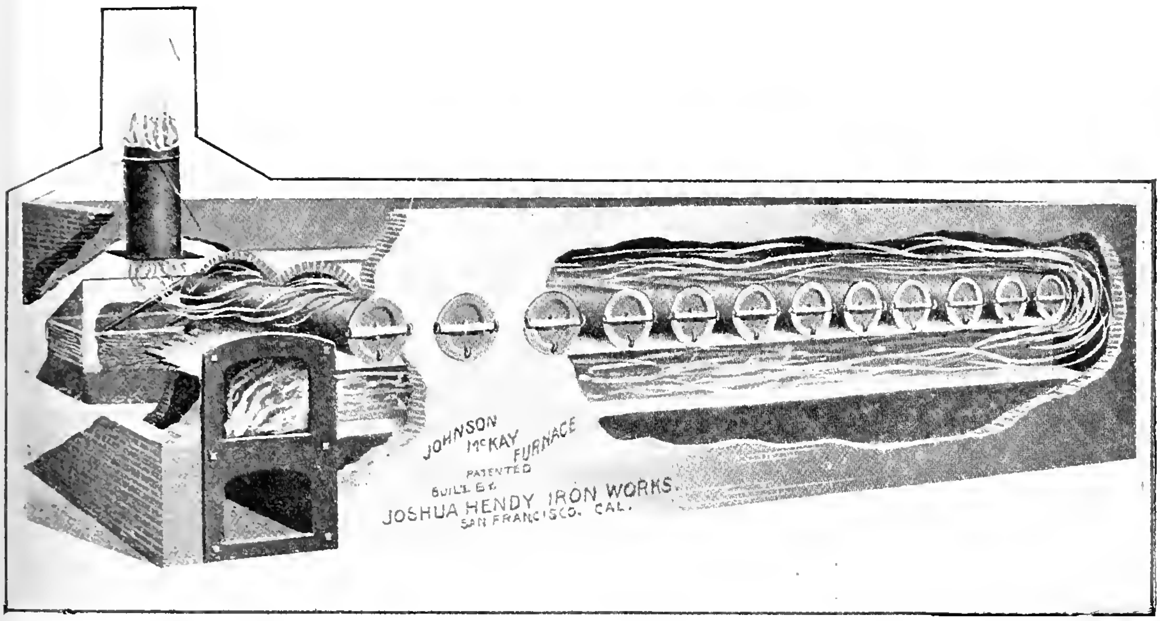


Photo No. 42. Johnson-McKay retort, showing circulation system.

door of the retort, and extends nearly to the back end of the interior. The exit pipe leads out from the side, just back of the door. In drawing off the burned ore and also while filling the retort with a fresh charge, the exit pipe is kept clear by inserting a plug in the opening. A fan in the condenser system, driven by a small water-wheel, maintains the draft through the retort. Both ore and concentrates were treated in these Aetna retorts.

The **Johnson-McKay** pipe retorts have a special arrangement of flues (see Photo No. 42), by which the portions of the pipe near the front and back ends receive the greater part of the heat. The following

[13]Bradley, W. W., Mines and Mineral Res. of Colusa, et al. Counties; Cal. State Min. Bur. chapters of State Mineralogist's Report, 1913-1914, p. 117, 1915; also in State Mineralogist's Report XIV, p. 289, 1916.

statement is furnished by the manufacturers,[14] the Joshua Hendy Iron Works, San Francisco:

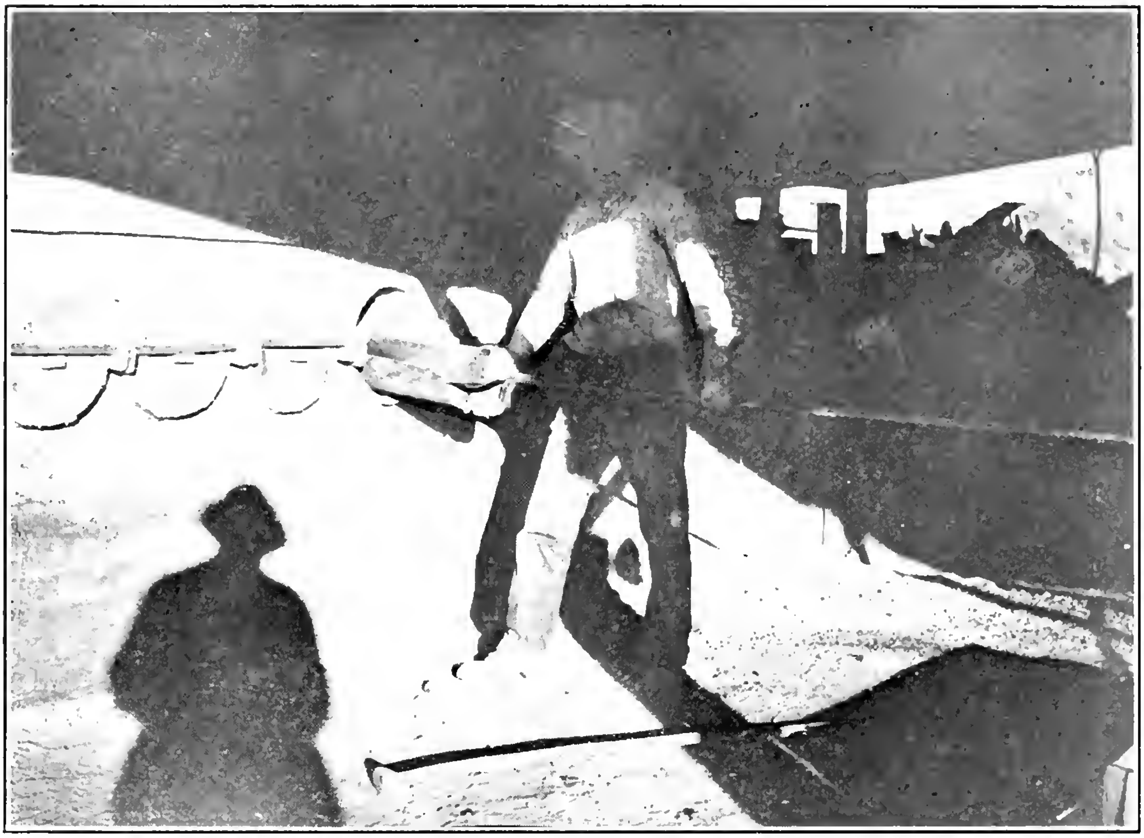


Photo No. 43. Charging a Johnson-McKay retort at the Patriquin Mine, Monterey County.

"The Johnson-McKay furnace consists of a battery of 12 retort pipes, each 12 in. diam. A less number of pipes may be used if desired. Also the retort pipes can be made 10 in. diam., but the standard size of furnace is better. The ironwork for the standard furnace consists of the following:

12 cast-iron retort pipes, 12 in. diam. by 6 ft. 5½ in. long.
14 cast-iron inside covers.
12 cast-iron outside covers.
12 cast-iron condenser pipes, 3 in. by 8 ft.
1 cast-iron furnace front with anchor bolts.
1 cast-iron stack-plate.

"Necessary frame rods, scrapers and chargers are also supplied.

"The approximate weight is 9100 lbs. For the setting of the standard furnace the following list of bricks, lime, cement and lumber will be required:

6000 common red brick.
1300 common fire-brick.
200 arch fire-brick.
10 bbls. lime.
1 bbl. cement.
3½ cu. yds. sand.
2 sacks fire-clay.
8 pieces 1 by 6 in. by 7 ft. 8 in. Oregon pine for frame.
12 pieces 1 by 6 in. by 3 ft. 6 in. Oregon pine for frame.
6 pieces 2 by 6 in. by 6 ft. 8 in. Oregon pine for frame.
2 pieces 2 by 12 in. by 16 ft. Oregon pine for frame.
3 pieces 2 by 12 in. by 16 ft. Oregon pine for trough.
2 pieces 1 by 12 in. by 16 ft. Oregon pine for trough.

"Any number of pipes could be used, but one could not operate so economically with a few pipes as with the standard equipment. Based on a 12-hour roasting period for each charge of ore, the operation of the standard furnace is continuous, since one pipe is unloaded and re-charged every hour. When the pipes are sufficiently heated, the first pipe is charged, and then one pipe every consecutive hour until all have been charged. By that time the ore in the first pipe will have roasted 12 hours, at the end of which period it is ready for unloading and a fresh charge put in its place. At the end of the next hour, the second pipe would be unloaded and re-charged, and so on indefinitely.

[14] Min. & Sci. Press, Sept. 8, 1917, p. 22 adv.

"As the ore is heated the quicksilver volatilizes and thus separates from the gangue. It then passes to the condenser-pipes, and thence the condensed mercury drains to the water-filled trough at the rear of the furnace, where it is collected. The cycle of operations described is based on a 12-hour roasting period for each charge of ore, but the length of the roasting period may vary. That depends on the character of the ore, the intensity of the heat maintained in the furnace, the experience of the attendant, and other factors. The standard size of furnace should treat from 3 to 5 tons daily. Some users have treated as many as 7 tons per 24 hours. Using wood for fuel, the consumption is from 1¼ to 1½ cords per day."

In 1916, the iron-work for a battery of these retorts cost $840 f. o. b. San Francisco; while in October, 1917, the same material cost $950. On the basis of the 1916 prices, it cost approximately $2500 to $3000 to build such a furnace under average conditions. The figures will vary with local conditions.

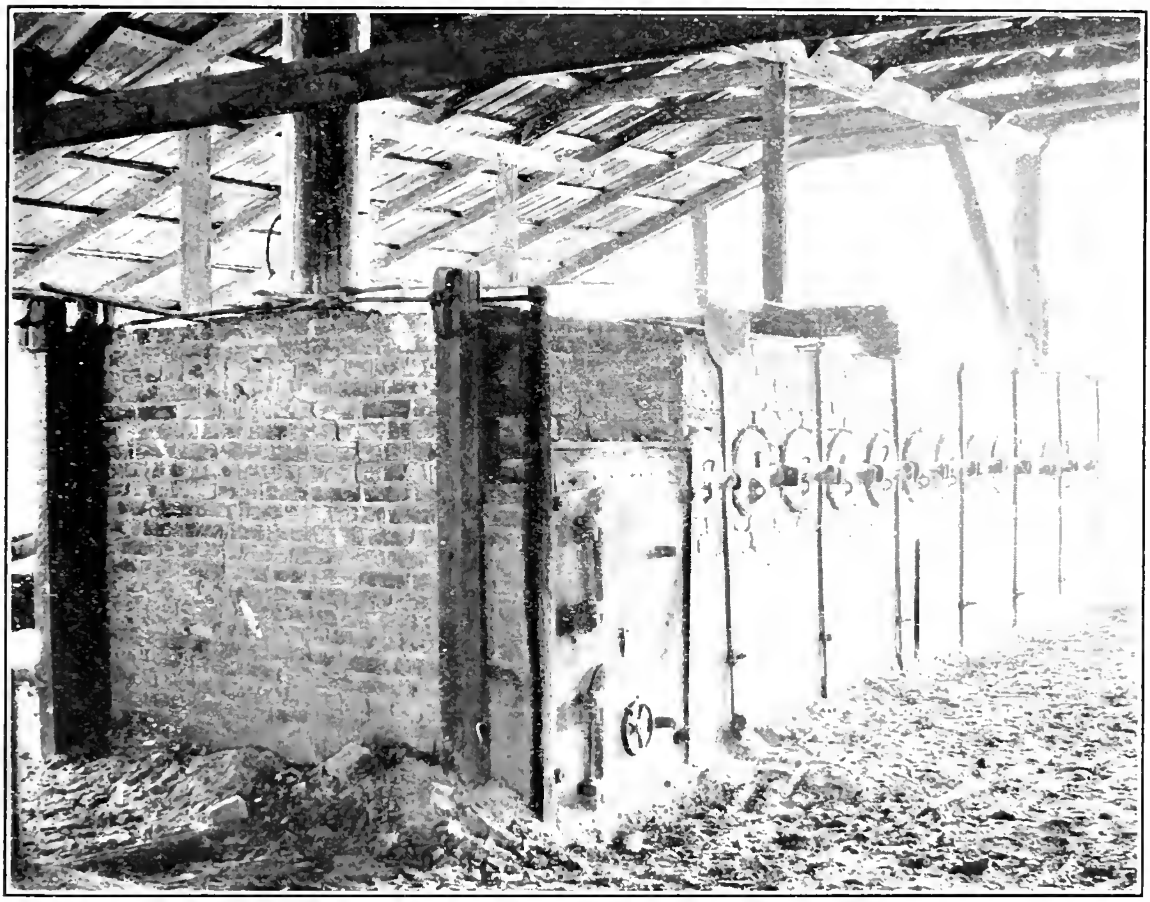


Photo No. 44. A battery (12 pipes) of Johnson-McKay retorts at the Klau mine, San Luis Obispo County.

Retorts are, of necessity from their construction, limited in capacity and require more labor to treat a given tonnage than do shaft furnaces. For these reasons they can be profitably used only for relatively high-grade ores and concentrates. From the standpoint of the life of the mine, it is doubtful economy in most cases to use them, as one must gouge the high-grade ore for them. Some attempts have been made to develop a continuous-feed retort.

The **Fitzgerald** furnace, a continuous-feed, inclined retort, was described by Forstner:[15]

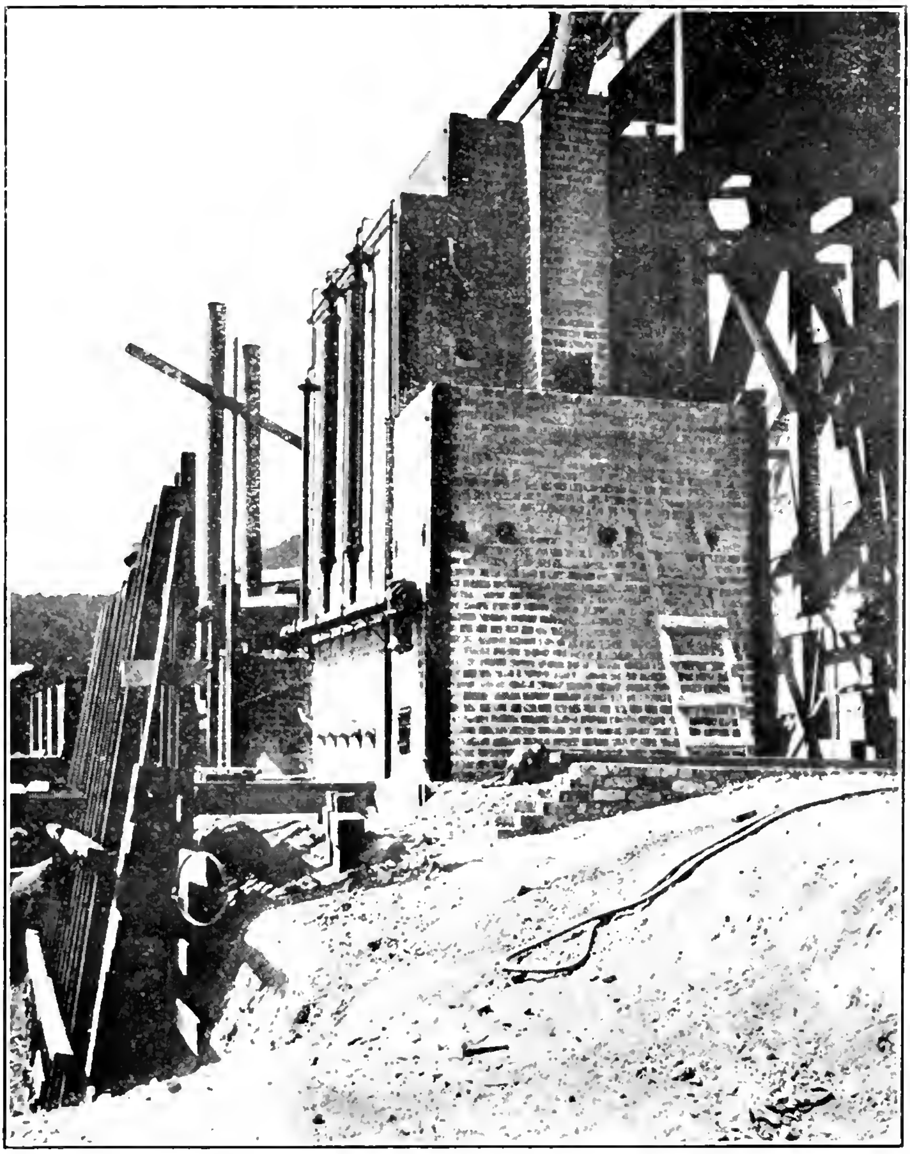


Photo No. 45. Livingston Furnace under construction at La Joya Mine, Napa County.

"This furnace consists of an inclined, arched channel of fire-brick (angle 35°) with a tile floor. It has a charging hopper at the upper end and a discharge chamber with door at the lower end. The flames from the fire chamber pass under this ore chamber along two center flues, return along two outside flues, pass to the top of the arch of the lower end, and go from the upper end to the smoke-stack. The vapors from the ore chamber are conducted through an iron exit pipe which is placed near the upper end of the ore chamber and is water-jacketed outside of the furnace, to two condensers. In the second condenser an air current for exhaust is created by a water spray under 100 feet pressure, working on limestone to catch the flour mercury. The capacity of each chamber is rated at 10 tons per 24 hours, using one cord of pine wood. In practice the capacity is less."

At the time of Forstner's report (1903), three of these furnaces had recently been built in California, but at the present time, so far as the writer knows, there are none in operation in the State.

[15]Forstner, Wm., Quicksilver Resources of California; Cal. State Min. Bur., Bull. 27, pp. 204, 205, 1903.

A recently patented furnace of the continuous-feed retort type is known as the **Livingston**, having been patented by Mr. A. W. Livingston of Oakland, Cal. It consists of two vertical chambers with walls of thin fine-brick, and the fire on the outside. One such furnace was built in 1916 at the Esperanza Mine near Cloverdale, Sonoma County, but only a small amount of rock put through it, principally because the furnace was erected before the mine was ready to supply it with ore. More recently a second one has been built, at the La Joya mine (Photo No. 45) near Oakville, Napa County; and was just being dried out at the time of the writer's visit in September, 1917. A water spray in the vertical, condenser pipes (seen on the outside of the furnace wall) creates a draft to draw the fumes into the condensers and prevent their escape through the upper part of the ore charge to the outside. A special discharge hopper and door are a part of the design. Since the mine was visited, the writer is informed that this furnace has been discarded after a trial run on ore. One difficulty appears to be that the furnace is not high enough, resulting in there not being a sufficient depth of charge to keep hot ore in contact with the mercurial vapors until they pass out by the exit pipe. There is also insufficient draft in the condensing system to completely pull the fumes from the ore chamber. The result of these two defects is that the quicksilver volatilized near the bottom of the ore chamber, condenses upon the cold ore in the upper part before reaching the fume exit. The water-spray in the condenser has a tendency to flour the mercury.

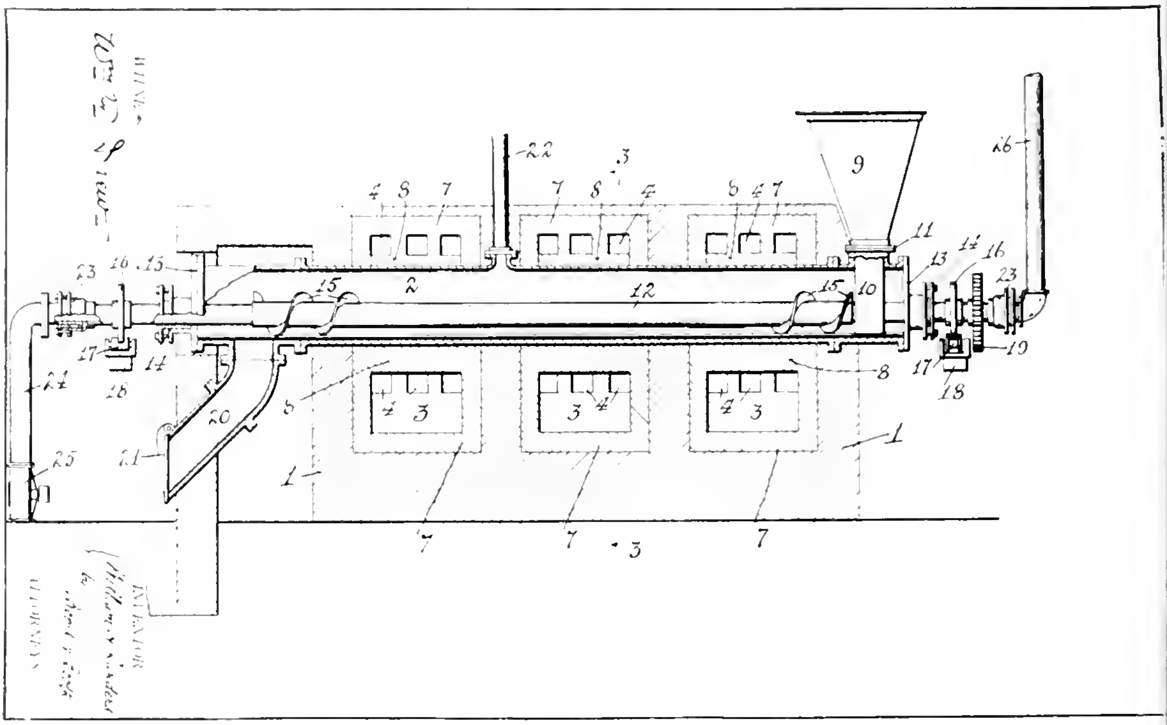
At the Bella Union mine, also near Oakville, the Rutherford Mining Co. was, when visited (September, 1917), building yet another arrangement of a 'continuous-feed retort', recently patented by their superintendent, Mr. E. E. Lillard. This consists of a circular, cast-iron ore chamber (the retort proper) set vertically, within the fire-box. It is two feet inside diameter, about 25 feet high, and has interior projecting baffles cast with the shell, which is cast in three pieces to facilitate installation. There is a discharge door arrangement at the bottom and a flue connection near the top to lead off the mercurial vapor to the condensers which will have a draft circulation.

In 1916, at the Senator mine of the New Almaden company, a **Lander's** quicksilver retort, a special form of continuous-feed retort built by the Pacific Foundry Co., San Francisco, was installed to handle concentrates (see Plate XXV). It is stated to have given satisfactory results. As described by the manufacturers:[16]

"The capacity of this retort is from 100 to 200 lbs. per hour, the inside diameter being 12″ and the length approximately 12′.

[16]Personal letter to the author.

PLATE XXV.



Lander's Continuous Retort.

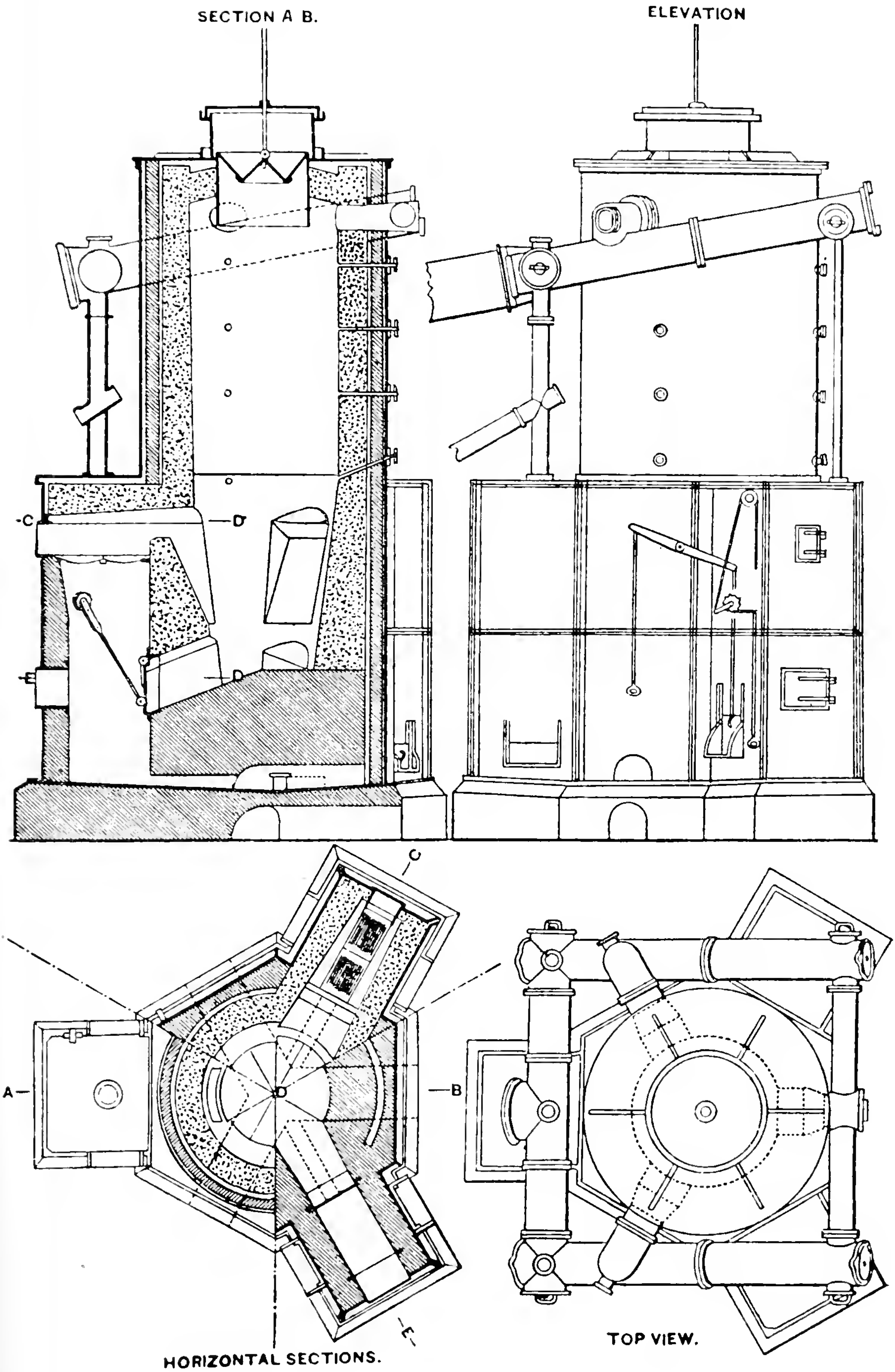
"The iron work for this retort at the present time [Nov. 1, 1917] is worth approximately $1200. The general plan of operation is that the ore is fed into hopper #9 where it automatically seals the retort. The conveyor screw #15 which is mounted on an air-cooled shaft moves the ore forward where it is discharged through outlet #20. An automatically closing gate #21 prevents the inlet of air to the retort. Outlet #22 is for purpose of taking off the mercury vapors to a standard type of condenser. #25 indicates a fan which is to force air through the hollow shaft to the conveyor and which is for the purpose of keeping this part cool so that it will not warp on account of the heat of the retort."

This retort could also be used to treat limited tonnages of high-grade ore at a small mine, where only a small amount of capital is available for equipment.

The **Whitton** furnace, invented by W. W. Whitton, Oakland, Cal., (U. S. Pat. #1,222,251, Apr. 10, 1917) is a multiple, vertical, continuous-feed retort, consisting of a series of any desired number of pipes from 4 to 17, arranged with a draft circulation to a condenser manifold. The 17-tube furnace is estimated to have a capacity of 25 tons per day, and to cost from $6,000 to $8,000 installed.

The **Pevear** furnace has been developed by Waldo S. Pevear, #315½ W. 2d St., Los Angeles, Cal., patent for which, the writer understands, is now being applied for. It consists of a series of revolving circular, cast-iron chambers with interior-projecting lugs or teeth like the old-

IRON CLAD SHAFT FURNACE
(CONTINUOUS)



Exeli Furnace.

fashioned thrashing-machine cylinders. It requires that the ore be crushed as fine as 10 to 20 mesh. On such material, a practically complete distillation of the mercury is claimed in a very short roasting period.

COARSE-ORE FURNACES.

Coarse-ore furnaces, as the name indicates, are built to treat coarse or lump ore. In construction and method of operation they are similar to an ordinary, vertical-shaft, lime kiln, and the ore as fed to them may vary from 3″ to 9″ in size. The principal varieties of this type of quicksilver furnace, which have been used to any extent are the Exeli, Knox-Osborne, Neate, and New Idria. Some fine ore can be, and at times is, charged with the lump ore; but it should be done sparingly, as it would otherwise choke up the spaces between the ore chunks and prevent circulation of the products of fuel combustion. The addition of any fine ore is apt to materially reduce the capacity of a coarse-ore furnace.

The **Exeli** furnace was first built at Idria, Austria, in 1871, by Bergrath A. Exeli. In California, two of them were built at New Almaden in 1874–1875, and have been in use until quite recently; in fact are still in working order. The accompanying cut, (Plate XXVI) shows the construction of the Exeli furnace. Forstner[17] describing these furnaces at New Almaden in 1903, says they were

"treating 12 tons of ore every 24 hours; the ore remains 48 hours in the furnace. While it is generally taken for granted that ores carrying a great amount of metallic mercury can not well be handled in shaft furnaces, these two furnaces in former years gave very satisfactory results when burning the ore from the 1500 foot level, Randol shaft, which contained large quantities of native mercury. The charge consists of about 1600 pounds of ore. These two furnaces require two men per shift and burn 0.605 cord of wood per 24 hours. The cost of treatment per ton is:

Labor	$0.4166
Fuel	0.3025
Total	$0.7191"

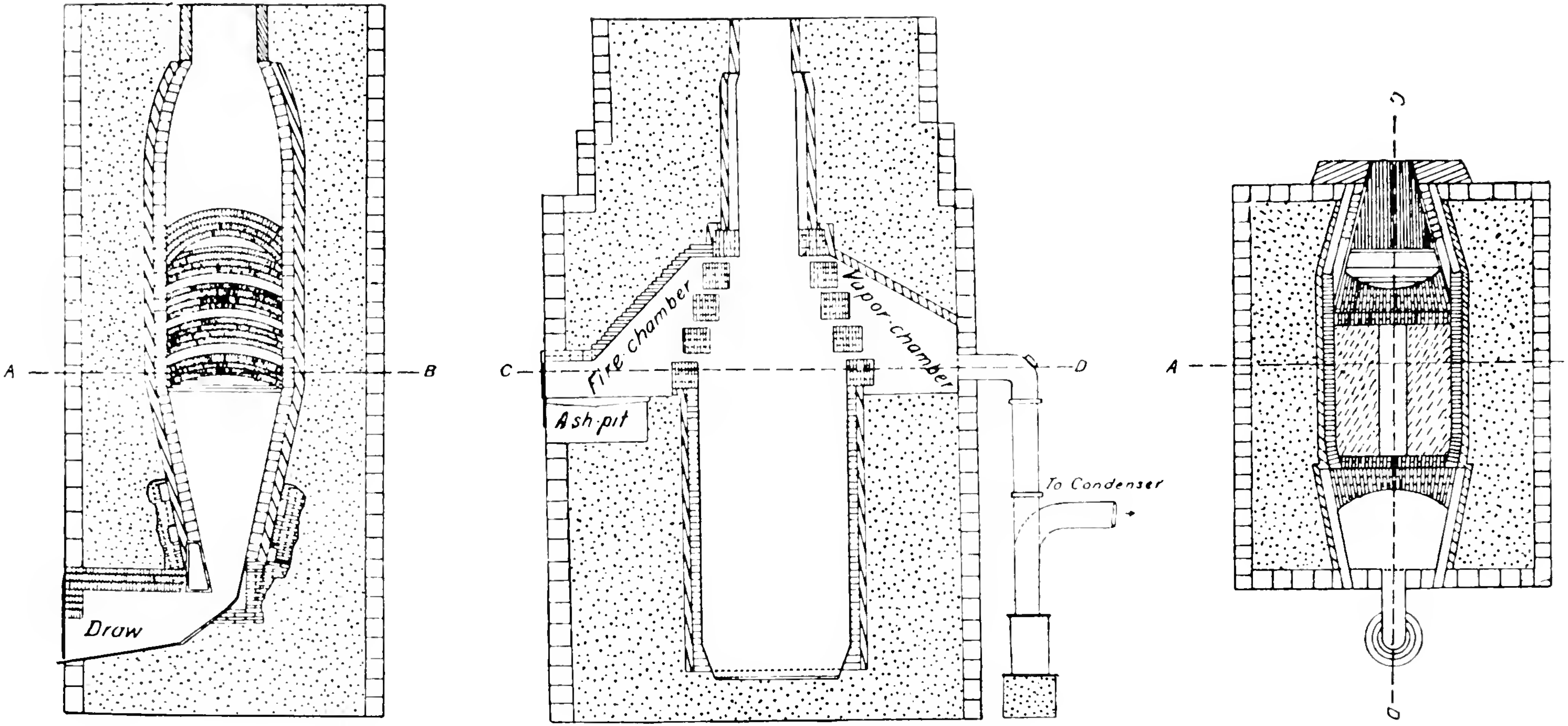
The **Knox-Osborne** coarse-ore furnace was patented in 1872, and at one time several of them were in use in California. There is one at the Manhattan mine, Knoxville, Napa County, though at present idle; and one in operation at the Culver-Baer mine, near Cloverdale, Sonoma County.

"The cubic content of the furnaces is about 75 tons, and as it handles about 24 tons per day, the ore remains about three days in the furnace. The wood consumption on coarse ore is from 1 to 1½ cords of oak per 24 hours. Three men per shift are required."[18]

The **Neate** coarse-ore furnace, patented by John Neate, is distinguished from other furnaces of this type by its having no separate fire-box. (See Plate XXVIII.)

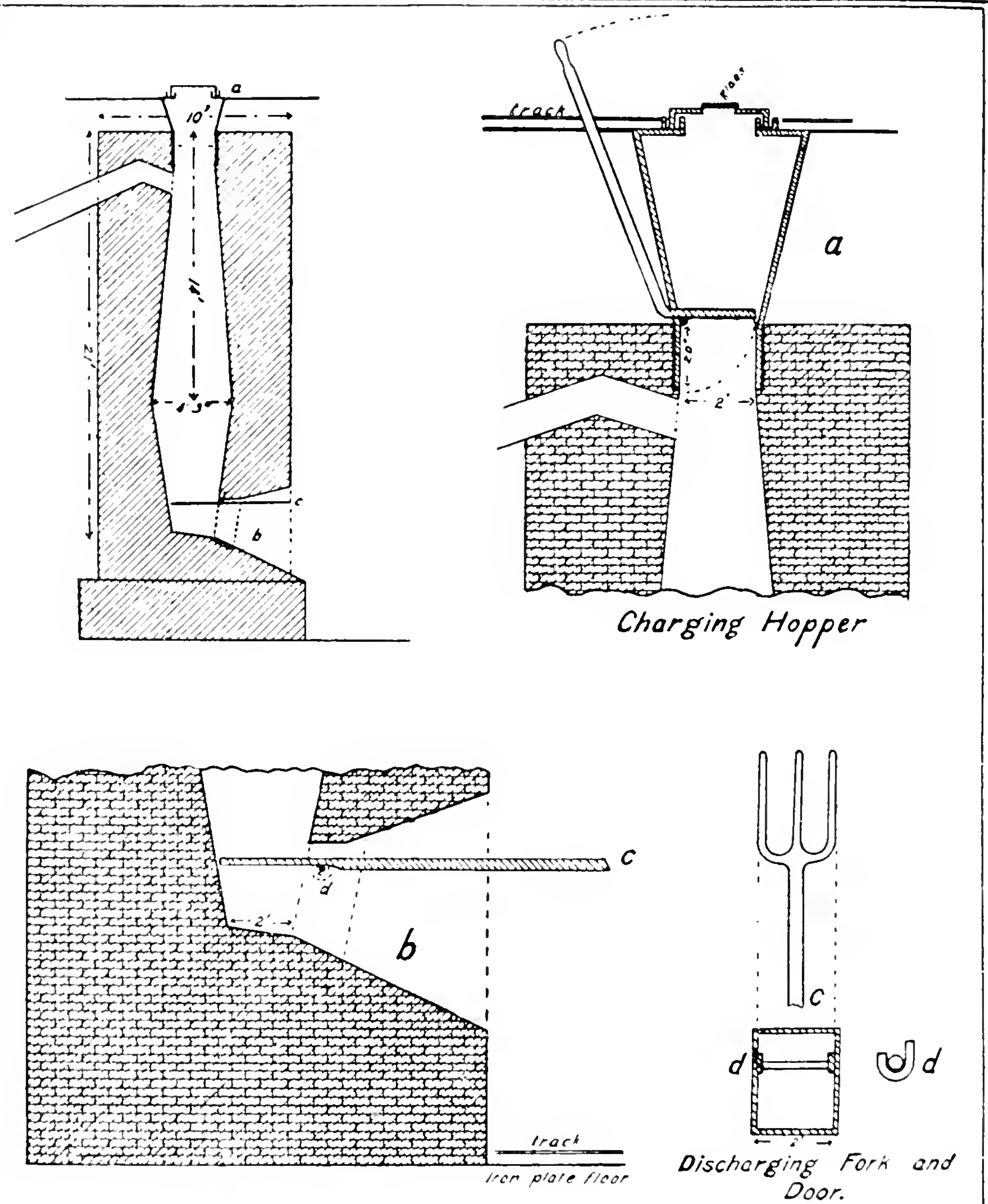
[17] Cal. State Min. Bur. Bull. 27, p. 208.
[18] *Idem*, p. 210.

PLATE XXVII.



Knox & Osborne coarse-ore furnace.

PLATE XXVIII.



COARSE ORE FURNACE.

JOHN NEATE PAT.

[19]"The ore is charged with coke in alternate layers, using from 3½% to 4% of coke, depending on the draft in the furnace. The drawing space in the bottom of the furnace is open, leaving access to the air and furnishing the draft. The top of the furnace consists of a hopper, with doors at the bottom, moved by levers from the charging floor. At this floor there is besides a cover with a water seal, and provided with a glass panel to judge of the condition of the charge. When the latter is at red heat a charge is withdrawn from the bottom. This is done by withdrawing the fork (c), resting on the bar (d). The drawing is done at intervals varying from 1¾ to 2¼ hours according to the draft which is dependent upon atmospheric conditions. The ore must be in pieces of 1½ inches or over. Judging from the furnace dump, a certain amount of clinkering takes place in the furnace."

There are two of these Neate furnaces, of 20 tons daily capacity, each, in operation at the St. John's mine, near Vallejo, Solano County, and one at the Hastings mine in the same county. In 1916, an old

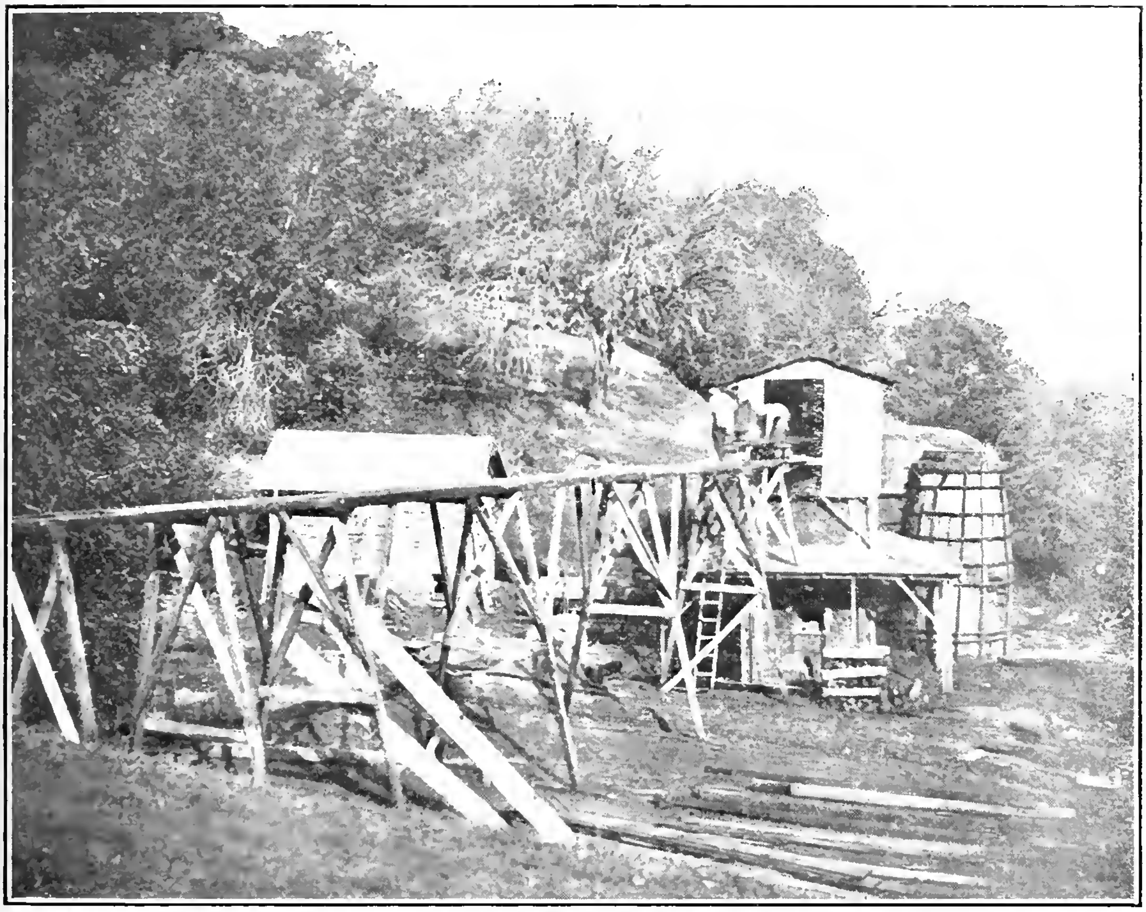


Photo No. 46. Neate Coarse-ore Furnaces, at the Bella Union Mine, Napa County, February, 1916.

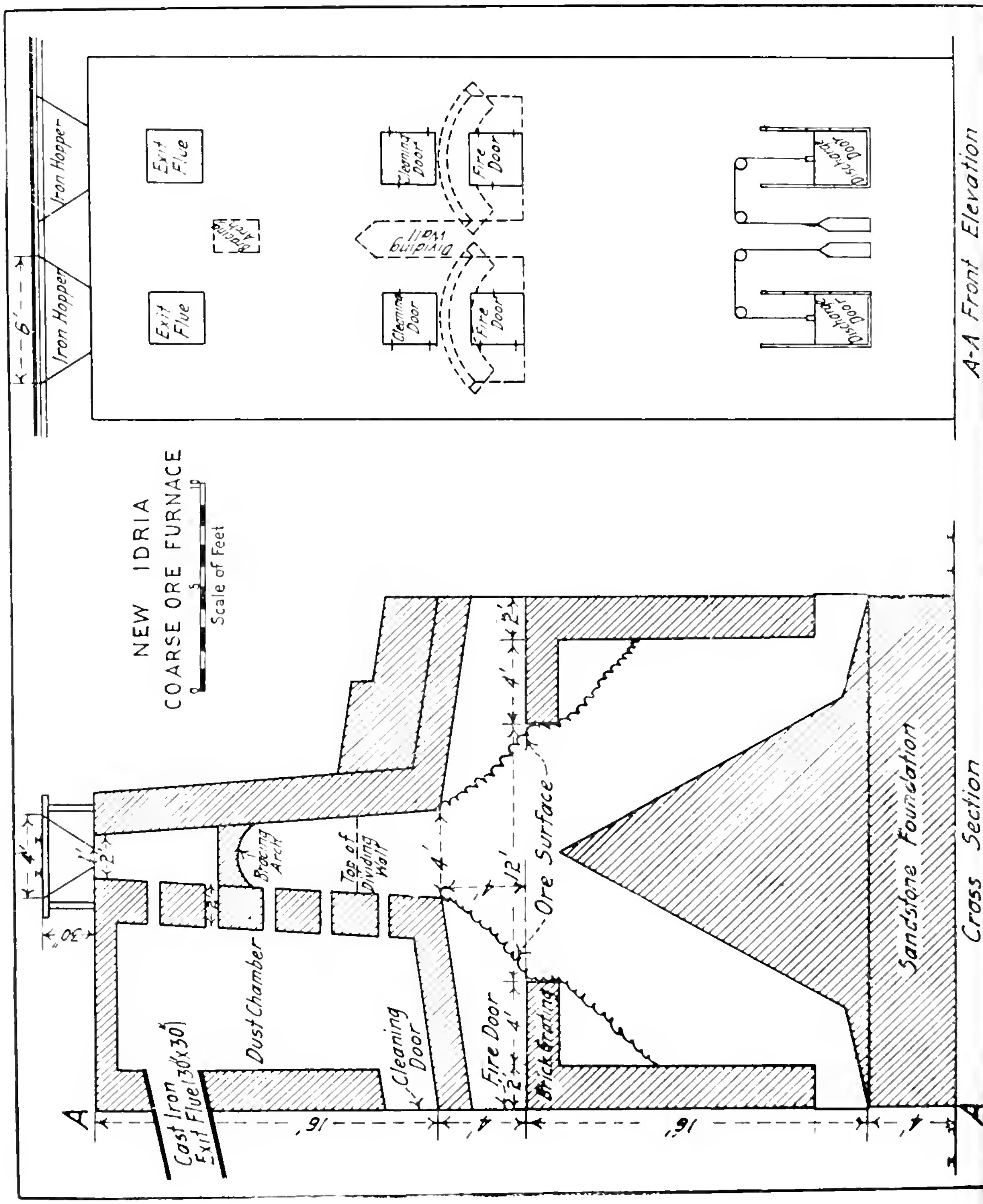
furnace of this type at the Bella Union mine, near Oakville, Napa County, was repaired (see Photo No. 46) and again put into service; but its use is at the present writing discontinued.

The **New Idria** coarse-ore furnace (see Plate XXIX) was developed and designed by Mr. B. M. Newcomb, for a number of years general superintendent of the New Idria Quicksilver Mining Co., and previously of the Oat Hill, Ætna, and Knoxville groups. As described by Forstner[20]

"the fire is applied on both sides of the charge, which is only 4 feet through, and 6 feet long in each compartment at the level of the top of the fire chambers, and is

[19]Cal. State Min. Bur., Bull. 27, p. 210.
[20]Op. cit. p. 213.

PLATE XXIX.


NEW IDRIA
COARSE ORE FURNACE
Scale of Feet
Iron Hopper
Iron Hopper
Exit Flue
Exit Flue
Bracing Arch
Cleaning Door
Cleaning Door
Fire Door
Fire Door
Dividing Wall
Discharge Door
Discharge Door
A-A Front Elevation
Cast Iron Exit Flue (30"x30")
Dust Chamber
Bracing Arch
Top of Dividing Wall
Cleaning Door
Fire Door
Brick Grating
Ore Surface
Sandstone Foundation
Cross Section

heated at three sides, while besides, as it comes into the fire chambers, the charge spreads, thus causing its speedy heating to the highest temperature in the furnace. The depth of the discharge doors below the level of the fire chamber gives the ore a chance to cool off, and to give off the mercury vapors not volatilized during its passage in front of the fire chamber. This furnace is 17 feet wide, 24 feet through at the level of the fire chamber, and has a total height of 42½ feet from drawing floor to charging track. It handles from 90 to 100 tons per 24 hours; its cubic capacity is 2400 feet, hence the ore remains a little above 24 hours in the furnace. It is run by two shifts[21] of five men each—one furnace man, two chargers, and two drawers—and requires not quite 2½ cords of wood per day.[22] The excessively low fuel consumption is partly due to the high [?] percentage of iron sulphide in the ore."

There are two of these furnaces in operation at New Idria—#2 and #3. Their output is 25,000 to 30,000 tons of ore each per year, which they would handle at approximately $0.45 per ton, before the war; this figure including only direct furnace operation items, of labor, fuel, supplies, and soot treatment.

Top losses from coarse-ore furnaces.

While in the case of a fine-ore furnace like the Scott the fine material in the throat and hopper serves as an effective top seal, in the coarse-ore furnaces some other means must be provided to prevent the escape of fumes from the top of the charge. Unless care be used, particularly during charging, the workman is liable to become salivated. An effective form of seal is that employed with the Exeli furnace (see Plate XXVI, *ante*).

Observations of Dr. Duschak on coarse-ore furnace operations are summarized in the following notes:

"Temperature distribution.

"The following temperatures were observed in a coarse-ore furnace at New Idria treating 60 to 80 tons, oil being used as fuel:

Fire box	900° to 1,000° C
Ore in shaft at level of top of fire-box	550° to 600° C
Exit pipe gases	180° to 200° C

"Gas leakage.

"Drafts are usually so regulated that pressure in excess of atmospheric exists in the upper part of the furnace. There is, therefore, a tendency for the escape of furnace gases resulting not only in the loss of mercury vapor, but also in exposing workmen to the danger of mercurial poisoning, a condition which favors a neglect of the furnace by the attendants. In contrast to the Scott fine-ore furnace, the coarse ore in the charge hopper is of little use in sealing the top of the shaft. It is, therefore, necessary to provide such devices as accurately fitting slide gates and water-sealed hopper covers to avoid gas leakage.

"On one occasion when gas leakage about the top of the furnace was particularly troublesome the introduction of an ⅛″ air jet with 60 to

[21]In 1917, three shifts.
[22]Crude oil is now used.

70 pounds air pressure in each of the two furnace exit pipes, together with the lowering of the ore column in the furnace, greatly reduced the difficulty.

"The proportion of fine ore in the furnace charge should be strictly limited as it restricts the gas passages through the material in the furnace shaft, thus causing a back pressure in the combustion chambers with attendant escape of mercury-laden gases from the fire doors.

"It was observed with a coarse-ore furnace in good repair that the air supplied for combustion of the fuel oil could be nicely regulated so that the excessive air, as indicated by a CO_2 determination in the exit gases, averaged from 0 to 20%. This is considerably better regulation than has been observed in any Scott fine-ore furnace."

FINE-ORE FURNACES.

With the exception of the Livermore and the revolving type, the fine-ore furnaces are practically all of the tile or baffle type. The one most frequently adopted in California is the Scott, also known as the Hüttner-Scott. Of the others—a Litchfield furnace was in operation for a number of years at the Great Western mine, near Middletown, Lake County; and a Knox-Osborne fine-ore furnace each, at the Manhattan

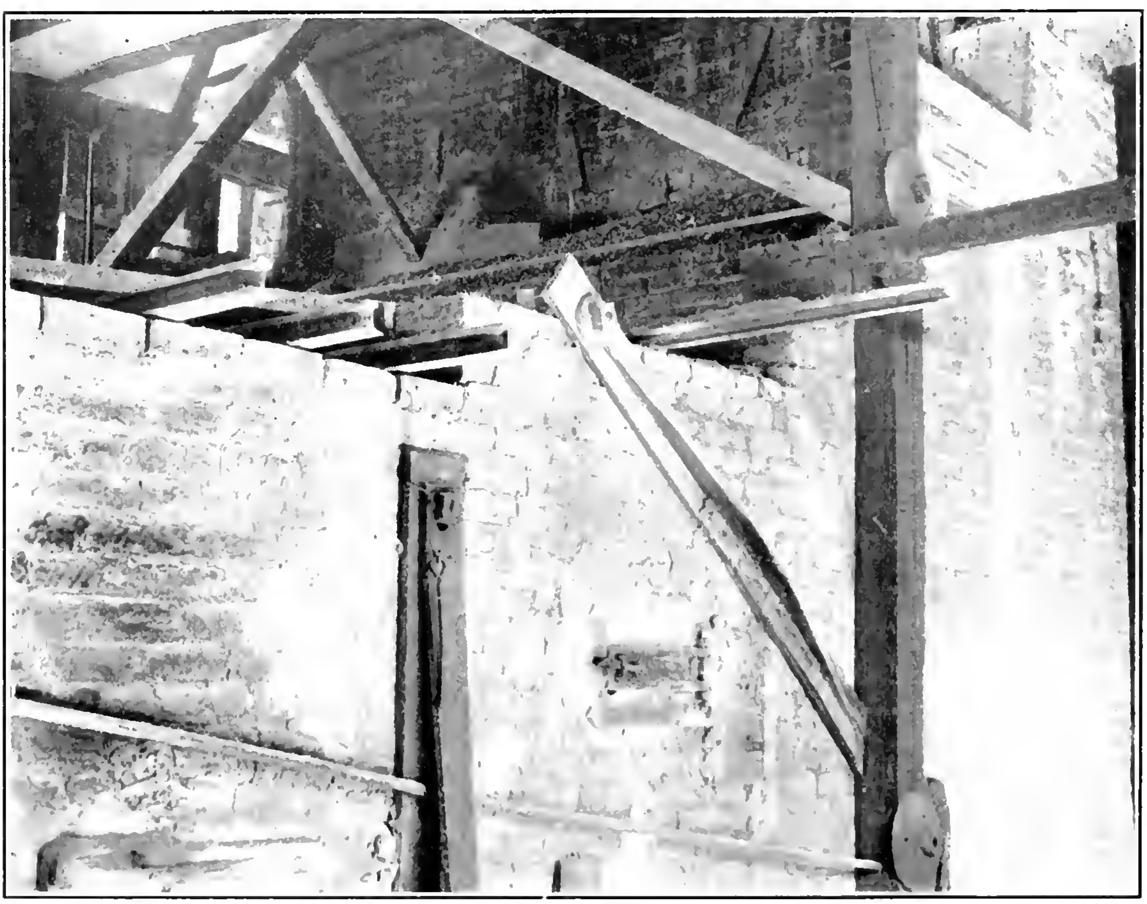


Photo No. 47. Livermore Furnace at Cloverdale Mine, Sonoma County.

mine in Napa County, and at the Altoona and Integral mines in Trinity County. The **Cermak-Spirek** furnace in operation and construction is similar to the Scott and to the Knox-Osborne fine-ore furnace, but a somewhat different form of tile is used. It is employed notably at Monte Amiata,[23] where it is credited with yielding excellent results; but there are no furnaces of this make in California. The **Litchfield** furnace resembles the Scott, except that the heat ascends in the ore

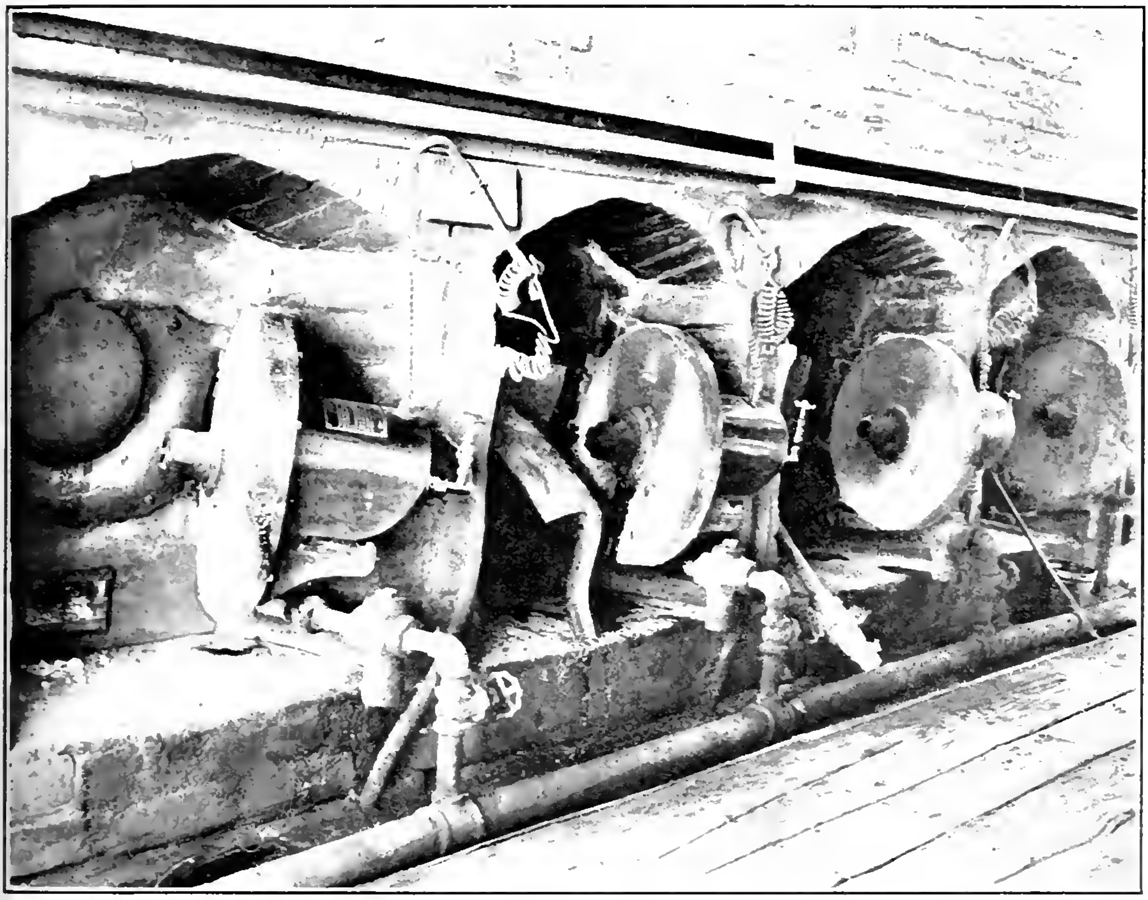
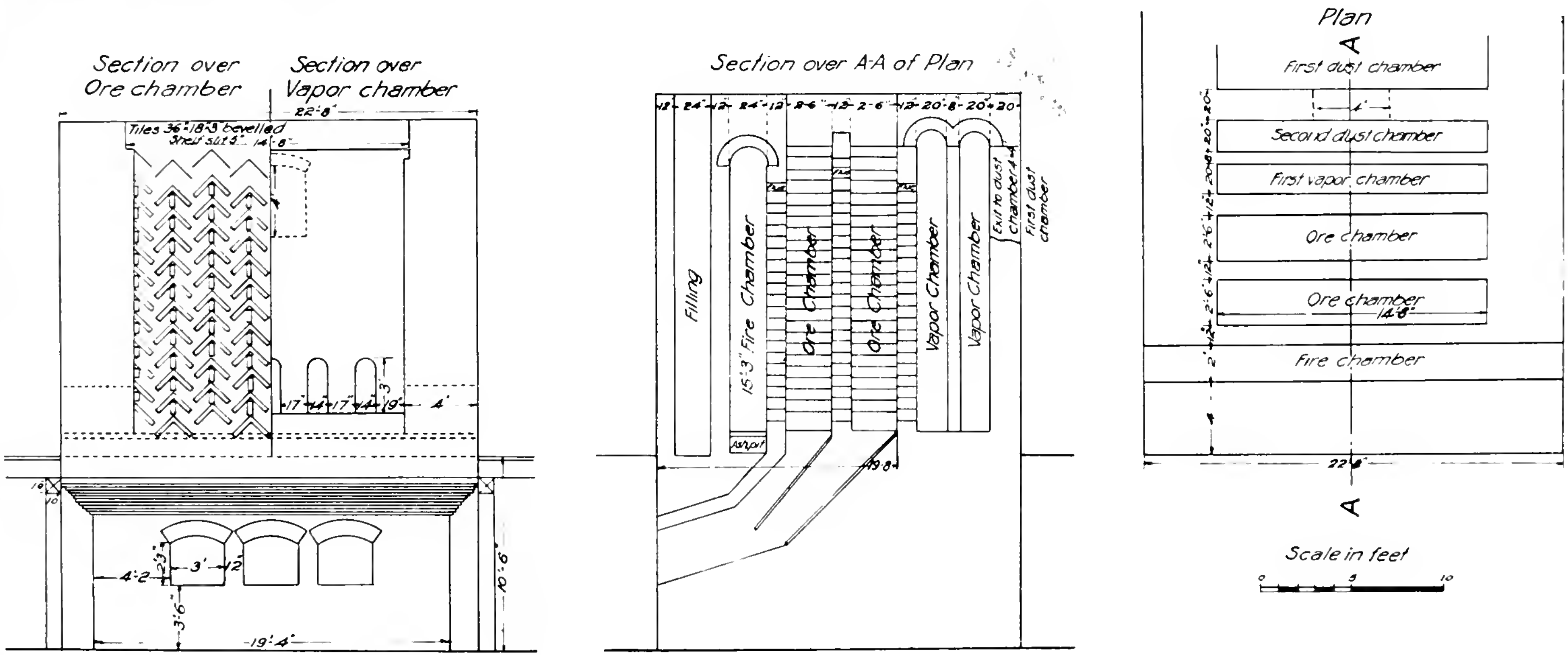


Photo No. 48. Ray Electric Oil-burners on Livermore Furnace at Cloverdale Mine.

chambers between the walls and the tiles, instead of being forced to pass over the tiles. The **Knox-Osborne** fine-ore furnace has a capacity of 24 tons per day and[24]

"consists [see Plate XXX] of two ore chambers, across which the inclined tiles are placed in a checkerboard manner; the two upper rows of tiles are of cast-iron, the others of fire clay. The ore glides down along the channels formed by the inclined planes. The double fire chamber is at one side of the ore chamber. The partition walls between the fire chamber and the first ore chamber, between the ore chambers, and between the second ore chamber and the first dust chamber, are pierced with pigeon holes through which the flames pass, heating the tiles and the ore. The partition wall between the first and second dust chamber, both of which form an integral part of the furnace, has five openings 3 feet high on the level of the floor of the fireplace, creating a down draft in the furnace. The second dust chamber is provided in its outer wall with a large opening near the top, through which the fumes pass into the first condenser, which is built at the Integral mine contiguous to the furnace. The top of the furnace is open; the charge is placed directly on the upper rows of tiles; the down draft above mentioned being deemed sufficient to prevent the escape of gases from the furnace."

[23]Spirek, Vincenzio, The quicksilver industry of Italy: Min. Ind., vol. VI, pp. 568–582, 1898.
[24]Cal. State Min. Bur., Bull. 27, p. 215.



Knox & Osborne Fine-ore Furnace

The **Livermore** furnace (see Plate XXXI) has been described in detail by Egleston.[25] It is essentially an inclined-hearth furnace, with the products of fuel combustion pasing directly over the ore. So far as noted, there are but two examples of this furnace remaining in California. One, a modified form, is in operation at the Cloverdale mine, near Cloverdale, Sonoma County. (See Photo No. 47.) Formerly wood

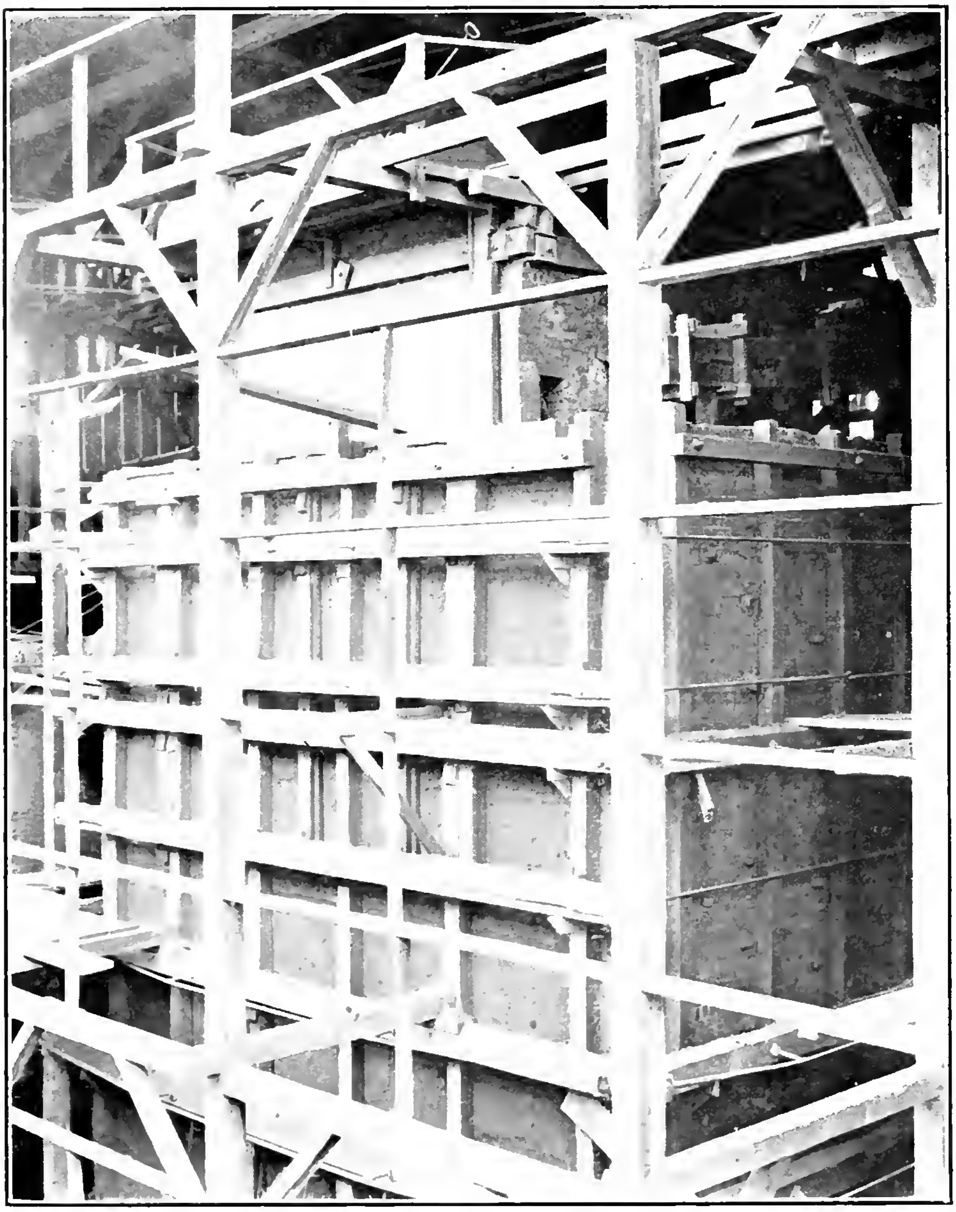
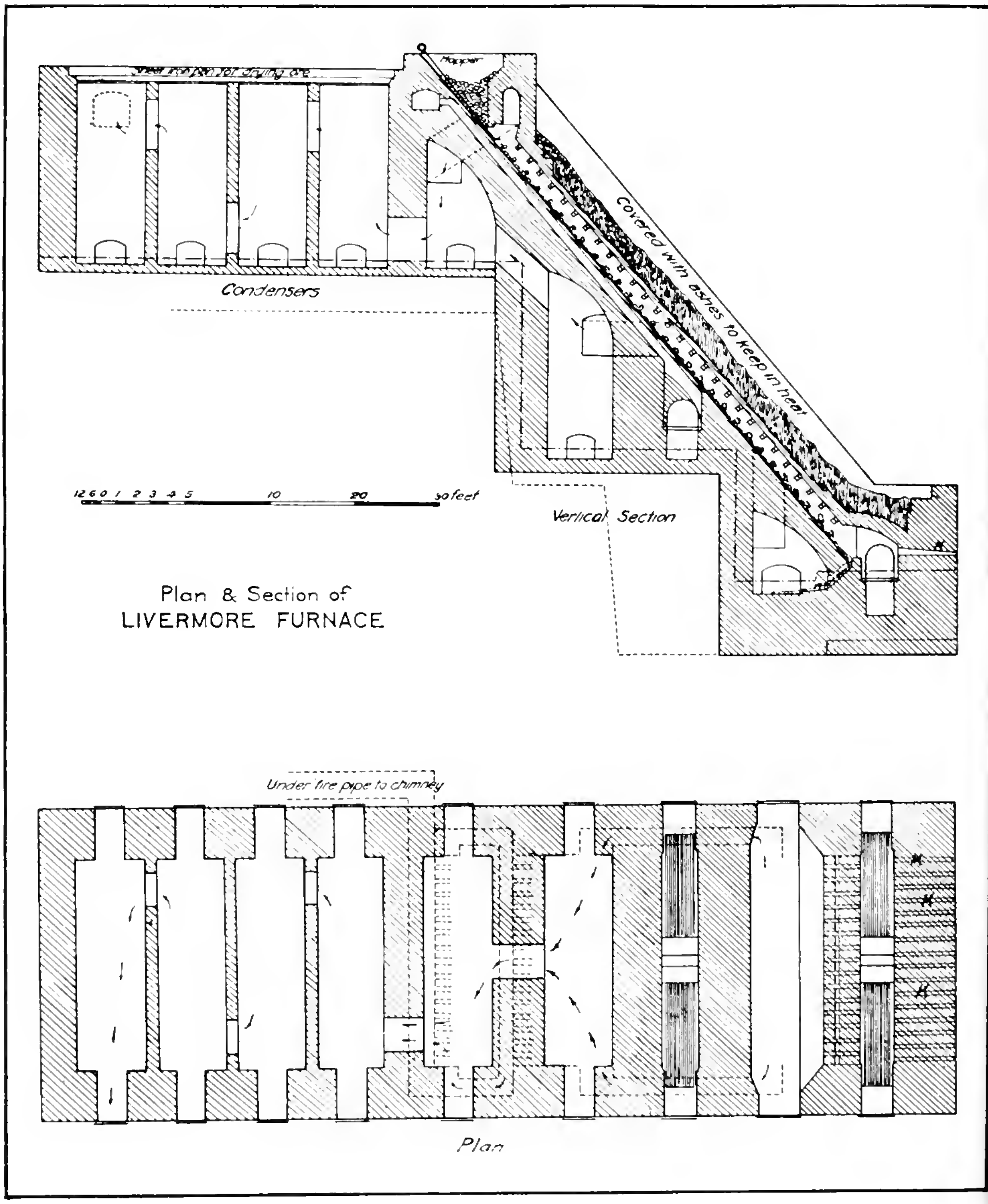


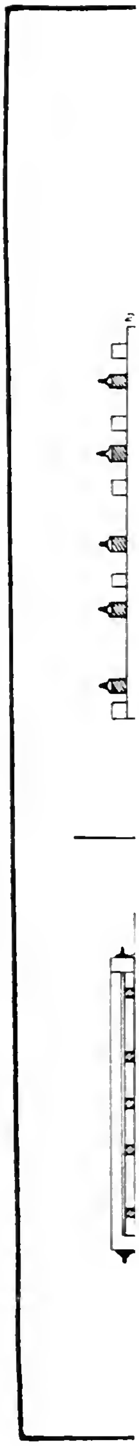
Photo No. 49. Side view of 50-ton Scott Furnace at Oceanic Mine, San Luis Obispo County.

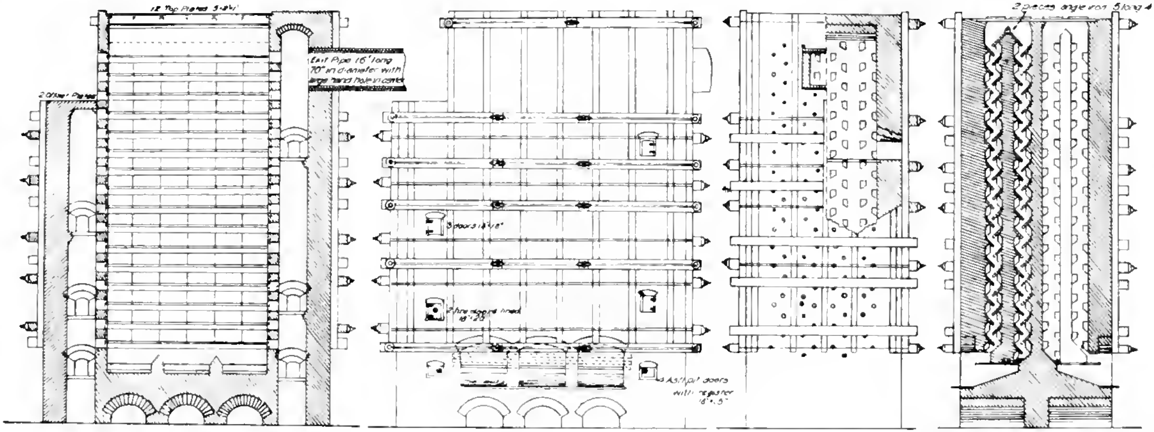
was used for fuel, but at present, crude oil. The burner being used is a Ray electric, (see Photo No. 48) in which the oil is atomized by a current of air created by an electric fan, the driving motor being direct-connected, and all self-contained in a single housing for each unit. The other furnace of the Livermore type is at the La Joya mine, near Oak-

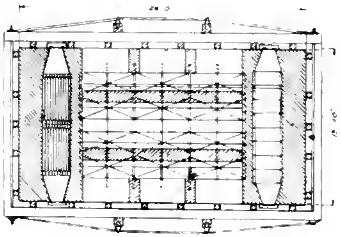
[25]Egleston, T., The Metallurgy of Silver, Gold and Mercury in the U. S., Vol. II, p. 887, 1890.

PLATE XXXI

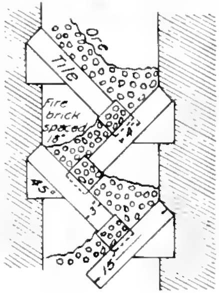

Covered with ashes to keep in heat
Condensers
12 6 0 1 2 3 4 5 10 20 30 feet
Vertical Section
Plan & Section of
LIVERMORE FURNACE
Under fire pipe to chimney
Plan







PLAN
OF
HÜTTNER AND SCOTT'S
8 TILE FURNACE
SCALE
0 5 10 15 FT



ville, Napa County, and was in operation during a part of 1916 and 1917. This furnace, as originally built, was supposed to be a Fitzgerald[26] inclined retort; but it appeared to the writer to have been operated like a Livermore, with the flames from the fuel passing directly up the ore chamber instead of around it. It is now idle, having been supplanted by retorts.

The **Hüttner-Scott** furnace, (now generally referred to as the Scott), was developed by H. J. Hüttner, Robert Scott and J. B. Randol in 1875–1876 at the New Almaden mine,[27] Santa Clara County, as an improvement on the earlier, European, Hasenclever furnace, to treat the 'tierras' or fine ore which had previously been molded into adobes before burning. The opening, or shelf-slit, between the edge of one tile and the face of the one next below it was originally set at 3 inches. This has been widened in later furnaces, up to as much as 8 inches (usually 5″ or 6″), so that medium-sized ore up to say 3½ inches may now be treated in these furnaces. As will be noted from Plate XXXII, the tiles form a zig-zag channel for the passage of the ore as it moves from the top to the bottom of the ore chamber.

The tiles generally used are flat, being 3″ x 15″ x 36″ in size. According to Forstner,[28] in 1903 they were imported and cost, laid down in San Francisco, $3.50 apiece. More recently some have been made by certain California fire-brick and pottery manufacturers, and are reported to be giving satisfactory service. These cost approximately $3 apiece, f.o.b. shipping point. In some cases, as in Furnace No. 3 at New Almaden[29] and the Cermak-Spirek[29] furnace used in Europe, a special form of tile is used; but the same zig-zag channel effect for the ore is obtained, while the tile is stated not to have given as satisfactory service as the flat form.

The fire-box of the Scott furnace is on one side of the ore chamber, and a vapor chamber on the opposite side. The furnaces are built in daily capacities of from 10 to 60 tons. The capacity is governed by the number, length, and height of the ore chambers—each additional tile increasing the length of the chamber by 36 inches, and the height varying with the number of tiles placed one above the other. Usually the outer walls are braced with iron tie-rods. (See Photo No. 49.) Two of the furnaces at New Almaden were 'iron-clads', or enclosed with iron plates; but this appears unnecessarily expensive. Peep holes are placed in the end walls, to enable observation of the condition of the ore at different levels in the furnace.

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[26]Forstner, Wm., Quicksilver Resources of California: Cal. State Min. Bur. Bull. 27, p. 81, 1903.
[27]Christy, S. B., Quicksilver Reduction at New Almaden: Trans. Am. Inst. Min. Eng., Vol. XIII, p. 553, 1885.
[28]State Min. Bur. Bull. 27, p. 221.
[29]*Idem*, p. 221.

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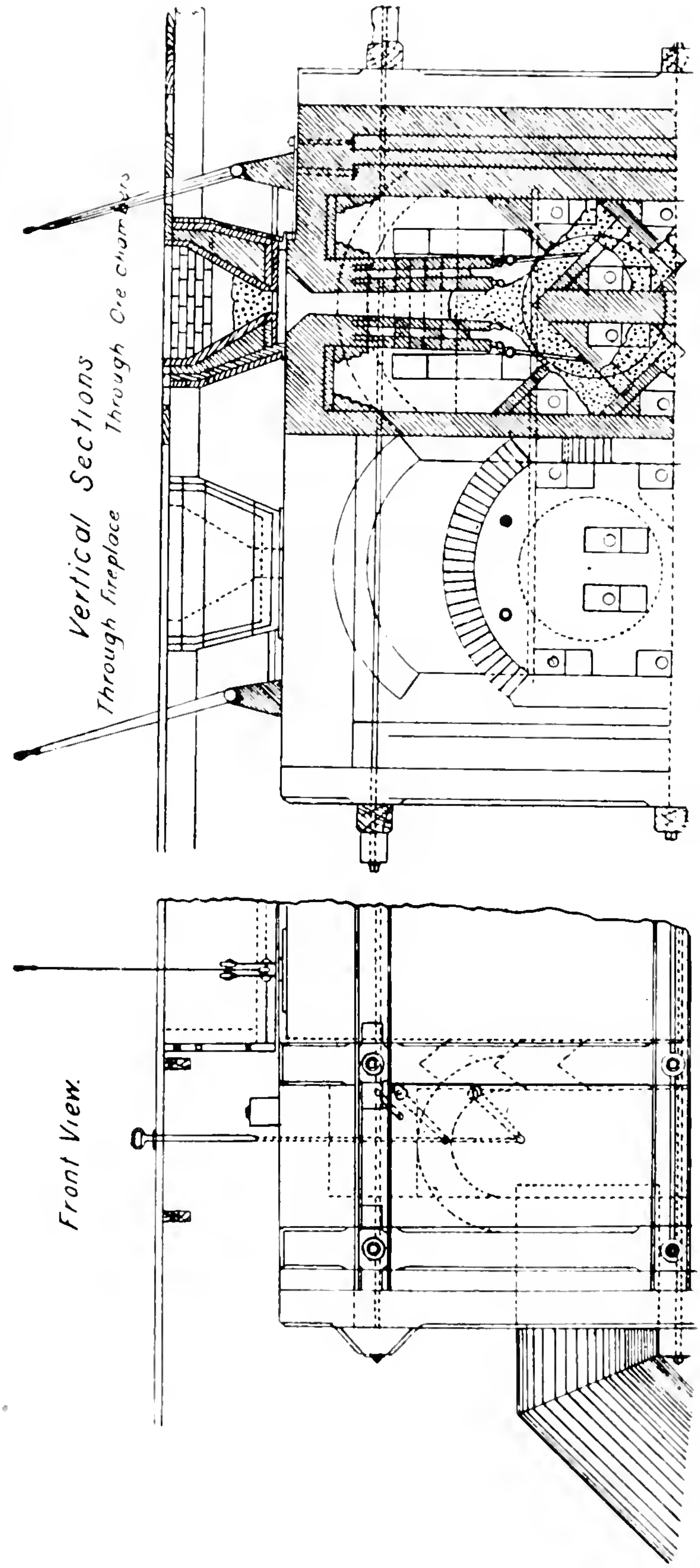
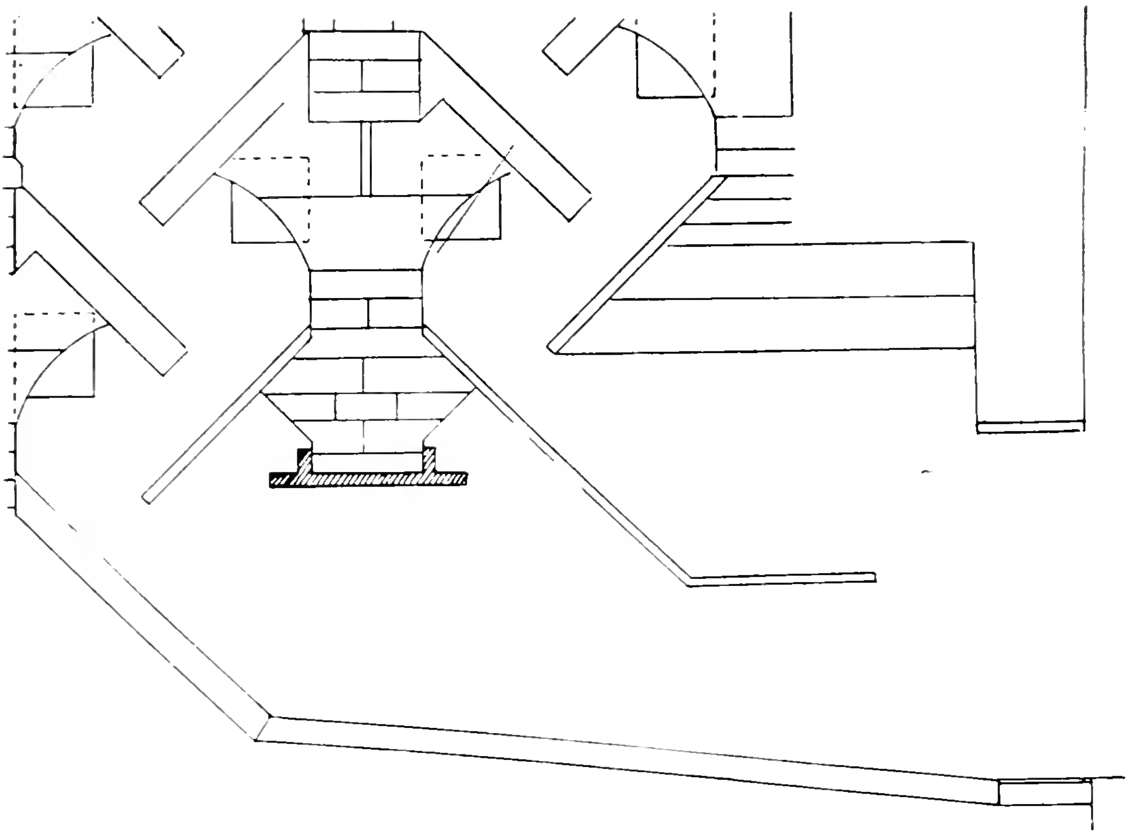
[26]Forstner, Wm., Quicksilver Resources of California: Cal. State Min. Bur. Bull. 27, p. 81, 1903.
[27]Christy, S. B., Quicksilver Reduction at New Almaden: Trans. Am. Inst. Min. Eng., Vol. XIII, p. 553, 1885.
[28]State Min. Bur. Bull. 27, p. 221.
[29]*Idem*, p. 221.

PLATE XXXIII.



Top of Huttner-Scott furnace

PLATE XXXIV.



Discharge of Scott Furnace.

The charging and discharging arrangements for the Scott furnace are shown by Plates XXXIII and XXXIV, also Photo No. 4. (*ante*).

The following two tabulations by Forstner[30] give the dimensions of some of the Scott furnaces in California in 1903 and the materials required in construction:

[30]Op. cit. p. 223.

Data Regarding Some Tile Furnaces.

Name	Daily output, tons	Cubic capacity, tons	Time charge remains in furnace, hours	Outside dimensions: Horizontal, feet		Outside dimensions: Total height above, feet	Outside dimensions: Length, feet	Ore chamber: Width, inches	Ore chamber: Shelf slit, inches	Ore chamber: Height from roof to point of discharge, feet	Number	Fuel per 24 hours, cords	Men employed per shift	Remarks
New Almaden—														
No. 1	36	-----	30	17½	25½	36	11½	25½	8	27¼	4	1½ to 1¾	3	When worked together only 5 men per shift.
No. 2	18	-----	30	12½	24	36	11½	25½	8	27¼	2	-----	3	
No. 3	36	-----	52	20¾	24¼	41½	11½	22⅜	5	36	6	2½	-----	
No. 8	24	32	32	9 5/12	37	41	8⅔	18	3	30¾	4	2	2	
Boston	60	-----	-----	13 10/12	26	37	14½	18¾	3	29¾	4	2	-----	70 per cent of the mercury in the soot.
Oathill	50	40	20	16	22	37	8½	-----	6	31¾	4	2¾	4	
Mirabel	30	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	2¼	-----	
Karl	60	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	
New Idria	60	-----	24	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	
Sulphur Bank	40	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	1¼	-----	
Sulphur Bank	30	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	1	-----	
Sulphur Bank	15	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	⅝	-----	
Great Western (Litchfield furnace)	40	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	2¼	-----	

Materials Required for a Scott Furnace.

	10-ton	40-ton	50-ton
Common brick	150,000	300,000	400,000
Fire brick	12,000	20,000	30,000
Tiles	188	360	428
Cement (barrels)	25	40	50

Fire-clay, timber for frame, iron for frame, grates, hopper, etc.

The common brick are frequently burned from local clays near the mine. Fire-brick in 1903 cost $32.50 per 1000 in San Francisco; while in 1917 they were approximately $30–$40 per 1000 depending on quantity bought.

The total cost of a Scott furnace, complete, with brick condensers, will amount to approximately $1000 per ton-day capacity. Some have been built for less, and the cost will vary with freight rates, labor, availability of local clays for brick, and other local conditions. With wooden condensers, instead of brick, the plant cost will be appreciably lowered. Present economic conditions are abnormal to such a degree, that any cost data given as of the moment, would not represent a fair basis for comparison.

The Scott furnace could be built with thinner walls, with an insulating layer such as diatomaceous-earth blocks between the outer brick and the fire-brick lining. To strengthen these lighter walls, they could be iron-clad, but it need not be so heavy as were the iron-clad furnaces at the New Almaden mine. The insulating layer would reduce loss of heat by radiation, and thus economize on fuel consumption.

Among other things, there is one feature of Scott furnace operations which has impressed itself upon the writer:—that is, the number of times that the ore is handled at many of the plants before it is finally discarded. Nor is this an unusual fault nor confined to the quicksilver mines. It is of frequent occurrence at many other kinds of mines, till the ore gets 'worn-out' with handling, as the saying goes. An automatic feed could be readily provided for a Scott furnace. In fact, there is one such installation, at least, in California, at the Guadalupe mine, Santa Clara County.* The ore from the bins is fed automatically to a rotary drier which in turn discharges directly into the hopper of the Scott. An automatic discharge would probably be more difficult to arrange, but it could doubtless be accomplished. Such features would materially reduce the labor item in the cost of operation.

As ordinarily conducted, the roasting period of the ore in a Scott furnace is approximately 24 hours—that is, 24 hours is the time

*Since the above was written, the new 90-ton Scott furnace has been built at the Senator mine of the New Almaden company, with an automatic, belt-conveyor feed.

required for a given charge to pass from the throat to the discharge pit. At the Black Butte Mine, Oregon, in 1909, W. B. Dennis,[31] developed an accessory wood-gas producer with a gas heating arrangement for the 40-ton Scott furnace, by which he reduced the roasting period from 24 hours to 4 hours, "with a cleaner and in every way more satisfactory roast." We have not heard of this system having been adopted elsewhere, at least not in California; but it would appear to merit investigation.

In the high temperature parts of the furnace, wherever there is a dead space due to a corner or lack of draft (as in the square corners of the flues and dust chambers), the SO_3 and volatilized mercury unite to form a deposit of mercuric sulphate scale. The author has specimens of such material which were gathered from furnaces being torn down at the Sulphur Bank mine, and at New Idria. Goodyear[31a] describes the formation of sulphate in the furnaces at New Idria and notes that more of it formed in the summer months, than in the winter.

Observations of Dr. Duschak relative to temperature distribution and regulation, and fuel consumption, in the Scott furnace, are summarized in the following statements:

"Temperature distribution.

"Both wood and fuel-oil are used in the Scott furnace in California. The range and distribution of the temperature in the furnace varies somewhat with the fuel, and the distribution also depends on whether an auxiliary fire is used at the back of the furnace in the chamber opposite the main fire box. This point will be made clear by reference to the accompanying diagram (Plate XXXV) which represents a vertical cross-section parallel to the side of the furnace. The hot gases from the main fire-box 1, have a tendency to rise to the arch and seek passage through the upper rows of flues, thus leaving the lower part of the furnace, particularly at the rear, in the vicinity of 2, relatively cold. When, however, a small fire is introduced at 2 a draft is created which tends to draw the gases from the main fire-box through the lower flues thereby making the lower portion of the furnace more effective. In the following tabulation, column A shows the range of temperatures in a wood-fired 50-ton Scott furnace without auxiliary fire at 2. Column B gives similar data for an oil-fired 70-ton Scott furnace with a small fire at 2. The numbers refer to the accompanying diagram. (Plate XXXV.)

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[31] Dennis, W. B., Shortening the roasting period for mercury ores: Eng. & Min. Jour., Vol. LXXXVIII, pp. 112–116, 1909.

[31a] Goodyear, W. A., Report on examination of the quicksilver mines of California: Geol. Surv. of Cal., Geol. Vol. II, pp. 116, 117, 1882.

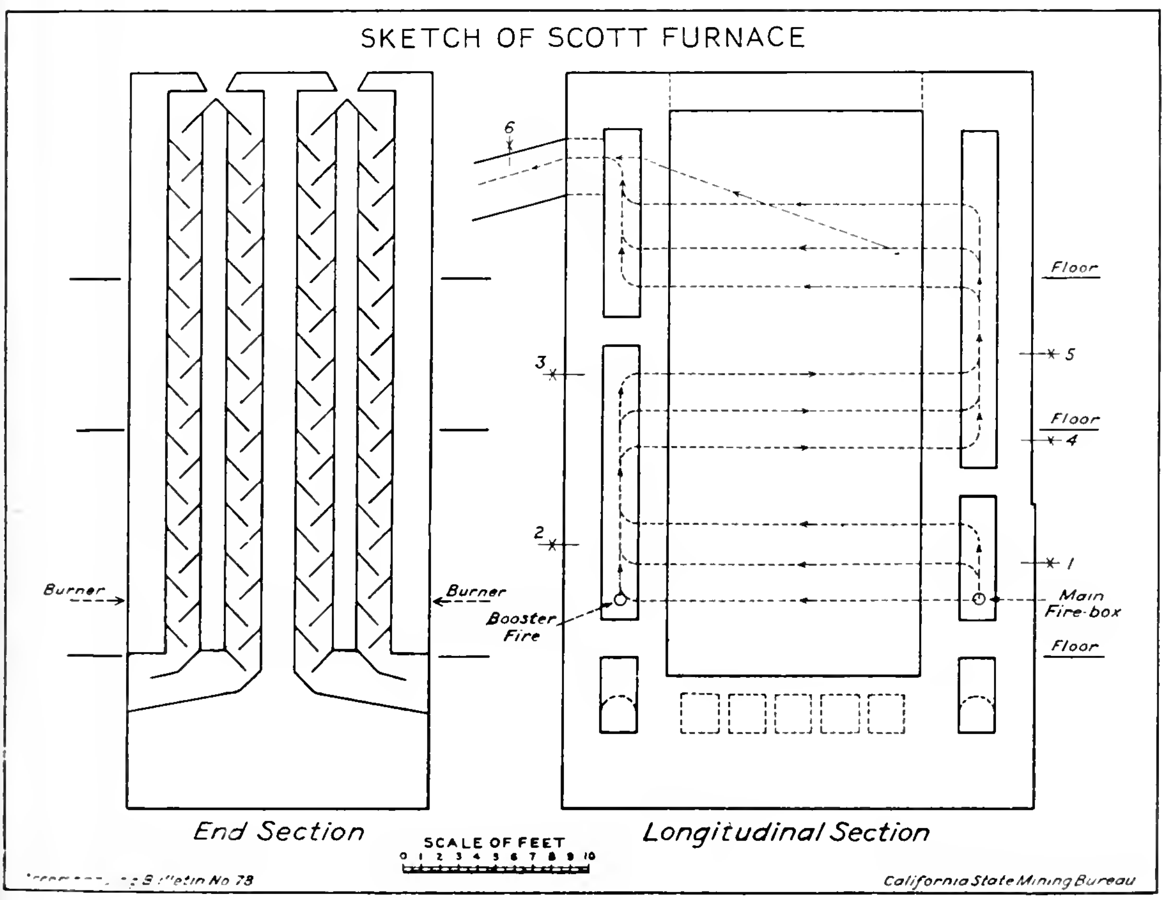
	A	B
1.	700° to 900° C	900° to 1100° C
2.	---- ----	600° to 700° C
3.	500° to 550° C	600° to 700° C
4. } 5. }	300° to 350° C	400° to 450° C
6.	150° C	200° C

"As is pointed out in succeeding paragraphs, the proper exit-pipe temperature varies with the grade of ore and the volume of gas leaving the furnace per ton of ore treated. Taking these points into consideration the exit-pipe temperatures shown in the above tabulation both represent safe practice.

"**Exit Pipe Temperature.**

"The temperature of the gases leaving a quicksilver furnace must be sufficient to prevent the condensation of any quicksilver in the furnace. On the other hand an excessive temperature means a waste of fuel and throws an unnecessary burden upon the condenser system. The temperature at which quicksilver vapor will begin to condense depends upon its concentration in the furnace gases which in turn depends upon the grade of ore and the volume of gases leaving the furnace per unit

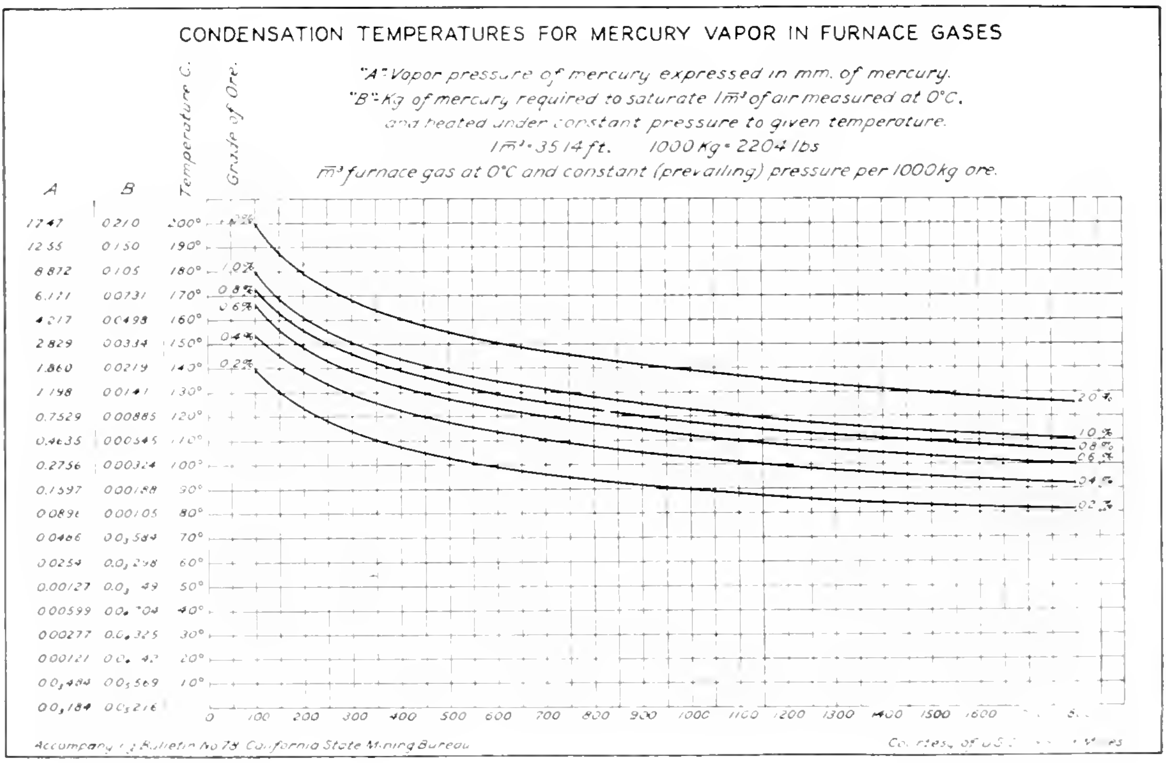
PLATE XXXV.



SKETCH OF SCOTT FURNACE

weight of ore treated. The relation between these several factors is given by the curves in the accompanying diagram. (Plate XXXVI.) The temperature at which the furnace gas will be saturated with quicksilver vapor, or in other words, below which condensation will begin, is given by the abscissa. The volume of furnace gas in cubic meters per metric ton of ore is plotted as ordinate and the several curves correspond to ores containing the indicated percentages of mercury. For ordinary Scott furnace practice the volume of gas measured at 0° C. and at the average atmospheric pressure at the furnace amounts to 400 to 700 cubic meters per metric ton of charge.

PLATE XXXVI.



"By way of illustration assume that the furnace charge carries 0.8% Hg and that the gases leaving the furnace amount to 500 cubic meters measured under the above conditions per metric ton of charge. By reference to the chart it will be seen that the theoretical saturation temperature is about 134° C. In practice, however, a certain margin of safety is necessary in order to make due allowance for normal fluctuations in furnace temperature and for the chilling of the gas when cold and damp ore enters the furnace. A temperature of 175° C. would be about right under the above conditions. At this temperature the gases leaving the furnace per metric ton charged would occupy a volume of 820 cubic meters (corresponding to 26,200 cubic feet per short ton).

"Extending the practical illustration a little further, suppose that a furnace operating under the conditions just assumed, handles 50 metric tons (55 short tons) of ore in 24 hours. At the exit-pipe temperature of 175° C., 28.5 cubic meters (1000 cubic feet) of gas will leave the furnace per minute. Assuming that the gas stream increases 25% in volume through leakage in passing through the condenser system and leaves at 40° C., the mean linear velocity in the usual 3-foot diameter flue leading to the stack will be about 36 meters or 120 feet per minute. This will serve to give some idea of the conditions obtaining in good furnace practice."

"Temperature regulation.

"Quicksilver operators have not yet fully appreciated the advantages along the line of fuel economy and safer and more certain furnace operation to be gained by careful temperature control. A suitable installation for this purpose consists of an indicating pyrometer, situated near the furnace for use of the furnace men, a recorder in the superintendent's office or at other convenient point, and preferably, at least two thermocouples in each furnace. By the use of suitable switches a single indicator and recorder can be used for several furnaces.

"The location of the thermocouples requires some consideration. Referring to the diagram (Plate XXXV), although there would be some advantage in placing a thermocouple at point 1 in the main firebox, the temperature range with oil firing at least is such that a base-metal couple is likely to undergo deterioration and thus render its indication somewhat uncertain. Moreover, the advantage to be gained by permanently locating a couple at this point hardly justifies the high cost of a precious-metal couple. Point 3 is suggested as a good permanent location for a base-metal thermocouple and a second one may be advantageously placed in one of the exit pipes (point 6). Regular observation of the temperatures at these two points should be sufficient for good regulation of the furnace, but it is suggested that an extra set of leads be provided from the indicator to the furnace so that a portable base metal couple may be used in making temperature observations at points 1, 4 and 5 or elsewhere. With the usual Scott furnace construction certain peep holes may be selected for use in making a thorough survey of the furnace temperature. It is believed that such a survey should be particularly useful in locating the cause of any disturbance in regular furnace operation.

"Fuel consumption.

"With ore carrying only a few per cent of moisture, but devoid of any considerable quantity of metal sulphides, which would serve as fuel, a fuel oil consumption of 5 to 6 gallons per ton of ore treated, or roughly, 2.2% by weight, may be considered as good practice. With wood as fuel the consumption ranges from 0.03 to 0.05 cords per ton, or roughly, 4% by weight, depending somewhat on the quality of the wood.

"A high moisture content in the furnace charge will not only increase the fuel consumption, but increase the danger of hang-ups and other disturbances in furnace operations. When moist ore is to be handled it should be dried before charging to the furnace. A Scott furnace is not designed as an ore drier. Generally speaking, the evaporation of a given amount of moisture calls for a given fuel consumption. There is therefore, no fuel economy in feeding wet ore to the furnace, but on the other hand, hang-ups resulting in the reduction of furnace capacity and other difficulties are likely to result.

"Observations made in the field, recently, indicated that sufficient attention has not been given to the regulation of the air entering the Scott furnace. With oil firing under the best practice so far observed nearly 100% air in excess of that required for combustion leaves the furnace exit pipes and with wood firing an excess of 200% to 300% has been observed. This excess not only increases the fuel consumption, but also throws an unnecessary burden on the condenser system.

"The entrance of unnecessary air to the furnace can be controlled partially at least by suitable regulation at the fire door and other openings into the combustion chamber and also by careful luting about the peep holes, or any cracks in the furnace walls. Counterpoised gates for closing the openings through which the burnt rock is withdrawn may also assist in this direction. *The object to be attained is to allow no air to enter the furnace except at the combustion chamber and this in sufficient quantity to burn the fuel completely but no more.* The problem of burning wood efficiently closely resembles that of efficient use of bituminous coal in a boiler plant. The fuel should preferably be introduced frequently in small quantities and sufficient air admitted above the grate immediately after the addition of the fuel to burn the gases distilling from the wood. As the charing of the wood advances the air supply above the fire should be reduced and more air admitted below. It is recognized, owing to the variety of duties which the furnace attendant is usually called upon to perform, that it may be difficult to approximate ideal fire-box conditions. Some effort in this direction seems worth while, however, as incomplete combustion with the attendant formation of carbonaceous soot not only favors the formation of mercurial soot in the condenser but constitutes a waste of fuel. Objections to excess of air have been mentioned above."

TOP LOSSES.

In fine-ore furnaces of the Scott type, the fine material in the throat and hopper serves usually as an effective seal. This will vary some with the nature and dryness of the ore as well as the amount of really fine material in the mixture. However, the precaution should be observed of keeping the hopper *full*. The Innes fume trap as installed at the Oceanic mine is effective. This has been described, accompanied by a diagram, by Heberlein;[32] but it is now built with a single fume exit between and serving the two throats of each furnace, instead of an exit for each throat separately. Also, wood is used in the construction, instead of cast iron as there shown. This resembles an arrangement utilized at Idria, Austria, described by Cástek.[33]

Referring to this device at the Oceanic mine, Duschak observes that it is "probably useful also in removing water vapor which escapes from the ore as it descends the throat of the furnace, and which might otherwise condense in the cold upper layers of the charge, rendering the ore sticky and favoring hang-ups.

"A study was made of the volume and mercury content of the gases escaping from the special condensing chamber attached to the fume trap of the newer of the two 50-ton Scott furnaces. The following data were obtained:

Average temperature of escaping gas, 30° C.

Volume per minute at 30° C., 5 cu. meters (175 cu. ft.).

Mercury loss per 24 hours, 0.25 kg. (0.55 lbs.)."

ABSORPTION AND DISCHARGE LOSSES.

With the Scott furnace, carefully operated, there should be practically no values in the spent ore as discharged. With care, it is a relatively simple matter to expel all of the quicksilver from the rock. If, however, the furnace be crowded and the heated rock drawn off too soon from below, there will be values remaining in it. If the rock be still hot enough for any remaining mercury to volatilize, such remaining metal might escape into the air, and an assay of the tailings might thereby indicate a clean 'extraction', though obviously not a clean recovery. That this is not only possible, but sometimes does occur, is shown by the fact that the draw-man generally wears some sort of nose and throat protection, and sometimes they have been salivated, though not often.

The investigations of the U. S. Bureau of Mines have shown the stack fume losses to be much smaller than it had been expected to find them.

[32] Heberlein, C. A., The mining and reduction of quicksilver ore at the Oceanic mine, Cambria, Cal.: Bull. Am. Inst. Min. Eng., Feb., 1915, p. 500. Also, in Trans., Vol. LI, p. 113.

[33] Cástek, Franz, Die Bestimmung und Verminderung der Verluste beim Quecksilberhüttenwesen: Berg- u. Hüttenmännisches Jahrbuch, LVIII, Band, Wien, 1910.

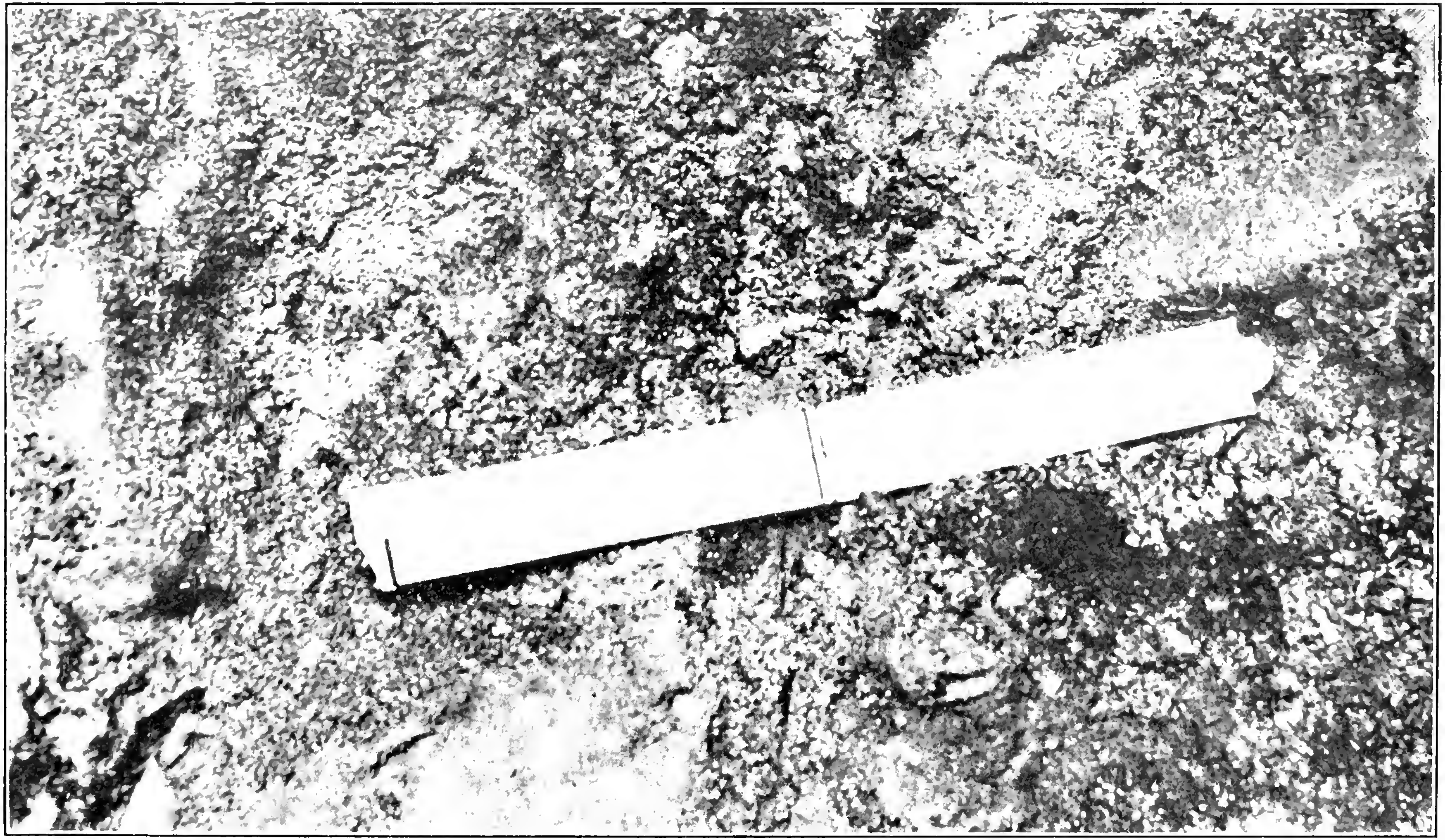


Photo No. 50. Quicksilver in earth and gravel under site of old furnaces at New Almaden. The numerous 'white' spots are globules of quicksilver.

At New Idria, on 0.7% ore, the loss was but 4½ pounds of quicksilver per 24 hours treating 75 tons of ore. At the Oceanic mine, on 0.3% ore, it was 6½ pounds, treating 90 tons. While top, stack, and discharge losses are controllable to a greater or less extent, there is one form of loss, that of absorption, which is impossible to measure and practically impossible to control where brick or stone are used in the construction of furnace and condenser walls. The Scott fine-ore furnace with its usual system of brick condensers is notorious for its hoarding up of absorbed quicksilver. Of course, it is not an ultimate loss, as it can some day be recovered by wrecking the plant; but to all intents and purposes, as long as it remains there, it is a loss. One superintendent who still very much favors the Scott furnace recently made this observation to the writer: "If you will take the recovery of absorbed mercury from the wrecking of a given plant, and divide it by the number of tons of ore which passed through that furnace during its service, you will find the percentage of the loss very small. The absorption in a new plant is considerable in the first three or four months of operation; but after that it reaches a point of saturation." Any absorption is a loss, and therefore objectionable. Its extent will depend on the construction of the plant. Recent improvements in condenser construction, discussed under that heading, will minimize that loss.

It seems to the writer that the point of saturation may often be a long time arriving, especially in view of the depth to which quicksilver has been found in the soil and earth under some plants. At the present time at New Almaden, they are recovering quicksilver to a depth of 30 feet under the site of certain of their old furnaces. The earth and gravel there are literally 'alive' with globules of the metal, as the accompanying photograph (No. 50) shows. A tunnel recently run under one of the furnaces at New Idria shows a similar condition to exist there. While the percentage loss may be small as suggested above, the uncertainty of it is in the apparent inability to determine currently what it is or to control it. Here again enters the subject of technical control of operations, of which we have already mentioned the lack in quicksilver reduction in California. Without regular sampling and assaying, it is impossible to know what a plant is doing.

COST OF OPERATING A SCOTT FURNACE.

The costs of operating a Scott furnace plant will of course vary, as they will vary in any other metallurgical process, with local conditions, tonnage treated, and efficiency. Figures of from 50¢ per ton to 75¢ per ton have been given for plants of at least 50 tons daily capacity, working under favorable conditions and carefully managed. Smaller plants and those less favorably situated will cost more. These figures include only the day-to-day running expenses. They do not include any item of interest, depreciation or amortization on the high initial installation capital, nor for repairs and general overhead charges. Figured conservatively these may total anywhere from 25¢ to 50¢ per ton. Material repairs should not be required oftener than about once in four or five years; but when they do come they are costly. At New Idria the lining in the coarse-ore furnaces usually lasts three years, and in the fine-ore, four years. It is usually not necessary to completely re-line, nor to replace all of the tiles.

At the Oceanic mine, San Luis Obispo County, the direct operating costs as recorded by Logan[34] in November, 1915, amounted to $0.57 per ton with a 50-ton furnace; and were divided, as follows:

3 furnacemen @ $2.50	$7 50
3 chargemen @ $2.50	7 50
1 foreman	4 50
1 helper	2 00
1 cord pine wood, delivered	5 50
Estimated cost of soot treatment per ton of ore, $0.03; per day's run, 50 tons	1 50
Total cost for 50 tons	$28 50

Present costs (September, 1917), as furnished the writer by Mr. Ellard W. Carson, now manager of the Oceanic Mine, show a material increase due mainly to advances in wages. There are now two 50-ton furnaces, treating an average total of 90 tons daily, and the items are distributed as follows:

3 furnacemen, each, i. e. 6 @ $3	$18 00
3 chargemen, each, i. e. 6 @ $3	18 00
1 foreman	5 00
1 helper	2 75
1¼ cords, pine wood, each, i. e. 2½ cords @ $6.50	16 25
Soot, 90 T. @ $0.03	2 70
Total cost for 90 tons	$62 70

This gives a per-ton figure of $0.697, to which should be added the item of superintendence, at least, as the owner, Mr. Murray Innes, does not now personally supervise operations as in 1915.

At the Cambria mine, San Luis Obispo County, in 1915, Carson[35] reported the following cost of operating a 50-ton Scott furnace: "Actual operating costs treating 50 tons per day on a basis of a 30-day month, average us somewhat under $1000 per month, or 66⅔¢ per ton. This cost is distributed approximately as follows:

"6 furnacemen @ $2.50 per day	$450
Foreman and overhead	210
Total labor	$660
Wood, 1½ cords per day, @ $6	270
Miscellaneous supplies	70
	$1,000

[34] Logan, C. A., in Cal. State Min. Bur., Report on Mines & Minerals of Monterey etc. counties, 1917, p. 124.

[35] Personal correspondence with H. G. S. Anderson re comparative costs of a wet method for quicksilver.

"1500 tons of 10-pound ore, with 90% extraction, would yield 13,500 pounds of quicksilver at a cost of 7.44 cents per pound. * * * On a basis of a 100-ton plant treating ten-pound ore in a Scott furnace the cost of production should not exceed 8 cents per pound for the metallurgical treatment. * * *"

In 1914, a certain Scott fine-ore furnace in California treated 22,000 tons of ore at a cost of $0.715 per ton. During a part of the year this furnace was idle while being repaired; for in 1915, it handled 27,000 tons at a cost of $0.652 per ton. These figures include only the direct items for furnace operation, of labor, fuel, supplies, and soot treatment.

PERCENTAGE OF EXTRACTION OBTAINED BY SCOTT FURNACES.

Very few operators really know what their furnaces are actually doing, because of the absence of systematic sampling and assaying. Some of them will tell you that because of the erratic nature of most quicksilver deposits, it is quite impossible to accurately sample the ores. It should not be any more 'impossible' than on an ore carrying free gold occasionally, and that is done with fair precision, daily, in many localities. We will acknowledge that it is a difficult matter to adequately and accurately sample the feed of a coarse-ore furnace, but it can be done; while it should be a relatively simple matter for fine ore.

At the Cambria mine in 1915, as incidentally mentioned in the preceding section under the heading of costs, Carson credits his plant with obtaining 90% extraction. At the present time, (October, 1917) at the Oceanic mine, his practice and results are: The head sample is a dip by hand with a small scoop from each bucket of the aerial tramway just after loading at the upper terminal. The furnace reject is sampled by taking a shovel full from each third car. These samples are quartered down, once a week, and sent to an assaying firm in San Francisco. The heads are averaging 0.26% to 0.36% mercury, and the tailings 0.02% to 0.03%. This is an indicated extraction of 91.7%. It is to be noted that these heads assays are made on *dry* material, whereas the ore as it reaches the furnace carries from 8% to 10% moisture.

At one other mine in California where sampling and assaying is at present being carried out, the Scott furnace heads for the month of July, 1917, averaged 0.66% mercury and the discharge 0.10%, or an indicated extraction of 84.8%. For the month of August, 1917, the heads averaged 0.61% Hg, and the tails 0.069% Hg, an indicated extraction of 88.6%. This plant is equipped with an electric, indicating pyrometer, so that a careful tab is kept on the furnace temperatures.

At one mine in a western state outside of California, a 30-ton Scott furnace under careful supervision during a short period of operation in 1914, is stated to have shown an indicated extraction of 86% by assays of heads and tailings samples, on a 0.36% Hg ore.

These are all favorable cases, at well-equipped and carefully supervised plants, and their results are undoubtedly much better than the average. These figures, too, are *indicated* extractions, not quicksilver actually bottled. It is questionable if the average plant as ordinarily conducted in California for some years past, has been recovering 75% of the value in the ore.

Egleston[36] in discussing this phase of quicksilver operations, says:

"While the price of mercury was very high no assays of any kind were made at the mine. The superintendent of the works or the mines judged by 'experience' that the ore contained 1, 2, 3, 10, or 20 per cent., as the case might be. There was consequently very little dependence to be placed upon any statements of the advocates of the different kinds of furnaces that their furnaces actually yielded a higher percentage than those of their neighbours, or, in fact, that they yielded any given percentage at all. The only statement that could be relied upon was, that they produce in twenty-four hours a given number of pounds of mercury."

Also[37]:

"At New Almaden, after taking a sample from each car-load for thirty-nine days, they report their loss to be 7.29 per cent. The difficulty of sampling ores of mercury, and the probability of getting too low rather than too high an average, makes the loss appear much lower than it really is.

"According to the best California authorities, the loss in the best constructed furnaces, as near as can be approximated, is not less than 15 to 20 per cent; and in many works the loss will probably amount to double that. In the best works it would probably cost more to save the 15 or 20 per cent loss than it is worth; and the works which are not well managed probably could not save it at all."

Christy, relative to condensation at New Almaden, in discussing losses of treatment, says:[38]

"There is perhaps no subject on which greater differences of opinion exist, than upon the losses which occur in roasting quicksilver ores. These losses have been variously estimated by different persons at all the way from 50 per cent by pessimistic critics to 0.01 per cent by optimistic inventors.

"Unfortunately for the purpose of this inquiry, it is not customary at New Almaden, or at any of the quicksilver mines of California, to take careful and systematic samples for assay, as is done at Idria, Austria. * * *

"Furthermore, I have been unable to find, in the whole range of quicksilver literature, any adequate determination of what must be the inferior limit of the losses on the plan of treatment selected. In other words, there is at present no criterion by which we may judge as to whether a given condensing system is doing the best that can be expected of it, or by which we can even approximately estimate the relative value of different systems."

Nor has anyone seemed to try or to bother themselves much to improve furnace and condenser conditions on a systematic, scientific basis since Christy's experiments at New Almaden, until the present investigations of the United States Bureau of Mines, herein recorded.

Also, he concludes:

"The loss [by 'vapor' and 'mist'] is dependent on the volume of fumes, at the same escape-temperature; and the latter, of course, depends on the amount of fuel and ore used, and not on the richness of the ore. Hence, the percentage-loss will be less on rich than on poor ore." * * *

[39]"As a minimum net loss is the real objective point, this can be reached only by a careful adjustment of these conflicting losses (*i.e.*, fume and residue). Thus, with a given furnace reducing 12 tons per 24 hours with a residue loss of 0.5 per cent, and a chimney-loss of 10 per cent of the ore content, it would evidently be better to treat 24 tons per 24 hours with a residue loss of 1 per cent and a chimney loss of 6 per cent of the ore content; for in the first case, the losses would net 10.5 per cent, and in the latter, 7 per cent. Such adjustments, are, however, only possible where the ores and residues are systematically sampled and assayed."

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[36]Egleston, T., The Metallurgy of Silver, Gold and Mercury in the United States, Vol. II, p. 806, 1890.

[37]*Op. cit.* p. 899.

[38]Christy, S. B., Quicksilver condensation at New Almaden: Trans. Am. Inst. Min. Eng., Vol. XIV, p. 231, 1885.

[39]*Op. cit.* p. 261.

REVOLVING FURNACES.

A revolving cement-kiln type arranged for quicksilver ore roasting has in the past been tried on at least two mines in California with mainly negative results. At the Socrates mine, Sonoma County, a White-Howell rotary roaster was installed in 1903,[40] but its use was discontinued after a short period of operation. It was 50 feet in length, with an outside diameter of 5 feet, and lined internally with 6 inches of fire-brick, this cylinder being set on an incline of 6 inches in 50 feet.

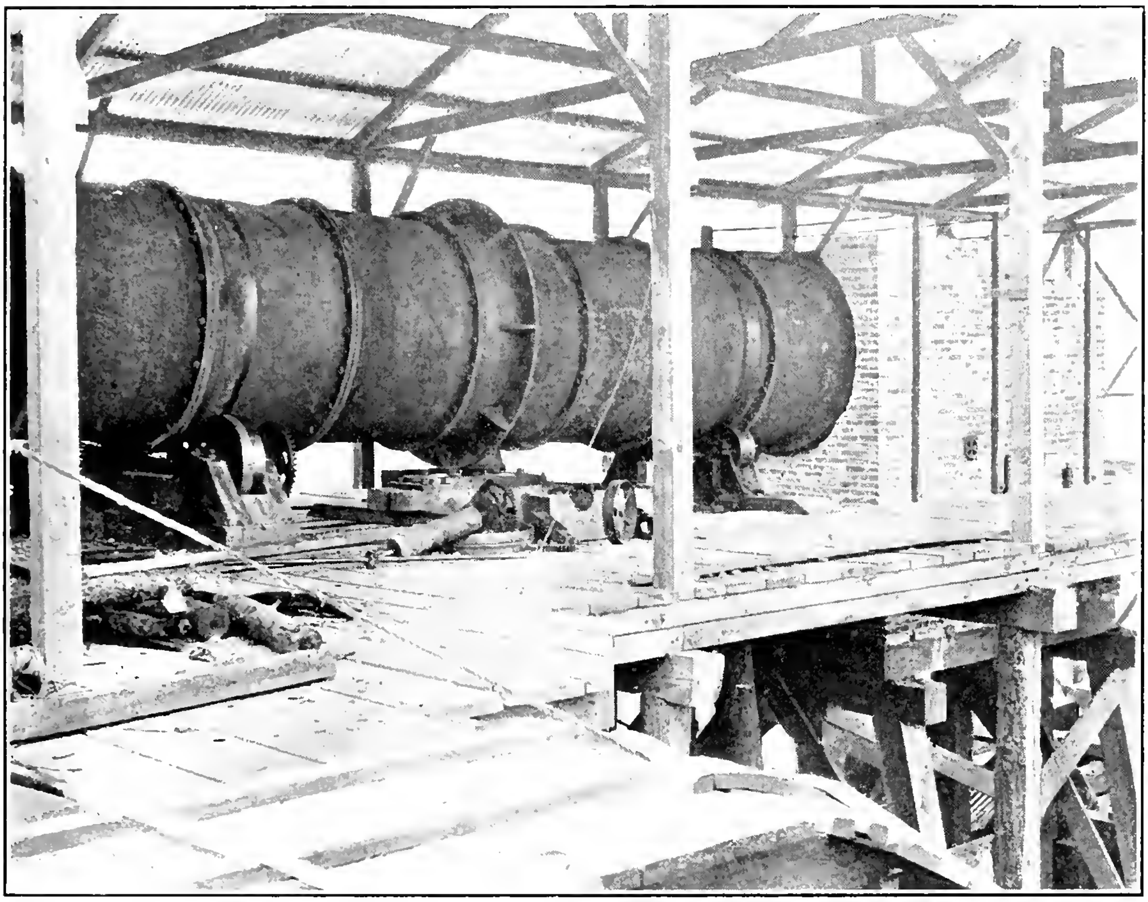


Photo No. 51. Rotary Ore-drier above Scott Furnace, at Socrates Mine, Sonoma County.

The ends of the furnace were fitted into sockets or collars which in turn were fastened into the brickwork of the stack and fire-box. It was driven at 22 revolutions per hour, by a 25 h. p. engine. This carried the ore through in 3¾ hours, and 1.6 cords of wood were consumed per 24 hours. The present operating company has recently cut down the length of this kiln, and re-installed it as a rotary ore-drier above the new 40-ton Scott furnace. (Photo No. 51).

Another furnace of this type was built in 1911 at the Aurora mine,[41] San Benito County, but owing to mechanical difficulties was operated

[40] Min. & Sci. Press, Vol. XC, Jan. 14, 1905, p. 22. *Also*: Forstner, Wm., Quicksilver resources of California; Cal. State Min. Bur., Bull. 27, p. 116, 1903.
[41] See the author's report in Mines & Mineral resourses of Monterey etc. counties; Cal. State Min. Bur., 1917, pp. 57–58. *See also* Photo No. 18, *ante*.

at that time for only one day. In October, 1915, this furnace was repaired and refitted and operated for a few weeks, until severe winter storms damaged the roads over which the fuel-oil supply was brought in. Several flasks of quicksilver were produced. It is at present reported that work will be resumed there shortly.

REVOLVING FURNACES AT NEW IDRIA.

An experimental, revolving unit, (see Photo No. 52), was put in operation in March, 1918, at the New Idria Mine, San Benito County, which has certain new accessory features connected with it, by which it is hoped to make this type of furnace successful for the treatment of

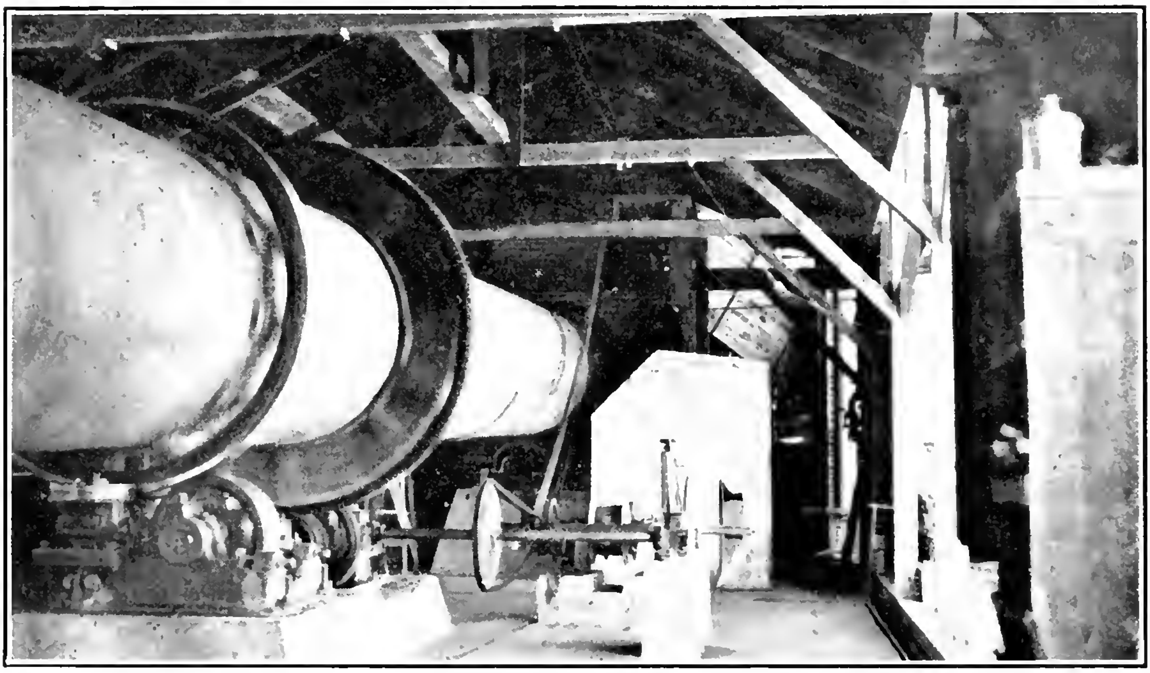
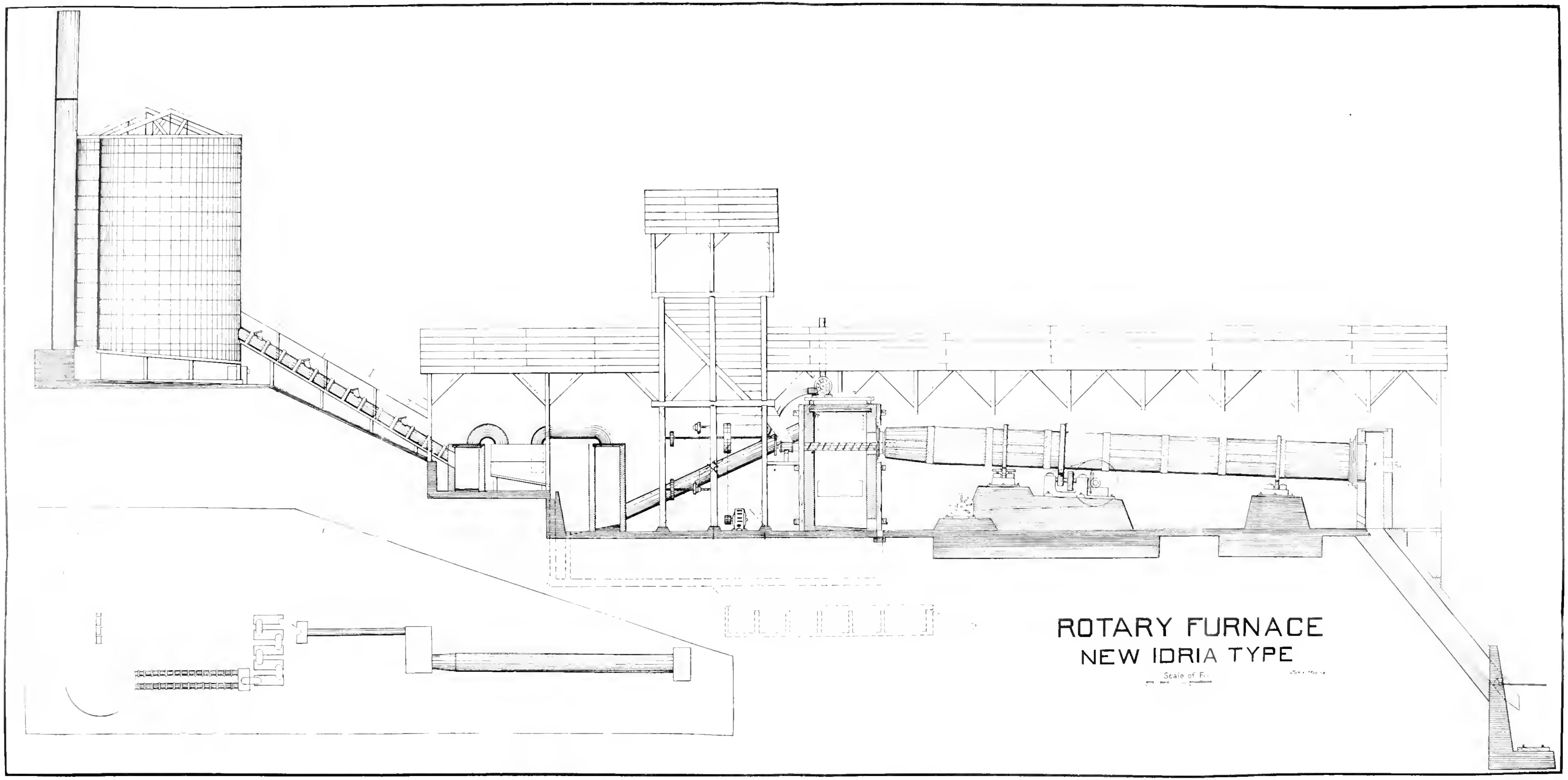
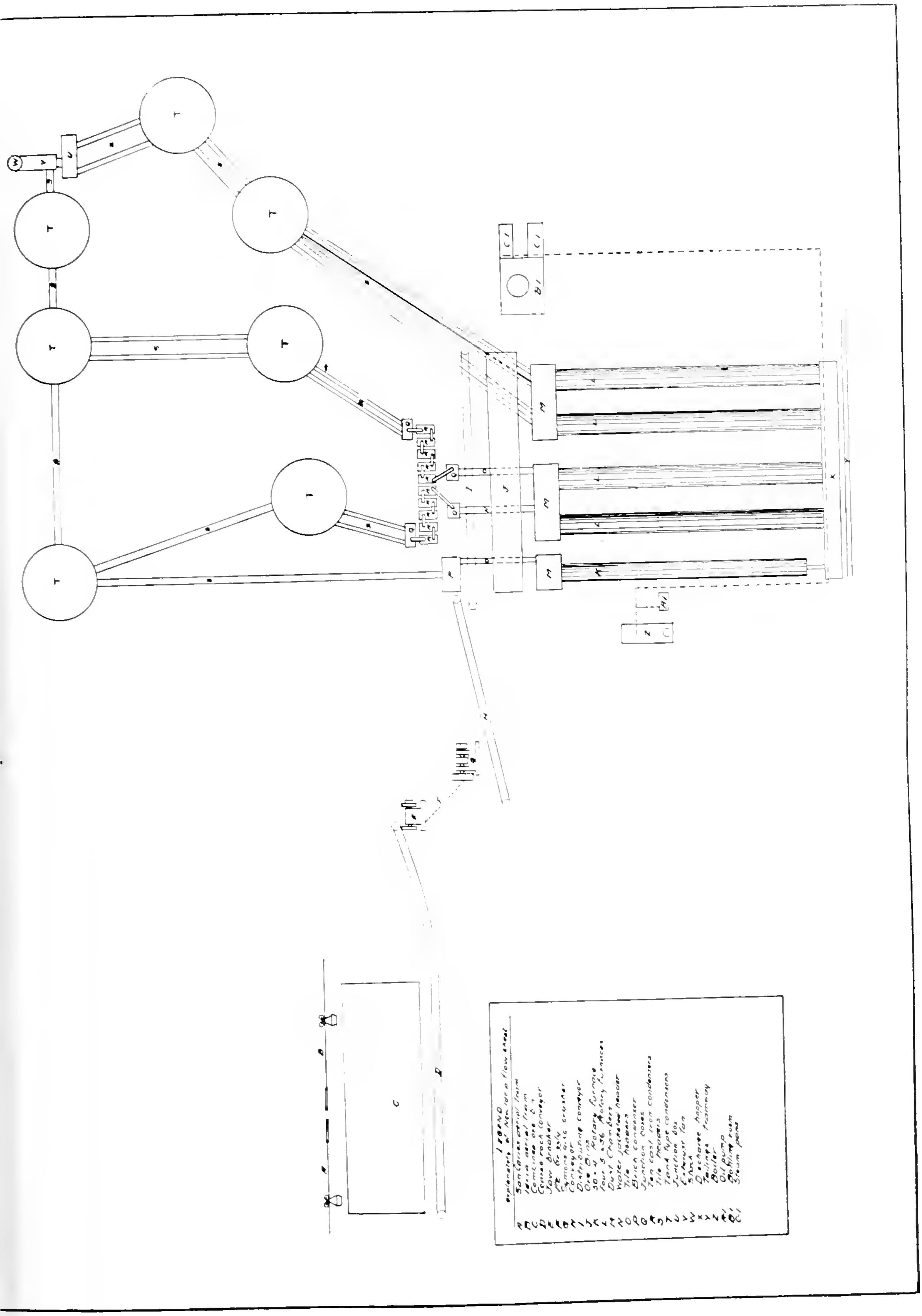


Photo No. 52. New Rotary Quicksilver Furnace at New Idria Mine, San Benito County, "after 58 days' continuous and successful operation." Photo by H. W. Gould.

quicksilver ores. Mr. H. W. Gould, general superintendent, considers that the rotary has great possibilities. Thus far, it appears that their cost is one-fourth to one-half that of the Scott per ton-day-capacity; consumption of fuel one-third to one-half; labor one-fifth to one-half. It is more flexible than the Scott, the ore passes through in 15 to 30 minutes, with all of the mercury apparently expelled. There are no absorption losses in the furnace, as all the brick are hot. There is no personal element attached to the rotary, the feed and discharge being automatic, as against the irregularities possible with the hand labor on a Scott. Salivation of the workmen cannot result from the end joints of the furnace, because of the inward suction due to the stack draft.

This first furnace at New Idria is 4′ diam. x 50′ long, arranged to drive at $1\frac{1}{2}$ to 4 r. p. m., and at first treated 96 tons of $1\frac{1}{4}''$ ore daily. At present writing (April, 1918) it is handling 72 tons of $1\frac{1}{2}''$ ore.


ROTARY FURNACE
NEW IDRIA TYPE
Scale of Feet



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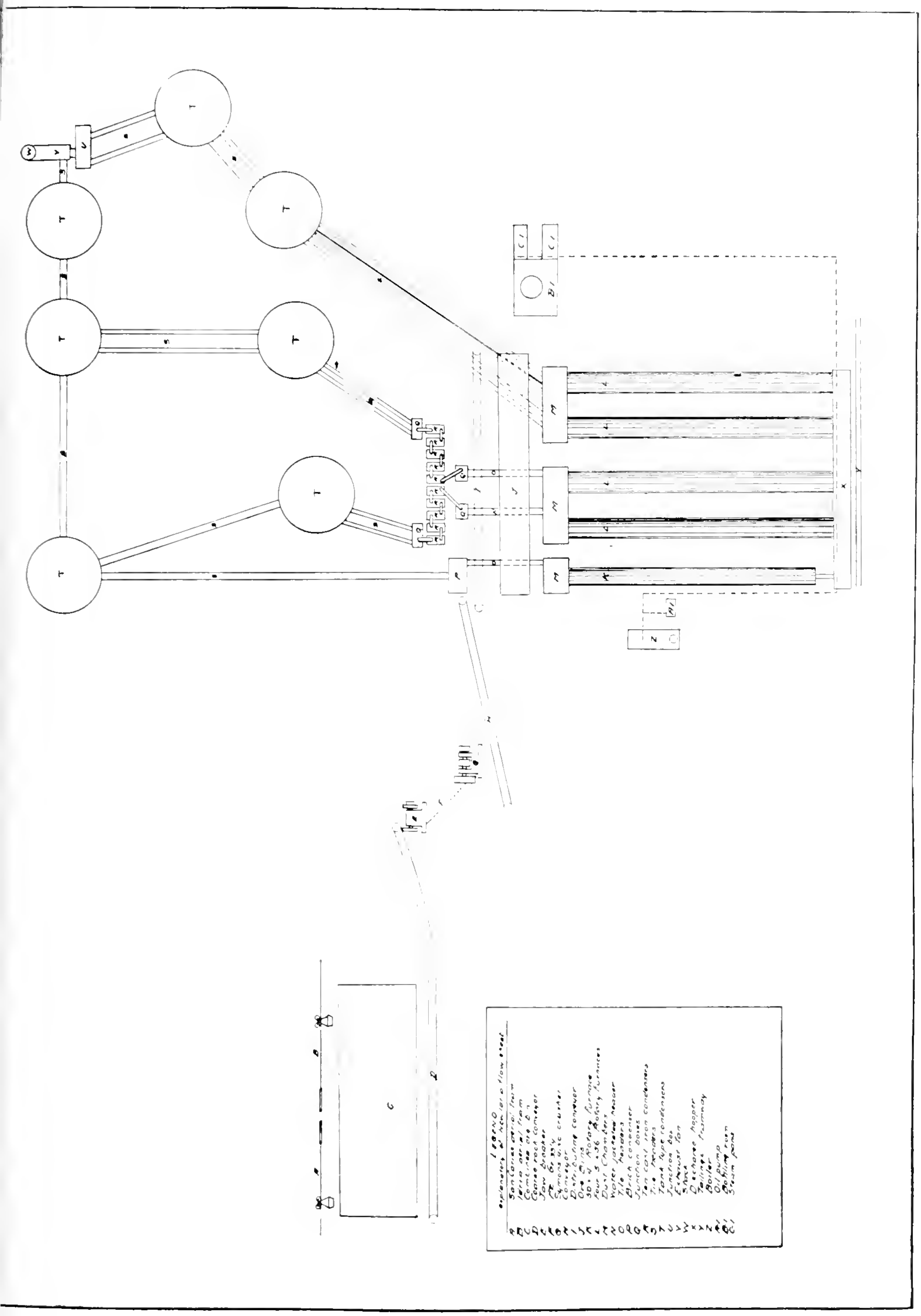

Gould thinks that ultimately $\frac{3}{4}''$ to 1″ will be found the economic size for the feed. The capacity of the furnace and the time of passage of the ore through it, depend on the speed of revolution and the thickness of the stream of ore, in addition to the size of the ore pieces. A thin stream of ore revolving rapidly can be completely burned and passed through the furnace in about 15 minutes; but a thicker stream must be run more slowly, or all the metal will not be driven out of the rock.

A second furnace 5′ x 56′ is now being installed, and contracts have been let for 4 others of the same dimensions. It is too early yet to go further into the details of this installation, and its operation, but it is expected that with the financial backing of such a company and the the technical advice which it can command, that the device will be given an adequate and efficient trial.*

MULTIPLE-HEARTH TYPE.

The earliest furnace of this type was the McDougall, but the later, improved forms include the Herreschoff and Wedge. Some of the McDougall pattern are water-cooled.

A **Herreschoff,** mechanically rabbled, circular furnace has been in operation over a year, at the Senator mine of the New Almaden company, Santa Clara County. (See Photo No. 53.) It was installed early in 1916, by the then manager, W. H. Landers,[42] who also, in connection with this installation, patented certain features of the condenser system. This furnace is 14 feet inside diameter and has 6 hearths, plus a drying floor on the top (see Photo No. 54). There are two fire-boxes on #5 hearth (next to bottom) level, set opposite to each other. On #2 hearth level, about one-third of the way around from the top exit-pipe, a third fire-box has been added in order to keep the temperature of the gases above 600° F. while going through the Cottrell dust precipitator which follows. The central column and the rabble arms are air-cooled, the resulting hot air being utilized for concentrate drying and other purposes. A Brown recording pyrometer is connected in at the furnace exit to enable regulation of the fume temperature.

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*Since the above was written, Mr. Gould has very kindly loaned the writer the drawings of this new plant, and its provisional flow-sheet, with permission to reproduce. Fortunately, it was not too late to include them herewith. (See Plates XXXVI-A, and XXXVI-B.) The first kiln has now been in operation for five months; the second will be fired up early in August; the third has been set on its foundations, and the concrete is being poured for the foundations of Nos. 4 and 5.

The burner (see Plate XXXVI-A) sets in an air-tight door. Air for combustion is allowed to enter near the tailings discharge-door below, and must pass up over the hot tailings before reaching the combustion chamber, being thus pre-heated. At present, steam is used for atomizing the fuel-oil, but compressed air will later be substituted. The burned rock from the furnace discharge drops into an inclined bin built of concrete.—July 26, 1918.

[42]See Eng. & Min. Jour., Vol. 102, Oct. 7, 1916, p. 634.

This furnace is stated not to work economically on material coarser than ¾ inch. Up to 58 tons have been treated in 24 hours; but it seems to do its best work at between 40 and 50 tons. Feeding and discharging are both automatic. The feed hopper is shown in Photo No. 54, while the housing for the discharge may be seen in the lower left-hand corner of Photo No. 55. A steel ore-car is kept under the discharge chute, and when filled is trammed out by hand to the dump.

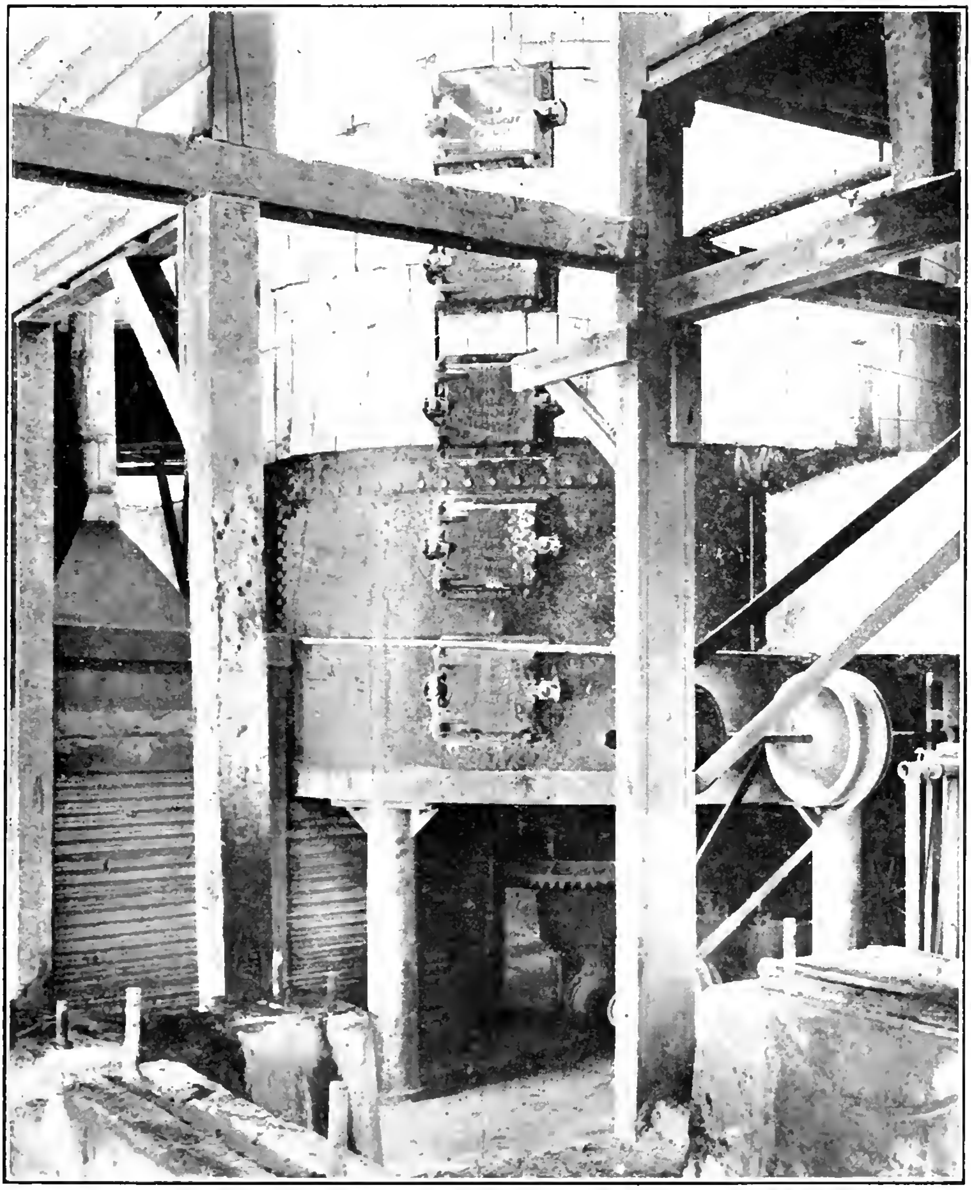


Photo No. 53. Herreschoff Multiple-hearth Furnace at Senator Mine of New Almaden Company, Santa Clara County.

By reason of the dust raised and thrown into the fume circulation as the ore is mechanically scraped from one hearth to the next, a bothersome accumulation of dust was at first obtained in the condensers. To correct this and keep the dust from passing into the condensers, a Cottrell fume precipitator, called the 'hot treater' was installed between the furnace and the first condenser. (See Photo No. 35, *ante*.) To prevent the mercury from condensing in this treater, the temperature of the gases (as already mentioned) is kept above 600° F. on leaving the furnace. As a precaution to recover any quicksilver which might have condensed in case of irregularities occurring in the furnace operation, the hot-treater dust is run into a settling tank before being discharged to the dump. Following the last condensing chamber is a second Cottrell precipitator (Photo No. 55), called the 'cold treater,' to throw down any remaining mercury 'mist' in the fumes.

The fuel consumption of this furnace is stated to have proven rather high, being approximately 8 gallons of oil per ton of ore treated, as

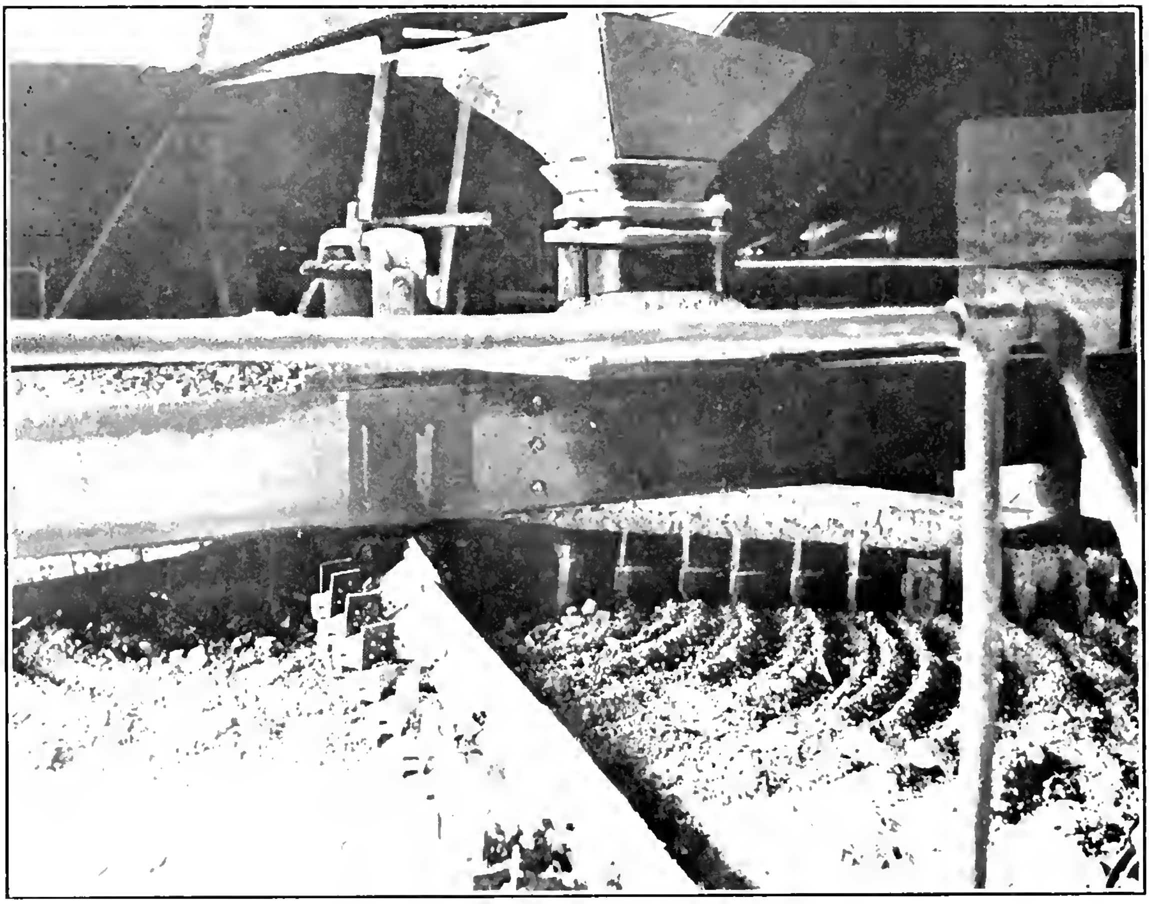


Photo No. 54. Top, or Drying-hearth, of Herreschoff Furnace. Feed hopper is seen in upper part.

against 5–6 gallons per ton for a 50-ton Scott furnace. The installation cost of the multiple-hearth type of furnace is much less than the Scott, being stated to be about $20,000 for a 100-ton plant, or $200 per ton-day capacity (1916; but for 1917 nearly double that). The cheapest operation of this type of urnace is obtained with the larger units or with several units under a single roof, as a single machinist can attend to the mechanical features of several units. To repair the rabble arms or other parts of the interior mechanism, the furnace must be shut down and cooled off. This is apt to occur oftener than interior repairs are required in a Scott furnace, though Herreschoff units have been in operation on copper ores for more than two years without such repairs. Another furnace of the multiple-hearth type which might prove adaptable for the treatment of quicksilver ores is the Wedge muffle-fired, in which the products of fuel combustion would be kept separate from the distillation fumes from the ore. This feature is taken up again, elsewhere herein, under the subject of concentrate reduction.

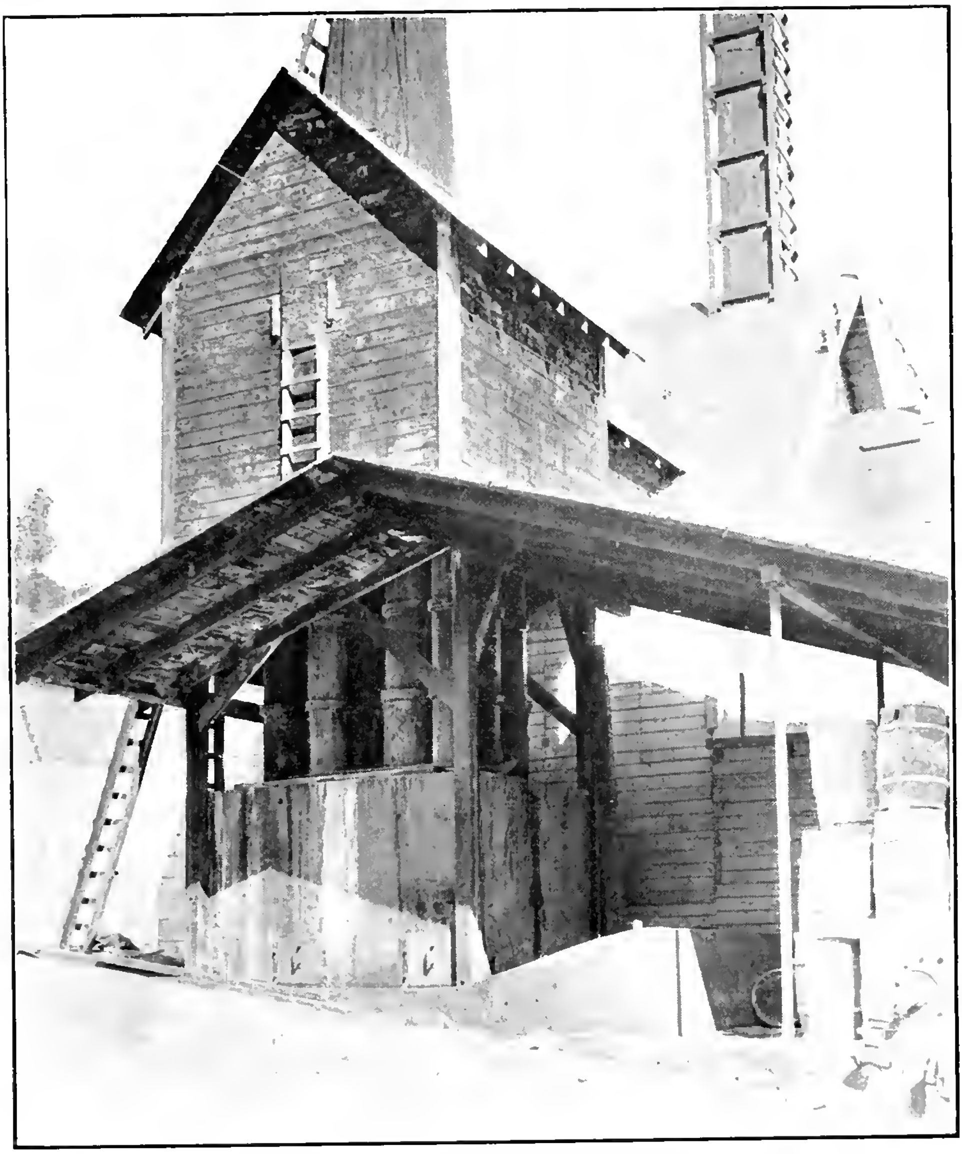


Photo No. 55. Cottrell Precipitator, or 'Cold Treater,' at Senator Mine.

It is stated that an 82% recovery of the assay value of the feed was obtained with this furnace for the 4 months ending with July, 1917. The heads assayed approximately 0.9% mercury, and contained from 3 to 5 tons, daily, of concentrates assaying up to 4%, which were mixed with the mine-run ore.

A second Herreschoff furnace was installed in 1916, at the Goldbank quicksilver mine, near Winnemucca, Nevada. It is stated to have been in successful operation for a number of months up to June, 1917, when the plant was destroyed by fire. No special appliances were added to take care of dust, from which it is inferred that the Goldbank ore yielded too small an amount of dust to interfere with condensation. Mr. W. G. Adamson, president of the company, states that such was the case, as the ore is a quartzite (?) breccia, recemented by silica, and extremely hard. (See p. 288, *post.*) Juniper wood was used for fuel.

DRYING THE ORE.

Though operators may differ as to the degree of drying necessary before charging the ore to the furnace, all are agreed that it is poor policy to feed wet ore. Moisture not only increases the amount of fume to be condensed, and seems according to some to cause part at least of

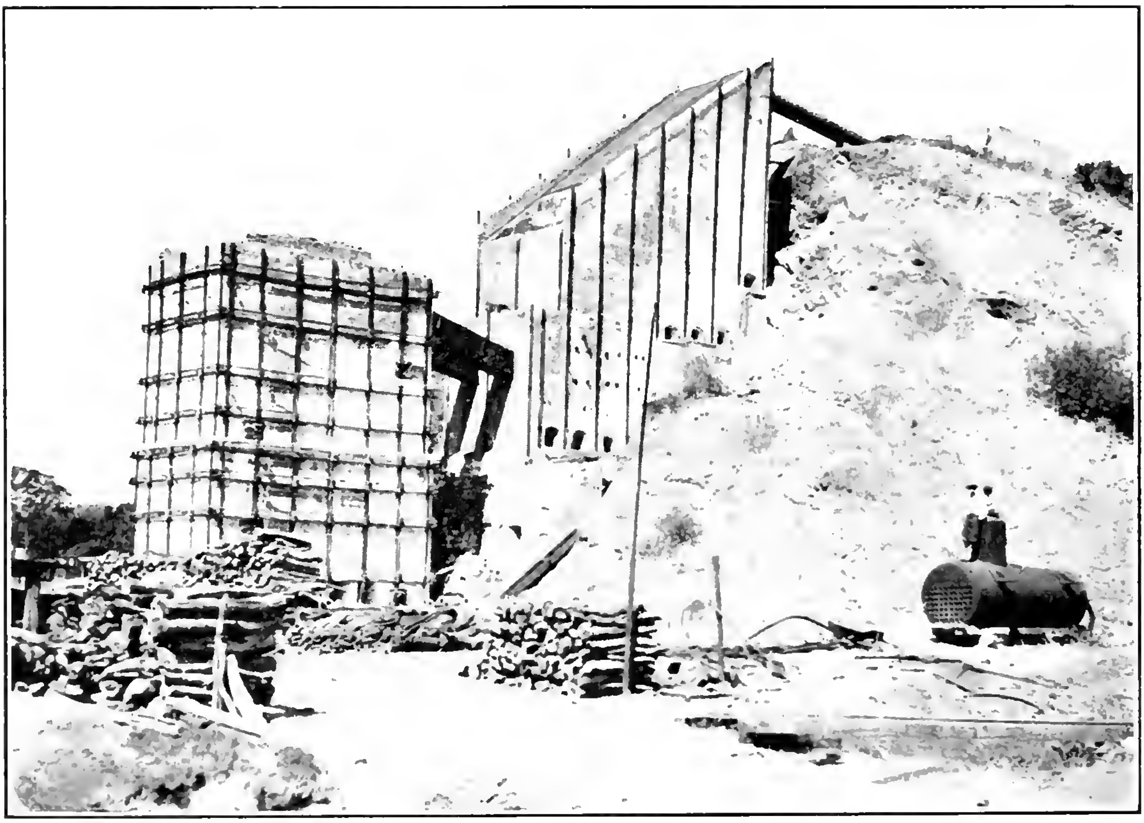


Photo No. 56. Scott Furnace and Condensers at Klau Mine, San Luis Obispo County. Sloping top of condenser chambers was covered with sheet-iron and used as an ore drier. The enclosing building was destroyed by fire a few years ago.

the mercury to form a mist rather than larger collectable globules, but it also forms sulphuric acid which attacks the condenser walls and floors. Wet ore will sometimes hang up in the upper part of the furnace, and in barring down there is always danger of breaking tiles. Moisture in the ore results in a larger amount of condenser soot, and obviously will require more heat to bring the ore to the distillation temperature of the mercury. Hence, there are more heat units to be dissipated in the condenser system. This is referred to by Duschak (see p. 239, *ante*), under the head of fuel consumption.

At the Great Eastern mine, near Guerneville, Sonoma County, the ore is spread out on a sort of patio and dried in the sun, while some furnace plants have iron plates covering the tops of the first condensers, on which the ore is spread before charging. Special driers are used in other instances. In some, where steam power is employed, the exhaust steam is utilized in the ore drier. At the St. John's mine, near Vallejo, Solano County, Mr. Clifford G. Dennis has built an ore drier of sheet iron (see Photo No. 57), with special flue arrangements and fired

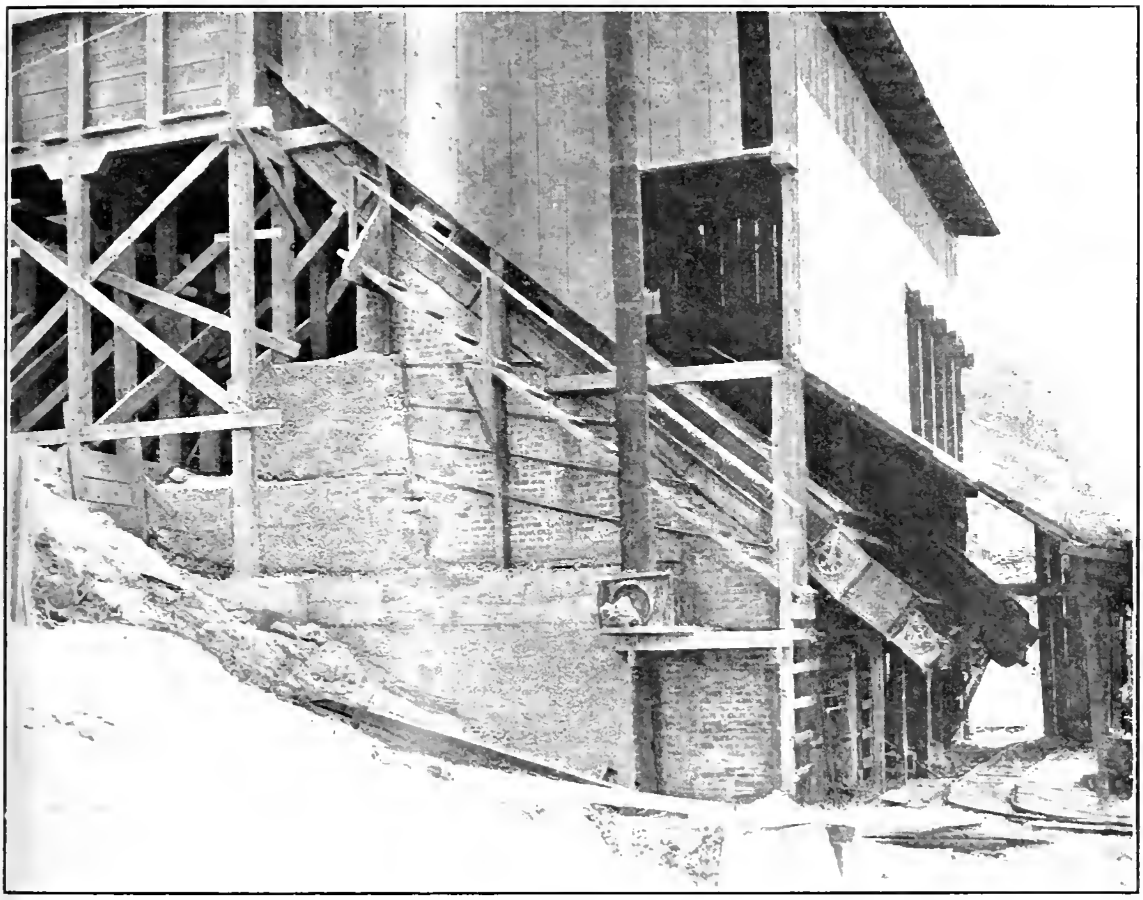


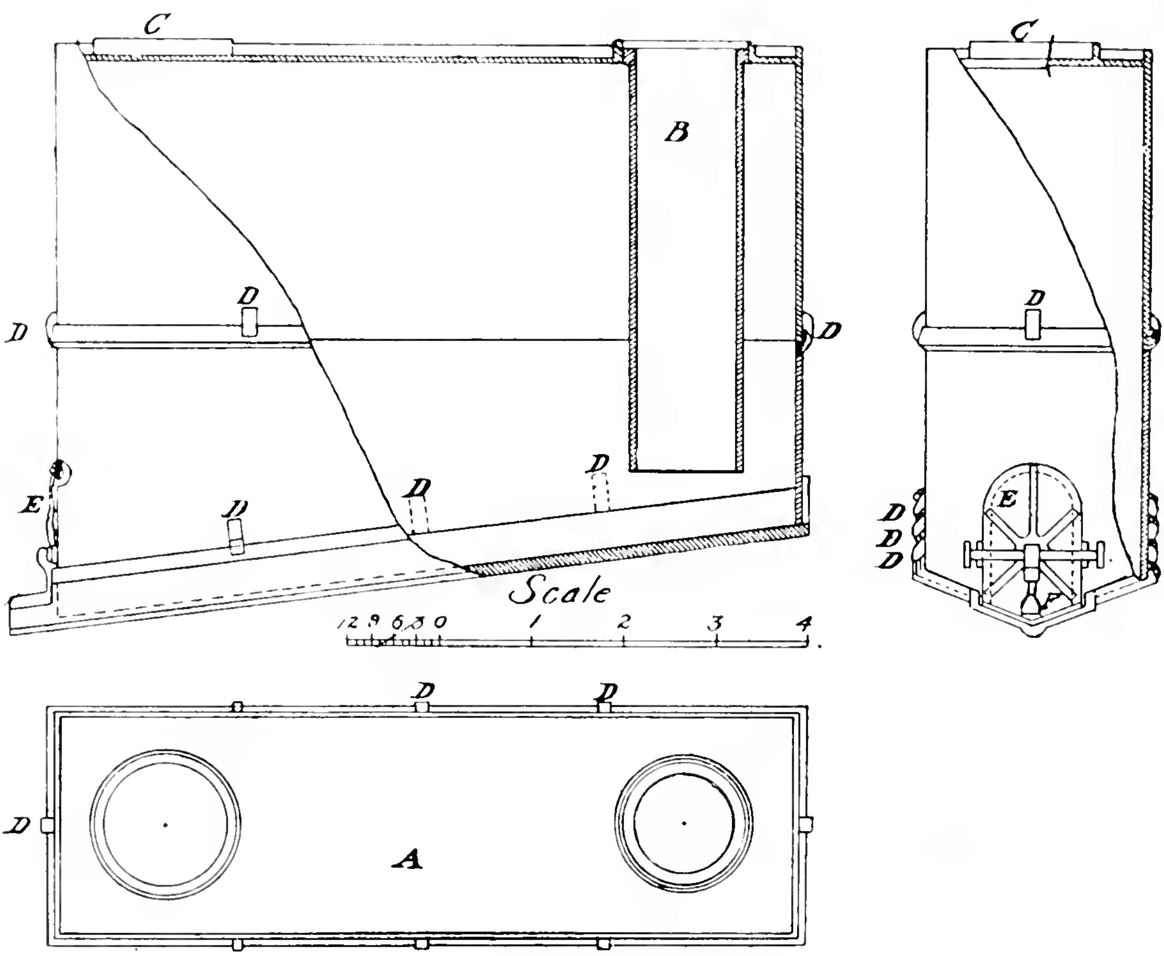
Photo No. 57. Ore Drier at St. John's Mine, Solano County.

by crude oil. Rotary ore driers are in use at the Socrates (see Photo No. 51, *ante*), and the Guadalupe mines; while at New Idria a special rotary drier removes the moisture from the table concentrates before they are charged with the fine ore to the Scott furnace.

CONDENSERS.

Condensing arrangements for retorts are relatively simple; but with the large, continuous-feed furnaces, both coarse and fine-ore, the condensers become more complicated and more extensive. Iron condensers like the old Knox-Osborne style (see Plate XXXVII; also Photo No. 58) have been used, and though of small capacity may do with non-pyritic ores; but if appreciable amounts of pyrite are present, the sulphuric acid formed attacks the iron. The Cermak-Spirek condenser[1] is a similar condenser, made with cast-iron pipes, and used at Monte Amiata, Italy. Up to quite recently, the condensers built with Scott furnaces have been almost entirely of brick. (See Photo No. 7, *ante*.) At New Idria they were built of stone, also in part of wood. (Photo No. 59.) Lately, wood has been substituted for their construction at the Oceanic mine, San Luis Obispo County, the New Idria mine, San Benito County, the Ætna mine, Napa County, and at the Cloverdale mine,

PLATE XXXVII.



Knox Ironclad Condenser.

Sonoma County. At New Idria the round form is being adopted, while at the other three they are built rectangular. Wood has the advantage of being cheaper to build, easier to clean up, and absorbs less quicksilver. At least, where they absorb quicksilver (and they do, more or less), they are easier to tear down and run through the furnace, than those of brick or stone.

Quicksilver is comparatively easy to volatilize, its distillation temperature being 360° C. or 680° F. The Scott furnace, when properly constructed and carefully operated has apparently proven to be an efficient

[1] Spirek, Vincenzio, The quicksilver industry of Italy; Min. Industry, Vol. VI, pp. 570, 576, 1898.

agent for expelling this metal from its ores; but once we have this precious substance in its vapor form the fun begins when we try to get it back into a collectable condition.

Retort condensers.

With retorts, particularly the Johnson-McKay arrangement, frequently the condenser is simply a $3\frac{1}{2}$-inch pipe, 7 feet long (see Photo No. 62), open to the air, as at the Patriquin mine, Monterey County; or the exit ends may deliver into a closed box (being often so arranged); or further elaborated upon and extended into other condenser chambers and flues with a circulatory system as at the Sulphur Bank mine, Lake County (see Photo No. 63; also Photo No. 41, of

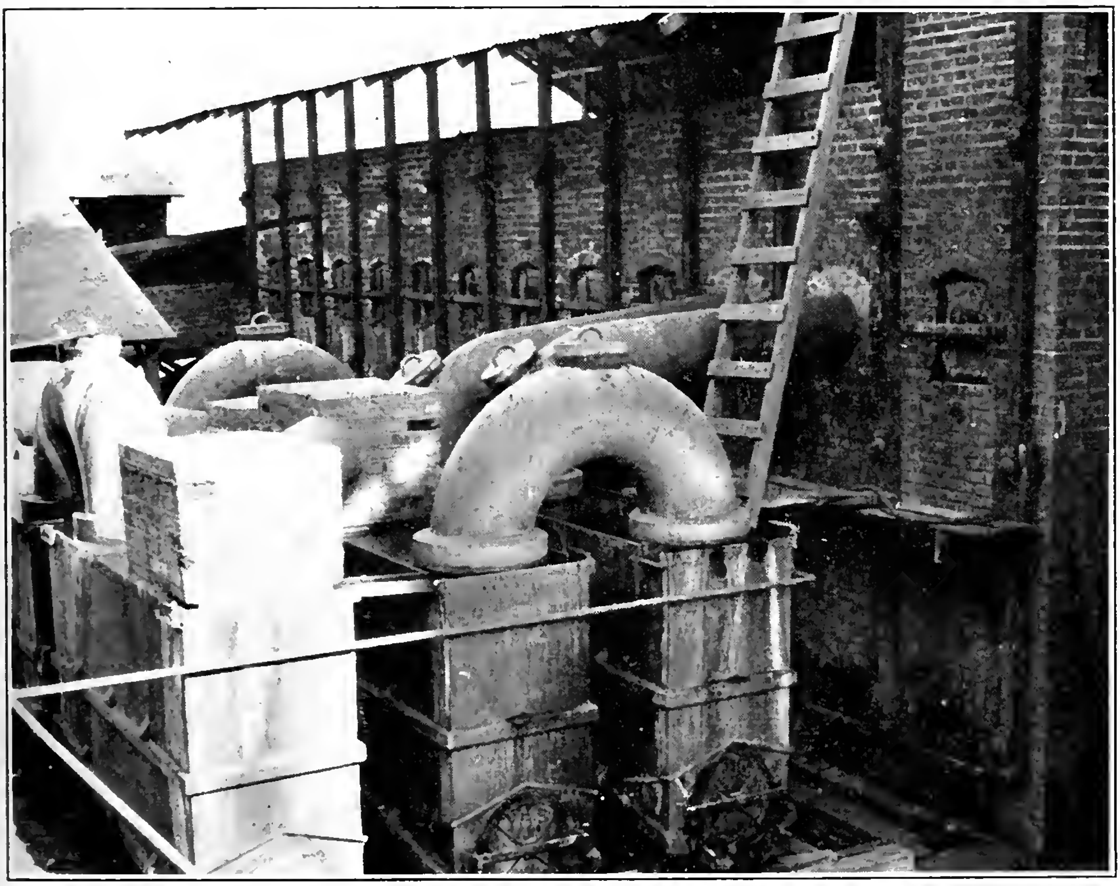


Photo No. 58. Condensers at New Mercy (Pacific) Quicksilver Mine, Fresno County.

Ætna mine retort, *ante*). In the first case above-mentioned, Patriquin considers that complete condensation is obtained with the arrangement as it stands. He points to the fact that after the steam ceases to come off (about 45 to 60 minutes after charging), that the condenser pipe is cool up to within 18″ to 24″ from the retort wall. Also that, at one time for awhile, he had a cover over the ends of the condenser pipes as a safeguard against theft, during which period the pipes were always hot for their full length, and mercurial fumes could be detected coming from the end of the box. With the present, open arrangement, except for the steam already noted, there are no visible fumes nor noticeable mercurial odors. It does not seem reasonable to expect that condensation could be complete in so short a distance. This point can be definitely determined only by sampling and analyzing the escaping gases over a period of operation. However, the volume of gas to be

Photo No. 59. Barrel Condensers, at New Idria Mine, San Benito County.

cooled from a retort is very much less in proportion to the tonnage of ore treated, as compared with the large furnaces.

Large Chamber Condensers.

When we come to condensers for the larger, continuous-feed furnaces (the Scott will be taken as typical, as there are more of them in use, and the condensing problem is practically the same for all the large types, both coarse-ore and fine), the situation become more complex. Here we have to deal with not simply the vapors driven out from the ore mass, but mixed with them are the products of fuel combustion. The questions of relative sizes, volumes and numbers of condensing chambers, materials for their construction, gas velocities, and temperatures, become essential. So far, they have been almost entirely worked out on the 'guess and try-on' system. Previous to the investigations now under way by the United States Bureau of Mines, the only attempt at scientific research in California in this direction was the

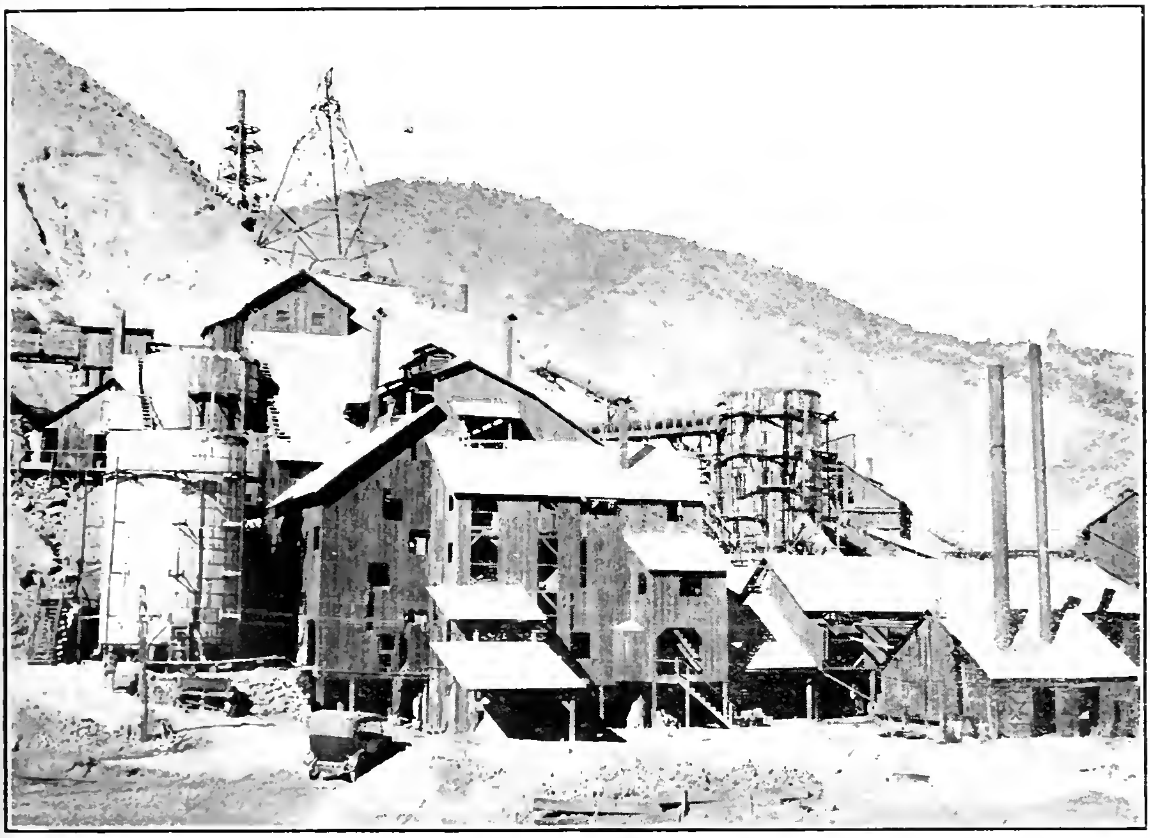


Photo No. 60. Round, Wooden Condensers at New Idria Mine, San Benito County.

work of Christy at the New Almaden mine in 1883–1884 from whom we quote the following:[43]

"* * * The quicksilver-fumes furnish often less than 1 per cent, by volume, of the products of combustion with which they are mixed. Even the weight of the quicksilver is inconsiderable, compared with that of the gases which pass through the condensers. At New Almaden it is only about 2 per cent of the latter. * * * The minute condensed globules of liquefied quicksilver are likely to be carried off in the form of *mist*. The gases which escape from the condensing system, are necessarily saturated with quicksilver *vapor* at the temperature of escape. Then there is the ever-present mercurial soot, which requires separate treatment. The quicksilver itself is ready to escape from any crack or crevice of the condensers, either as a liquid or as vapor. * * * Finally, as soon as the condensers become cool enough to act effectively, they are attacked by the dilute sulphuric acid formed from the oxidation of the sulphurous acid in the fumes. This agent slowly attacks and destroys almost every material out of which the condensers can be made. The use of lead is of course out of the question, as that would be attacked by the quicksilver itself.

"The system in use at New Almaden is based on the following well-known principles:

"1. Cooling of the furnace-fumes by contact with large radiating surfaces exposed to air and water.

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[43]Christy, S. B., Quicksilver condensation at New Almaden: Trans., Am. Inst. Min. Eng., Vol. XIV, p. 207, 1885.

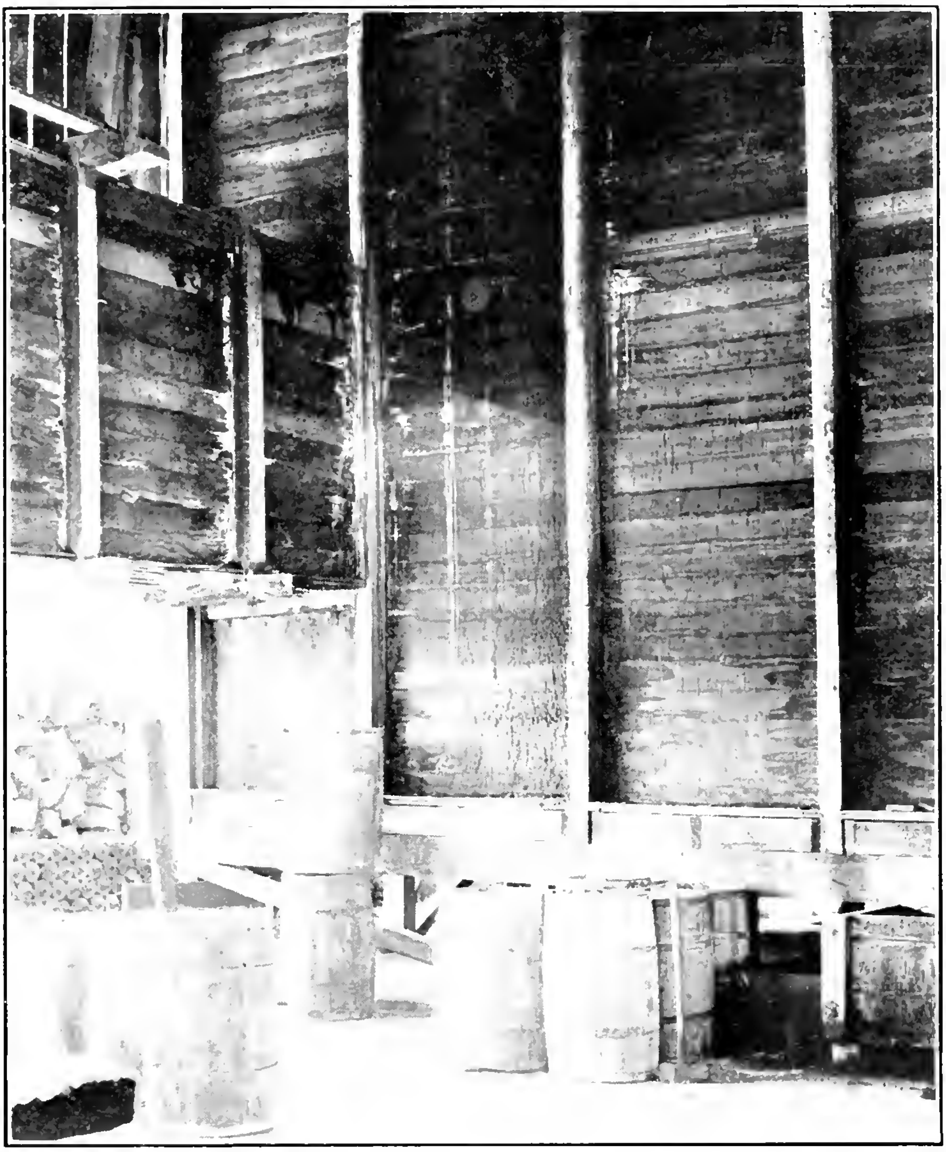


Photo No. 61. Rectangular, Wooden Condenser and Flue, at Oceanic Mine, San Luis Obispo County.

"2. Sedimentation of the condensed quicksilver particles in enlarged chambers where the velocity of the gaseous mixture is reduced.

"3. Constant exposure to friction-surfaces, cross-currents and vortex-motions to remove the globules of metal by calling into play the force of adhesion."

[44]"* * * brick condensers cannot be regarded as very effective cooling agents. The brick is among the worst conductors of heat, and it is found unsafe to build the walls thinner than nine inches. Besides, the mortar is slowly attacked by the acid fumes; gypsum and other sulphates being formed. These salts crystallize between the bricks, so that in some cases the walls of the older condensers have been so bent out of shape by this cause as to be unsafe. The bricks themselves are often attacked, and some of the outside walls of the old condensers are whitened by thick crusts of sulphates."

[45]"* * * It has long been noticed at New Almaden that the rapidity of condensation depends not only upon the cooling-surface and sedimentation volume, but also upon the area of friction—or adhesion—surface to which the fumes are exposed. * * * The utility of eddies and cross-currents in the fumes themselves has also been well recognized."

His conclusions[46] relative to quicksilver condensation are summed up as follows:

"1. *The volume of permanent gases passing through the condensers should be reduced to a minimum.* The reduction in the vapor loss would be in the direct ratio of this reduction, and the reduction of the mist loss in a greater ratio. * * * In

[44]*Idem*, p. 212.
[45]*Idem*, p. 219.
[46]*Op. cit.*, pp. 253–255.

addition, the reduction of the amount of permanent gases would also reduce the number of heat units that must be removed by the condensing system. * * * [The minimum volume of permanent gases is governed by the amount of air necessary to produce complete combustion of the fuel.]

"2. *Next in importance is sufficient volume for sedimentation, and surface for friction and cooling action.* * * * It would seem possible to make some reduction in * * * [mist loss], by reducing the velocity of escape, and by the use of greater friction surfaces. * * *

"3. The temperature of escape should not exceed 15° or 20° C. * * * As a cooling agent, water is the best, either as a bath about iron condensers, or better, as a spray in a current of air, so as to utilize the evaporation of the water. Sprays coming in contact with the fumes have never been successful, on account of the difficulty of separating the floured quicksilver from the water.

"Air is the cheapest cooling agent, and the condensers, where not water cooled, should be so constructed as to secure a strong natural circulation of the air about them.

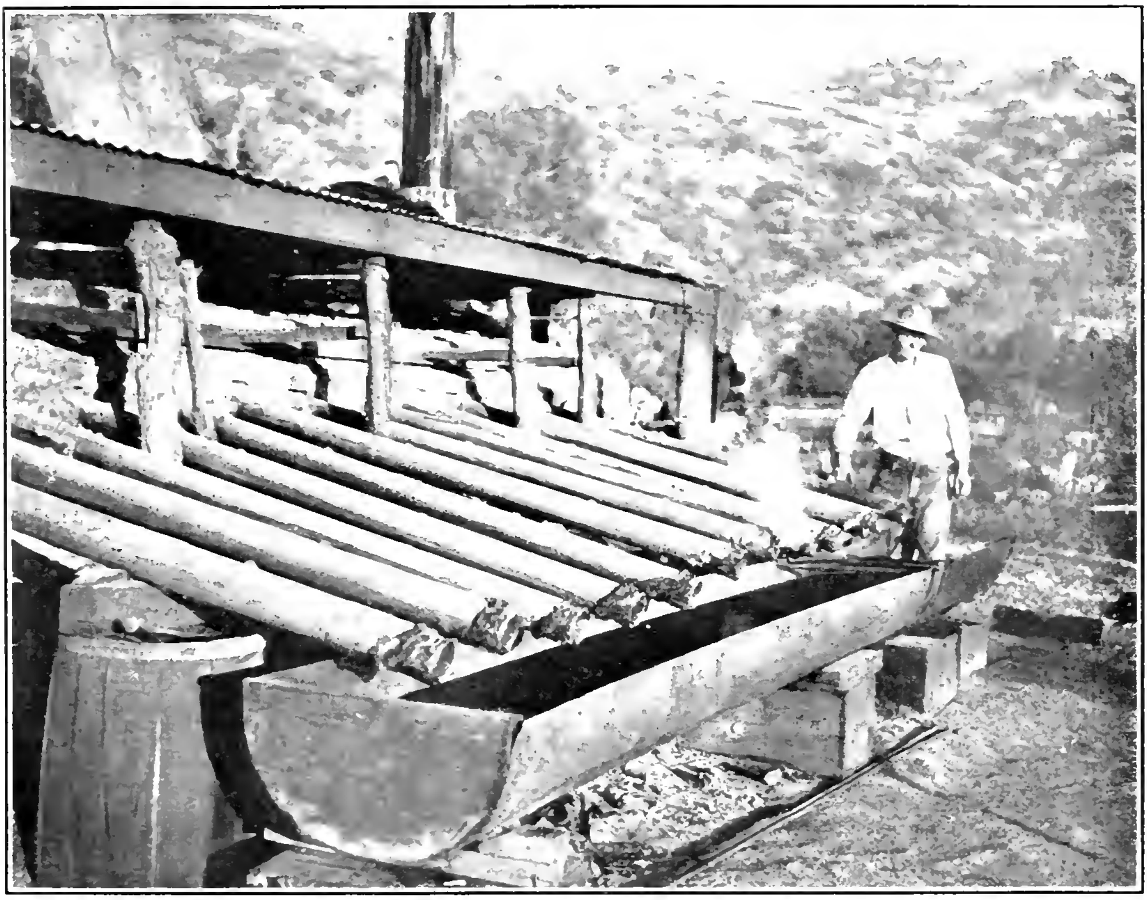


Photo No. 62. Condenser Pipes of Johnson-McKay Retorts at Patriquin Mine, Monterey County.

"4. *Material for construction.* There is a fine field for invention in the discovery of some substance strong enough to be made very thin, a good conductor of heat, which will resist abrasion and the alternate action of heat and cold, without cracking or leakage, and which will resist, at the same time, the action of quicksilver and warm dilute sulphuric acid. * * *

"5. *Next must be mentioned the use of an artificial draft.* This is all the more necessary as the cooling of the gases becomes more perfect, and their temperature approaches that of the outside air. Auxiliary fire-places and steam-jets * * * are wasteful of power and heat the hill-side flues, putting an effectual stop to further condensation. A simple suction fan * * * is the best arrangement. * * * more draft than is necessary to maintain combustion and to protect the men from salivation should not be used, as the chimney loss would be thus increased.

"6. *The condensers should be easily and completely cleaned without interrupting the action of the furnaces.* * * *"

Scott considers[47]

"the condensing room required for a 40-ton furnace 17,000 cubic feet, and for a 50-ton furnace, 20,000 cubic feet, which must be increased as the ore diminished in

[47]Forstner, Wm., Quicksilver Resources of California: Cal. State Min. Bur., Bull. 27, p. 246, 1903.

grade. * * * in this data for furnace No. 1 at New Almaden, the totals are: Path of vapors from furnace to top of chimney, about 1000 feet; interior volume, 26,667 cubic feet; cooling area, 18,653 square feet; ratio of cooling area to interior volume is 0.69. It must be remarked that the brick condensers give only a ratio of 0.5. In the brick condensers at present [1903] built by Robert Scott, the interior volume is about 1927 cubic feet; the cooling area, 922.5 square feet; giving about the same ratio."

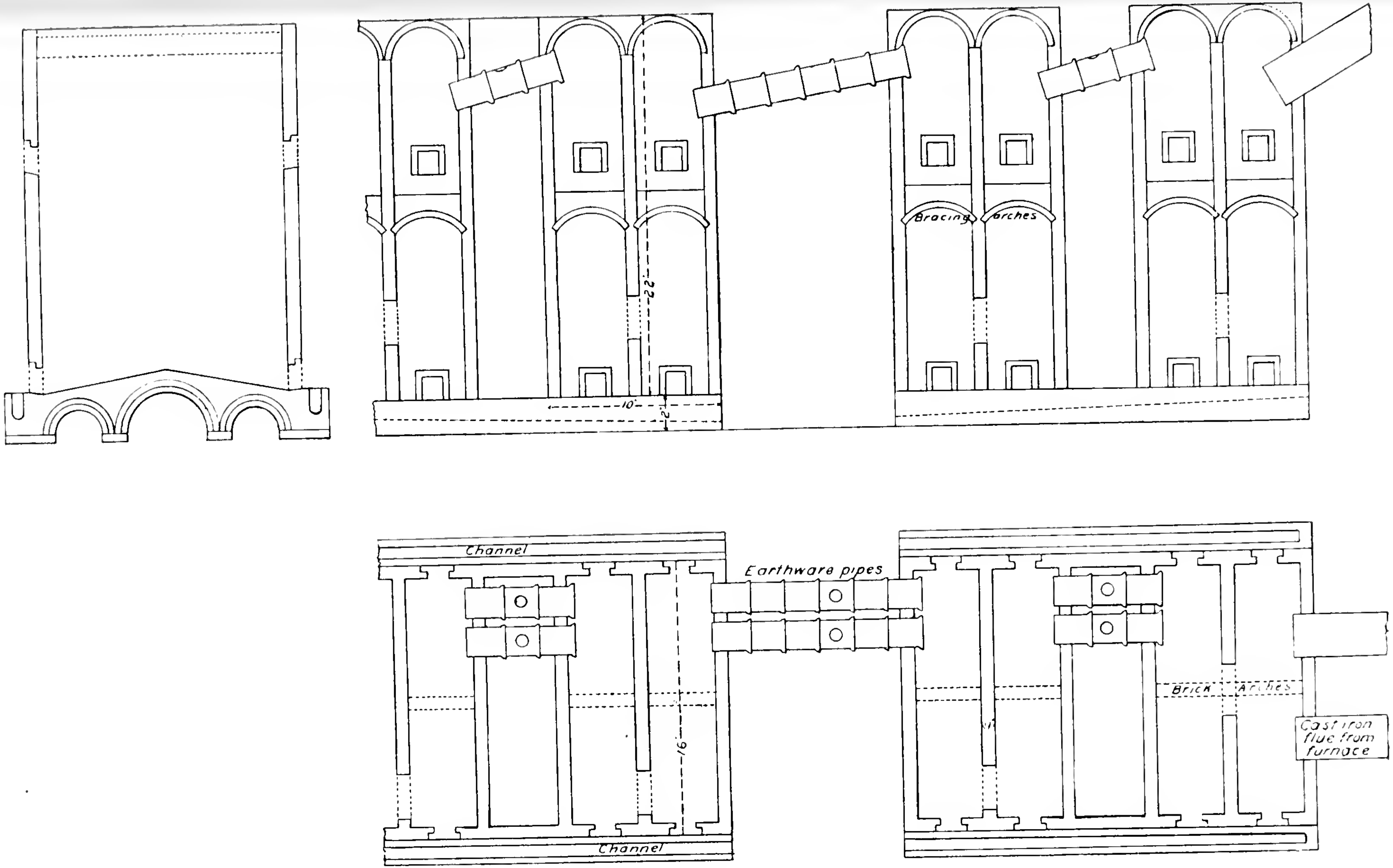
At various times and places, the use of a spray of water has been tried in quicksilver condensers, both with retorts and the large furnaces. The chief objection to this method is that a noticeable portion of the quicksilver is 'floured', that is, condensed into such extremely fine globules that it floats away on the water. This effect was noted by Goodyear[48] in 1871, as having been observed at New Almaden.

Photo No. 63. Condenser System on Johnson-McKay Retorts at Sulphur Bank Mine, Lake County.

Materials for condenser construction.

As to materials for construction of condensers, iron is of course, the best radiator of heat, but is too readily attacked by dilute sulphuric acid, as already noted. C. G. Dennis at the St. John's mine, Solano County, says that he has found vitrified sewer-pipe the best for condensers; that it is a good radiator (being sufficiently thin) and resists the action of acids, the principal objection being the difficulty of obtaining it in as large sizes as desirable. It has been in use for a number

[48] Goodyear, W. A., Report on an examination of the quicksilver mines of California: Geol. Surv. of Cal., Geol. vol. II, p. 122, 1882.



Scott's Brick Condenser Plant.

of years at various quicksilver plants for flues between condenser units. It is liable to crack when subjected to changes of temperature. Sewer-pipe flues connect the iron chambers in the series now in use at the new plant of the Ætna mine, Napa County (see Photo No. 64), and the brick with #1 vertical, wood-stave chamber at the New Idria mine, San Benito County (see Photo No. 65).

Window-glass[49] was tried at one time at New Almaden. Wood has been tried in a number of forms for years at different mines (for the most part as flues (see Photo No. 26, *ante*), but the development of the

Photo No. 64. Condensers and Vitrified-pipe Flues at Aetna Mine, Napa County.

large rectangular, wooden chambers now being adopted at several California properties, we believe is largely creditable to Murray Innes who began such construction at the Oceanic mine,[50] San Luis Obispo County, several years ago. Both redwood and pine are utilized. A horizontal, barrel-form of wood-stave construction (Photo No. 59, *ante*) has been in service for some years at the New Idria mine, and was described by the writer[51] in a recent report. These will, in the near future, be replaced by the new, vertical, circular form (see Photo No. 69, *ante*), which has so far given very satisfactory service. Those shown in the

[49] Christy, *op. cit.*, pp. 217–218.
[50] Cal. State Min. Bur., Report on M. & M. of Monterey, et al. Counties, 1917, p. 123.
[51] *Idem*, pp. 72, 73.

illustration have a flat bottom which must be scraped by hand in cleaning-up. They are set up on posts about 3′ off the concrete floor which is laid underneath to catch any metal from leaks. In future, any others built will have a sloping bottom, so as to obviate the necessity for scraping. The vertical form takes up less ground space, and the sides are very easily cleaned down by hosing with water under pressure, (which was being done at the time the photograph, No. 65, was taken). There are no dead, square corners.

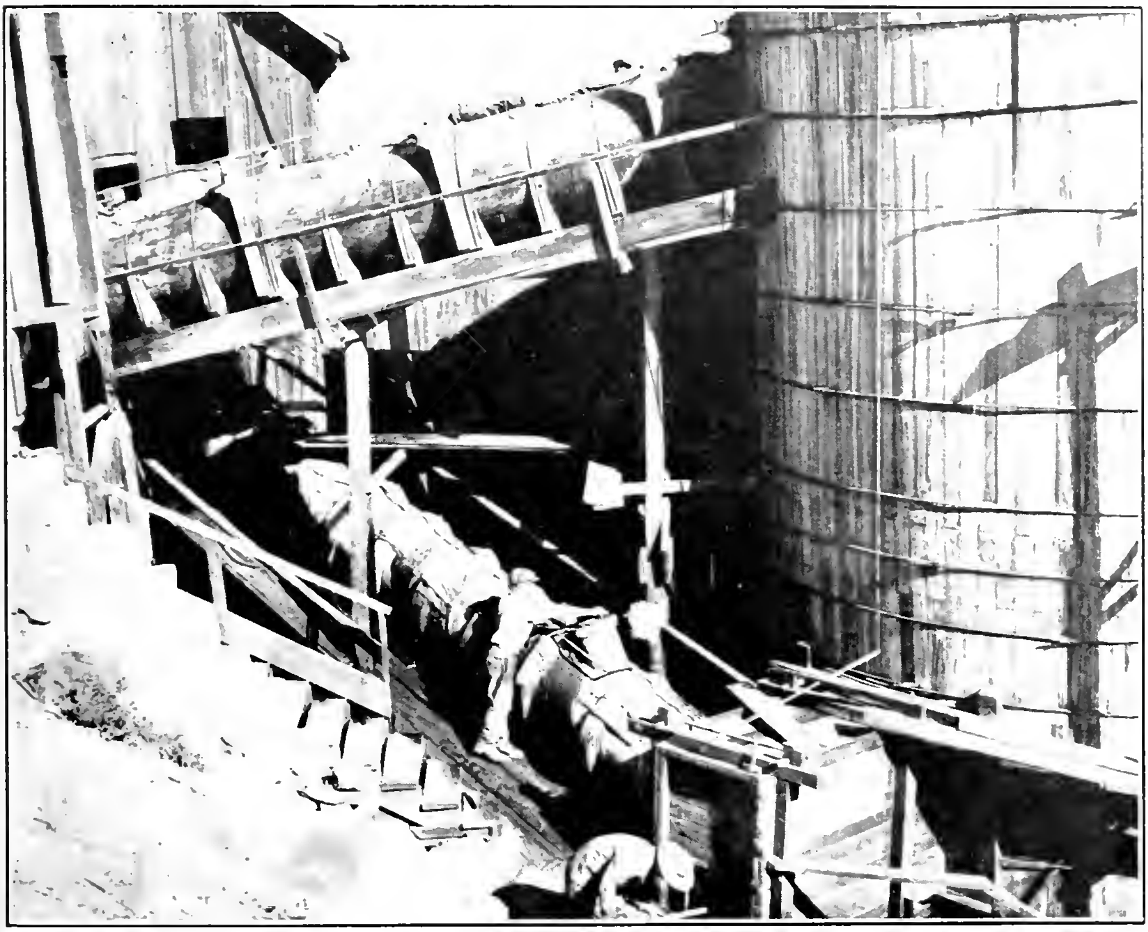


Photo No. 65. Condenser Flues—Vitrified Pipe (lower), and Wood-stave (upper),—at New Idria Mine, San Benito County.

Of course, wood can be used for the construction of only those units far enough removed from the furnace that the temperature of the gases will not burn or char the wood. This means, usually, all but the first chamber next to the furnace.

One of the most interesting of recent developments concerned with condensation, at the New Idria mine, is the introduction of a stream of cold, moist air into the flue leading from the first, brick condenser to the first of the wooden series. A No. 5 Sturtevant blower draws air through a wet burlap and water-spray, and the discharge pipe leads directly into the vitrified-pipe flue just outside the exit from #1 brick condenser. This creates the draft needed in the circulation system, besides the cooling effect. That the mercurial vapors should be cooled as soon as possible after they have left the furnace proper needs no argument; and the result in this New Idria installation has proven almost instantaneous and striking. The bulk of the quicksilver yield of #1 Scott furnace is now obtained from #1 wooden condenser, whereas formerly it was scattered through several. It is stated that a recent attempt to introduce air into one of the condensers at the Oceanic mine, resulted in a considerable increase of soot; but the details of the introduction were arranged differently.

At first glance, it would seem an unnecessary multiplication of units to have so many chambers in the condensing system, and that if one large chamber could be built, the collection and clean-up phases of the process would be materially simplified. A single collecting kettle for the quicksilver would then suffice. This certainly would simplify working conditions, and reduce operating expenses; but according to Christy, already cited,[53] and Egleston[54] the efficiency and rapidity of condensation are noticeably increased by friction surfaces, eddies, and obstructions to the gas flow. This same effect has been noted recently by Duschak[55] in the course of his investigations. He contributes the following on condensation to the present report:

"General considerations.

"The recovery of quicksilver from furnace gases involves two distinct operations: First, the cooling of the gases to a point at which practically all the quicksilver vapor will condense as liquid; and second, the collection of the liquid droplets suspended in the gas stream. In practice these two operations take place simultaneously to a considerable extent but it is believed that in the designing of condenser systems the advantage of regarding the recovery process as consisting essentially of the above two operations has not in all cases been fully appreciated.

"Condensation process.

"Under present practice the initial cooling of the gases amounting to 70 to 100° C. is usually accomplished in a brick condenser. Beyond this point the further cooling of the gases to about 40°., at which temperature the mercury in the form of vapor is entirely negligible as will be seen by reference to Column "B" of the chart (Plate XXXVI), is accomplished in wooden or a combination of masonry and wooden chambers. However, as the initial cooling condenses fully 80 to 90% of the mercury vapor, the principal function of the condenser system beyond the first brick condenser is that of collecting the fine mercury droplets suspended in the furnace gases.

[53]Trans. Am. Inst. Min. Eng., Vol. XIV, pp. 207, 219, 1885.
[54]Egleston, T., Metallurgy of Gold, Silver and Mercury, Vol. 2, p 897, 1890.
[55]Personal conversation with the writer.

"Red brick, owing to its ability to withstand the temperature involved as well as its moderate resistance to acid and also because a supply can usually be secured at moderate price, has been the common material of construction for the first section of the condenser system. Red brick is, however, a poor conductor of heat and as the principal function of the first section of the condenser is that of a cooler, it is believed that sufficient attention has not been given to the use of other materials. Stoneware pipes have been employed for this purpose in Austria and Italy for at least fifteen years and the possible application of the new corrosion resisting cast iron, such as Corros-iron and Dur-iron should not be overlooked.

"Recovery of mercury mist.

"As has been pointed out above, the principal function of the part of the condenser system more remote from the furnace is primarily that of collecting the mercury particles suspended in the gas stream. This problem resembles in many ways that of collecting dust and fume in connection with copper and lead smelting for which purpose the following devices have been employed:

1. Expanded sections of flue with or without baffles.
2. Bag-house filtration.
3. Electrical precipitation by the Cottrell process.

"Bag-house filtration of quicksilver flue gases is scarcely practical owing to the large amount of water mist which they carry and also the presence of sulphuric acid. Some types of mineral filtering medium might be employed but the cost of installing and operating would probably be found excessive.

"Electrical precipitation which has been for some time a matter of standard practice in various metallurgical and other industrial operations can be readily applied to quicksilver flue gases. It offers a highly efficient means of removing all suspended mercury particles from the gases and its use in this connection has already been demonstrated, as is mentioned elsewhere in this bulletin. Assuming that an effective system for cooling the gases is available, the use of electrical precipitation would permit the quicksilver to be recovered by an installation requiring little space as compared with the usual types of condenser system, thereby reducing the danger of mechanical loss in proportion to the reduction in area. The decision as to whether electrical precipitation can be advantageously employed must be arrived at through consideration of the cost of its installation and operation and the increased efficiency of recovery as compared with other available methods. These several factors will vary considerably with local conditions, but it may be said in general they will be relatively more favorable to the use of electrical precipitation in the larger plants.

"It will be recognized that the first method mentioned above is the one in general use at quicksilver plants at present, but in its application full advantage does not appear to have been taken of the considerable amount of work which has been done upon this problem in connection with other lines of metallurgy. In the design of a settling system, the object is to cause the suspended droplets to unite with one another or impinge upon the surface exposed within the chamber by taking advantage of gravitational action and particularly of the momentum of the suspended particles which can be utilized through changing the velocity and the direction of the gas stream. An elaborate series of experiments along this line were conducted at the Great Falls[56] plant of the Anaconda Copper Mining Company several years ago. Experiments were made with an unobstructed section of settling flue and with the flue equipped with the following types of baffling devices:

1. Surface plates.
2. Wide baffle plates.
3. Narrow baffle plates.
4. Constrictions in flue.
5. Wire baffles.

The surface plates were thin metal sheets hung parallel to the direction of the gas stream. The baffle plates were similar strips of metal hung at right angles to the gas stream. The wire baffles consisted of lengths of No. 7 B & S gauge copper wire hung vertically 2 to 2.25 inches apart. A careful analysis of the results of these tests as regards amount of dust collected, interference with draft and other important factors, including cost of construction, lead to the conclusion that the wire baffles were most effective, and the huge flue system of the Great Falls Smelter was built in accordance with these conclusions. It is to be pointed out that, while this type of catchment system is fairly effective in copper and lead smelting in collecting the coarser suspended particles or so-called flue dust, it is far from effective in collecting the finer particles or so-called fume, for the recovery of which bag-house filtration and electrical precipitation are now in common use.

"Our observations in the field and experimental study of fume losses in connection with Scott furnace operations which is mentioned again later on, indicate that the loss of mercury through the escape of fume from the condenser systems now in common use is in general not large. Improvement in the recovery system is therefore to be sought in the direction of reduction in size, which is important because of the corresponding decrease in the danger of leakage, in the amount of metal tied up in the system and also in the expense of the periodic clean-ups.

[56] Goodale, C. W. and Klepinger, J. H., The Great Falls flue system and chimney: Trans. Am. Inst. Min. Eng. Vol. 46, p. 583.

"The small fume loss just referred to does not necessarily mean that there are very few extremely fine particles of quicksilver formed in the condensers, but is to be explained rather on the ground that owing to the large amount of water vapor present these minute quicksilver particles become rapidly weighted with water which condenses on them as nuclei. This type of suspended matter is in general easier to recover than dry dust particles which do not readily adhere to one another or surfaces with which they come in contact. The suggestion then which may be taken from the Great Falls practice is that something resembling a wire-baffle fume-chamber, which for quicksilver practice might take the form of a redwood box, with narrow strips of redwood suspended within, might effectively replace a considerably larger volume of open settling chambers. Probably the more valuable conclusions to be drawn from these Great Falls experiments are rather of a negative character in indicating the lines along which efforts for the improvement of recovery systems are likely to be unproductive.

"Draft regulation.

"Under usual furnace practice a slight positive pressure exists in the furnace exit pipes, but beyond this point a negative pressure or in-draft is found throughout the condenser system. Some operators are inclined to favor a slight positive pressure in at least the first part of the condenser system, but this seems scarcely advisable as a small inleakage of cold air will cause very little, if any, increase in the usually negligible quicksilver loss from a stack, whereas, the escape of gas from the condenser system inevitably involves a certain loss of metal. When the gas passages and connecting flues are of liberal dimensions a condenser system can be operated with surprisingly little draft. At one plant a maximum of 0.1 centimeter of water was observed and at another the maximum was 1 centimeter of water. Occasional observations of the draft at above points along the condenser system will be found useful as a control over its operation and will furnish a ready means of detecting any partial stoppage of the gas passages. Owing to the small pressures involved, an inclined U-tube or Ellison gauge giving a multiplication of ten or twenty times is necessary."

"Fume loss from stack.

"Among the possible sources of loss of mercury from the condenser system, the escape of the metal from the stack in the form of vapor and fume has received considerable attention from some operators in the last year or two. First, as to the possibility of vapor loss; taking 40° C. as a representative stack temperature it will be observed by reference to the chart (Plate XXXVI)[1] that 0.00007 kilograms of mercury are required to saturate one cubic meter of air measured at 0° when

[1] See p. 238, *ante*.

heated under constant pressure to 40° C. Assuming, in line with previous discussion, that 500 cubic meters of gas measured at 0° C. and atmospheric pressure leave the furnace per metric ton charge, only 0.035 kilograms mercury are required to saturate this volume of gas. This corresponds to 0.0035% of the weight of the ore which would be only 1% of the mercury content of about the lowest grade ore charged to furnaces at present. With a stack temperature of 60° C. the vapor loss would be four times as great, corresponding under the above assumption as to volume of gas leaving the furnace per ton of charge to 7.5 kilograms or 16.5 pounds of mercury per day for a 50-ton furnace. This loss will, of course, increase as the volume of gas leaving the furnace increases and also probably to a somewhat lesser extent in proportion to the air leaking into the condenser system.

"A series of actual determinations of vapor and fume loss was carried out at two plants. These determinations involved an accurate sampling of the stack gases and a measurement of the volume of gas leaving the stack. In one case the stack carried the gases from a single Scott furnace treating about 70 tons of material averaging 1% mercury and in another case the gas stream sampled was derived from the treatment of about 100 tons of lower grade ore. The stack temperature ranged from 30° to 50° C. The maximum loss observed amounted to about 3.5 kilograms (7.7 pounds) in 24 hours. It is thus evident that so long as the stack temperatures and gas volumes are kept within reasonable limits, the quicksilver loss from the stack will be unimportant.

"Water losses.

"Another possible source of loss of quicksilver from the condenser system is through the condenser water. This may carry finely divided mercury in suspension as well as mercury salts in solution and as sulphuric acid is usually present in varying amounts it is not unreasonable to suppose that a certain amount of mercury may have been dissolved by the acid. As the recovery of the mercury in suspension is merely a matter of settling or filtration, particular attention was given to a determination of the chemically combined mercury in solution. The highest mercury content found in any sample of clear condenser water under normal running conditions amounted to 0.04 grams per liter. As the flow of water from the condenser system of a 50-ton furnace is not likely to exceed 1,000 to 2,000 liters (6 to 12 barrels) per day, the loss of mercury in solution is so small as to be negligible. Water leaving the condenser system at the time of the periodic clean-ups may carry somewhat greater quantity of mercury salts in solution, but it does not seem likely that the loss of mercury involved is important."

SOOT.

The quicksilver as thrown down in the condensers is always mixed with more or less fine-dust ore particles in the first condenser, and in the others with a black 'soot'. This was mentioned in the introductory section[57] under properties of mercury. According to Christy,[58] analyses show this soot to be

"composed mainly of unburned carbon and hydrocarbons of tarry empyreumatic nature. The ingredients come mainly from the imperfect combustion of the fuel, but also in some part from the tarry matter in the ore itself. The former cause might be removed by careful firing; but the latter * * * could hardly be avoided.

"The soot contains, mechanically entangled, large quantities of metallic quicksilver, most of which can be removed by mechanical treatment. * * *

"The New Almaden soot contains more or less scrapings from the walls of the condensers, and in the colder condensers, where the moisture has had time to condense and the sulphurous acid to oxidize, the soot is impregnated with dilute sulphuric acid. The hot condensers next the furances furnish mainly dry quicksilver and soot mixed with ore-dust. Further on they furnish quicksilver, acid waters, and damp soot, and the last condensers furnish dribbling streams of inky acid waters, holding various sulphates in solution, colored by the soot and carrying small amounts of finely divided quicksilver. The soot of these chambers is, of course, a black mud. Finally, the side-hill flues, deprived of the larger part of condensable moisture and quicksilver, furnish nearly dry soot which rarely shows to the eye any free quicksilver."

The soot was mixed with wood ashes, and placed on an inclined cement floor; then worked with a wooden hoe as long as any metal would run out; after which the residue was re-charged to the furnace with the ore feed. In 1882, the soot produced 4% of the mercury yield of the two coarse-ore furnaces; and the soot of the two fine-ore furnaces, 5.6% of their yield.

Soot is generally worked by a similar hoeing at most plants, with the exception that lime is more often used than wood ashes, and the residue is generally retorted. The relative amount of soot obtained, and the percentage of mercury carried by it vary considerably at different plants. At the Oceanic mine, San Luis Obispo County, with pine wood fuel, some 40% of the total mercury recovery is through the soot. After working out as much as possible by mechanical means, the balance is retorted.

From the recent investigations of the U. S. Bureau of Mines Experiment Station, Dr. Duschak contributes the following on soot formation:

"The formation of mercurial soot in the condenser system is a source of considerable annoyance and expense to the operator. With the thought that an understanding of the constitution of soot might give a clue as to the conditions which favor its formation and eventually suggest ways of reducing the amount formed, a number of samples were

[57] See p. 209, *ante*.

[58] Christy, S. B., Quicksilver condensation at New Almaden: Trans. Am. Inst. Min. Eng., Vol. XIV, pp. 227, 228, 1885.

collected from the condenser systems at two plants and a few representative analyses are given in the accompanying tabulation:

"Analyses of Mercurial Soot.

	Per cent	Per cent	Per cent	Per cent	Per cent
Hg—free	17.00	61.58	78.83	58.72	39.50
Hg as HgS	0.62	3.53	0.28	0.54	2.83
Hg as $HgSO_4$ and Hg_2SO_4	3.34	none	0.68	0.06	0.06
R_2O_3 (mostly Fe_2O_3)	1.12	5.53	0.58	0.76 }	
CaO	1.51	0.07	0.74	0.16 }	2.26
MgO	0.16	0.15	0.07	0.14 }	
SO_3	7.41	2.05	2.41	3.63	3.96
S (in HgS)	0.10	0.57	0.04	0.09	0.45
Carbon	not det.	not det.	not det.	not det.	9.90
Acid insol.	23.52	12.25	11.06	15.98	23.2
Moisture at 110° C.	14.10	10.74	7.18	10.52	11.9
Totals	98.88	99.47	101.87	90.60	94.06

"These analyses are neither complete nor highly exact since the alkali metals have not been determined and where carbon is reported it probably occurred partly in the form of heavy hydrocarbons of which only the carbon content was determined. Both the amount of free mercury and moisture present are more or less accidental, depending on the method of collecting and handling the sample before analysis and, owing to the presence of a certain amount of sulphuric acid, drying at 110° C does not expel all the moisture.

"These analyses coincide with the prevailing idea that the soot consists of minute particles of mercury mixed with small amounts of mercury compounds, with finely divided mineral matter from the ore and often carbonaceous material. Generally speaking, the amount of chemically combined mercury in the soot is small. Mercurous and mercuric sulfate are usually present, but the greatest amount of mercury found in combination as sulfate in any sample was 3.3% of the total mercury present, which latter amounted to 41%. This sample was taken from the portion of the condenser system nearest to the furnace and its high content in sulfates of mercury (mercurous and mercuric sulfate were not differentiated) is consistent with observation made by quicksilver operators that sulfate is more apt to form in the warmer part of the condenser system, particularly if any sort of pocket exists where the circulation of gases is not good. This is what one would expect from a chemical standpoint. Sulphur trioxide and water vapor with possibly some undissociated sulphuric acid vapor occur in the furnace gases and as these cool, droplets of sulphuric acid will form at about the same time that the condensation of mercury vapor begins. The first sulphuric acid to condense will be moderately concentrated and we thus have at some point in the condenser system droplets consisting of mercury or sulphuric acid and in most cases probably both at a temperature high enough to cause fairly rapid interaction.

"The amount of mercuric sulfide present in soot is usually small, but in a few cases a considerable amount was noted. This sulfide may be due to cinnabar dust from the furnace charge, to sulfide volatilized as such in the furnace in the absence of sufficient oxygen for combination with the sulphur, or to the formation of mercuric sulfide through chemical action of sulphur compounds in the gas stream upon free mercury. Some observation in the field, as well as laboratory experiments, indicate that this last source of sulfide in soot is by no means negligible.

"Soot then is to be regarded as consisting essentially of minute particles of mercury which are prevented from coalescing by other substances present. It is evident that the amount of soot will be less, the smaller the amount of mineral dust and carbon soot accompanying the mercury laden gases from the furnace. A dust chamber, which may be built either as part of the furnace (as in the Scott furnace) or as a separate structure, will collect a certain amount of the coarser dust, but unfortunately it is the smallest dust particles, which can not be stopped in this way, that are most effective in the generation of soot. When the amount of this dust is excessive, electrical precipitation by the Cottrell Process offers an effective means of cleaning the gases. The 'treater' required for a furnace of ordinary size occupies comparatively little space and, as electrical precipitation of suspended matter can be accomplished at elevated temperature, it is possible to remove ore dust and other suspended matter from the furnace gases without condensing any of the mercury vapor.

"Several considerations indicated that the influence of the factors promoting soot formation, namely, the mechanically carried dust particles and the chemical formation of mercuric sulfide could be minimized by very rapid condensation. This idea was at least partially confirmed by some small-scale experiments in which gas was drawn from the furnace down-take through a water-cooled tube. The mercury condensed in this way coalesced readily and the amount appearing in the form of soot was in all cases less than 5% of the total mercury recovered. These experiments, together with the points mentioned above in speaking of condenser operations, point to the desirability of devising a practical method for the rapid cooling of quicksilver furnace gases."

Because of its susceptibility to closer regulation, it would seem that better combustion could be attained through the use of oil as fuel than with wood. Landers[59] considers that

"Fuel oil, such as is used in California needs a great amount of air for complete combustion and has the disadvantage of making a very greasy soot that is carried over into the condensers and greatly retards the collection of the mercury. To prevent this, it is necessary to have large fire boxes in which the combustion of the oil can take place, allowing only the hot gases to escape into the furnace."

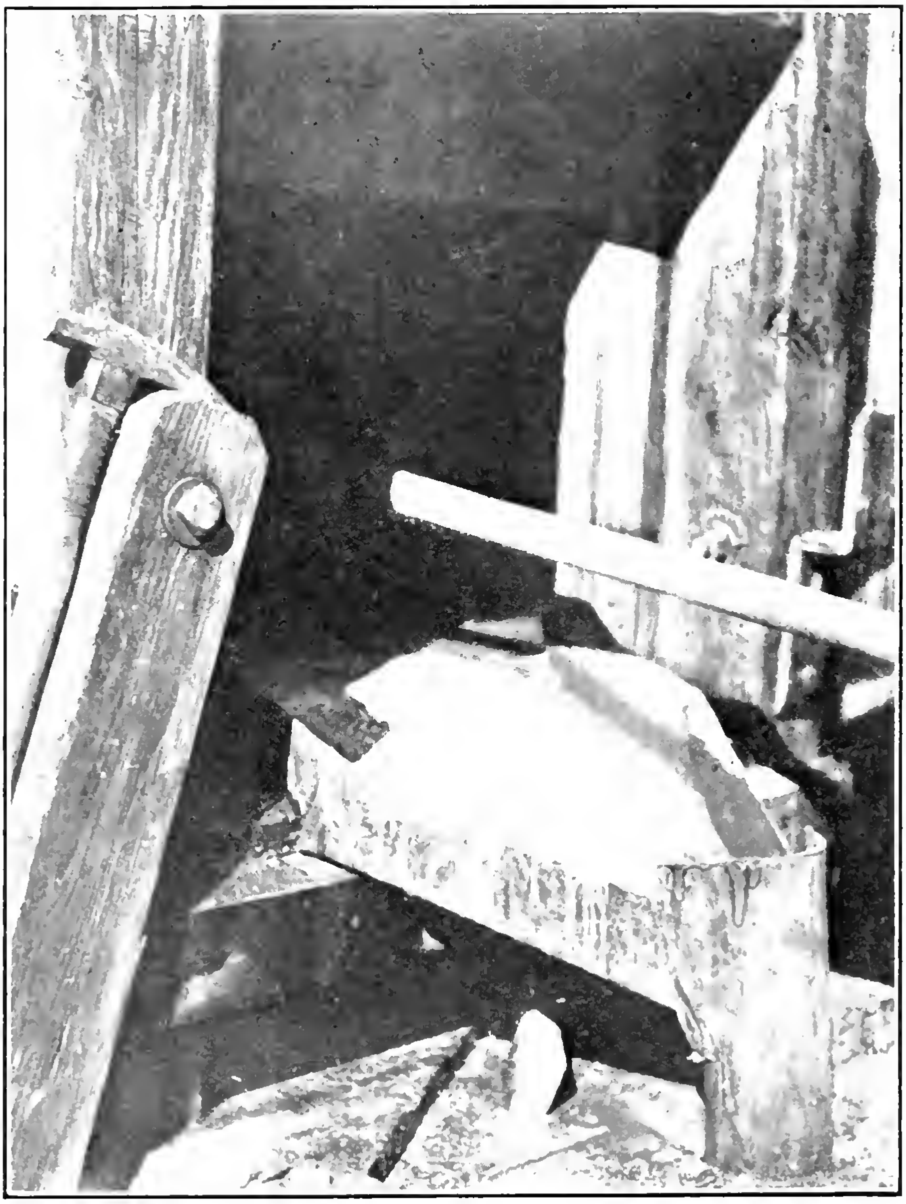


Photo No. 66. Cleaning up one of the new, wooden condensers at New Idria. The bright globules of metallic quicksilver and the 'gray mud' may be seen on the discharge lip.

In contrast to this, is the result at the Great Eastern mine, Sonoma County, where wood has recently been replaced by oil as fuel. It is stated that whereas before the change considerable soot had to be handled and was retorted, now a few buckets of dry dust are obtained

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[59]Landers, W. H., The Smelting of mercury ores: Eng. & Min. Jour., Vol. 102, p. 632, 1916.

in the first condenser, only, and it is not necessary to run the retort. This, too, with an ore carrying a noticeable amount of natural bitumen.

Though the composition of soot will vary according to the time and place of sampling, analysis of a typical sample of soot at the New Idria mine (January, 1917) showed: Mercury 63%; silicates 21%; small amounts of iron oxides, lime, soluble sulphates, and occasionally a little carbon. There is also a little mercuric sulphide carried over in the dust. Most of the soot they are now getting there is from the condensers of the coarse-ore furnaces, which have not yet had the improve-

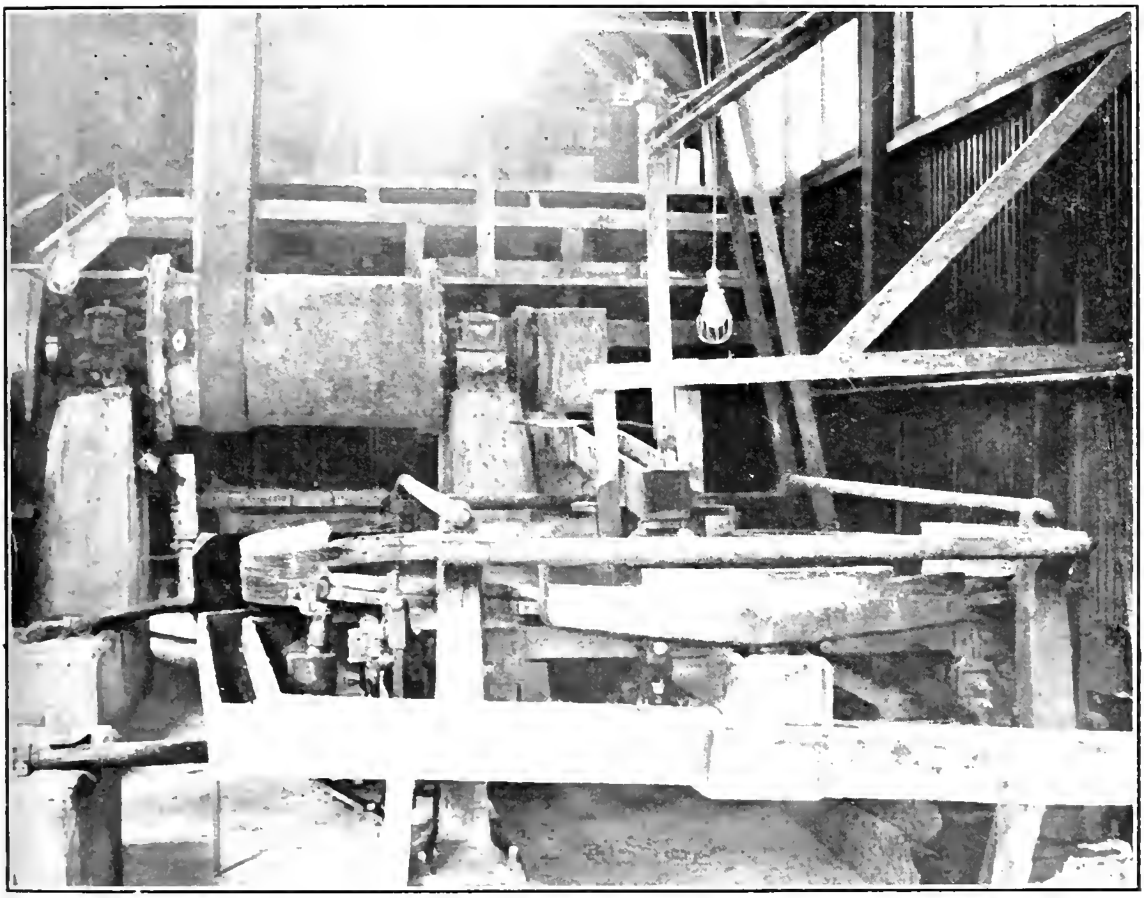


Photo No. 67. Soot Mill at New Idria Mine, San Benito County. Ball-mill in rear. Senn pan-amalgamator in foreground.

ments added that are in service at #1 fine-ore furnace—namely: the vertical, circular, wooden chambers, and the introduction of cooled air. In cleaning up the new wooden condensers of #1 furnace, the materials washed down and scraped out are globules of quicksilver mixed with a gray mud (see Photo No. 66) which is *practically all* quicksilver. By working it mixed with some lime, with hoes on an inclined plate, the metal particles coalesce and run down a launder to the bottling room.

When visited by the writer in October, 1917, the soot at New Idria was being treated in a special plant installed within recent months, and giving very satisfactory results. As stated in the preceding paragraph, the material came mainly from the older brick and stone condensers, with a little mud from the new, wooden chambers. It was mixed, by hand shoveling, with 3% by weight of lime (CaO), in a wooden tank, to neutralize acidity and fed through a screened opening (1″) into a Hendy laboratory ball-mill. This mill is unlined, but with cascades cast in the shell, being 4′ long and 30″ diameter. It has a helical-screw feed and center discharge. Chrome-steel balls of 1½″ diameter were used, and were obtained by sorting out the small sizes from the large ball-mill in the concentrator plant. The ball-mill polished the disseminated quicksilver and allowed it to coalesce. This took place, immediately, to such an extent in the ball-mill, that the accumulated metal there had to be drawn off at least once each shift. The pulp next passed to a Senn pan-motion amalgamator (see Photo No. 67), the surface of which is covered with a silver-plated copper plate, and the 'concentrate' discharge was through the center to a mercury well. The tailings from the Senn passed to concrete settling tanks, whence the water was drawn off, the sludge dried and sent to #1 fine-ore furnace. The final Senn tailings assayed up to 60 lb. of mercury per ton (3%), from heads carrying as high as 1200 lb. per ton (60%). This plant was driven by a 10 h. p. Type Y, semi-Diesel, Fairbanks-Morse, oil engine. Condenser conditions have recently so far improved that at the present writing (March, 1918), use of this soot mill has been discontinued.

QUICKSILVER ASSAYS.

There are two main systems of assaying ores for quicksilver, one involving distillation, and the other solution. The methods in the first named are more direct and reliable, quicker and require less manipulation. Among the earlier of these, the most reliable one was that of Eschka,[1] which is essentially that of heating a weighed sample of ore mixed with iron filings in a crucible with a gold foil on top kept cool by a weighted cover filled with water. Though following the same procedure, Whitton[2] while a senior student in the College of Mining, University of California, developed an improved form of apparatus for this assay, now known as the 'Whitton apparatus,' which has since been adopted commercially. This method and its manipulation is taken up more in detail in subsequent paragraphs. Another similar apparatus is known as the James.

The 'glass tube method' is another, involving distillation. This is summarized by Thornhill[3] as follows:

"To determine the total mercury (both metallic and sulphide), 0.5 gm. of the material is well mixed with cast-iron filings, free from grease, and placed in a hard glass tube, sealed at one end, with a contraction at about 2 in. from the sealed end. The mercury is distilled off, by heating the bulb containing the charge, and condensed, in the tube just beyond the contraction. After the distillation is complete, the contracted portion of the tube is heated, the bulb portion pulled off, and the end of the tube sealed. The tube containing the condensed mercury is allowed to cool, filled one-half full of 0.1% KCN solution, and 10 to 15 100-mg. gold beads added. Each bead will amalgamate with about 1-mg of mercury. The tube is shaken until all the mercury is amalgamated; the beads are transferred to a small porcelain cup, washed with water, dried with alcohol and weighed. After retorting off the mercury, they are again weighed. From 10 to 12 determinations can be made in one hour by this method and it is accurate enough for control of operations."

Of those involving solution, the best is probably that known as the Krieckhaus Volumetric Method, described in detail by Low.[4] It is essentially as follows: Dissolve 2 gm. of ore in 2 cc. HNO_3+10 cc. HCl, by allowing to stand cold an hour or more. Dilute, filter, and add stannous chloride solution to filtrate. After standing 2 hours the precipitated mercury will have settled to bottom. Filter and wash free of chloride; dissolve Hg in conc. HNO_3; add ferric nitrate as indicator, and titrate cold with standard potassium thiocyanate solution.

The latest, improved quicksilver assay, adopted within the past few months by the assayers at the New Idria and Sulphur Bank mines is a combination of the last two above-mentioned methods. It is essentially: Distillation in a closed tube; then dissolve mercury in conc. HNO_3 and titrate with thiocyanate. This method seems to have proven to be the best yet, and bids fair to become generally adopted for commercial

[1] Zeit. f. anal. Chem., Vol. 11, p. 344; also, Low, Technical Methods of Ore Analysis, p. 156, 1905; Furman's Manual of Practical Assaying, 1893, p. 133.
[2] Whitton, W. W., The determination of mercury in ores: Cal. Jour. of Tech., Vol. 4, No. 1, pp. 35–39, 1904.
[3] Thornhill, E. B., Recovery of mercury from amalgamation tailing; Bull. Am. Inst. Min. Eng., No. 104, 1915, p. 1653; also, Min. & Sci. Press, vol. 111, p. 212, Aug. 7, 1915.
[4] Low, A. H., Technical Methods of Ore Analysis, pp. 156–158, 1905.

work. Dr. Duschak has recently investigated it quite thoroughly, improving the finesse of the process in some of its details, and has also made some comparisons with other methods. His observations are summarized for this present report[5] as follows:

"A considerable number of both wet and dry methods of mercury assaying have been tested. Of these the Eschka method (Whitton apparatus) was found to be convenient and reasonably accurate for ordinary low-grade ore and furnace tailings. With high-grade material, such as concentrates, the results were not satisfactory and the method fails entirely when pyrite, free sulphur or organic matter are present in any quantity. The method now used at the Berkeley Experiment Station is a combination of older procedure with various new features developed in our laboratory. With slight modifications it may be applied to high and low-grade products and to material containing free sulphur, pyrites and organic matter.

"Eschka method.

"The apparatus used in the trials of this method was that due to Whitton. Silver foil was used to collect the mercury. This method was not found accurate for ores containing more than a few per cent of sulphur or a trace of organic matter. With low-grade material containing 1% or less mercury there appeared to be a tendency toward high results to the extent of a few per cent of the mercury present. High results are frequently accompanied by a discoloration of the silver foil. This occurred even with iron filings which had been purified with great care and in some cases was traced to excessive heating of the crucible. An ordinary Bunsen burner flame about 4 cm. high with the tip of the inner blue cone just touching the bottom of the crucible was found to supply the right amount of heat. The usual heating period was fifteen minutes.

"With material carrying over 15% mercury the results were apt to be low and erratic, due presumably to escape of mercury vapor between the crucible and foil. Occasionally a few globules of mercury were found adhering to the upper part of the crucible.

"Bureau of Mines method.

"This consists, in brief, in heating the ore mixed with a powdered reagent in a glass tube closed at one end, dissolving the distilled mercury in nitric acid and titrating with a standard thiocyanate solution.

"Apparatus.

"The glass tubes are heated in an iron block 13x9x8 cm., resting on a 13x9 face, and enclosed on all sides except the bottom with ½" asbestos board. This may well be further covered by ¼" transite board and the coverings fixed on the block by machine screws. Twelve 11-mm. holes are bored through the block and its coverings, passing through the 9x8 faces. These holes are in three tiers of four holes each. The block is placed on a sheet of asbestos board which rests on a tripod support. A 2½" hole is previously cut in the asbestos board so that the flame of a Meker burner may impinge directly against the iron. A six-inch Meker burner gives adequate heat but in the absence of gas a Dangler gasoline lamp would unquestionably be efficient. Asbestos aprons reaching from the bottom of the furnace to the table top shield the front and rear faces of the furnace from hot ascending air currents.

"The glass tubes may be of common soda glass or of Pyrex or similar heat-resisting glass. If of common glass a new tube is used for each determination, as the glass softens and distorts at the temperatures used. The tubes should not exceed 10 mm. in external diameter and the walls should be fairly thin, less than 1 mm. through. The length should be from 22 to 25 cm. In the case of soft glass the closed end should be rounded off (like a test tube) and a large drop of glass at the tip should be avoided. On the other hand, Pyrex glass tubes which may be used repeatedly should be drawn out to conical ends and a tiny button of glass should be left at the tip of the cone. As will be described later, this tip is broken off in removing the mercury from the tube. The small hole is easily sealed again by drawing out the glass in the flame (with an auxiliary bit of Pyrex tubing) and reforming the small button. The tube is thus made ready for another assay.

"With soft glass tubes loose plugs of asbestos fiber may be used to hold the charges in place. If the plug is at all tightly packed it may hinder the flow of mercury vapor. Owing to the manipulation involved in the use of hard glass tubes a different sort of plug, which may be made as follows, is necessary. A piece of brass or copper gauze of about 50-mesh is cut into rectangles about 12 mm. wide by 18 to 25 mm. long. Four equidistant incisions about 5 mm. deep are made in one of the longer edges. The gauze is then bent around a piece of small tubing into a cylinder and the flaps are bent inward, closing the cylinder at the bottom. A piece of nichrome wire, about 28B. & S. gauge and about 3 cm. long is woven into four holes, punched by a needle in the gauze, in such a way as to leave two small loops projecting from the walls of the cylinder. These loops are bent along the cylinder walls toward the open end of the cylinder. Nichrome retains considerable elasticity at the temperature of the furnace and these plugs, inserted with the closed ends against the charge, keep their positions in spite of the expansions and contractions attending the temperature changes. Several dozen plugs should be made ready for use. Before inserting, the nichrome wire should always be bent out a little to make sure of a snug fit.

[5]By permission of the Director, U. S. Bur. of Mines.

"A soft steel rod 3 or 4 mm. in diameter and about 40 cm. long should be bent into a ring at one end and a short sharp, lateral spur should be formed at the other end. This rod serves to push the plugs in and to draw them out when the assay is finished.

"Special reagents.

"A few drops of rather strong potassium permanganate solution are needed for each assay. This is most conveniently delivered from a dropping bottle.

"A ferric sulphate indicator for the titration is prepared by heating 10 g. of salt with 100 cc. of water. This must be absolutely free from all halogen compounds. The 2 cc. needed for each assay may be measured with a pipette fixed in the stopper of the indicator bottle. As the indicator imparts some color to the solution the amount used should be consistent.

"Titration is made with either a tenth or hundredth normal potassium thiocyanate solution, both of which should be kept in stock for use according to the quantity of mercury to be determined. The solution is quite stable and keeps its titer unchanged for at least several months.

"The solutions are standardized against pure mercury. For the hundredth-normal solution about 10 to 50 mg. mercury should be taken. This small pellet can be obtained by using a pipette like the ordinary medicine dropper, but providing it with a capillary tip 6 to 8 cm. long. A thread of mercury of about the right length (determined by a few trials) is drawn up, the pipette withdrawn from the mercury and pressure further relaxed until the mercury pops up into the wide part of the stem. The pipette is weighed, the mercury expelled into a flask or beaker, and the pipette re-weighed. It is advisable always to make two such weighings for each drop of mercury because when the mercury pops up into the stem a minute pellet is sometimes detached from the rest of the mercury and remains in the pipette without detection. The mercury is dissolved in about 10 cc. concentrated nitric acid, diluted to about 30 cc. and treated as in regular titrations as described below.

"In addition to the above, granular CaO (about 60-80 mesh), powdered and finely granular CuO and 3% H_2O_2 are required. When the material to be assayed contains much sulphur or organic matter, $KClO_3$ is needed. A supply of crushed granite or other hard rock through 10 and on 20-mesh is needed in charging the tubes.

"Procedure for samples low in sulphur and organic matter.

"One gram of ore is weighed in and about one gram of finely granular lime or fine, clean iron filings is added. The material is mixed thoroughly on a watch glass with a spatula and poured into the tube through a small short-stemmed funnel, brushing off with a camel's-hair brush. If Pyrex tubes are used a pinch of the crushed granite is placed in each tube before charging. If an appreciable amount of organic material or a rather high percentage of sulphur is present, from 0.5 to 1 gram of powdered copper oxide is added before mixing and a layer of about 1 to 2 cm. of granular oxide is placed on top of the charge in the tube. To each tube add a 5-mm. layer of crushed rock and seal in with one of the brass gauze plugs.

"The tubes should be tapped gently on the table to form an air channel along the side of the charge, and then placed in the furnace. The front of the charge should be at least 3 cm. from the face of the furnace. The furnace has, or course, been previously brought up to temperature (450°–550° C), about 1½ hours' heating over the Meker burner being necessary. After heating fifteen minutes the tubes are withdrawn and each is placed open end down in a test tube (⅝"x5") containing 10 cc. concentrated nitric acid. The test tubes are placed in a sheet-metal rack having a thin layer of sand at the bottom and placed on the hot plate. When the distillation tubes have cooled sufficiently for handling, the tips are broken. A piece of thin-walled rubber tubing is slipped over the broken tip and connection is thereby made with a small wash bottle containing strong alkali solution. Suction is applied to the wash bottle by mouth until the acid is drawn from the test tube above the mercury distillate. A fine frosting or mirror of mercury is instantly dissolved, while larger drops of mercury become loosened and drop into the test tube. After all the tubes have been thus treated the rack is replaced on the hot plate for complete solution of the mercury which requires 5 to 10 minutes. The contents of each test tube is then poured into a properly marked 100 cc. beaker, 10-15 cc. hot water added and drawn up by suction into the distilling tube. This washing with a second similar one, which is sufficient to remove all traces of mercury, is added to the original solution.

"To each beaker is added a small amount of permanganate solution, and the beaker rotated to secure thorough mixing. Successive portions of permanganate are added until the color becomes permanent. *If this treatment is omitted some of the mercury remains in the mercurous state and low results are obtained on titrating.* The excess of permanganate is destroyed by one or two drops of hydrogen peroxide. (Ferrous sulphate solution is equally effective.)

"Two cubic centimeters of the ferric sulphate indicator are added and as soon as it has cooled to room temperature the solution is ready for titration. If the amount of mercury was greater than about 50 milligrams, titrate with the tenth-normal KSCN; if less, use the hundredth-normal solution.

"With the more dilute solution the end point is, of course, not so sharp as with the tenth-normal solution, but the end can nevertheless usually be fixed within a tenth of a cubic centimeter.

"Since a single equivalent of mercuric mercury is 100 grams (100.3 to be exact) one cubic centimeter of hundredth normal KSCN is equivalent to one milligram of mercury.

"In all treatment subsequent to the distillation of mercury great care must be taken to avoid the introduction of any halides. A very small amount of chloride ion lowers the mercury titer to an appreciable extent. All liquid reagents and the water used must therefore be free from chlorides. The presence of chlorides in the ore charge presents no difficulty, for the theoretical amount of mercury has been found when pure calomel has been taken as the charge.

"The process as above described presumes the use of Pyrex tubes. If common glass is used the technic is somewhat modified. After the fifteen-minute heating in the furnace the assay tube is drawn forward about an inch and rotated on its axis while a glass rod around which is wrapped a layer of absorbent cotton saturated with cold water is held against the tube close to the furnace. The glass is shattered in a zone about the tube and a slight pressure releases the forward portion, which is slid, shattered end first, into the test tube of nitric acid. When the nitric acid has dissolved all the mercury (placing on the hot plate the while) the tube is lifted from the nitric acid and rinsed with a jet of water from the wash bottle. The titration is completed in the usual way, not omitting the treatment with permanganate.

"Modification for samples high in sulphur and organic matter.

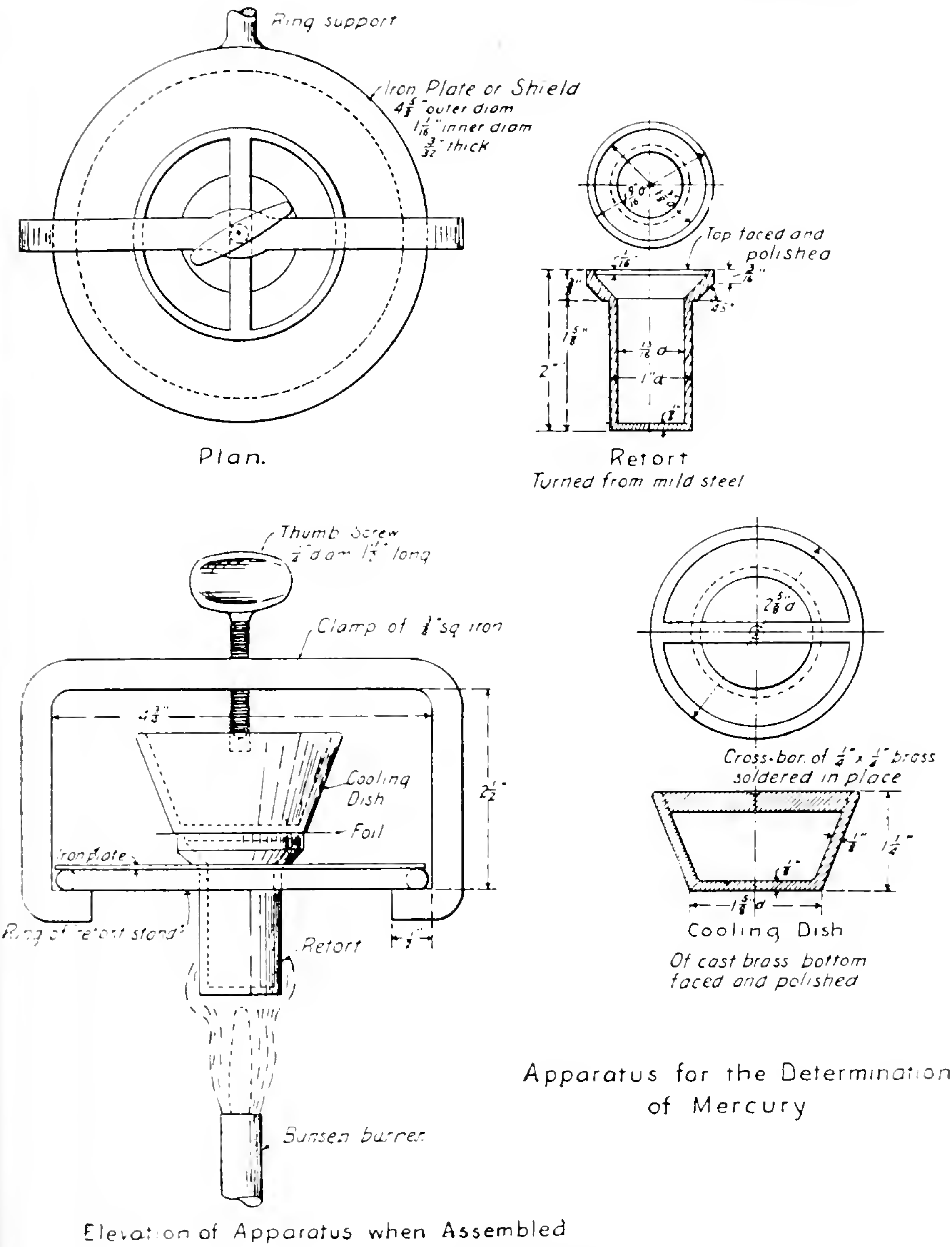
"If the material to be assayed contains a large percentage of sulphur or of organic material or if it consists of a precipitate on a filter paper, special procedure is necessary, otherwise the distilled mercury may be contaminated with sulphide or organic materials which will interfere with the titration. Some mercury, moreover, is often retained in the charge unless complete combustion is effected. To assure complete combustion the charge is made up as follows: One to two grams of potassium chlorate are mixed with about the same volume of crushed rock and poured into the bottom of the distillation tube which should be about 30 cm. long. This charge is covered with about 1 centimeter of the crushed rock and the material for assay then added. If the sample admits, a rather large proportion of powdered CuO should be well mixed with it before pouring into the tube. A filter paper, on the other hand, after drying should be coiled into a cylinder and pushed down the tube. A bulky precipitate should be removed from the filter, mixed with CuO and charged into the tube, on top of the coiled filter. The substance for assay having been charged, a mixture of granular CaO and CuO in the proportion of one part of the former by weight to two of the latter is poured into the tube to a depth of five or more centimeters. This reagent should contain no particles below 60 or 80-mesh in size as they may reduce the porosity of this column to such an extent that gases accumulating behind may blow the column forward, spoiling the assay. The column is capped by a thin cover of crushed rock followed by the usual brass-gauze plug. The total length of charge must not exceed 12 cm.

"The tube is tapped gently to make an air passage above the material for assay, but a channel above the CuO–CaO mixture should be avoided as far as possible. The tube is then inserted in the furnace, pushing it rapidly through the iron block until the material for assay is clear at the back. The CuO and CaO mixture remains in the furnace and is thus preheated. After three or four minutes the tube is gradually drawn forward bringing the charge into the furnace. From now to the end of the heating the tube requires the constant attention of the assayer. It is advisable to insert, in the open end of the distilling tube through a small one-hole stopper a glass tube of about 2 mm. internal diameter, which is bent down at right angles and passes through a two-hole stopper into a small test tube containing 3-5 cc. concentrated nitric acid. This device acts as a bubbler to indicate the rate of flow of gases and also as a washer to absorb at least the major part of any mercury vapor that may pass this far. After titrating at the close of the experiment the contents of this tube may be added to the titrating breaker to determine if any additional KSCN solution is required. Ordinarily no appreciable amount of mercury is found here. The passage of the distilling tube into the furnace is so regulated that the bubbler shows a succession of passing bubbles which never coalesce into a continuous stream. At first the volatile organic matter and free sulphur are expelled and are completely oxidized upon entering the column of CuO. The acid gases produced are largely absorbed by the CaO. When the potassium chlorate charge begins to enter the hot zone oxygen is evolved and especial care is needed here not to make the evolution too rapid. The nonvolatile carbon is consumed in the oxygen stream and the mercury completely expelled from the charge. If, however, the forward part of the column is lacking in porosity the oxygen pressure may become high enough to cause the precipitation of mercuric oxide and part of the mercury may thus fail to distill out. After the mercury is distilled the bubbler is disconnected, the tube removed from the furnace and the assay completed in the usual way. It is recommended that the assayer on first using this method acquire confidence in his technic by weighing out a drop of pure mercury as for a standardization of thiocanate, dissolving it in a small amount of nitric acid, diluting, precipitating with hydrogen sulphide, filtering and assaying filter paper and percipitate."

THE WHITTON METHOD.

When the author began the laboratory experiments connected with the present investigation, it was deemed important to get early results from the practical standpoint relative to concentration. For this reason, it was decided to utilize an assay already 'perfected' rather than to take up any time on research involving a comparison of assay methods or their improvement; except such as might incidentally arise during the progress of the work. After a short study of the methods

PLATE XXXIX.



Whitton Quicksilver Apparatus.

then in vogue, the Whitton was chosen, and was followed, throughout. The details, as originally described by Whitton[6] are as follows:

"The method of the author possesses novel features which render the assay more accurate and reliable, manipulation is simpler [than the Chism[7] method, which he had used previously], and the time is not lengthened.

"The details of the apparatus are readily seen by referring to the accompanying cut. [Plate XXXIX], which will serve as a working drawing for its construction. Briefly it consists of a steel retort, with a cover of sheet silver, and above this a flat-bottomed cooling dish of brass, these three essential pieces being clamped tightly together as shown. Thus arranged the distillation is performed in a closed retort, which prevents the escape of mercury vapor, and renders careful regulation of the heat unneccesary. Another important advantage lies in the use of the steel retort. It should be recognized that mercury vapors will condense upon any surface below the boiling point of mercury, 357.82° C., whether that surface be ore with which they will amalgamate or not.[8] The steel retort is a good conductor of heat, and thus all portions of it are readily brought above this temperature, while the foil is kept below this temperature by its contact with the bottom of the cooling dish; thus the vapor must condense upon the foil, and not upon any other portions of the exposed inner surface of the retort.

"The retort or crucible is turned from mild steel to the sizes shown, and the top surface should be faced off true and smooth. Several forms of retort were tried, but this design gives the most satisfactory results. It has a small capacity and exposes a comparatively large surface to the action of the vapor.

"The cooling dish is of cast brass; this metal is a good conductor of heat and does not readily corrode. The cross-bar may be soldered in place; the bottom should be faced off true and smooth. Several forms were tried; in one the flat bottom of the dish was cut out, leaving a ring-shaped "dish" in which the water was in direct contact with the foil. But trial has shown that it is not necessary that the water be in direct contact with the foil, and in the form used dessication of the foil is avoided; thus shortening the assay materially.

"The clamp should be of such size as to include the ring of the retort stand used to support the apparatus; it can be made by any blacksmith.

"The sheet-iron shield should be at least 1/16 of an inch thick, preferably 3/32; if much thinner it will buckle when the clamp is screwed down.

"As a recipient silver foil is used in pieces about 1¾ inches square, and of such thickness that a piece of this size weighs about 1.4 grams. It can be obtained from almost any dealer in assayer's supplies at a cost of two dollars per ounce. Foil 2" wide and free from holes and cracks should be specified. Thus one square costs about eight cents, and as a foil will last for from five to ten assays, the cost per assay is inconsiderable. Upon the surface exposed in the retort as much as 0.15 grams of mercury may be deposited, but it is preferable to use such quantities of ore that not over 0.05 grams will be deposited, when the amalgam formed adheres firmly to the foil.

"As a desulphurizer, or flux, iron filings are used. The preparation of the filings is important. They should be put through a 50-mesh sieve, washed very thoroughly with alcohol or carbon disulphide to remove grease, and heated for an hour or more in the muffle or upon a hot plate. It is not advisable to have them too fine, and all that will go through an 80-mesh sieve should be discarded if the best results are desired. A blank test with the filings should not increase the weight of a new foil nor discolor it.

"The assay is conducted as follows: Take from 0.15 to 2 grams of the ore, according to richness, place in the retort, and mix very thoroughly with about 6 grams of the prepared filings, adding 3 grams more as a cover. Weigh a square of foil, and assemble the apparatus, screwing the clamp down firmly. Fill the cooling dish with water, and heat for 17 minutes. If a bunsen burner is used regulate the heat as follows: have the bottom of the retort about 1¼ inches from the top of the burner. The gas flame should be turned down quite low, and the blue cone should just strike the bottom of the retort while the flame runs up the sides of the retort for about ½ an inch. The tendency of a beginner is to have too high a heat. The water in the cooling dish should come to a boil in six or seven minutes, and should be allowed to boil throughout the assay, being replaced only once or twice as it boils away. This keeps the foil above the boiling point of water, while below that of mercury; thus no water remains upon the foil at the conclusion of the assay, and dessication of the foil is unnecessary; it may be weighed almost as soon as it is removed from the retort as it cools very rapidly. No evidence of overheating has appeared in many assays; and the close attention of the operator is not necessary during the heating. At the expiration of the 17 minutes heating, the assay is allowed to cool until it can be handled; this takes about 5 minutes. It is then dismounted and the foil conveyed, under cover to avoid dust, to the balance and weighed. The increase in weight is due to mercury, and the percentage is readily calculated.

"The time required for an assay is about 30 minutes. By using two sets of apparatus, and four foils, weighing up the first pair of foils while the second pair is in use, they may be made in 15 minutes. With three sets of apparatus the time may be reduced to 12 minutes for continuous work. The deposit upon the foil should

[6]Whitton, W. W., The determination of mercury in ores: Cal. Jour. of Tech., Vol. 1, No. 1, pp. 36-39, Sept. 1901.

[7]Chism, R. E., A new assay for mercury: Trans. Am. Inst. Min. Eng., vol. 28, 1898.

[8]This is true only for the vapor of pure mercury at one atmosphere pressure. The pressure of other gases lowers the condensing temperature.

be white in color; if the heat is too long and high the deposit will assume a dark color; this dark deposit is volatile, and is apparently due to oxidation of the mercury. Assays in which this color has appeared are not very reliable; they may vary either way from the correct result, but generally high.

"In the case of ores containing much water, on removing the foil it is occasionally found to have filings upon the deposit, and also is stained a dark color in spots. This is due to a drop of water condensing upon the foil and falling back on to the hot charge in retort, where it boils violently and throws up the charge on to the foil. This may be avoided by heating up the charge slowly, or if very persistent, by the use of a shield above the charge. Probably asbestos wool would be good to use for this purpose. * * *

"Duplicates on ores carrying under 0.50% mercury should agree within 0.01%; on ores under 1% mercury they should agree within 0.02% at the most.

"The method has been frequently checked against the work of other assayers, giving results in close agreement."

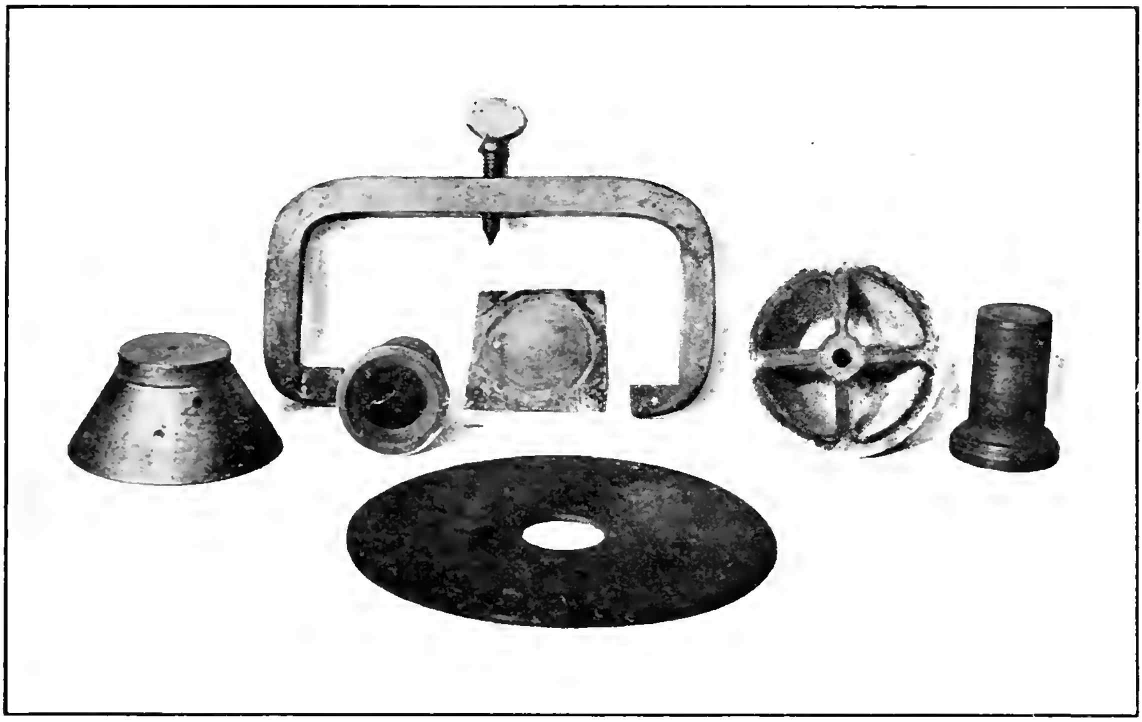


Photo No. 68. Whitton Quicksilver-assay Apparatus, showing component parts.

In this present work, the author used three sets of the apparatus,—two as put on the market by the Braun-Knecht-Heiman Co., San Francisco, and the third set being the original one made for Whitton in the machine shop of the Department of Mining & Metallurgy, University of California. Photo No. 68 shows the component parts of the apparatus (there being 2 crucibles or retorts, and 2 cooling dishes shown, so as to give top and side views), and Photo No. 69, the same assembled. The thumb screw should be of brass, and it would be better if the clamp were also of the same metal, because the steam rising from the water in the cooling dish in a very short time rusts the screw threads so that they do not work smoothly. The cooling dishes in the sets made by the Braun company have two cross bars for the clamp-screw bearing cast in the form of a + instead of a single bar as in the original Whitton set. The writer found this to be an advantage, as it was noticed that due to expansion on heating, the single bar had a tendency to warp the dish, thus preventing the bottom from remaining a plane surface. A plane surface, obviously, is necessary for a close contact with the foil and retort.

If iron filings, alone, are used as a flux or de-sulphurizer, they should be *absolutely* clean, and free from grease. Cast-iron was found not to be as suitable as cold-rolled, mild steel, or wrought-iron. Well-burned,

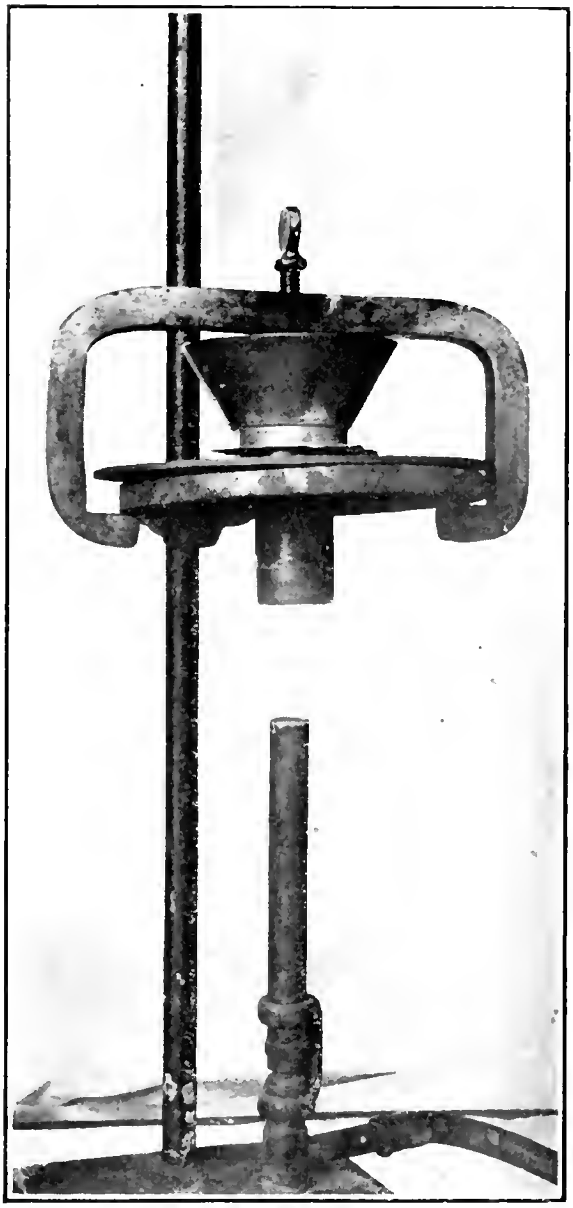


Photo No. 69. Whitton Quicksilver-assay Apparatus, assembled.

high-grade lime can also be used; but a mixture of iron filings and lime in equal parts seems to give cleaner and more uniform results than either alone. The lime apparently takes care of any irregularities in the iron. Sharwood[a] also considers a mixture of the two preferable to either alone.

[a]Sharwood, W. J., The determination of mercury in cyanide solution and precipitate: Min. & Sci. Press, Vol. 111, p. 663, October 30, 1915.

To expedite the work when assaying a number of samples, the writer kept in use 6 pieces of silver foil and 2 of gold. The gold foils have been used 26 and 28 times, respectively, and the silver from 22 to 31 times each, and they are *all still serviceable.* This is considerably more than Whitton's "from five to ten assays."[10] Before using, each foil was freshly ignited to redness over a bunsen burner, conveyed in a dessicator and weighed. After amalgamation, the foil was likewise conveyed under cover to the weighing room, following which it was ignited to redness to expel the mercury, then polished with very fine flouredemery paper to insure a fresh bright metallic surface. Apparently this ignition did not expel all of the mercury, as the foils gained in weight, especially after running a high-grade sample; though after such, notable increases there was always a slight falling back, when lower grade samples were run, but in no case, did any foil used by the writer return to as low as its original weight. The following typical cases will show the variations in weight of the particular pieces of foil *before* each assay:

No. 2 foil (gold) weight in grams: 6.3359; 6.3382; 6.3379; 6.3377; 6.3375; 6.3376; 6.3376; 6.3373; 6.3377; 6.3377; 6.3377; 6.3376; 6.3378; 6.3376; 6.3376; 6.3376; 6.3380; 6.3380; 6.3377; 6.3377; 6.3381; 6.3379; 6.3381; 6.3381; 6.3384; 6.3393; 6.3387; 6.3390.

No. 4 foil (silver) weight in grams: 3.0520; 3.0525; 3.0524; 3.0527; 3.0541; 3.0546; 3.0550; 3.0550; 3.0559; 3.0555; 3.0563; 3.0558; 3.0561; 3.0555; 3.0560; 3.0567; 3.0567; 3.0572; 3.0567; 3.0562; 3.0559; 3.0564; 3.0554; 3.0552; 3.0556; 3.0555; 3.0555; 3.0554; 3.0559.

Concordant results were obtained on the same samples with both gold and silver foils; but in some cases the silver gave slightly higher results, due possibly to sulphidizing, as in all such the surface was somewhat discolored. Gold is more satisfactory to use in all cases, but especially for close work; though silver does for the ordinary run of samples. Proof-metal was used in both cases, and cut into 2-inch squares. The writer has assayed up to 14 samples in 4 hours, with 3 sets of apparatus and 8 foils. With additional sets of the apparatus, a larger number of assays can be made. The samples were ground to pass 80 mesh.

The investigations of Duschak, quoted on a preceding page, indicate that the closed-tube and thiocyanate-titration method is superior to the Whitton especially for materials carrying above, say 10% mercury. For materials assaying less than 1% mercury, the Whitton has the advantage of capacity for a larger sample. Up to 3 gm. can be taken.

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[10]Whitton, W. W., The determination of mercury in ores: Cal. Jour. Tech., Vol. IV, No. 1, p. 38, 1904.

CHAPTER 2.

CONCENTRATION OF QUICKSILVER ORES.

In the author's investigations, the samples treated were stage-crushed to pass a given screen, the larger ones being coned several times before quartering down, and the smaller ones cut down with a Jones 10-division, hand-sampling grizzly. The crushers used (see Photo No. 70) were a Sturtevant roll-jaw crusher, 6″ x 6″, and Sturtevant labora-

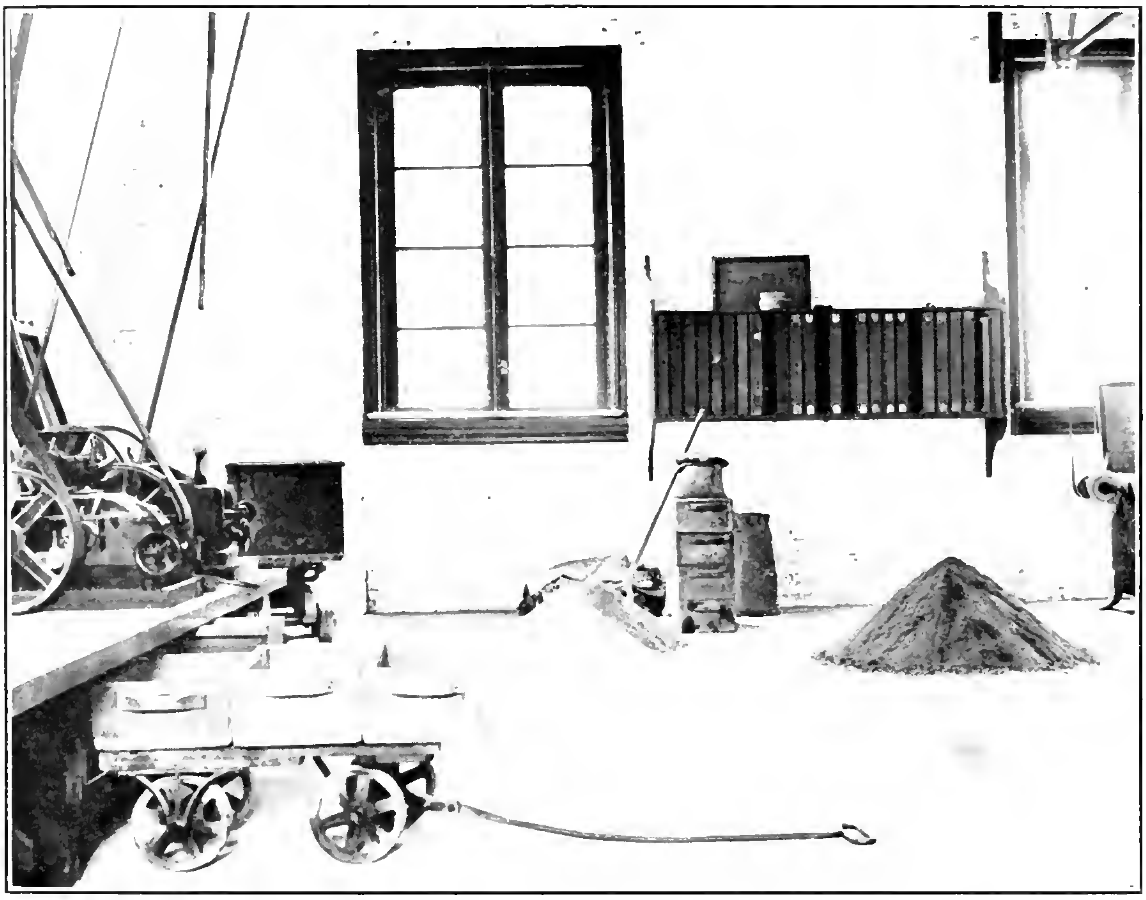

Photo No. 70. Crushing and Sampling Floor in Mill of Department of Mining, University of California, Berkeley.

tory rolls 8″ diameter x 5″ face. These were used in connection with a shaking screen (seen at right edge of photograph). The samples were all crushed and screened dry, because wet crushing could not be done with the rolls as installed.

Samples treated.

#1—Fines collected Feb. 21, 1916, from site of old fine-ore bin of Scott furnace, at **Oat Hill** mine, Napa County,—50 lb. This was fine material, all under ½ inch size, which had sifted through from the ore bin which had one time been above it. It was mostly of friable sandstone, with the cinnabar distinctly crystaline. Assayed 3.88% mercury. Screened through #10 mesh before sampling.

#2—**Oat Hill** mine, Napa County, Feb. 20, 1916—300 lb. of low-grade material, mostly sandstone, from #2 B-Fanny waste dump, with which was mixed 85 lb. of small, hard lumps carrying quartz, cinnabar and pyrite. Assayed 1.99% mercury. Screened through #4 mesh before sampling. These two Oat Hill samples were collected by the author through the courtesy of Mr. J. E. Miller, one of the lessees.

#3—**Ætna** mine, Napa County, Feb. 25, 1916—400 lb. of tailings from Colorado bumping tables.[1] These tailings were impounded during operation of the plant by a lessee in 1915. The ore had been ground by a Griffin mill to pass #18-mesh screen. It was in part, hard siliceous material from underground workings, and in part, soft ochreous material from surface cuts and dumps. Much of the cinnabar was fine, soft, and 'painty' even before grinding. This slimed and paint cinnabar largely remained in suspension and floated off from the tables. Assayed 0.385% mercury. The writer has no knowledge of what the bumping-table heads ran, as the operator did no sampling nor assaying.

#4—**Ætna** mine, Napa County, Feb. 25, 1916—200 lb. from old waste dump on Phoenix (?) claim. This material had considerable clay mixed in with it, and the cinnabar was very fine. Screened through #4 mesh before sampling. Assayed 0.157% mercury. Samples #3 and #4 were sent by Mr. A. A. Gibson, then superintendent for the operating company.

#5—**Patriquin** (formerly Parkfield) mine, Monterey County, February, 1916—200 lb. of hard, siliceous, low-grade, surface material. The rock is a silicified serpentine, and the gangue minerals chalcedony and calcite. The cinnabar is crystalline, occurring in veinlets and along the fracture faces, with a little associated pyrite. All screened through #10 mesh before sampling. Assayed 0.45% mercury.

#6—**Patriquin** (formerly Parkfield) mine, Monterey County, February, 1916—100 lb. from ore being retorted, and stated to be yielding an average of 4% quicksilver. As described by the author[2] in a recent report: "The country rocks are serpentine and Franciscan metamorphic sandstone. The ore body is a zone containing parallel stringers of cinnabar with the intervening rock and its fractures more or less impregnated with the mineral. It is in part stockwork. The vein filling is quartz, opaline silica, and chalcedony, and much of the serpentine is silicified. The cinnabar occurs as distinct crystals, not as 'paint'." All screened through #10 mesh before sampling.

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[1]See author's report on Ætna mine: Cal. State Min. Bur., Rept. XIV, pp. 283-285, 1916; also in advance chapter on Napa County, pp. 111-113, 1915.
[2]Cal. State Min. Bur., Report on mines and mineral resources of Monterey et al. counties, p. 19, 1917.

Assayed 1.42% mercury. Samples #5 and #6 were sent by Mr. Lewis Patriquin, part owner.

#7—**Big Injun** mine, Lake County, Feb. 21, 1916—20 lb. delivered to the writer by Mr. T. A. Peterson, lessee. The ore was mainly soft serpentine carrying native mercury and distinctly crystalline cinnabar. Because of having only brass screens available for the shaker at the time this sample was crushed, it was put through the rolls set at ¼ inch and not screened. It was then rolled on a cloth and a sample for assay cut out with a spatula. Later, before concentrating, it was again put through the rolls, set up close so as to crush to approximately #20 mesh; but not screened, as the native quicksilver would have amalgamated with the brass. Assayed 1.39% mercury. Still later a portion of the sample was ground on the bucking-board to pass a #40 mesh iron-wire screen, and an amalgamation test made with gold beads in a 0.1% KCN solution, which showed 0.51% native mercury present, or 36% of the total assay value.

#8—**St. John's** mine, Solano County March, 1916—630 lb. from mine-run ore being sent to Scott furnace. Sent by Mr. Clifford G Dennis, manager of St. Johns Mines Co. The ore occurs at the contacts of a series of faults and meta-andesite dikes. This meta-andesite macro-scopically resembles some Franciscan metamorphic sandstones. The cinnabar, mainly crystalline, is in part disseminated in this rock, and in such occurrences resembles the Oat Hill ore, but is harder and somewhat silicified. The cinnabar is also, in part, along the fractures. There is some shale present, a little associated pyrite, and occasional spots of a thick, brown petroleum. All screened through #6 mesh before sampling. Assaying 0.49% mercury.

#9—**Cambria** mine, San Luis Obispo County, March, 1916—238 lb. sent by Mr. Ellard W. Carson, manager. This is a hard, cherty, siliceous ore, carrying cinnabar and a little native quicksilver. The cinnabar was all crystalline, but some of it very fine, and occurred mostly in the fractures. All screened through #10 mesh iron-wire, before sampling. Assayed 0.31% mercury. An amalgamation assay with gold beads in a 0.1% KCN solution, on #40-mesh product showed 0.005% native quicksilver present, or 1.6% of the total assay value.

#10—**Goldbanks** mine, near Winnemucca, Humboldt County, Nevada, April, 1916—200 lb. of mine-run ore sent by Mr. W. G. Adamson, owner. This ore is a breccia (apparently quartzite or a rhyolitic tuff, but so altered that its original character is not readily determined), which has been re-cemented by silica, mainly chalcedonic. The cinnabar occurs almost entirely in the cementing silica and in the fractures, the cinnabar and silica apparently having been precipitated from solution simultaneously. The ore is extremely hard and fine-grained, the cinnabar being almost, if not quite, crypto-crystalline. Examination of a thin-section under the microscope by transmitted light, did not reveal any distinguishable crystal outlines at 250 diameters magnification. With a reflecting microscope, revolving the section on the stage, an occasional glint was noted of what was probably a crystal face reflection, at 175 diameters magnification but at none lower. (See colored reproduction on Plate IV, *ante*.)

Having seen a specimen of this ore at the Panama-Pacific International Exposition in 1915, the writer solicited a sample for concentration tests, recognizing in it an extreme case. Such it has proven to be, as is shown elsewhere herein. The cinnabar in this ore has not the brilliant vermilion color that one ordinarily finds in this mineral, because there is a yellow, iron oxide (probably limonite) intimately associated with it. A qualitative chemical test of a rather clean flotation-concentrate sample gave a strong reaction for ferric iron. The entire sample was crushed to pass a #16-mesh screen before the portion for assay was cut out. After crushing, the whole mass had a decided pink color, due to the cinnabar being so finely divided and so thoroughly scattered through the ore. Assayed 1.72% mercury. Tests as to the applicability of both flotation, and of solution in an alkaline sulphide, were made on this ore; but none were made with table concentration, as it is obvious from the nature of the cinnabar occurrence that such would prove futile.

#11—**Esperanza** mine, Sonoma County, September, 1916—150 lb. taken in the mine by the writer, through the courtesy of Mr. Carlos G. White, part owner. The cinnabar, which is coarsely crystalline, occurs, in part, in serpentine and is also found disseminated in sandstone. There is also a black shale. There is some native quicksilver. The vein minerals are quartz, dolomite (?), and calcite; and some chlorite is associated with the serpentine. All crushed to pass #10-mesh iron-wire screen before sampling. Assayed 1.67% mercury.

#12—**Bella Union** mine, Napa County, Mar. 15, 1917—410 lb. from old waste dump. The material is ochreous, and is made up largely of serpentine and a metamorphosed rock, probably a sediment, somewhat silicified.[3] The cinnabar where visible is crystalline and is accompanied by a little pyrite. Chlorite, an end product of the weathering of the serpentine is noticeably present. Crushed to ½″ before quartering down for assay sample. Later, entire sample screened through #10 mesh for table concentration. Assayed 0.14% mercury.

#13—**Bella Union** mine, Napa County, Mar. 15, 1917—325 lb. of ore from underground workings, not ochreous. Largely of serpentine—and a metamorphosed rock which seems to be in process of serpentin-

[3]See Becker, U. S. G. S. Mon. XIII, p. 377.

ization. Chlorite accompanies. The cinnabar is coarsely crystalline and massive, occurring in part as veinlets. Quartz also occurs in veinlets, and there is a little iron sulphide present. Crushed to ½″ before quartering down for assay sample. Later, entire sample screened through #16 mesh for table concentration. Assayed 0.50% mercury. Samples #12 and #13 were sent by Mr. Roger L. Beals through the courtesy of Mr. W. H. Hamilton, attorney for the owners.

#14—**La Joya** mine, Napa County, Mar. 15, 1917—45 lb. taken by shovel sample from a 10-ton lot in retort drier bin, and sent by Mr. R. H. Broughton, superintendent. Ore from 'Big Stope' on main adit level. Recovery for month of March, with the old Livermore (?Fitzgerald) furnace on this ore averaged one flask per day from 6 tons treated. From retort tests this ore was estimated to carry 1% mercury. This sample assayed 2.09% mercury. It consisted of serpentine and metamorphic sandstone, in part ochreous, with considerable chlorite associated with the serpentine. The cinnabar was coarsely crystalline, and occurred massive, in veinlets, and disseminated in the sandstone. There was a little pyrite and calcite and considerable chalcedony. All screened through #16 mesh before sampling.

#15—**Helen** mine, Lake County, April, 1917—5 lb. grab sample taken by the writer from the remains of the sample of T. D. Kirwan,[4] originally 150 lb. of 'mine-run' ore. It consisted mainly of serpentine, opal, and shale. The cinnabar was mainly crystalline, and accompanied by a noticeable proportion of pyrite. All screened through #100 mesh before sampling for assay. Assayed 1.75% mercury. Twelve assays by Kirwan varied from 1.76% to 1.83%; average 1.79% mercury.

#18—**Sulphur Bank** mine, Lake County, Apr. 18, 1917—40 lb. from a cut about 175 feet northwest of the hoist. The rock is a finely vesicular basalt, largely leached white by the thermal waters. The sample contained considerable native sulphur in crystals, and cinnabar, associated with opal which was mainly black with some white. There was a little 'paint' cinnabar very fine and earthy in the opal, similar to that in the Goldbank ore. Most of the cinnabar was distinctly crystalline, and some fine, needle-like, prismatic crystals were noted. All screened through #16 mesh before cutting out sample. Assayed 5.96% mercury.

In crushing a portion of this ore through the disk grinder to pass 100-mesh screen (for flotation tests), the odor given off resembled that of acetylene; and it was necessary to feed intermittently on account of the frictional heat melting the native sulphur if fed continuously. The ground ore was very light and voluminous, and showed a slightly acid reaction on litmus paper in water. It seemed to be hygroscopic,

[4]Unpublished. See extract from his statements, under flotation tests, *post*.

as in a short time after grinding it again became moist, though well dried out before grinding. To intelligently deal with such an ore, a complete chemical analysis should be made. Becker states[5] that "the gases escaping from the waters are carbon dioxide, hydrogen sulphide, sulphur dioxide, and marsh gas. The waters contain chiefly carbonates, borates, and chlorides of sodium, potassium and ammonium; but alkaline sulphides are also present."

Samples ♯16 to ♯19 inclusive, of 30–40 lb. each were sent from the Sulphur Bank mine by Mr. W. G. Luckhardt, superintendent, through the courtesy of Mr. G. T. Ruddock, owner. As they were received just as the author's experimental work was being brought to a close, lack of time prevented investigating them, except for a few preliminary tests on ♯18, which was selected as typical of the group and especially because of the notable proportion of native sulphur carried.

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[5]Becker, G. F., Geology of the quicksilver deposits of the Pacific Slope: U. S. G. S., Mon. XIII, p. 463, 1888.

SCREEN ANALYSES.

The following tabulation gives the results of screen analyses of some of the ores and products tested:

	Ore sample No.	Crushed to pass mesh	Assay per cent Hg	Weight taken, grams	Screen sizes: +20		—20 +48		—48 +80		—80		
					Per cent by weight	Assay per cent Hg	Per cent by weight	Assay per cent Hg	Per cent by weight	Assay per cent Hg	Per cent by weight	Assay per cent Hg	
Oat Hill	1	10	3.88	500	22.0	2.5	27.0	3.7	9.0	7.3	43.0	3.8	Leakage from fine-ore bin.
Ætna	3	18	0.38	500	13.6	0.31	43.5	0.35	10.6	0.38	32.4	0.52	Tailings from Colorado bumpers. Ground in Griffin mill before concentrating.
Parkfield	5	10	0.45	500	37.9	0.22	30.5	0.40	6.0	0.63	25.6	0.80	
St. John's	8	6	0.49	500	57.0	0.45	18.6	0.50	4.0	0.70	20.5	0.70	
Goldbanks	10	16	1.72	500	15.4	1.49	48.6	1.55	9.0	1.55	27.0	2.03	
							—20 +40		—40				
Cambria	9	10	0.31	300	50.0	0.19	22.0	0.19	29.0	0.57	--------	--------	Contained native mercury. No smaller available screen sizes in iron wire.
							—20 +65		—65 +150		—150		
Bella Union	13C	16	0.35	140	17.0	0.43	44.2	0.36	11.4	0.19	25.7	0.44	Tailings from Deister slime concentrator test.
							+150		—150 +200		—200		
Ætna	3K5A	100	0.17	100	--------	--------	33.0	0.21	12.0	0.18	55.0	0.16	Tailings from flotation test.
Goldbanks	10A11A	100	0.46	100	--------	--------	41.0	0.79	11.0	0.42	48.0	0.21	Tailings from flotation test.

Summary of screen analyses.

By an examination of the table of screen analyses, herewith, the following will be noted:

Oat Hill fines (Sample #1)—43% of the total value is in — 80; while over 26% is in — 20 + 48; balance being about equally distributed between + 20 and — 48 + 80.

Ætna bumper tailings (Sample #3)—practically 80% of total value is about equally divided between — 20 + 48 and — 80, with the latter in the lead. Balance about equally divided between + 20 and — 48 + 80.

Ætna—flotation tailings from test on bumper tails (— 100) (Sample #3K5A) — 50% of total value is in — 200 and a little over 33% in + 150.

Parkfield, low grade (Sample #5)—45% of total value is in — 80, and 27% in — 20 + 48; with 67% of balance in + 20.

St. John's (Sample #8)—a little over 50% of total value is in — 20, and nearly 25% in — 80; with 90% of balance in — 20 + 48.

Cambria (Sample #9)—over 50% of total value is in — 40, and about 33% in + 20.

Goldbanks (Sample #10) ore crushed to — 16 mesh — nearly 50% of total value is in — 20 + 48, and about 30% in — 80. A little over 10% in + 20, and a little under 10% in — 48 + 80.

Goldbanks flotation test tailings on — 100-mesh product (Sample #10A11A) showing 73% extraction—75% of total value is in + 150, and a little over 20% in — 200. Under the hand lens, cinnabar seen on coarser particles in *all* three sizes.

Bella Union tailings from Deister slime concentrator test (Sample #13 C) on — 16-mesh product, showing 30% extraction—44% of total value is in — 20 + 65; 31% in — 150; and 20% in + 20.

CONCENTRATION ON TABLES WITH WATER.

The author's experimental work in the metallurgical laboratory and mill of the Department of Mining and Metallurgy, University of California, covered two periods of continuous operation 8 hours daily—March 2 to April 15, 1916, and February 8 to May 12, 1917. In addition to this some weeks were spent each year, in the course of field work for the State Mining Bureau, particularly September and October, 1917, in gathering data on and observing the operation of plants at the various quicksilver mines throughout the State.

Rolls were used to crush the samples for concentration because they have been found to produce a minimum of slimed material. Cinnabar being very friable, 'grinding' should be avoided if possible, otherwise the sulphide will be slimed and it will then float away or remain in suspension until after it passes out the tail-race. Crushing and screening were done on the dry ore. Three tables were used: a regulation, standard-size Wilfley; a small, laboratory model Wilfley-type machine, built in the shop of the department under the direction of Prof. Christy shortly before his death; a half-size Deister slime concentrator installed in April, 1917,—a gift to the College of Mining from the Joshua Hendy Iron Works and the Deister Concentrator Company. The standard Wilfley operated at 250 r. p. m., and the laboratory model at 225 r. p. m. These speeds are about right, but the 'bump' at the end of the stroke is not decided enough—it should be sharper. A small test-run was also made on a new model Gates table at the Bay City Iron Works, Oakland. Samples #1, 6, 7, 11, and 18 were treated on the small, laboratory model; and #9, 12, and 13 on the Deister.

The concentrate discharge of the Wilfley table was so arranged at first, that when running samples #2, 3, and 5, it was necessary to get a part of the heavier tailings in with the middlings and a part of the middlings in the concentrates. The table could not be flattened, without throwing all of the middlings into the concentrate trough. For samples #4 and 8,—a double-spout trough was put on at the end of the table so that the deck could be run flatter, and thus spread out the concentrates and middlings, permitting a cleaner separation of them. The ore was fed by hand with a scoop into a stream of water in a 12-foot section of launder leading to the feed-box of the table. It was realized that this would not give as complete a mixing of the ore and water as would be obtained in a plant under normal continuous-operating conditions; but it had to serve the purpose during our experiments.

The following samples, #2, 3, 4, 5, and 8, were run over the standard Wilfley table:

Sample #2—Oat Hill mine. This was crushed to pass #4-mesh wire screen before treating. In concentrating, the cinnabar and the pyrite showed in two fairly distinct bands, on the table. With proper crushing, sizing, and classification of such an ore before feeding to the concentrator, an appreciable proportion of the pyrite could be eliminated on the table by a suitable cut at the discharge. The tailings assayed 0.083% mercury, or an indicated extraction of 95.8%. The middlings assayed 0.34%, and the concentrates 22.20% mercury, as compared with 1.99% mercury in the heads. These were unusually good results considering the coarseness of the feed.

Sample #3—Aetna mine. Of this sample, 270 lb. were put over the Wilfley table, the tailings assaying 0.185% mercury, against 0.385% in the heads, or an indicated extraction of 52%. The middlings assayed 0.25%, and the concentrates 5.16%. In clearing the table at the end of the test, it was noticed that there was considerable fine cinnabar on the bottom between the riffles, even well up toward the head, that did not seem to move much either forward or back. This was probably attributable to the lack of sharpness in the jerk of the table motion. Accumulating thus, no doubt resulted in some of it being washed over the riffles with the tailings. The coarser, crystalline cinnabar of the Oat Hill sample (#2), did not act in this manner. It must be remembered that this Ætna ore not only had 'paint' cinnabar in it before grinding, but that it had been ground rather fine and the coarser cinnabar taken out by the Colorado bumping tables. As shown by the screen analyses (see *ante*), approximately 40% of the value is in the — 80 material. On the whole, therefore, this sample presented an unfavorable problem for the table.

A 100-lb. portion of this sample was taken to the Bay City Iron Works in Oakland, April 29, 1916, and run over a new model Gates concentrating table set up there. The tailings from this test assayed 0.185% mercury, the middlings 0.22%; and the concentrates 2.52%. This is also an indicated extraction of 52%. The low grade of the concentrate is due to the fact that a considerable portion of the middling was unavoidably discharged with it. In a regularly installed and equipped plant, provision could be made against mixing.

Sample #4—Ætna mine. This was crushed to pass #4-mesh screen before concentrating. The tailings assayed 0.042% mercury, against 0.157% in the heads, or an indicated extraction of 73%. The middlings assayed 0.09% and the concentrates 3.12% mercury. Considering the low grade of the heads and the coarse feed, this was a better result than might have been expected.

Sample #5—Parkfield mine. This was crushed to pass #10-mesh screen before concentrating. The tailings assayed 0.19% mercury, against 0.45% in the heads, or an indicated extraction of 57.8%. The middlings assayed 0.175%, and the concentrates 10.24% mercury. As shown by the screen analyses, 45% of the value in this ore as crushed to #10 mesh was in the —80 mesh product. Finely ground cinnabar is difficult to recover, particularly with an unclassified feed, as we were obliged to handle it in these tests.

Sample #8—St. John's mine. This was crushed to pass #6-mesh screen before concentrating. The tailings assayed 0.29% mercury, against 0.49% in the heads, or an indicated extraction of but 41%. The middlings assayed 0.54%, and the concentrates 5.50%. Reference to the screen analyses shows a little over 50% of the total value in the + 20-mesh material, when crushed to pass 6-mesh. It is very evident that the ore should have been crushed finer before concentrating, as much of the cinnabar was not released from the enclosing gangue.

The following samples, #1, 6, 7, 11 and 18, were concentrated on the small, laboratory machine. No middlings samples were taken:

Sample #1—Oat Hill mine. This was crushed to pass #10-mesh screen before concentrating. The tailings assayed 0.325% mercury, against 3.88% in the heads, or an indicated extraction of 91.6%. The concentrates assayed 31.64% mercury. The screen analyses showed 43% of the total value of this sample in the —80-mesh product from 10-mesh crushing, and 26% in the — 20 + 48. The cinnabar being entirely crystalline and fairly coarse, while the gangue was friable and required but little crushing to release the cinnabar, made a high recovery possible by concentration. This was also the case with sample #2, from the same mine. The Oat Hill ore being a friable sandstone with disseminated crystals of cinnabar, is particularly amenable to table concentration. The classification of the cinnabar from the pyrite was also noticeable with this sample as with #2 on the larger table.

Sample #6—Parkfield mine. This was crushed to pass #10-mesh screen before concentrating. The tailings assayed 0.35% mercury, against 1.42% in the heads, or an indicated extraction of 75.5%. The concentrates assayed 3.76% mercury. From a comparison with the results on sample #5, a lower grade material from the same property, it seems probable that the tailings loss is in both the — 80-mesh material and the unreleased sulphide.

Sample #7—Big Injun mine. This sample was crushed to approximately #20 mesh, but not screened, as the native quicksilver would have amalgamated with the brass. The tailings assayed 0.31% mercury, against 1.39% in the heads, or an indicated extraction of 77.7%. The concentrate assayed 4.48% mercury. The differences in the specific gravities of the several heavier constituents of this ore were well illustrated in the classification shown on the table at the concentrate discharge. At the back, first came the native quicksilver (sp. gr. 13.6); next the cinnabar (sp. gr. 8.1); then a black mineral, probably magnetite (sp. gr. 5.17); and finally pyrite (sp. gr. 5.0) in the edge of the middlings. The low grade of the concentrate is due to a considerable portion of the middlings being mixed in.

Sample #11—Esperanza mine. This sample was crushed to pass a #10-mesh iron-wire screen before concentrating. The tailings assayed 0.43% mercury, against 1.67% in the heads, or an indicated extraction of 74.3%. The concentrates assayed 12.02% mercury. It was evident from the appearance of the material on the table, that a 10-mesh feed was too coarse. Also, the lack of complete wetting of the ore resulted in values floating away over the tailings discharge.

Sample #18—Sulphur Bank mine. This sample was crushed to pass a #16-mesh screen before concentrating. The tailings assayed 2.72% mercury, against 5.96% in the heads, or an indicated extraction of 54.5%. The concentrate assayed 17.16% mercury. As noted in the description of this sample (see p. 290, *ante*), the ground ore was very light and voluminous. For lack of proper wetting and mixing of the pulp, both cinnabar and native sulphur could be seen floating away over the tailings discharge. They were carried in a film on top of the water. No middling sample was taken, but unreleased cinnabar was noted in some of the coarser material in the tailings. This small table operated at 225 r. p. m., which was apparently too slow. It did not have a sufficiently sharp and positive motion.

The following samples, #9, 12, and 13, were treated on the Deister slime concentrator:

Sample #9—Cambria mine. This sample was crushed to pass a #10 mesh iron-wire screen before concentrating. It was the author's intention to run this sample on the new Deister-Overstrom sand table that had been put in the mill at the same time as the slime table, and the test was so started. As the sand table proved not to be in proper adjustment, the test was transferred to the slime table, but the feed was too coarse for it. The 'tailings' showed only about 15% extraction, and there was much coarse sand that went over the concentrate discharge. The 'concentrates' were afterwards cleaned by panning and quite a large globule (about ¾ inch across) of native quicksilver was obtained with the cinnabar.

Sample #12—Bella Union mine. This sample was crushed to pass #16-mesh screen before concentrating. The table looked to be working fairly well with this material, but the assays show an extraction of only 35% (tailings 0.09% Hg) and a concentrate carrying 2.68% mercury, from heads of 0.14%. No separate middling product was made, this material being divided between the tailings and the concentrates. Some cinnabar was noted adhering to coarser portions of the gangue. To begin with, this was a rather low-grade material to attempt to handle on a commercial scale. With quicksilver at $100 per flask, such an 'ore' would have a value of but $3.70 per ton.

Sample #13—Bella Union mine. This sample was crushed to pass #16-mesh screen before concentrating. The tailings assayed 0.35% mercury, against 0.50% in the heads, or an indicated extraction of but 30%. The concentrates assayed 4.48% mercury. A separate middlings product was not made, this material being divided between the concentrates and tailings. It was noted during the run on this ore that flat pieces of the coarser cinnabar would ride along on top of the gangue, particularly in the middlings area, and finally be washed over into the tailings launder. The writer was informed by Mr. S. E. Woodworth of the firm of Hamilton, Beauchamp and Woodworth who had made a series of milling tests on ore from this mine, that they had noted the same behavior in their experiments; and that the ore required crushing to 40–50 mesh before this tendency could be overcome,—that is, before the particles were crushed fine enough to lack that flatness which caused them to ride on top of the gangue. The coarser, crystalline cinnabar in the Bella Union ore has a platy structure. Reference to the screen analyses (*ante*) on the tailings from this test shows 44% of the total value in the — 20 + 65 material, 31% in — 150, and 20% in + 20.

Sample #14—La Joya mine. This sample was crushed to pass #16 mesh screen. No table test run was made on this ore, as the sample was small and it was evident after a panning test that table concentration, alone, would make a low recovery. In panning, the slimed cinnabar floated off in air bubbles on the surface of the water. There was an abundant concentrate of the coarser, crystalline cinnabar, but much cinnabar was washed overboard due to being held in uncrushed particles of the gangue. A combination treatment of flotation (for the fines) and tabling (for the coarse) would probably yield a good recovery from this ore.

Summary re table concentration tests.

The one point which impressed itself most strongly upon the writer during these experiments was the necessity for classification of feed when concentrating. The table (or belt machine, either) is not made which can successfully concentrate materials of more than a narrow range in size at a single operation. Another point is, that apparently 'paint' and slimed cinnabar are not recoverable by tables, as such products remain in suspension in the pulp, even float off as a film on the surface of the water. It must be borne in mind that these experiments were carried out under somewhat unfavorable circumstances, at least so far as irregularities of pulp consistence were concerned, and the irregularities of pulp flow resulting from the intermittence of hand feeding. In spite of these irregularities, excellent results were obtained with the favorable Oat Hill samples, and fair results with certain others which could be improved upon with more favorable manipulation. Native quicksilver is readily recoverable by tables, though large globules have a tendency to roll around and jump the riffles instead of advancing along them. In view of the excellent results obtained at New Idria with the Senn pan-motion amalgamator operating on soot, this machine would doubtless work well on ores carrying native quicksilver. Possibly a settler with revolving arms, similar to the settlers used in the old Washoe-pan process of silver amalgamation, would work well on such ores.

CONCENTRATION BY FLOTATION WITH OILS.

APPARATUS.

In the first few flotation tests made by the author in this series, in March, 1916, a Hyde ('Slide') machine was used, but clamped and the pulp allowed to overflow (see Photo No. 71). In the balance of the series, in February–April, 1917, which covered a far greater range of ores and oils, and a greater number of tests, the Case (Hoover type) laboratory flotation machine was employed. (See Photo No. 72.) These and various other laboratory. testing units are well described by Ralston and Allen[1] in the most complete paper as yet published on this phase of flotation practice, and to which the reader is referred for more detail than is here given.

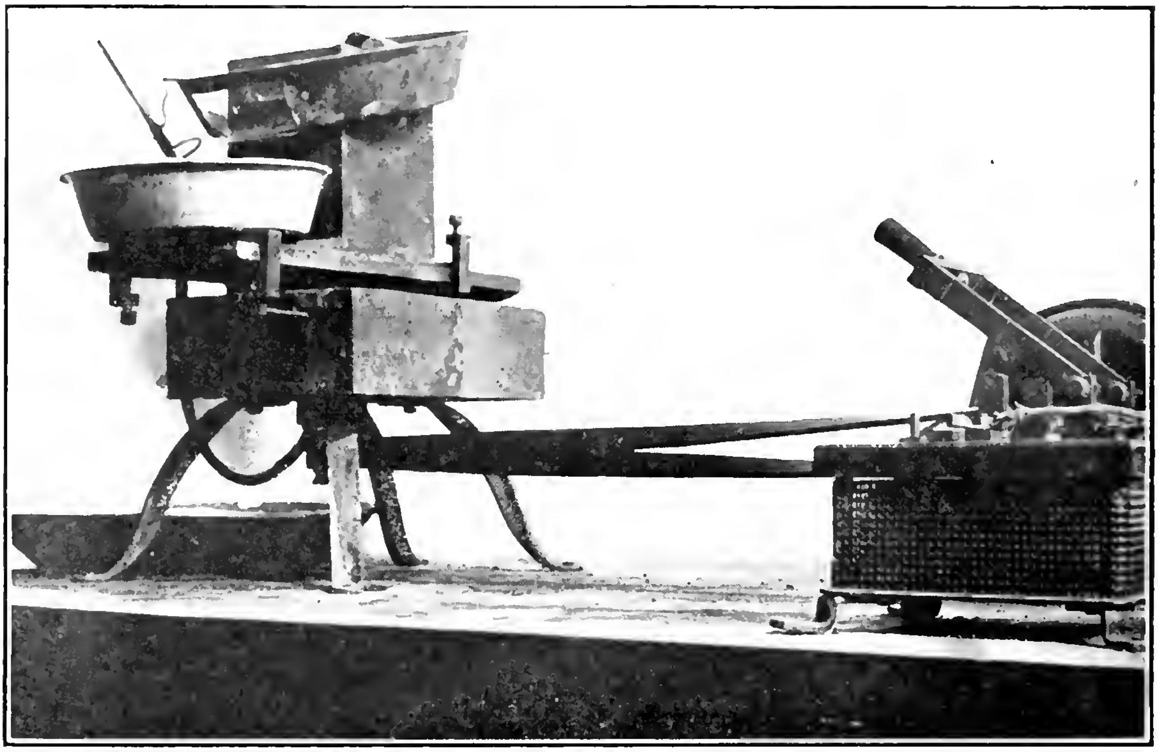

Photo No. 71. Hyde ('Slide') Laboratory Flotation Machine, as used in the metallurgical laboratory of the Department of Mining, University of California.

As above stated, the **Slide** or **Hyde** laboratory flotation machine as used by the author was clamped so that the upper and lower parts were not separable. A tin pan was soldered around the top (see Photo No. 71), to act as a sloping discharge launder for the overflowing froth and concentrate. Sub-aeration was introduced through the tube shown at the left, drawn in by suction of the propeller blades in the bottom of the agitation compartment. Power was furnished by a 60-cycle, $\frac{1}{2}$ h. p., 220-volt, 4-amp. induction motor at 1800 r. p. m., driving the agitator shaft at 1500 r. p. m. A charge of 300 grams of ore with 2400 cc. of tap water (temperature 20°–25° C.) was used. The water was first put in, the air tube closed, motor started and 10 drops of oil

[1]Ralston, O. C., and Allen, G. L., Testing ores for flotation process: Min. and Scientific Press, Vol. 112, pp. 8-13, 1916.

added. After 2 minutes agitation, for the oil and water to emulsify, the ore was added in a small steady stream, and allowed to agitate for 2 minutes before opening the air-supply tube. Agitation was then continued for 20 to 25 minutes, during which the froth arising was occasionally raked off with a spatula on a level with the top of the agitation compartment. At the close of the test, the tailings were

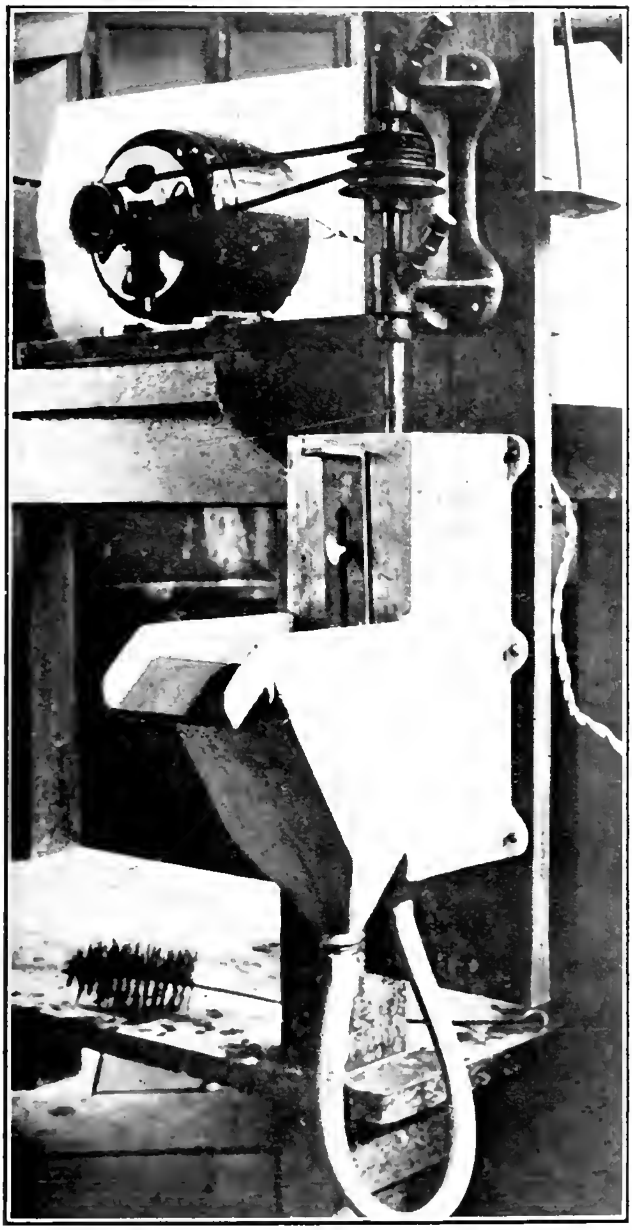

Photo No. 72. Case Laboratory Flotation Machine.

drawn off through an opening in the bottom of the agitation compartment. Both tailings and concentrates samples were dried and weighed.

At the end of all tests, both with the Hyde and the Case apparatus, the inside of the machine was thoroughly washed out to avoid contamination of the oils used.

The **Case** (Hoover type) Flotation Machine (see Photo No. 72) is a laboratory unit built by the Denver Fire Clay Company, Denver, Colo. It consists of a single aluminum casting comprising the agitation cell and a spitzkasten for the collection of the froth. Within the agitation cell are hung the shaft and impeller, the four blades of which are set at 90°. The steel shaft is coated with lead and the impeller blades are made of an alloy to resist the corrosive action of acids. A piece of heavy rubber tubing connects the spitzkasten and agitation cell at the bottom. About half way down from the top of the spitzkasten, an opening (¾ inch high x 1 inch wide) in the wall also con-

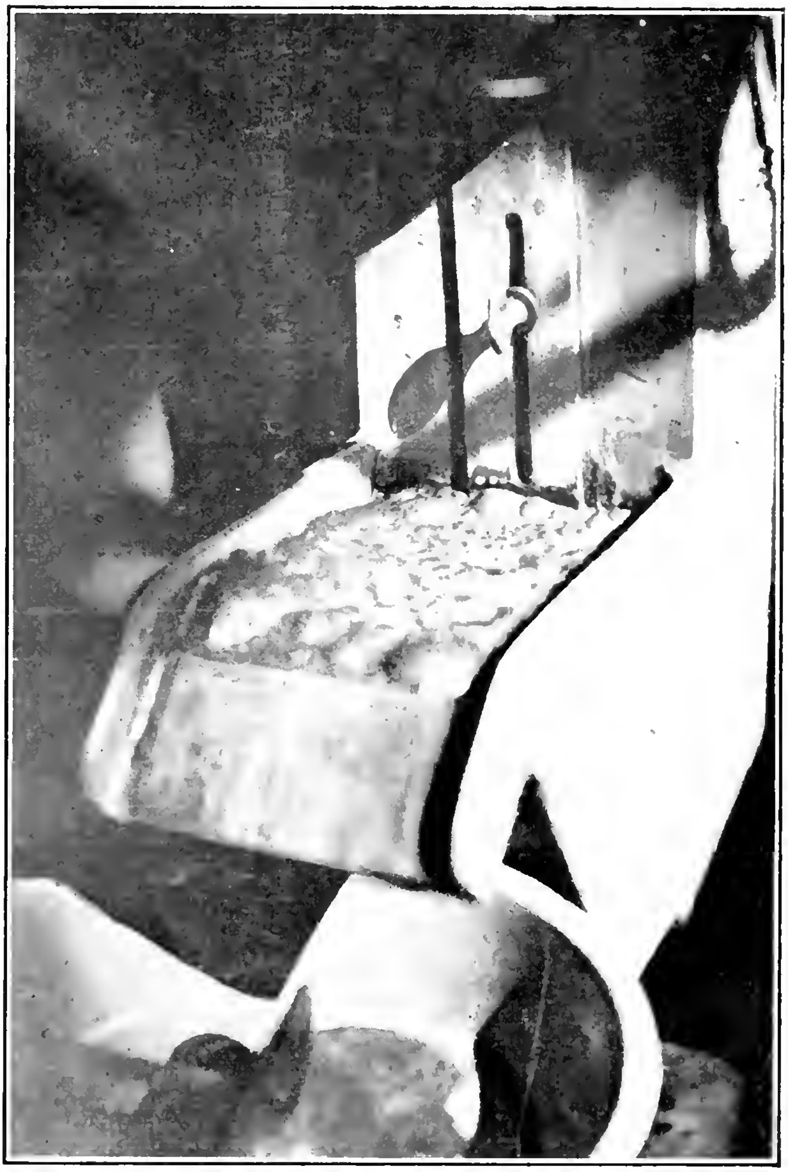

Photo No. 73. Froth on a Flotation Test with the Case Machine.

nects with the agitation compartment. This opening is controlled by a vertical, slotted plate, with a baffle at its lower end. When the machine is in operation the pulp and froth work from the agitation compartment, through this opening to the spitzkasten from which the gangue on settling to the bottom is drawn through the rubber tube by the suction of the impeller blades back into the agitation compartment. This gives a continuous circulation of the pulp through the two cells as long as the test lasts. The impeller shaft is driven by a G. E.

induction motor, type DSS, W33, 220 volts, ⅛ h. p. 60 cycles, operating at 1800 r. p. m. The larger two of the pulleys give the impeller speeds of 1800 and 1300 r. p. m., respectively. A lip on the edge of the spitzkasten provides for the overflow of the froth (see Photo No. 73), which may also be skimmed off from time to time with the small metal hoe provided.

In the earlier tests by the writer with the Case machine, the impeller was started, and 2000 cc. of tap water put in—temperature 22° ± C., then 10 drops of oil added. After running two minutes to allow the oil and water to emulsify, 500 grams of ore (— 100 mesh) were added gradually. After 10–15 minutes, as the volume of pulp and froth required to give an overflow became reduced, more oil and water were added, gradually. The capacity of the machine is 3000 cc. The test was continued for a total of 20–30 minutes, or as long as any concentrate seemed to make its appearance on the top of the froth. There was no sub-aeration in the Case machine, as with the Hyde.

Following the first few tests, the order of adding oil and ore was reversed. Also, a Mohr pipette of 1 cc. total capacity, graduated to 0.01 cc., was employed for measuring the quantity of oil used. In the tabulations, 'drops' of oil have been converted to cubic centimeters, in the figures representing the earlier experiments. The impeller was started, with 2000 cc. of water; then 500 grams of ore added gradually and allowed to agitate 2–3 minutes for mixing, with the side hole closed. Then, the oil and any other reagents were added, following which the side hole was opened, and the test proceeded as before. Time of treatment was counted from the introduction of the oil.

In most of the tests with the Case apparatus, the impeller was driven at 1800 r. p. m.; but a few were run at 1300 r. p. m.

OILS USED.

Through the courtesy of Mr. Niel Nielsen, Commissioner, and Mr. A. C. Gilleland, chief clerk of the Trade Commission to America for the Government of New South Wales, stationed in San Francisco, the writer received samples of three Australian eucalyptus oils, which were utilized in several of the tests detailed herein. These have been designated for convenience of reference, #1, #2, and #3, Eucalyptus, respectively. The descriptions were furnished by the donors, and the specific gravity determinations were made by the writer.

#1 Eucalyptus—Rectified oil of the 'White Top' or 'Gully Ash,' *Eucalyptus smithii,* R. T. B., from New South Wales and Victoria. One of the richest in eucalyptol, and containing no phellandrene. Specific gravity 0.912.

#2 Eucalytus—Crude oil of the 'Broad-leaved Peppermint', *Eucalyptus dives* Schau, from New South Wales and Victoria. It consists largely of the terpene phellandrene, eucalyptol, being present only in minute quantity. This oil is largely used for mineral separation. Specific gravity 0.908.

#3 Eucalyptus—'Citronella,' crude oil of the 'Citron-scented Gum,' *Eucalyptus citriodora* Hook, from Queensland. It consists almost entirely of the aldehyde citronellal, and contains no eucalyptol. Specific gravity 0.874.

Through the courtesy of Mr. Frank E. Mariner, president of the Pensacola Tar and Turpentine Company, Gull Point, Florida, samples of a number of their pine oils were received and utilized in various tests. The following summary of the constants and characteristics of these oils is condensed from the company's catalogues. "The constants given are averages. Most of the oils are crudes, and constants are apt to vary slightly, though not sufficiently to interfere with practical operations."

#75—Crude Wood Turpentine. Sp. gr. 0.887. Dis. Pts. 65°–217° C. Ref. index 1. 456. Viscosity, 0.9. Non-polymerizable matter 10–12%.

#90—Redistilled Pine Tar Oil. Sp. gr. 0.982. Dis. Pts. 160°–368° C. Ref. ind. 1.5636. Visc. 5.8. Non-polymerizable matter (see note). It is free from pitchy matter.

#350—Special Crude Pine Wood Oil. Sp. gr. 1.019. Dis. Pts. 70°–345° C. Ref. ind. 1.525. Visc. 2.9 Non-polymerizable matter 4%. Has a low pitch content, and "is not a gangue lifter ordinarily, but combines excellent frothing and collecting qualities."

#400—Crude Wood Creosote Oil. Sp. gr. 1.025. Dis. Pts. 190°–360° C. Ref. ind. 1.4977. Visc. 2.9. Non-polymerizable matter (see note). A mixture of pine oil and wood creosote oil recovered from the caustic soda still bottoms of the refinery. It is stated to be an excellent all-round flotation agent, but only a limited quantity of it is recovered.

#750—Heavy Pine Tar Oil. Sp. gr. 1.063. Dis. Pts. 165°–350° C. Ref. ind. 1.557. Visc. 41%. Non-polymerizable matter (see note). It is "the total crude dropped out of the steam rougher still after the light products have been taken off, and therefore contains some pitchy matter. It is a good collector and is extensively used."

#1580—Combination Pine Oil. Sp. gr. 0.980. Dis. Pts. 85°–352° C. Ref. ind. 1.5361. Visc. 2.3. Non-polymerizable matter (see note). This is a mixture of one part of #80 (crude pine oil) with two parts of #15 (thin rosin oil). "Apparently a useful oil in special work * * * does not seem to be of general adaptability."

Samples of Nos. 15, 80, and 200 were also received but not utilized, for lack of time.

Note: "The heavier oils which contain more or less redistilled rosin oils or heavy tar oils cannot be successfully tested for Non-polymerizable matter by the sulphuric acid test."

From samples in the storeroom of the metallurgical laboratory, the following oils were utilized in certain tests:

Calol Flotation Oil "B", Standard Oil Company, Richmond, Cal. Sp. gr. 0.878–0.892. A compound of mainly mineral oil, with some pine products.

A California crude petroleum, of asphaltic base, from "Well #16, Sec. 15" (probably Midway field); 15° ± Baumé, or 1.115 sp. gr. In those tests where this oil was employed, it was added before the pine oil; but in no case did it give any appreciable froth, alone.

Through the courtesy of Mr. S. S. Skelton, of the Georgia Pine Turpentine Company, the author has received samples of several of their flotation oils since the laboratory experimental work was closed; and regrets that lack of time has prevented utilizing these oils in some further tests.

EXPERIMENTAL DATA.

The tabulation herewith gives in condensed form the results of the tests made by the writer. They are all shown,—good, bad, and indifferent, that comparison may be had of the variations resulting from changes of oils with the same ore, changes of ores with the same oil, changes of dilution of pulp, changes of agitation speed, and other possible combinations. The 'indicated' percentage of extraction (*i. e.*, tails: heads) is shown rather than the actual, partly because it involved a simpler calculation, and partly because the results on the whole are merely relative, anyway. A sufficient comparison can be had one with another so long as they are all calculated upon a common basis. The necessary elements (weights of tailings and concentrates) for figuring actual 'recovery' are present if it be necessary to determine it in any particular case. The concentrates of only a few of the most satisfactory tests were assayed. It was anticipated that difficulty would be encountered in assaying flotation products, particularly concentrates, with the Whitton apparatus. It did not prove so, in most instances. In the majority of cases, there seemed not to be enough oil present to interfere, neither in concentrates nor tailings. This was particularly true where pine products were utilized. Where a mineral oil had been used in the combination, it was necessary to wash the concentrate sample with ether before assaying, otherwise the results were low, and not concordant.

DATA OF

Number of sample	Wt. of ore taken, grams	Mesh of samples	Oil used: Kind	Oil used: Amount: At start, cc.	Oil used: Amount: Total added later, cc.	Other reagent added: At start	Other reagent added: Total added later	Time of test, min	Pulp ratio, water: ore
3B6	300	80	#350 P.	0.47	------	------	------	20	8:1
3B7	300	80	1500 P.	0.38	------	------	------	20	8:1
3B8	300	80	2 Euc.	0.35	------	------	------	20	8:1
3B9	300	80	Calol B.	0.34	------	------	------	20	8:1
3K2	500	100	#75 P.	0.34	0.51	(a)NaOH 5 cc.	10 cc.	50	6:1
3K3	500	100	75 P.	0.34	0.68	(b)H_2SO_4 5 cc.	10 cc.	40	6:1
3K4	500	100	#2 Euc.	0.35	0.50	------	------	45	6:1
3K5	500	100	#750 P.	0.40	0.70	------	NaOH 10 cc.	35	5:1
10A6	500	100	#400 P.	0.47	0.23	------	------	25	5:1
10A7	500	100	#75 P.	0.34	0.27	------	------	30	6:1
10A8	500	100	#75 P.	0.34	0.07	NaOH 5 cc.	------	30	6:1
10A9	500	100	#2 Euc.	0.30	0.15	------	------	35	5:1
3K6	500	100	#400 P.	0.40	0.42 #750 0.90	NaOH 10 cc.	5 cc	40	4:1
3K7	500	100	#350 P.	0.40	0.40	NaOH 20 cc.	5 cc.	40	6:1
3K8	500	100	#90 P.	0.40	0.80	NaOH 20 cc.	10 cc.	35	6:1
3K9	500	100	#750 P.	0.60	------	(c)lime 64 gm.	------	30	4:1
3K10	300	100	#750 P.	0.40	0.30	NaOH 5 cc.	5 cc.	30	8:1
3K5G	500	200	#750 P.	0.20	------	NaOH 10 cc.	------	20	4:1

(a) 10% NaOH. soln. used in all tests where noted.
(b) Conc. H_2SO_4 used.
(c) Slaked lime paste.

FLOTATION TESTS.

Character and behavior of froth	Heads assay value, % Hg.	Tailings		Concentrates		Indicated extraction %	Remarks
		Wt., grams	Assay value, % Hg.	Wt., grams	Assay value, % Hg.		
Thin; not persistent; small bubbles.	0.38	278	0.255	20	-------	34	In Hyde machine.
Fair, but thin; small bubbles----	0.38	277	0.22	21	-------	43	In Hyde machine.
Fair, but thin. Better than preceding one. Small bubbles.	0.38	273	0.155	24	2.55	60	In Hyde machine.
Very thin, not persistent. Small bubbles.	0.38	277	0.32	12	-------	17	In Hyde machine.
Froth of emulsion subsided on adding ore. Then, practically no froth till addition of more oil at 10 min. Froth thin, small bubbles, temporary, shallow.	0.38	433	0.305	43	-------	20	In Case machine. Oil put in before ore.
Froth thin, temporary shallow. Bubbles fairly large, but thin, and did not seem to carry any sulphide.	0.38	478	0.37	16	-------	3	In Case machine. Oil put in before ore.
Froth up immediately, but slowly. Slightly thick, but not persistent. Small bubbles.	0.38	463	0.22	16	-------	42	In Case machine. Oil put in before ore.
At start, a few thin, large bubbles, which broke quickly. After 5 min. added NaOH. Fair froth, bubbles, both coarse and fine, somewhat persistent.	0.38	463	0.15	11?	-------	60	In Case machine. Oil put in before ore. ?—sample pan leaked.
Thick, persistent, deep, voluminous. Bubbles coarse.	1.72	403	0.77	94	-------	55	Oil in before ore.
Thick, persistent, deep, voluminous. Coarse and fine bubbles. On adding ore, froth rose immediately.	1.72	454	0.69	42	-------	60	Oil in before ore.
Thicker, deeper, coarser, than preceding test.	1.72	444	0.63	46	-------	63.4	Oil in before ore. Tailings slow to settle; liquid milky.
Froth up immediately. Thick, deep, persistent; large bubbles. As the oil was used up, the bubbles became smaller, but still persistent.	1.72	415	0.635	68	-------	63	Oil before ore. In balance of tests, ore put in before oil.
At first, a few thin, coarse, nonpersistent bubbles. After 12 min. added #750. Froth thicker, but small bubbles.	0.38	459	0.30	27	-------	21	Tailings slow to settle. This ore contains much ochre.
Thin froth and small bubbles. Thicker on addition of more water; also deeper.	0.38	412	0.38	49	-------	0	Tailings slow to settle.
A very little thin froth until addition of more oil after 10 min. Then fairly deep and persistent, with both coarse and fine bubbles. A rather good looking froth, but seemed to raise but little sulphide.	0.38	450	0.36	31	-------	5	Tailings slow to settle, in all tests using NaOH.
Very large, coarse, persistent bubbles; deep froth. Raised colloidal ochre, but no sulphide visible.	0.38	500	0.35	25	-------	8	After drawing off, pulp settled clear in few minutes.
Froth up, with sulphide immediately on adding oil. Medium deep and thick; slightly persistent. Raised some gangue. Deeper after adding more oil and caustic.	0.38	263	0.18	28	-------	53	Froth not thick nor persistent enough, but appeared better than with thicker pulp.
On adding NaOH, before oil, froth up immediately (probably from oil retained in pulp from previous charge). Deep thick, some persistent; small bubbles. A little sulphide but gangue also. Probably should not have added as much NaOH or oil.	0.165	461	0.165	25	-------	0 (Total 57%)	Sample made up of 250 grams, each, from tails of #3K5 and #3K10 (see above) — original head assay 0.38% Hg. A little cinnabar visible in coarser sand of dried tailings.

DATA OF FLOTATION

Number of sample	Wt. of ore taken, grams	Mesh of samples	Oil used: Kind	Oil used: Amount: At start, cc.	Oil used: Amount: Total added later, cc.	Other reagent added: At start	Other reagent added: Total added later	Time of test, min.	Pulp ratio, water ore
3K11	300	100	Cal. Cr. #750 P.	0.20 0.40	0.10 0.30	NaOH 5 cc.	------------	30	8:1
3K12	500	200	#750 P.	0.50	0.20	NaOH 10 cc.	------------	30	4:1
8A6	500	100	#3 Euc.	0.30	0.05	------------	NaOH 10 cc.	30	4:1
8A7	490	100	#75 P.	0.30	------	NaOH 5 cc.	------------	30	4:1
10A10	500	100	#2 Euc.	0.30	0.10	------------	------------	45	5:1
10A11	500	100	#2 Euc.	0.30	0.20	------------	------------	35	5:1
10A12	300	100	#2 Euc.	0.30	0.30	------------	------------	30	8:1
10A13	300	100	#3 Euc.	0.30	0.70	------------	------------	30	9:1
10A14	300	100	#3 Euc.	0.30	0.70	------------	------------	30	8:1
10A11K	500	100	#2 Euc.	0.30	0.30	------------	------------	30	4:1
10A11L	467	200	#2 Euc.	0.20	------	------------	------------	30	4:1
10A15	300	100	Cal. Cr. #750 P.	0.20 0.40	0.10 0.20	NaOH 5 cc.	------------	30	4:1
10A16	500	200	#2 Euc.	0.30	0.20	------------	------------	30	4:1

(d) In all tests, following, on Goldbanks ore, some sulphide floated before addition of oil.
(e) Froths seemed to become shallow, sooner, at lower speed; and concentrates cleaner with thinner pulps.

TESTS—Continued.

Character and behavior of froth	Heads assay value, % Hg.	Tailings Wt., grams	Tailings Assay value, % Hg.	Concentrates Wt., grams	Concentrates Assay value, % Hg.	Indicated extraction %	Remarks
Cal. crude oil added after ore; then #750; then froth up immediately. Froth thicker, deeper; bubbles coarser; slightly more persistent, than without Cal. crude.	0.38	277	0.145	16	5.40	62	At 30 min. still raising a little concentrate.
Froth up immediately on adding oil. Thick, deep, fine and medium bubbles, only slightly persistent. Raising also some ochre with sulphide.	0.38	453	0.155	24	5.08	59	At 30 min. still raising a little concentrate. A very little cinnabar visible in sandy part of tailings, unreleased.
Some bubbles and sulphide before oil added. After oil, bubbles mostly fine, a few coarse, but not persistent. After 5 min. added NaOH-froth deeper, thicker and persistent, but raising some gangue also (less NaOH would suffice).	0.49	400	0.07	80	2.96	86	Pulp settled quickly.
Some concentrates before oil added. After oil—froth up immediately. Thick, deep, coarse bubbles, persistent. Some gangue raised also.	0.49	434	0.11	40	-------	78	A little cinnabar visible in coarser tailings.
Some bubbles and sulphide before oil added (d). After oil, deep, persistent froth, coarse bubbles.	1.72	443	0.56	62	-------	67	At 45 min. still raising a little concentrate.
Froth immediately, thick, deep, persistent. Also some gangue raised, but concentrate looks cleaner. Froth thinner after adding more water.	1.72	430	0.46	71	8.44	73	At 1300 r.p.m.(e). Only a little concentrate after 25 min.
Froth immediately thick, deep, persistent. Fairly clean concentrate. Froth thinner just before and thicker after each addition of oil.	1.72	270	0.575	26	-------	63.6	At 1300 r.p.m. Only a little concentrate after 17 min.
Froth immediately thick, medium deep and persistent, but not as good as preceding test.	1.72	280	0.67	18	-------	61	At 1300 r.p.m. At 30 min. still raising some concentrate.
Froth immediately; but deeper and more persistent than at lower speed. At 30 min. still raising some concentrate.	1.72	274	0.64	22	-------	63	At 1800 r.p.m. (See photo #73.)
Froth immediately; medium bubbles; fairly thick; deep, and some persistent. Some sulphide but mostly gangue.	0.52	477	0.485	20	-------	8 (Total 72%)	At 1300 r.p.m. Sample made up of 250 gm. each from tails of #10A11 and #10A12.
Froth and concentrate before oil added (probably from previous charge). Deep, thick, persistent; bubbles, both fine and coarse. Raising dark part of gangue, also. At 30 min. still raising some concentrate.	0.485	363	0.24	97	-------	49.5 (Total 86%)	At 1300 r.p.m. Tails from #10A11K reground to —200. After retreatment, still some cinnabar on coarser quartz, though —200 mesh.
Froth and concentrate immediately on adding #750. Deep, thick, persistent; coarse bubbles. Raising some gangue also.	1.72	246	0.55	54	-------	68	At 30 min. still raising some concentrate.
Froth immediately. Deep, thick, persistent; coarse bubbles. Some gangue up.	1.72	395	0.255	103	-------	85	At 1300 r.p.m.

DATA OF FLOTATION

Number of sample	Wt. of ore taken, grams	Mesh of samples	Oil used			Other reagent added		Time of test, min.	Pulp ratio, water: ore
			Kind	Amount: At start, cc.	Amount: Total added later, cc.	At start	Total added later		
10B1	500	200	#750 P.	0.40	------	------------	------------	20	4:1
10B2	500	200	Cal. Cr. #750 P.	0.20 0.30	0.10 0.20	------------	------------	25	4:1
10B3	500	200	Cal. Cr. #750 P.	0.22 0.34	------	------------	------------	30	4:1 5:1
10B4	500	200	Cal. Cr. #75 P.	0.25 0.40	------ 0.10	NaOH 5 cc.	------------	35	4:1 5:1
12A2	500	100	#3 Euc.	0.40	0.30	NaOH 5 cc.	5 cc.	30	5:1
12A3	500	100	Calol B.	0.50	0.60	NaOH 5 cc.	30 cc.	25	5:1
12A4	500	100	#750 P.	0.50	0.50	NaOH 10 cc.	------------	35	4:1
12A5	500	100	#2 Euc.	0.50	0.20	NaOH 5 cc.	------------	25	4:1
12A6	300	100	#2 Euc.	0.40	0.10	NaOH 5 cc.	------------	25	8:1
12A7	300	100	#750 P.	0.40	0.20	NaOH 5 cc.	------------	30	8:1
12A8	300	100	Cal. Cr. #750 P.	0.20 0.40	0.10 0.20	NaOH 5 cc.	------------	30	8:1

(f) Tailings from #10B1-10B4 (inc.) showed some cinnabar still in coarser quartz, though —200. Dried concentrates from same tests were slightly ochreous, though 10B2 and 10B3 gave cleanest looking concentrates obtained from Goldbanks ore.

TESTS—Continued.

Character and behavior of froth	Heads assay value, % Hg.	Tailings Wt., grams	Tailings Assay value, % Hg.	Concentrates Wt., grams	Concentrates Assay value, % Hg	Indicated extraction %	Remarks
Froth deep, thick, persistent; bubbles coarse. Some gangue up. When baffle in spitzhasten was lowered, concentrate came cleaner. A larger cell would give a cleaner product, as it would allow gangue time to settle.	1.72	388	0.485	105	(f)	78	At 1300 r.p.m. At 20 min. belt broke, concentrate still coming.
Froth immediately on adding #750; deep, thick, persistent; bubbles coarse. After second addition of oil, much gangue up.	1.72	422	0.52	53	-------	70	At 13 r.p.m. Concentrate appears cleaner than without Cal. Cr.
Froth up immediately adding #750; deep, thick, persistent; bubbles, coarse. Concentrate clean, beautiful red. Froth thinner after adding more water.	1.72	450	0.50	53	11.08	71	At 1300 r.p.m. At 30 min. still raising concentrates.
Froth up immediately on adding #75; deep, thick, persistent; bubbles, coarse. By keeping baffle lowered, concentrate came cleaner. Concentrate not quite so clean looking as from 10B3, but showed more of a metallic luster. Froth thinner after more water.	1.72	425	0.275	76	9.10	84	At 1300 r.p.m. At 35 min. still raising a little concentrate.
Froth up immediately on adding oil. Deep, but not persistent; bubbles, medium. Some fairly clean concentrate. On adding more oil, NaOH and water, froth subsided; and no improvement till skimmed off what appeared to be film of oil on top. Then, deep and some persistent but raising gangue also.	0.14	430	0.035	66	-------	75	This ore contains ochre.
Practically no froth, with a few thin bubbles and a thin film of sulphide, until after increase of NaOH. Then a little froth and concentrate.	0.14	456	0.095	44	-------	32	
Froth thick, deep, persistent; bubbles, fine and medium.	0.14	422	0.03	73	-------	79	Raised some gangue.
Froth and concentrate immediately on adding oil. Deep, thick, persistent; medium bubbles.	0.14	450	0.03	50	-------	79	Raised some gangue.
Froth and concentrate immediately. Deep, thick, persistent; bubbles, coarse. Looked much the same as with thicker pulp. Some gangue also raised.	0.14	274	0.02	26	1.40	86	
Froth and concentrate immediately. Deep, medium thick, not persistent; bubbles, medium. Up again after second oil.	0.14	277	0.04	21	-------	73	At 30 min. still raising a little concentrate.
Froth and concentrate up immediately on adding #750. Deep, thick, some persistent; bubbles, coarse and medium. Better looking than without Cal. Crude.	0.14	268	0.025	29	-------	82	At 30 min. still raising a little concentrate.

DATA OF FLOTATION

Number of sample	Wt. of ore taken, grams	Mesh of samples	Oil used: Kind	Oil used: Amount: At start, cc.	Oil used: Amount: Total added later, cc.	Other reagent added: At start	Other reagent added: Total added later	Time of test, min.	Pulp ratio, water: ore
13A2	500	100	#3 Euc.	0.30	0.05	NaOH 5 cc.	------------	30	4:1
13A3	500	100	#3 Euc.	0.30	0.45	------------	------------	30	5:1
13A4	500	100	Calol B.	0.30	0.20	------------	------------	25	5:1
13A5	500	100	Calol B.	0.30	0.40	NaOH 5 cc.	5 cc.	25	5:1
13A6	500	100	#90 P.	0.40	0.20	------------	------------	25	4:1
13A7	500	100	#2 Euc.	0.40	0.20	------------	------------	30	4:1
13A8	300	100	#2 Euc.	0.30	0.10	------------	------------	25	8:1
15A2	500	100	#3 Euc.	0.30	0.80	------------	------------	35	5:1
15A3	300	100	#3 Euc.	0.30	0.70	------------	------------	35	8:1
15A4	500	100	Calol B.	0.40	0.60	------------	------------	35	5:1
15A5	300	100	#75 P.	0.30	0.40	NaOH 2 cc.	2 cc.	30	7:1
15A6	300	100	Cal. Cr. #75 P.	0.20 0.30	0.20 0.40	NaOH 5 cc.	------------	30	7:1
18A3	500	100	#2 Euc.	0.30	0.60	------------	NaOH 10 cc.	30	4:1
18A4	500	100	#750 P.	0.30	0.40	NaOH 5 cc.	------------	25	4:1

First figure in sample numbers refers to mine, as follows: #3, Ætna; #8, St. John's; #10, Goldbanks; #12 and 13, Bella Union; #15, Helen; #18, Sulphur Bank.

TESTS—Continued.

Character and behavior of froth	Heads assay value, % Hg.	Tailings Wt., grams	Tailings Assay value, % Hg.	Concentrates Wt., grams	Concentrates Assay value, % Hg.	Indicated extraction %	Remarks
Froth up immediately. Deep, thick, persistent; bubbles, coarse. Some gangue up also.	0.50	394	0.08	91	-------	84	At 5 min. belt broke. Restarted after 3 min. Some cinnabar visible in coarser sand.
Froth up immediately. Bubbles, both large and small but not as deep, nor as persistent as with NaOH. Concentrate cleaner.	0.50	463	0.095	33	-------	81	Some cinnabar visible on larger particles of sand.
Froth thin; medium bubbles; not persistent.	0.50	478	0.15	21	-------	69	Concentrate fairly clean.
Froth thin; medium bubbles; slightly more persistent than without NaOH. Raised some gangue.	0.50	476	0.115	23	-------	77	
Thick, coarse, tough, persistent bubbles. Froth, medium deep. Sulphide raised, but much gangue also.	0.50	463	0.175	34	-------	65	
Froth and concentrate immediately. Thick, deep, persistent; bubbles coarse. Some gangue up also.	0.50	453	0.095	40	-------	81	A little concentrate up before adding oil.
Froth and concentrate immediately. Thick, deep froth. Bubbles smaller and somewhat less persistent than thicker pulp.	0.50	263	0.085	32	3.92	83	
Froth up immediately, shallow to medium deep, some persistent; bubbles fine and coarse, tough. Clean looking concentrate. Froth deeper on adding more oil at 15 minutes.	1.75	429	0.29	63	-------	83	Some sulphide up before oil added, with Helen ore. Concentrates carry large per cent of pyrite. In tailings, cinnabar on coarse gangue.
Froth up immediately, shallow to medium deep. Fine bubbles swelling to large.	1.75	241	0.27	41	-------	85	
Practically no froth. A few large, not persistent bubbles. Much water (?) skimmed over.	1.75	318	1.32	173	-------	25	
Froth and concentrate up immediately on adding oil. Froth, shallow, thin, only slightly persistent; bubbles, fine and coarse. Cinnabar came up on top with pyrite just underneath.	1.75	264	0.33	29	15.84	79	At 1300 r.p.m. Concentrate appears to be fairly clean cinnabar and pyrite. In tailings, some pyrite; also cinnabar on coarser gangue.
Froth up immediately on adding #75: of medium depth, thickness, and persistence; bubbles, coarse to medium. Concentrate appeared of cleaner cinnabar; less pyrite visible, except towards end of test.	1.75	274	0.69	20	20.37	63	At 1300 r.p.m. At 30 min. still raising a little concentrate. Noticeably less pyrite in concentrate, than in preceding test. In tailings, much pyrite noted; also some cinnabar in coarser gangue.
Some froth before oil. After oil, froth thick, sticky, shallow, some persistent; bubbles, fine and coarse. Raising mainly gangue. On adding fresh oil, bubbles immediately became coarse and kidney-like but quickly subsided to small. No improvement on adding NaOH.	5.96	429	7.00	44	-------	?	The 'tailings' became 'concentrates' by elimination of part of gangue, while retaining cinnabar. A little cinnabar noted in dried froth.
Some froth before oil. After oil, froth medium thick, some persistent; coarse bubbles. Raised gangue, but apparently no cinnabar.	5.96	420	6.76	43	-------	?	(See preceding test.)

RESUMÉ OF FLOTATION RESULTS.

With the Ætna table tailings (Sample #3), the poor flotation results were at first attributed to the 'paint' cinnabar present. It was thought that the oils possibly had little affinity for the cinnabar in that form because of its not being distinctly of a metallic luster, or because the sulphide might have became coated with an oxidized film while exposed in the dump. Further tests, however, place the blame on the colloidal ochre of the gangue, large amounts of which were present. Colloidal slime seems to cover up or enclose the metal sulphides, thus preventing access of oil to them; or the colloids may react against the oil directly. The addition of caustic soda improves the situation, and permits a better recovery. This has also proven the case with ores other than those of mercury. C. S. Parsons[1] says:

"that the caustic soda, instead of flocculating the slime, deflocculates it. The mineral particles that were locked up in the floccule of slime are set free, which allows them to be more easily oiled. Before the caustic soda was added the oil had to penetrate the floccule of slime in order to reach the mineral particle."

In reply to Parsons, J. F. Mitchell—Roberts[2] referring to conditions at Tul Mi Ching, Korea, with a gold-copper ore, states:

"So far as present investigations have gone there appear to be few mineral particles in the colloidal slime in the ore, but without the addition of caustic soda the colloidal slime appears to have a greater affinity for coating the mineral particles than does the eucalyptus oil. * * *

"The addition of caustic soda to the circuit has entirely altered the settling properties of the pulp, the calcitic slime-aggregates or flocks remaining in suspension long after the other solids have settled out. To such an extent has this been the case that whereas in former tests an allowance of 6 sq. ft. per ton per 24 hours to obtain a clear overflow from a Dorr thickener was sufficient, 36 sq. ft. is necessary after the addition of two pounds of 72% caustic soda per ton of ore, in a pulp having a dilution of 3 parts water to 1 part of ore."

The writer, also, noted the slow settling properties of those pulps where caustic soda had been employed.

The best results obtained with this Ætna material in these experiments yielded only 62% indicated extraction, with a concentration of 19 to 1, and a concentrate assaying 5.40% mercury. The oil used was a combination of a California heavy crude petroleum and a heavy pine-tar oil, with caustic soda.

With the St. John's ore a fair percentage of extraction (86%) was obtained with a eucalyptus oil, and 78% with a crude wood turpentine; but the concentrate in the former case was low grade, carrying only 2.96% mercury, with a concentration of 6 to 1. In both cases considerable gangue was floated with the sulphide. No doubt more satisfactory results could have been obtained with this ore had time permitted further experimentation. The gangue has no noticeable ochre, being quartzose, with some calcite. With a pine oil, and with 'Zerolene', C. G. Dennis[3] obtained a good concentration on this ore:

"With an old ice cream freezer for apparatus he produced a heavy froth and a clean separation that promises well for commercial results with standard apparatus."

[1]Under 'Discussion': Min. & Sci. Press, Vol. 114, p. 222, Feb. 17, 1917.
[2]Min. & Sci. Press, Vol. 114, p. 362, Mar. 17, 1917.
[3]Editorial: Min. & Sci. Press, Vol. 109, p. 585, October 17, 1914.

On the Goldbanks ore, the best result was obtained using a combination of California heavy crude petroleum and crude wood turpentine with caustic soda, —200-mesh pulp and slower speed. An indicated extraction of 84% was obtained, with a concentration of 7 to 1, and a concentrate assaying 9.10% mercury. Fair results (70%–80%) were yielded with both pine tar and eucalyptus oils; also one of 85% extraction with a eucalyptus oil, but considerable gangue was also floated, so that the concentrate was low grade. Because of the physical condition of this ore, it would be necessary to *slime* it, in order to completely release all of the cinnabar. Examination of the flotation tailings with a hand lens revealed the presence of cinnabar still on pieces of the gangue, though crushed to — 200 mesh.

The Bella Union dump material was ochreous, but to a lesser degree than that of the Ætna mine. The best result, 86%, was obtained with a eucalyptus oil and caustic soda, in a thin pulp (8:1), yielding a concentration of 11 to 1 and a concentrate assaying 1.40% mercury. On the fresh ore from the Bella Union underground workings, higher average results were obtained than with the dump material, partly due to its being of higher grade and partly because it contained no ochre. Eucalyptus oils gave fair results with both thin and thick pulps. Tests on ore from the Bella Union mine were made by Hamilton, Beuchamp & Woodworth of San Francisco. Mr. Woodworth informed the writer that over 90% extraction was obtained by crushing to — 40 + 80; floating with a combination of crude petroleum and a heavy pine-oil product, to recover the slimed cinnabar; then concentrating out the coarse cinnabar on a table. Flotation was placed before tabling rather than after, as it avoided the necessity for de-watering. In their experiments, water from the mine was utilized as it would have to be employed in a commercial plant there. This mine water has an acid reaction, and they tried neutralizing it with lime, with unfavorable results. They were able, finally, to get a satisfactory recovery without neutralizing the slight acidity of the water. Thick pulp yielded better results than thin; though Woodworth stated that sometimes cinnabar gave remarkable results in thin pulps. He also stated that they had found that a combination of crude wood turpentine with a crude asphalt-base petroleum would select cinnabar in preference to pyrite from a mixture of the two. This was verified by the writer with the Helen mine ore. (*q.v.*)

Some flotation tests were made by R. L. Beals[4] on a sample of ore from the Bella Union mine carrying about 0.7% mercury. The results of three of his tests with a Hoover type laboratory machine were as follows, the assays of his products having been made by the writer:

"A—500 grams ore, 3000 c.c. water

Concentrate #1, 11.2 grams	17.5 % Hg
Concentrate #2, 11.9 grams	1.72 % Hg
Tails +100 mesh 60 grams	0.075% Hg
Tails —100 mesh 230 grams	0.05 % Hg
Tails unscreened 150 grams	0.075% Hg

"B—500 grams ore, 3000 c.c. water
Oil—10 drops of following mixture:
20 c.c. Whittier Fuller Pine Oil
5 c.c. Calol A
15 c.c. Calol C

Concentrate 18.2 grams	10.28 % Hg
Tails 50 grams	0.115% Hg

"C—500 grams ore, 3000 c.c. water
15 drops oil mixture used in B
15 drops pine oil

Concentrates 6.1 grams	32.88 % Hg

Tailing not assayed.

"The idea of the tests was to see how clean a tailing and how high a concentrate could be produced the same to be obtained in a plant by the proper arrangement of machines."

He noted that in flotation of low-grade material the best work was not done until a fair grade of concentrate had been built up, so as to "have some body of sulphide to float." In a commercial plant this would be accomplished by the continuous process with several cells in series.

A complete chemical analysis should be made of a material containing so many active chemical constituents as does the Sulphur Bank ore, before one attempts to work out an ore-dressing or metallurgical scheme for it. The cinnabar occurs to a considerable extent mixed with native sulphur in the leached basalt in the lower zone of oxidation, though the principal deposits are below this level. It is associated also with much silica, in part amorphous. As to the solfataric springs at the Sulphur Bank, Becker[5] says:

"The gases escaping from the waters are carbon dioxide, hydrogen sulphide, sulphur dioxide, and marsh gas. The waters contain chiefly carbonates, borates, and chloride of sodium, potasium and ammonium; but alkaline sulphides are also present."

As already noted herein, the moistened material of this sample tested, showed an acid reaction with litmus paper. Only two flotation tests were made on this ore, both with negative results. Practically only gangue material was floated, resulting in the residue yielding a higher mercury content than the heads assay showed.

With the Helen mine ore, the writer obtained fair results with both eucalyptus and pine oils. The highest extraction, 85% was with a eucalyptus oil, giving an 8 to 1 concentration, but the concentrate carried considerable pyrite. A cleaner concentrate, assaying 15.84% mer-

[4] Personal communication to the writer.
[5] Becker, G. F., Geology of the quicksilver deposits of the Pacific Slope: U. S. G. S. Mon. XIII, p. 463, 1888.

cury, was obtained with #75 Pensacola oil (crude wood turpentine) in a 10 to 1 concentration at 79% extraction. The cleanest concentrate, 20.37% mercury, was obtained with a combination of #75 Pensacola and California crude petroleum, yielding a 15 to 1 concentration but only 66% extraction. This concentrate contained visibly less pyrite than those from all other tests made by the writer on the Helen ore. This combination of crude wood turpentine and an asphaltic base crude petroleum, therefore, has a preferential selective action for cinnabar in the presence of pyrite.

The tabulation herewith gives some results selected from a somewhat larger number of tests made by T. D. Kirwan[6] on this same sample of Helen mine ore, with the Hyde machine. The oils there noted as having been employed by him, in addition to those used by the writer, were: 226 Pensacola, a pine oil; Union Oil Co., San Francisco, Cal., 'corrosive flotation oil'; Standard Oil Co., Richmond, Cal., Calol flotation oils 'A', and 'C', both compounded oils, mainly mineral, with some pine products; General Naval Stores Co., New York, N. Y., #8 flotation oil. In his conclusion, he states:

"* * * it would be advisable to crush the ore in all cases to at least 80 mesh. In some cases it would be well to crush to 100 mesh, this depending more or less on the oil used. Crushing above 100 mesh does not seem to increase appreciably the percentage of extraction. * * *

"Distinctly acid solutions injure the results.

"It is interesting to find that over 70% of the cinnabar constituent of the ore can be floated without the aid of a frothing agent. Air was allowed to be sucked into the bottom of the pulp as in the other tests.

"* * * tailings were not re-treated. * * *

"As previously stated, the ore contains considerable pyrite, consequently the concentrates are largely made up of this mineral."

The higher average percentages of extraction in Kirwan's tests as compared to the author's with the same ore and oils may be creditable to the sub-aëration utilized in the Hyde machine. A similar attachment could be added to the Case unit. Sub-aeration is employed in the Minerals Separation Co. machines.

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[6]Kirwan, T. D., Concentration of Cinnabar by Flotation: Unpublished. A thesis presented "in partial satisfaction of the requirements for the degree of B. S. in Mining Engineering." University of California, May, 1916.

Recapitulation of Tests on Helen Mine Ore by T. D. Kirwan.

Test No.	Weight of ore, grams	Mesh	Oil used	No. of drops: At start	No. of drops: Later added	Minutes agitation	Character of froth	Weight of concentrate, grams	Weight of tailings, grams	Total weight, grams	Degree of concentration	Per cent extraction
19	300	100	None			20	b, c, d, g, h	11.6	281.2	295.8	25.9	72.5
25	300	100	None			20	b, c, d, g, h	21.9	271.5	296.4	12.0	73.2
26	300	150	None			25	b, c, d, g, h	11.7	285.5	297.2	25.6	70.8
46	300	200	None			25	b, c, d, g, h	15.0	253.6	298.6	6.7	60.1
27	300	100	None + H_2SO_4	40 H_2SO_4		20	b, c, e, g, h	16.2	281.3	297.5	18.5	11.8
28	300	100	None + NaOH	20 NaOH		20	a, c, d, g, h	32.6	266.3	298.9	9.2	83.6
52	300	60	Denatured alcohol	20 alcohol		25	b, c, d, f, h	16.0	278.6	294.6	18.7	61.2
45	300	100	Denatured alcohol	30 alcohol		20	a, c, d, f, h	26.1	270.8	296.9	11.5	90.1
10	300	100	Union Oil Co.	10		20	b, c, e, f, h	36.4	261.6	298.0	8.2	87.9
41	300	80	Calol B.	10		25	a, c, d, f, h	19.3	277.4	296.7	15.5	87.6
21	300	100	Calol C.	10		20	a, c, d, e, g, h	28.4	269.0	297.4	10.6	86.5
32	300	100	#1 Euc.	10		20	a, c, e, f, (i?)	37.1	258.3	295.7	8.0	87.5
31	300	100	#2 Euc.	10		20	a, c, e, f, (i?)	29.8	265.8	295.6	10.1	85.2
33	300	100	#3 Euc.	10		20	b, c, d, f, i	20.8	268.1	288.9	14.4	89.0
34	300	100	#8 Gen. Nav.	10		20	a, c, e, f, i	47.0	251.3	298.3	6.4	88.3
8	200	100	#15 P.	10		20	b, c, d, e, g, (i?)	32.3	265.3	297.6	9.3	90.6
12	300	100	#75 P.	10		20	b, c, g, h	28.2	265.3	293.5	10.6	87.7
15	300	100	#75 P.	10		20	b, c, e, g, h	14.2	282.7	296.9	21.1	81.7
12	300	80	#75 P. + NaOH	10–20 NaOH	5	25	a, c, d, f, h	32.8	266.4	299.2	9.2	90.1
35	300	80	#226 P.	10	4	25	a, c, d, e, f, i	41.2	247.3	288.5	7.3	85.3
11	300	100	#750 P.	15		20	a, c, d, f, i	96.6	197.8	294.1	3.1	93.1
21	300	100	#1580 P.	10		20	b, c, e, g, h	33.2	262.8	297.0	0.0	85.3

Character of the froth: a, voluminous; b, sparingly; c, watery; d, coarse bubbles; e, fine bubbles; f, tough; g, brittle; h, temporary; i, permanent.

In actual, large-scale flotation practice on ores other than those of quicksilver, commercial results in general have shown an improvement of 3%–5% in the total extraction as compared to the laboratory test results. Also, oil consumption is less, especially if the water used be clarified and returned to the circuit. It seems to be not possible in most cases to get both a clean tailing and a clean concentrate at a single operation with a laboratory machine. One may be obtained at the expense of the other. One or both must be retreated to obtain the final, desirable product. In commercial plants, several cells or units are operated in series, so that by the time the pulp emerges from the lower end it is supposedly 'clean'; and, in addition to this, a portion at least of the concentrates may be recleaned. Water utilized at the mine should be employed in the tests. In their admirable paper on laboratory flotation manipulation, Ralston and Allen[7] have called attention to some of these eccentricities, if they may be so termed:

"None of the literature mentions the fact that it is difficult to get a high percentage of extraction and a high grade of flotation concentrate at the same time. * * * It is difficult to manipulate a small machine to give as good results as a large one, until after considerable practice. So the small machine is generally pessimistic, compared with the large one. * * *

* * * * * * *

"Beginners are likely to dilute their froth with too much gangue. In a large-sized machine the froth can travel over from four to eight feet of spitzkasten before it is discharged, while in this test-machine [Janney] it only has a travel of about 10 inches. Consequently, the small machine is liable to yield concentrate of too low a tenor. The same applies to most other machines for making tests on flotation.

* * * * * * *

"If it is so desired, this rough concentrate can be put back into the machine and treated in the same way as the original sample, or the concentrates from several tests combined to give enough material for retreatment. If this is done three products are made, namely:

"A 'rougher' tailing, to waste.

"A clean concentrate, for shipment [or for immediate retorting in the case of cinnabar].

"A 'cleaner' tailing or middling, which in actual practice is returned to the head machine.

"When these conditions are observed results only slightly lower than those possible with a big machine can be obtained. A test can be run in from 5 to 30 minutes in such a machine with 500 grams of ore in anything from a 3:1 to a 5:1 pulp. * * * Clean tailings generally mean only medium-grade concentrates due to entrainment of gangue in the removal of all the mineral.

* * * * * * *

"As a rule laboratory machinery for the pulverization of ore is of the dry-grinding type, with the exception of small ball-mills that can crush from 1 to 100 lb. charges in the wet. Consequently, most people start with weighed charges of finely-ground dry ore, a known quantity of water, of oil, and of acid or alkali. * * * In nearly all laboratory work finer grinding than is used in practice seems to be necessary. This may possibly be due to the smaller amounts of froth that are formed. Such small quantities of froth can not form layers as deep as those made in the large machines. If a big particle of sulphide can be entrained with a number of smaller particles, it can be floated, but with a thin froth the chance of such entrainment would seem to be less. Some experimenters have informed us that they were able to float even as large as 30-mesh material, but our own experience is that 60-mesh material is often hard to float with any chance of getting a high extraction, while the operation is performed with much more ease and expedition when the ore is crushed somewhat finer.

"Wet grinding is more desirable, as it parallels conditions in practice, where most of the finer grinding of ore is in Chilean, tube, and other mills. However, wet grinding is harder to manipulate in a small laboratory and requires more time. * * *

"The measuring and testing of flotation-oils in the laboratory has been very inexact in many instances witnessed by us. It is common practice to count the number of drops of oil falling from a small piece of glass tubing. We are using a Mohr pipette of 1 c.c. total capacity for measurement of the amount of oil used in each test. * * * This pipette allows measurement of the oil to the nearest 0.01 c.c.

[7]Ralston, O. C., and Allen, G. L., Testing ores for flotation process: Min. & Sci. Press, Vol. 112, pp. 8 *et seq.*, 1916.

which is as close as will ever be desired. If the density of the oil is known, the volume as measured by this method is quickly converted into the weight of oil used * * *.

"Many reports of flotation test-work with mechanical-agitation machines give the speed of the rotation of the agitating-blades. We have found that it was possible to get much the same work done with quite a variation of speeds, the only effect being to lengthen or shorten the time of treatment. We feel that the importance of this matter has been much exaggerated. Some means of speed-control is necessary and the speed can be adjusted in each case until the froth presents the proper appearance as to depth, size of bubbles, color, etc. Speeding towards the end of a test in order to give a deeper froth with a faint line of concentrate on the very top is often advisable. We recommend adjusting the speed in each test to suit the other conditions, rather than running a series of tests with different speeds. * * *

"When a good set of conditions has been found for the flotation treatment of an ore, it is best to recover the water from each test to see what effect a closed circuit of the mill-water will have. Some oil and chemicals are thus recovered, cutting down the amounts necessary for operation. In fact, a car-boy or two of the water to be used in the large mill should be used to make certain that no deleterious contamination will ensue from this source. Under these conditions filtration for recovery of the water is necessary. * * *

"Finally, it is well to be prodigal in the amount of analytical work connected with flotation testing in order to discover interesting differences in gangue-constituents carried into the concentrate, as well as to find the best conditions for leaving out some gangue constituent that is less desirable than the rest. If an experimenter does his own analytical work he can be expected to spend three-fourths of his time analyzing what has been done during the other fourth."

EXTRACTION OF MERCURY BY SOLUTION WITH $Na_2S + NaOH$.

The solubility of mercuric sulphide in alkaline sulphide solutions has been known to experimental and industrial chemists for more than 100 years. The preparation of vermilion in the wet way, as described by Kirchoff[1] in 1799 is based on these reactions. Becker[2] reviews somewhat in detail the literature relative to such solubility, and also describes a series of experiments made in his own laboratory along the same lines. These were carried out with a view mainly of shedding light on the source and nature of the solutions which brought about the deposition of the cinnabar ore-bodies found in nature. Obviously, such data would also be of value in an investigation of the reverse of the deposition,—that is, the re-solution of the precipitated cinnabar for its commercial recovery. He states that the solubility of HgS in $Na_2S + NaOH$ solution depends on the quantity of Na_2S present, not that of NaOH, so long as there is even a small amount of the free caustic hydrate present.[3]

"A very small quantity only of the hydrate is sufficient to secure to the alkaline sulphide its maximum solvent power over mercuric sulphide. * * * The greater part of the experiments made to test the maximum solubility of HgS in Na_2S in the presence of NaHO shows that the relation of the weights of the two substances is very nearly in the proportion of one molecule of HgS to two molecules of Na_2S."

In the practical application, of course, a slight excess is necessary over this theoretical proportion.

Among the more recent of detailed research experiments related to mercury sulphide, solution and crystallization, is the work of Allen and Crenshaw[4] of the Geophysical Laboratory, Washington, D. C. They state:[5]

"Any form of mercuric sulphide dissolves readily in concentrated solutions of sodium (20% Na_2S and K_2S were actually used) or potassium sulphide. * * * The alkali sulphides form with mercuric sulphide two compounds. $HgS.2M_2S$ and $HgS.M_2S$."

According to Schnabel and Louis,[6] these double sulphides contain

"variable quantities of water according to the temperature and the concentration of the solution. A portion of these double sulphides is soluble in water in the presence of caustic alkalies, but at a certain degree of dilution is decomposed again into its constituents."

Some other proposed wet methods for the extraction of mercury are described by Schnabel and Louis,[7] including the method of Sieveking[8] which involves treatment of cinnabar with a solution of cuprous

[1]Kirchhoff, G. S. C., in Allg. Jour. der Chemie, Scherer, Vol. 2, p. 290.
[2]Becker, G. F., Geology of the quicksilver deposits of the Pacific Slope; U. S. G. S. Mon, XIII, pp. 419-437, 1888.
[3]*Idem*, p. 422.
[4]Allen, E. T. & Crenshaw, J. L., the sulphides of zinc, cadmium and mercury; their crystalline forms and genetic conditions: Am. Jour. Sci., Vol. XXXIV, pp. 341–396, Oct. 1912.
[5]*Idem*, p. 368.
[6]Schnabel and Louis. Handbook of Metallurgy, Vol. II, 2d ed. 1907, p. 332.
[7]*Idem*, p. 439.
[8]Oesterr. Zeitschr. 1876, No. 2; Berg- und Hüttenm. Ztg., 1876, p. 161.

chloride in the presence of a granulated alloy of copper and zinc; also the method of Wagner,[9] which involves the use of bromine water and hydrochloric acid.

The following tabulation by Abegg[10] gives the relative solubilities of the black ('schwarz'), amorphous mercuric sulphide and of cinnabar in various strengths of Na_2S solution, at 25°:

Mol.* Na_2S	1.5	1.0	0.75	0.5	0.375	0.15	0.1
Mol. HgS (schwarz)	--------	0.46	0.31	0.175	0.111	0.023	0.011
Mol. HgS (zinnober)	0.75	0.42	0.27	0.15	0.092	0.018	0.0086
HgS (schwarz) / Zinnober	--------	1.09	1.12	1.19	1.21	1.30	1.29
Na_2S : zinnober	2:1	2.04:1	2.8:1	3.3:1	4.1:1	8.3:1	11.6:1

*'Mol.' means gram-molecule.

EXPERIMENTAL DATA.

In the writer's experiments, a 10% solution was made up, with 'Baker's Analyzed' $Na_2S.9H_2O$ crystals (moleculer weight 240.3). The NaOH solution used was also 10% being the laboratory reagent, of 100 gm., c.p. NaOH per liter. The ore samples were ground to —200 mesh, and a 10-gram charge taken in each case. In Test A, each was agitated with 20 cc. Na_2S and 0.5 cc. NaOH, for 20 minutes in a test-tube, then filtered and washed with three changes of distilled water. Total time of contact of solution on the ore was approximately one-half hour. In Test B, each was agitated with 20 cc. Na_2S and 0.5 cc. NaOH for 5 minutes, then filtered, washed once with 5 cc. Na_2S and finally with three changes of distilled water. Total time of solution contact 15 minutes. In Test C, each was agitated with 20 cc. of 5% Na_2S (10 cc. diluted to 20 cc.) and 0.3 cc. NaOH for 5 minutes, then filtered and washed successively with Na_2S and water. Total time of solution contact 15 minutes. The following tabulation summarizes the results:

Heads, per cent Hg.	Test A			Test B			Test C		
	Sample*	Residue per cent Hg.	Per cent extraction	Sample	Residue per cent Hg.	Per cent extraction	Sample	Residue per cent Hg.	Per cent extraction
1.39	7A2	0.31	78	--------	--------	------	--------	--------	------
0.49	8A8	0.05	90	8A9	0.095	81	--------	--------	------
0.31	9A2	0.02	94	9A3	0.015	95	9A4	0.12	69
1.72	10B5	0.05	97	10B7	0.36	79	10B8	1.16	33
0.14	12A9	0.02	85	12A10	0.02	85	12A11	0.08	43
0.50	13A9	0.02	96	13A10	0.05	90	13A11	0.21	58
1.75	15A7	0.97	45	--------	--------	------	--------	--------	------

*7A, Esperanza mine; 8A, St. John's; 9A, Cambria; 10B, Goldbanks; 12A, Bella Union dump; 13A, Bella Union mine; 15A, Helen.

[9] Wagner, R.: Dingler, Vol. CCXXVIII, p. 254; Chem. Centralblatt, 1878, p. 711.

[10] Abegg, R.: Handbuch der Anorganischen Chemie, Vol. II, Pt. 2, p. 632, 1908.

In nearly all cases, more or less of a greenish-black colloidal precipitate of iron sulphide was formed. It was especially noticeable with 12A (due to the ochre) and in 7A and 15A (doubtless due to the presence of soluble iron compounds, though there was no ochre in either. Both contained considerable serpentine).

A piece of aluminum plate placed in the filtrate from 10B5 showed small globules of metallic mercury reduced upon it in a few minutes time. Some bright zinc shavings placed in the filtrate from 10B7 showed no reaction up to 48 hours.

In addition to the above, 10 grams of #10B was agitated with 20 cc. of a saturated solution of Na_2S and 1 cc. NaOH, for 10 minutes; then filtered and washed with one change of water. Total time of solution contact approximately one-half hour. A large amount of the colloidal, black sulphide was precipitated, and made filtering very slow. The residue asayed 0.18% mercury, or an extraction of 90%. Evidently the residue was not completely washed, as it showed more mercury than the test with 10% Na_2S. A test was also made on a sample of Sulphur Bank ore (#18A2), — 150 mesh, with 20 cc. 10% Na_2S and 0.5 cc. NaOH, agitated 10 minutes; then filtered and washed with two changes of solution and three of water. The residue showed no extraction, though the sample carried 6% mercury; but there was an abundant, black, iron sulphide precipitate, which apparently took up all of the available Na_2S in the solution. Possibly this might have been obviated by a preliminary water-wash of the ore. As noted under the flotation experiments, a complete chemical analysis should be made of such a material, to intelligently work with it.

With longer solution contact than given in the above tests, even fairly coarse, crystalline cinnabar will be dissolved. Some — 80-mesh concentrate (from Helen mine ore) left standing without agitation in a test tube was completely dissolved after three days. The pyrite present was apparently not affected.

PRACTICAL APPLICATION OF THE Na_2S SOLUTION METHOD.

Though it has been suggested at various times, to date there has been no application of this method on a working scale to natural mercurial ores. In 1911, Mulholland[11] proposed to fine grind the ore in a ball mill with the solvent—alkaline sulphide containing free alkaline hydrate; and to recover the dissolved mercury by adding zinc hydrate in excess to the filtered solution,

"when zinc sulphide and mercuric sulphide are precipitated." * * * The barren solution may be regenerated by H_2S. "The mixed precipitates are * * * treated with dil. H_2SO_4 and steam," H_2S being evolved. "On treatment with H_2SO_4, zinc sulphide goes into solution as zinc sulphate, and there remains behind a mixture of mercuric sulphide and metallic mercury. This precipitate is mixed with lime and iron turnings and distilled in a retort in the usual way. * * * It is, of course, possible to treat the sulphide liquors containing the mercury by electrolysis, when

[11]Mulholland, C. A., Treatment of low-grade cinnabar ores; Australian Mg. St'd. June 8, 1911, pp. 565 *et seq.*

mercury will be deposited on the cathode; and the solution will be converted partly or wholly into alkaline sulphate, sulphite, and thiosulphate;" but "cost of current and chemicals would be high."

"It is not altogether possible from small scale experiments to predict the cost of chemicals. * * * of a necessity, tentative * * * give * * * a rough idea of the character of the costs."

He estimates operating costs (here converted to U. S. currency), to be as follows, assuming an ore of 0.3% mercury, a friable sinter, 80% efficiency extraction (net value \$3.06 per long ton, on basis of \$43.75 per flask for quicksilver), 100 long tons per day handled, mining and crushing costs low:

	Per ton
"Mining and ore delivered to works	\$0 60
Crushing, lixiviation and distillation	0 84
Cost in chemicals	0 36
Technical costs	\$1 80

"This leaves \$1.26 per ton to cover remaining costs, and will give a reasonably good profit on the tonnage basis given."

"The advent of improvements in the mechanical handling of large bodies of wet materials, invented by metallurgical engineers of the cyanide process, brings the author's method well within the bounds of practicability."

Later[12] in a discussion of the reactions involved, he contends:

"a proper concentration of sodium sulphide and alkaline hydrate being necessary to the complete dissolution of HgS: the reaction outlined may be thus represented:

$$2\ Na_2S + HgS + H_2O \rightleftarrows Na_2\ HgS_2 + NaSH + NaOH$$

"Under varying conditions of dilution and temperature the reaction is reversible; hence the necessity for carefully determining these points by actual tests on the ore to be treated."

Various other investigators[13] have stated the reaction to be represented by the equation:

$$HgS + Na_2S = HgS.Na_2S$$

or by:

$$HgS + 2Na_2S = HgS.2Na_2S.$$

The only commercial application of these reactions, of record to date, is that at the Buffalo Mines, Cobalt, Ontario, Canada, and described by Thornhill[14] in 1915. In this case, however, the process is utilized to recover an artificial mercurial product. In the amalgamation of high-grade silver ores and concentrates in strong cyanide solution, as practiced there, the quicksilver losses proved to be rather high. Chemical investigations revealed the fact that in addition to a certain loss due to flouring, very appreciable amounts of quicksilver were converted to the sulphide by the grinding contact with the silver sulphides. (The writer has seen mercuric sulphide formed, in the laboratory, by grinding quicksilver and flour sulphur together in an agate mortar, dry.)

[12] Mulholland, C. A., Wet method of mercury extraction: Min. & Sci. Press, Vol. 111, p. 346, Sept. 4, 1915.

[13] See below, and p. 321, *ante*.

[14] Thornhill, E. B., Wet method of mercury extraction: Min. & Sci. Press, vol. 110, pp. 873-874, June 5, 1915; also, Recovery of mercury from amalgamation tailing: Am. Inst. Min. Eng., Bull. 104, pp. 1653-1657, 1915; and Min. & Sci. Press, vol. 111, pp. 211-212, Aug. 7, 1915.

[15]"The process developed at the Buffalo mines for this purpose consists in leaching out the mercuric sulphide with a caustic alkaline sulphide solution, then precipitating the mercury from solution with metallic aluminum. The equations for solution (1), and precipitation (2) are:

$$HgS + Na_2S = HgS.Na_2S \qquad (1)$$
$$3\ HgS.\ Na_2S + 8\ NaOH + 2\ Al = 3\ Hg + 6\ Na_2S + 2\ NaAlO_2 + 4\ H_2O \qquad (2)$$

"Small-scale experiments showed that a complete extraction of the mercuric sulphide could be made by an 8 to 10 min. treatment of the residue with the alkaline sulphide solution. Advantage was taken of this fact in the commercial plant, by applying the solvent to the residue on the filter-leaf, as no agitation of any sort was required.

"The operation of the commercial plant is essentially as follows: The residue in the pregnant cyanide solution is caked on a Moore filter-leaf of the usual construction and the cake washed free of silver solution with water. The basket is then lowered into the sodium sulphide solution and this solution drawn through the cake until the effluent shows only a trace of mercury. Usually 1 ton of solution per ton of residue is sufficient. This mercuric sulphide solution is pumped to a precipitating-tank and the mercury thrown down by adding granular aluminum to the agitated solution. Agitation is then stopped, the precipitate allowed to settle, and the clear solution decanted. The precipitate of mercury is then run into a small wash-tank by sweeping it through a hole in the bottom, by means of a raking mechanism similar to a Dorr thickener, pieces of old rubber belting being riveted to the bottom of the rakes. The precipitate is then washed with water by decantation and drawn off into a steam drying-pan. After drying, the fluid mercury and the powdered metallic portion are separated by raking the latter off with a hoe. The fluid is strained through a canvas and is ready to return to the circuit. The powdered material, containing approximately 75% mercury, is then retorted, and the mercury condensed in the usual manner.

"The strength of the solvent is kept up to 4% sodium sulphide and 1% sodium hydroxide. Weaker solutions can be used with equally good results, but the quantity required was found to be directly proportional to the strength; that is, with a 4% sodium sulphide solution, 1 ton of solution would extract the mercuric sulphide from 1 ton of residue, but if a 2% solution was used, 2 tons would be required per ton of residue treated. The concentrated solution offers the advantage of less solution to handle and an economy of aluminum in the precipitation. The sodium sulphide used is the commercial salt costing $1.25 per cwt. in barrels f. o. b. cars Toronto.

"The precipitant used is a waste product of aluminum-casting foundries, containing 75% aluminum, the impurities consisting of varying proportions of copper, silica, wood, waste, grease, etc., the grease being burned off before using the aluminum. About ¼ lb. of this material is used per pound of mercury precipitated.

"It was anticipated that the sodium aluminate would accumulate in the solution to such an extent that some special means would have to be taken to remove it. This, however, has not been the case. Some aluminum, as hydrate, falls with the mercury on precipitation, and some is removed during the process of leaching, presumably as calcium aluminate, which collects on the filter-cake. This precipitation of the aluminum regenerates caustic soda so that the consumption of this chemical is reduced to 1/10 lb. per pound of mercury recovered, instead of ½ lb. as shown by the theoretical equation for precipitation. Sodium sulphide is also regentrated in precipitation, but there is also a mechanical loss of approximately 20% of the solution used in leaching, as no water is used to recover the retained sulphide.

"From May, 1914, to March, 1915, 37,650 lb. of mercury has been recovered at a cost of approximately 13c. per pound for labor and chemicals.

* * * * * * *

"The strength of the sodium sulphide solution is determined by titrating against a standard zinc chloride solution, using sodium nitro-prusside as an outside indicator.

"The mercury produced by this process is of exceptional purity."

In his earlier paper noted,[16] he remarks:

"With a clean cinnabar ore, the mercury would be obtained wholly in the fluid form without retorting, and by straining through canvas it would be made ready for market.

"The cost of installation should not exceed $500 per ton of capacity." Standard cyanide equipment would be utilized. Quicksilver could be placed on the market in 3 to 4 days after the plant starts.

The last-named feature would be a distinct advantage over the furnace mode of having to wait weeks and even months for the plant to reach a state of 'saturation.' (See p. 243, *ante*.)

Mr. H. G. S. Anderson, who was associated with Thornhill in the work at Cobalt, Ontario, has since made numerous experiments with

[15]Thornhill, E. B., Recovery of mercury from amalgamation tailing: Min. & Sci. Press, vol. 111, p. 211, Aug. 7, 1915.

[16]Thornhill, E. B., Wet method of mercury extraction: Min. & Sci. Press, vol. 110, p. 873–874, June 5, 1915.

this process on cinnabar ores, and has very kindly furnished the author with a statement relative to his results, which is incorporated herein:

"This double salt of mercury sulfid and sodium sulfid is unstable in solution except in the presence of caustic soda, hence the presence of the latter is necessary in order to hold the former in solution.

"The addition of metallic aluminum or chromium to a solution of the double salt of mercury sulfid and sodium sulfid will precipitate metallic mercury, regenerate sodium sulfid, and dispose of the aluminum and chromium as aluminates and chromates.

* * * * * * *

The addition of lime precipitates the aluminate as an insoluble calcium aluminate and regenerates caustic soda. In a simple hydrolysis the sodium aluminate will break up regenerating caustic soda and aluminum hydrate.

"Theoretically, one (1) pound of aluminum will precipitate eleven (11) pounds of mercury, but practically one (1) pound of aluminum will precipitate seven (7) pounds of mercury due to the fact that some hydrogen is given off during the precipitation.

Interfering Elements.

"Limonite, or iron hydrate, in excessive amounts precipitates the sulfur from the solvent and causes losses of the latter.

"Sulfid of antimony reacts in the same manner as does cinnabar, but the metallic antimony will not contaminate the precipitated mercury since the antimony will float on the fluid mercury and may be separated from the latter by skimming off the black amorphous precipitate of antimony.

"Sulfid of arsenic will form sodium arsenate. The arsenic is not precipitated out of the solution by either of the foregoing precipitates and hence consumes the solvent.

"If any or all of the foregoing interfering elements are not present in excessive amounts the loss of the solvent, due to their presence, will not be great.

Proposed Methods of Recovering Mercury from Cinnabar Ores.

"A reduction plant to recover mercury by this means would be similar to a mill for cyaniding gold and silver ores excepting agitators, which would not be necessary. The similarity may be made more apparent when it is considered that the reduction of the ore will be made in the same manner, but instead of employing cyanide for dissolution and zinc for precipitation, sodium sulfid and caustic soda is used for dissolution and aluminum for precipitation; agitation in separate tanks seems to be unnecessary.

* * * * * * *

"I have made numerous experiments on cinnabar ores from California, Nevada, and Arizona, and find that when the interfering elements before mentioned are not in too large amounts, these ores would be commercially amenable to such a method of extraction.

* * * * * * *

"The following figures give the results of two such tests:

"NEVADA CINNABAR COMPANY, IONE, NEVADA:

Percentage of Mercury in Ore	0.7%
Strength of Solution, Sodium Sulphide	1.0%
Strength of Solution, Sodium Hydroxide	0.5%
Pulp Ratio	1 of ore to 3 of solution
Time of Treatment	20 to 60 minutes
Fineness of Ore	40-mesh
Percentage of Extraction	96%

"ARIZONA CINNABAR ORE, FROM MATZATZAL MOUNTAINS:

Percentage of Mercury in Ore	1.0%
Strength of Sodium Sulphide Solution	1.5%
Strength of Caustic Soda Solution	0.5%
Pulp Ratio	1 of ore to 2½ of solution
Time of Treatment	30 minutes to 1 hour
Fineness of Ore	40-mesh
Percentage of Extraction	97%

"You will note that the extractions have been 96% and 97%.

"The recovery has been and would be a percentage or two lower, due to the loss of dissolved values along the lines of losses in cyanidation."

In the course of some correspondence[17] relative to comparative costs of the wet method and the Scott furnace, Anderson wrote:

"The advantages of reducing [mercury] ores by a wet process will be as follows:

(1) First cost of plant from 35% to 50% of that of a Scott furnace of the same capacity.
(2) Low cost to treat per pound of mercury produced.
(3) Higher extraction possible.
(4) Ability to work ores of a lower grade.
(5) No danger of salivation to workmen.
(6) Less time to make the original installation.
(7) No mercury absorbed or tied up in dust chambers or furnaces.
(8) No shut-downs to clean up dust chambers or furnace.
(9) Purer mercury than by the furnace method.
(10) Mercury 'in process' for shorter period. (1 to 5 days.)

* * * * * * *

[17]With E. W. Carson, in November, 1915. See also p. 214, *ante;* and reproduced in part here with the consent of both parties.

"On a basis of a 100-ton plant working on a 10-pound-per-ton mercury ore, we estimate that the cost of production will be approximately ten cents (10¢) per pound for the metallurgical treatment only; the mining will, of course, be independent of the milling cost. This includes all costs, overhead, etc. We have recovered about 60,000 pounds of mercury in Canada during the past 18 months at a cost of 18¢ per pound but have treated only a small tonnage daily and there has been a large chemical loss due to the ore or rather concentrate containing from 20% to 25% arsenic, 5% cobalt and nickel, and 5% antimony together with varying amounts of other metals. The mechanical loss was also larger than it should have been due to arrangement of filters. While it is not proper to attempt to make a direct comparison in costs with the plant in Canada, still it acts as a check on estimates.

* * * * * * *

"The costs as shown by your operations are from two to three cents less than my estimates of the cost for treating by the wet method. Not taking into consideration the difference in extraction, the furnace method shows a less cost per pound produced on your grade of ore than what I think can be done by the method I have outlined; however, the additional extraction will offset this difference in costs. For instance, on a basis of 50¢ per pound mercury, an additional extraction of ¾ lb., which is entirely probable, will entail a charge against a furnace method of $37.5 \div 10 = 3.75$¢ per pound, bringing up the real cost of the furnace product to 7.44¢ + 3.75¢ = 11.19¢ per pound on a 10 lb. ore. Nevertheless, your figures are facts and mine are estimates, although I am certain that I am within the limits. Since receiving your letters, I am inclined to be pleased that my estimates are so close to the figure that it is actually costing to produce in a vicinity which I presume has the lowest costs of any in this California field. I should venture the opinion that your location being favorable would be inducive to lower cost for labor and supplies.

"I am submitting for your perusal my estimates of the different operating cost items which would prevail in a mill using the wet method, these being outside figures. While fine grinding would be necessary, it will not be relatively as costly as in the case of such reduction for cyanidation of gold and silver ores, for the reason that we have found that the leaching action is relatively fast and the cinnabar seems to be exposed to the action of the solvent before it (the ore) is ground to the same degree of fineness as are gold and silver ores previous to cyanidation.

"Estimated Milling Costs. (10 lb. ore)

"40¢ per ton Coarse & Fine Grinding (including power, repairs, etc.).
10¢ per ton Filtering.
15¢ per ton Chemical Loss.
15¢ per ton Mechanical Loss.
10¢ per ton Repairs & Renewals.
5¢ per ton Precipitation.
10¢ per ton Overhead Expense.

$1.05 per ton Total Operating Expense.

$1.05 ÷ 10 = 10.5¢ per pound for 10 lb. ore. (50 tons daily.)

* * * * * * *

"I am certain that this price is an outside figure when basing the selling price of mercury at its base price of approximately 50¢ per pound, upon which we make all of our estimates. At the present time [November, 1915] scrap aluminum is selling somewhat higher than in normal times and the precipitation expense is larger, but under normal conditions with scrap aluminium at 2½¢ per pound, the precipitating cost is about ¾¢ per pound of mercury precipitated. The last quotation on this scrap was 7¢ per lb., so that the cost now would be about 2¢ per pound of mercury.

"In my opinion, the additional extraction possible would more than offset the difference in the cost of furnacing, at 8¢ per pound as against an outside figure of 10¢ or even 12¢ with precipitation at a higher cost at the same time. I am reasonably sure that a wet method would make an additional extraction of ¾ lb. of mercury, which at present prices would be worth at least 75¢ and on a basis of a ten pound ore would create an additional charge, against each pound of the 90% saved by the furnace method, of 7½¢, making the real cost as compared to the apparent cost, somewhere near 15¢ per pound of mercury produced. I feel that I am justified in assuming that this additional amount of quicksilver will be saved since all of our tests on ores from California, Arizona, Nevada, and Texas show that a practically total extraction is an economic possibility in addition to the fact that in our eighteen months' operating in Canada recovering both metallic and chemically precipitated quicksilver, we found that our tailings assays from the filters invariably were a trace; checks against our assays for the entire period by means of actual knowledge of the amount that we used in amalgamation process showed that our losses were less than a quarter of a pound per ton and most of this was dissolved loss as our installation did not permit of a thorough displacement of the pregnant solution of mercury. In an installation of a reduction plant for a commercial mercury ore proper means could be taken to prevent an excessive loss of any dissolved values and hence provide a large saving. I am aware that my assertion of such a high percentage saving is taken by many people with 'a grain of salt' but actual practice and testing bears the statement out. The mechanical difficulties of filtering is the problem as the dissolution of values is readily accomplished.

"You will have noticed from the theoretical equation that there is a regeneration of the solvent Na_2S to twice its former strength due to precipitation of mercury. This is accomplished at the expense of the caustic soda. Sodium aluminate is generated but lime added or by means of lime in the ore the precipitation of the calcium as calcium aluminate and regeneration of the caustic soda really makes the loss of caustic soda 1/10 lb.; caustic soda sells for 3¢ per pound. We have found one ore which approaches this theoretical very closely. There are some ores high in arsenic which we could not treat; 12 or 13 lbs. of "hydrated iron" is beneficial, more is detrimental.

"I think that you will agree with me when I say that any ore irrespective of its metal content will have the same mechanical costs to be charged against it for reduction to its required degree of fineness in order that its contained mineral may be subjected to the action of the solvent; then the additional charge to be made against any added metal content will be the chemical charge. This actually amounts to but 1 to lb. of caustic soda for every pound of mercury precipitated, so that the additional cost of treating an ore ten pounds in excess of any other ore at hand will be but 3¢. Other ingredients in the ore which might be harmful to the solvent will exercise their harmful effects regardless of the metal content of the ore in mercury.

"Of course, there would be no additional charge per pound for additional pounds of mercury produced in a furnace, but the difference is very slight in any case. For this reason, while I believe that the greatest field will be in mines of a lower grade than it is possible to treat at present by the furnace, I do not concede that the slight additional cost of recovery per pound of mercury from the lowest grade it is possible to treat at present by means of a furnace to any number of pounds per ton above this amount, will be a valid argument against treating higher grade ores.

"I am aware that a wet process is not a panacea for all the ills of mercury production and wish to ascertain its limits."

ELECTROLYTIC DEPOSITION.

The present prices (November, 1917) prevailing for aluminum, though about one-third less than the market prices of November, 1915, noted by Anderson in the foregoing quotation, are still above the normal pre-war level. There would appear to be a field for investigation as to the applicability of electrolytic deposition of the mercury from the alkaline sulphide solution. The writer would like to have undertaken some research work on this phase of the subject, but the necessity of getting the main features of this report printed at as early a date as possible, prevented. The advantage would appear to be with the aluminum method of precipitation because of its regenerative features with respect to both the Na_2S and the NaOH. Whether an electrolytic method would have similar regenerative features seems not to have been determined, as yet. Dr. Duschak of the U. S. Bureau of Mines, Experiment Station, Berkeley, informs the writer that he hopes to undertake an investigation of this phase of the subject, in the near future. Electrolytic deposition has been suggested by Mulholland,[18] and by Schnabel and Louis:[19]

"No attempts have yet been made to extract mercury electrolytically. * * * It must, however, be admitted that cinnabar is readily soluble in solutions of alkaline sulphides containing caustic alkalies, and that the electrolysis of the solutions of mercury sulphide and oxide thus obtained should offer no difficulties, and would not require any very high electric tension.

"According to Brand, [20]cinnabar is readily decomposed at the anode of an electric current, whilst mercury is thrown down at the cathode, a solution of common salt or dilute hydrochloric acid being employed as a bath. The tension in the bath is said to amount to 1 volt. The power to extract 1 kilogram of mercury in this way would accordingly amount to

$$\frac{1 \text{ volt} \times 266.5 \text{ amperes}}{650 \text{ watts} \times 0.75} = 0.54 \text{ horsepower per hour,}$$

since 266.5 amperes can deposit 1 kilogram of mercury per hour, and since one horsepower, assuming 12% of loss in conversion, would yield not 735, but 650 watts, and since the loss of current by conversion into heat, by short-circuiting, etc., amounts to 25%. * * * A. v. Siemens (Eng. Pat. No. 7123, April 1, 1896) proposes to convert mercuric sulphide (like the sulphide of antimony and arsenic) into a soluble double sulphide by treatment with sulph-hydrates of calcium, barium, strontium, or magnesium, and to electrolyse this without diaphragms. In this way the hydrogen liberated at the cathode combines with the sulphur of the mercuric sulphide, setting free mercury and forming the sulph-hydrates of calcium, barium, strontium, and magnesium, which latter are then converted into bisulphides by the oxygen evolved during the electrolysis. * * * This process has not found practical application."

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[18] See p. 323, *ante*.

[19] Schnabel & Louis: Handbook of Metallurgy, vol. II, 2d ed., 1907, p. 410.

[20] Dammer, Chem. Technologie, vol. II, p. 41.

PRACTICAL APPLICATIONS OF CONCENTRATION TO QUICKSILVER ORES IN CALIFORNIA.

Quicksilver operators, particularly the older men, have until quite recently almost uniformly maintained that "you can't concentrate quicksilver ore." From the standpoint of relative density, it does not appear reasonable that cinnabar cannot be successfully concentrated, having a specific gravity (8.0) practically double that of chalcopyrite (4.2) which is also quite friable, and nearly double that of pyrite (5.0). Both of these others are economically recovered by concentration in various tonnages at numerous mines all over the world, the former for its copper contents and the latter for gold values. This skepticism was voiced by Egleston, in 1890:[1]

"Generally the ore, as it comes from any of the mines, is more or less hand-picked. The attempts which have been made to treat the ores mechanically have usually not been successful, as cinnabar is so friable that more floats off with the water than is concentrated; the most successful machine has been the Frue vanner. * * * It is doubtful whether the concentration by any of the methods now in use, except a moderate amount of hand-picking, will be worth making. No concentration of the fine ore has as yet been successful."

This, too, notwithstanding the statement of Hanks[2] in 1884, relative to assays for mercury:

"The best practical test, especially for the prospector, is to use the horn spoon, and treat the pulverized rock as for gold. If the rock contains cinnabar an intensely red powder fringing the residue, will be obtained for a 'prospect.' If in a metallic state, minute globules will be the result. After a few trials the prospector will feel the utmost confidence in his assays, and will decide at a glance whether his ore contains mercury, and approximately the quantity. The best vessel for this assay is the batea. * * * If there is a particle of cinnabar present, it will be found at the point of the prospect, clearly distinct from all other substances."

Richards[3] states that at Idria, Austria, "wet crushing was carried on from 1694 to 1842 when the losses were found to be too great" and a system of stage-crushing, trommel-screening, and picking on belts substituted. He also summarizes the wet concentration method in use in 1895 at the Cornacchino mine, Tuscany, Italy, which is described by Rosenlecher.[4]

The following descriptions are taken up in approximately the chronological order of the plant installations.

The first recorded practical concentration of cinnabar on a commercial scale in California was at the San Carlos mine of the New Idria company in San Benito County, in 1871. The ore then mined consisted largely of 'tierras' (fines[5]).

"chiefly from a soft, somewhat decomposed clay rock, which is impregnated with cinnabar. * * * Nearly all the material mined here now crumbles to a mass of earth. This earth is first packed by donkeys down to the San Carlos Creek, where it is concentrated by washing, after which the tierras so obtained are hauled to the New Idria hacienda."

[1]Egleston, T., Metallurgy of Silver, Gold and Mercury in the U. S., vol. II, p. 804, 1890.

[2]Hanks, H. G., Cal. State Min. Bur., Report IV, p. 332, 1884.

[3]Richards, R. H.: Ore Dressing, vol. I, p. 481, 1905; vol. II, p. 1074, 1905; vol. IV, p. 1919, 1909.

[4]Rosenlecher, R., Description of the method of dressing quicksilver ores in Tuscany by use of trommel, hand jig, hand picking and tie: Berg. u. Hütt. Zeit., vol. LIV, p. 373, 1895.

[5]Goodyear, W. A., Report on examination of the quicksilver mines of California: Geol. Surv. of Cal., Geol. vol. II, p. 120, 1882.

It is not stated what appliances were used, but presumably the washing was done with sluices or with rockers.

Another early recovery of cinnabar by concentration in California was from the stream gravels on the upper waters of the Trinity River,[6] Trinity County. During the early days of placer gold operations there, fragments of a crimson-colored rock were found by the miners, intermixed with the gold-dust, its weight being such as to prevent their easy separation. This 'red stuff' was considered very much of a nuisance, and no attempts at utilizing it were made until 1873, when the high prices of quicksilver

"induced parties to commence gathering it in the vicinity of the locality now known as Cinnabar, where the surface soil over a considerable area contained these particles of rich ore, much of which had been carried by the water and lodged along the adjacent ravines. Washing these ravines with rockers afforded the miners good wages for some time, when they finally came upon the veins from which these fragments had escaped" (the Altoona and Integral mines).

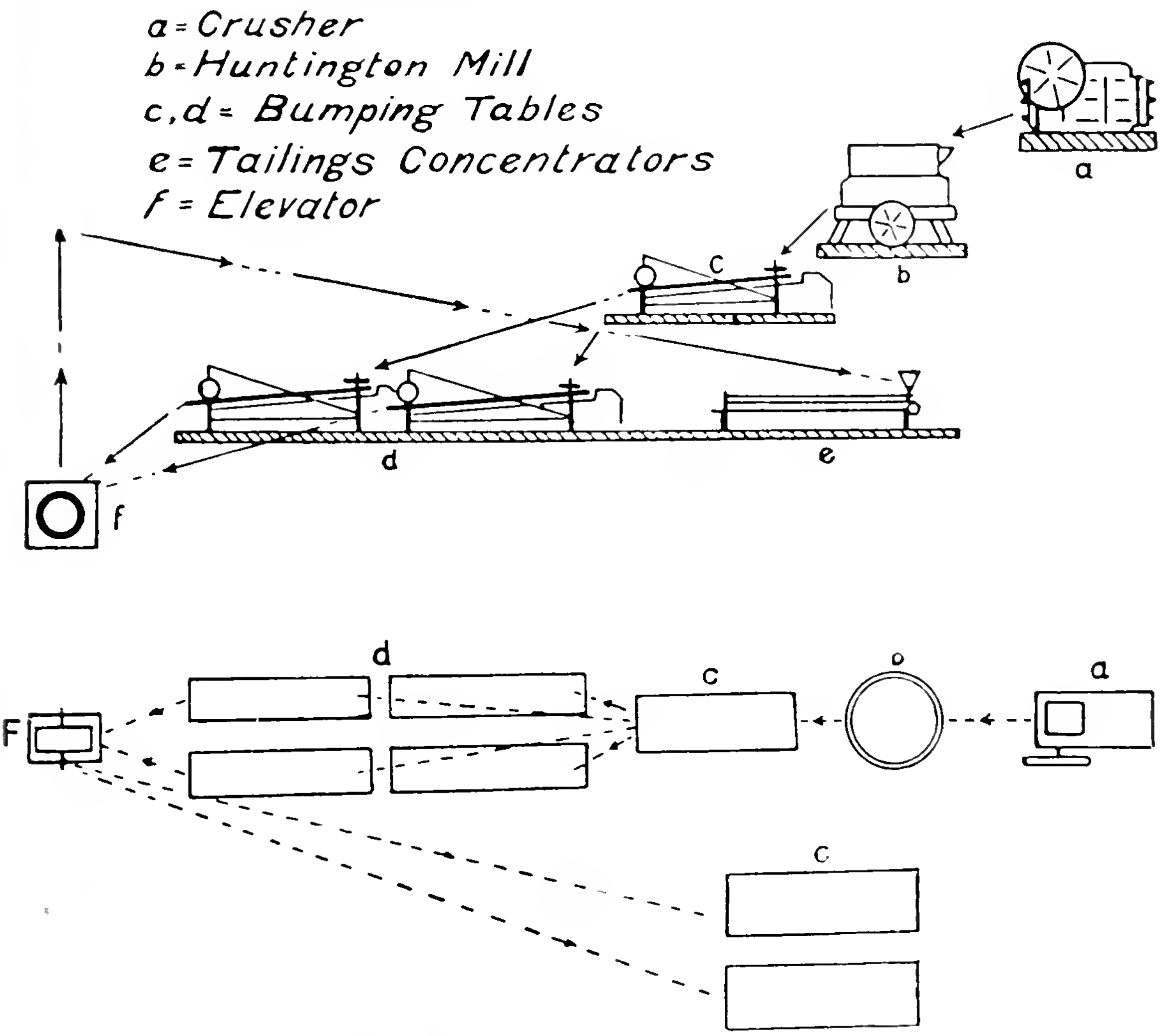
Later,[7] soft ochreous ore from the lode was concentrated in boxes on Brussels carpet, and the concentrates retorted.

The first 'modern' concentration plant in successful commercial operation on quicksilver ores in California was that of G. V. Northey at the **Manzanita** mine in Colusa County. This was described by Northey,[8] and by Forstner,[9] from whose report the accompanying flow-sheet (Plate XL) is taken. See also the writer's[10] report on the Manzanita mine in 1913. The total quicksilver production of the mine approximates 2000 flasks, the most of which was obtained by means of concentration during the eight years ending with 1912. The ore was broken in a No. 1 Gates crusher to pass a 1-inch screen, then through a 5-foot Huntington mill with 20-mesh screen. Six Gilpin County (Colorado) bumping tables were used (later moved to the Ætna mine, Napa County, *q.v.*), the tailings from which passed to cone classifiers. The underflow from the cones was passed to a Bartlett concentrator, and the overflow for a time to a belt vanner but later discarded. The Huntington mill was provided with regulating arms and screws which regulated the pressure of the rollers on the inside of the large ring or die. This is stated to have produced a minimum of slimed cinnabar. The crushing end of the plant was driven by a 25 h. p. distillate engine, and the concentrators by a separate unit. One machine man and two helpers were required. Northey states[11] that the mill treated from two to five tons of ore per hour, the concentrates averaging 35% quicksilver (often as high as 68%), "while the tailings for several months' mill-

[6]Raymond, R. W., Statistics of mines and mining in the states and territories west of the Rocky Mountains: Report VIII, for year 1876, p. 19.
[7]Miller, W. P., in Report X of State Mineralogist, p. 716, 1890.
[8]Northey, G. V., Concentration of cinnabar ores: Eng. & Min. Jour., vol. 96, pp. 783-784, Oct. 25, 1913.
[9]Forstner, Wm., Quicksilver resources of California: Cal. State Min. Bur., Bull. 27, pp. 15, 198-202, 1903.
[10]Bradley, W. W., Mines & mineral res. of Colusa et al. counties: Cal. State Min. Bur., chapters of State Mineralogist Report, 1913-1914, pp. 17-18, 1915; also in Report XIV, pp. 189-190, 1916.
[11]*Op. cit.*, p. 783.

PLATE XL.

Plan and elevation of Concentrating System. Manzanita Mine.



ing averaged from 5¢–10¢ per ton." The dried concentrates, mixed with 10%–25% lime, were retorted. The cost of milling is stated to have been 60¢ per ton of ore treated, including fuel, wages, deterioration, etc., except office expenses. Under some favorable conditions the cost of milling was reduced as low as 25¢ per ton. This low cost applied to ore that occurred in the form of sand, the common name in the camp being 'brown sugar.' The average value of the ore was about $5 per ton, or about 0.5% quicksilver. Additional data with reference to this plant are given herein, under the head of retorts.[12] The Cerise Gold Mining Co. early in 1917, took over the Manzanita mine and the adjoining Cherry gold mine, and has since built a mill to extract the gold from the ores of both. Later, it is intended also to recover the quicksilver, by concentration of the cinnabar.

[12] See pp. 210–212, ante.

At the **Socrates** mine,[13] Sonoma County, during 1908 and 1909, the Socrates Development Co., operating the property under bond, made a small output of quicksilver, employing a Huntington mill and a Woodbury concentrator. The concentrates were retorted. The Socrates ore is characterized by a considerable proportion of native quicksilver.

At the **Elgin** mine, Colusa County near the Manzanita mine, some production was made in 1908–1909[14] with a Griffin mill and Colorado bumping tables. A few flasks of quicksilver in 1916 are stated to have been made by concentration on surface ore.

The above-mentioned accomplishments of Northey were largely ignored or overlooked, until R. P. Newcomb in 1913 began concentrating the dumps at the **Oat Hill** mine in Napa County, and whose work was described by the writer.[15] During the summer of 1913, Newcomb had in operation one New Standard concentrating table (Llewellyn Iron Works, Los Angeles), as a trial plant, screening, sluicing, and concentrating material from the old, low-grade, mine dumps. Later, he added two more tables and a revolving screen, with a 5 h. p. distillate engine to drive the screen and a 1½ h. p. for the concentrators.

With two tables operating one 8-hour shift daily, handling an estimated 10 tons each per shift or a total of 600 tons per month, Newcomb states his cost figures to have been:

Overhead	$175
Labor (2 men)	160
Gasoline and oil	15
Miscellaneous (including wood, powder, horse feed, etc.)	50
Total per month	$400

This is equivalent to $0.67 per ton of ore handled; and the yield was approximately 16 flasks (1200 pounds) of quicksilver per month. This 2-table plant cost him $1500 installed, including a two-pipe retort. The dump material was ground-sluiced to 500′ of riffled (1″) wooden flume, 12″ x 12″; then over a 1″ grizzly (to discard the coarser material): then through 2 riffled flume boxes (25′); then over an 8-mesh screen, and the fines sent to the concentrators. Occasionally a stick of 15% dynamite was used to loosen the dump. The concentrates yielded an average of 10 flasks of quicksilver per ton retorted, or 37.5%. Newcomb tried several different grades, but found this to be a good material to retort; and, at the same time, being not too clean saved the values on the concentrators with a minimum loss in the tailings. With a somewhat lower grade concentrate he found the tendency of the concentrate to pack, to such an extent that it was difficult to

[13] Bradley, W. W., *op. cit.*, p. 178; also Cal. Min. Bur., Report XIV, p. 350, 1916.
[14] *Idem*, p. 17; also Report XIV, p. 189, 1916.
[15] *Idem*, pp. 118–119; also Report XIV, pp. 290–291, 1916.

expel all of the quicksilver; while at the other extreme, a pure cinnabar would entirely volatilize, leaving no residue. To get the latter, however, cinnabar would be lost in the concentrator tailings. He estimated that he could handle at a profit material carrying as low as 0.15% mercury (3 pounds per ton). The ore being a friable sandstone with impregnated cinnabar, and having lain out in the weather for some years, it is more or less disintegrated and air-slaked, requiring little or no crushing; so that it is particularly favorable for low-cost concentration treatment. On the trails and roadways about the Oat

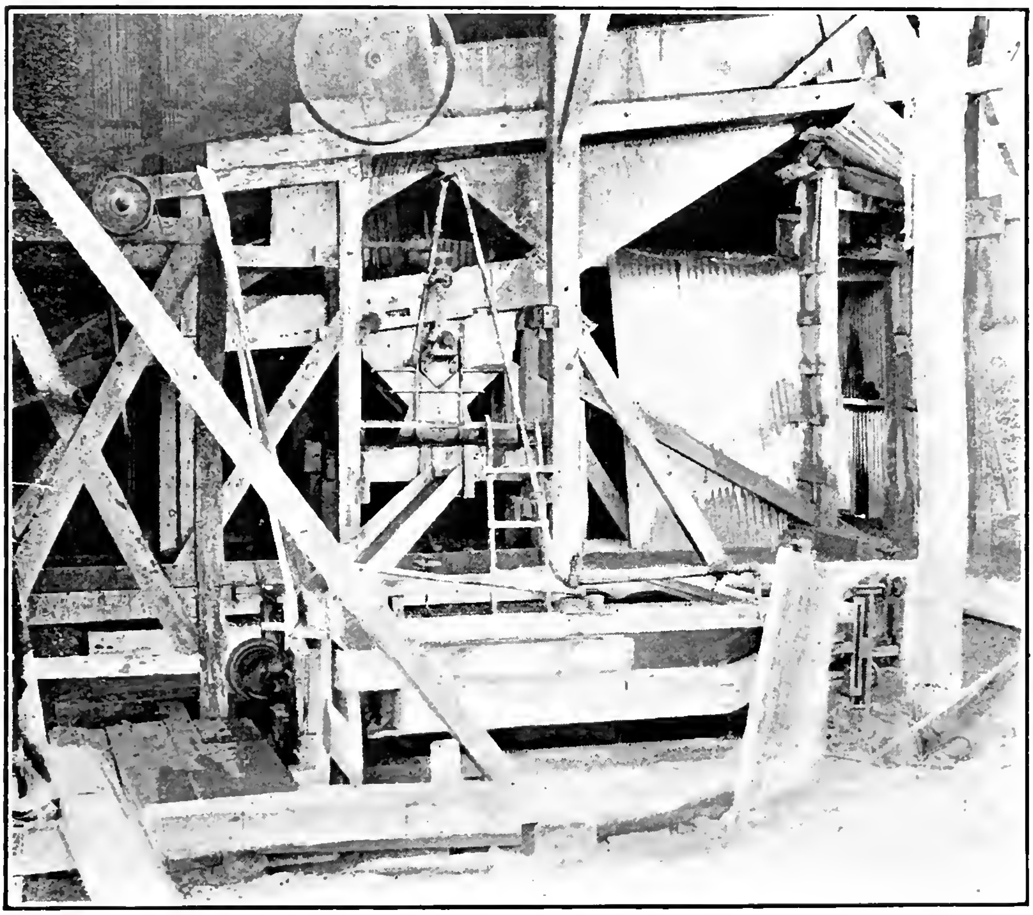
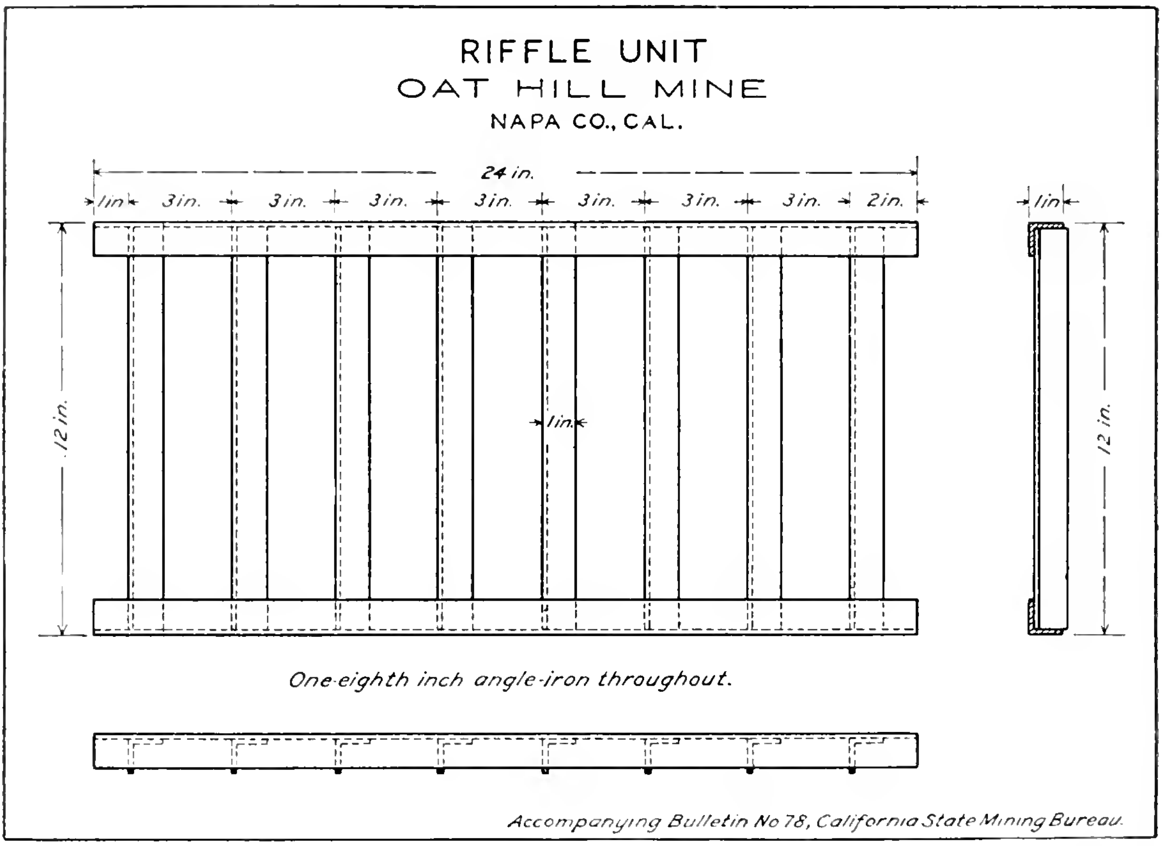


Photo No. 74. Neill Jig, and New Standard Table, in plant of Oat Hill Leasing Company, Oat Hill Mine, Napa County.

Hill mine, after a rain, cinnabar can be seen concentrated among the rocks and small crevices of the water-courses.

Later (1915), Newcomb sub-leased the property to the Oat Hill Leasing Co., who increased the equipment and operated up to July 1, 1917, on a larger scale. They started with a Neill jig and a single New Standard Table at the #1 B. Fanny and Eureka dumps, (see Photo No. 74) later adding two more tables; also, later putting in a similar jig and two-table plant on the Manzanita dump. The dump material was ground-sluiced to and through 400′–500′ of riffled launders (12″ x 12″). The riffles were made up of 1-inch angle-iron

PLATE XLI



(see Plate XLI). Considerable of the coarser cinnabar was caught in the riffles, besides which they also served to break up the clay lumps. At the end of the launder and just above the Neill jig a revolving screen with ½-inch round holes rejected the larger sized pieces, and was at first expected to also break up the clay lumps. The riffles, however, proved more effective for that purpose than the trommel. A ¼″ screen was used in the jig with small steel balls to form a bed, the underflow of which went to the tables. The bed of the jig was cleaned up every 3 or 4 days. It seemed to the writer that the jig was overcrowded—too much pulp and an excess of water. Considerable fine pulp boiled over the top and went out a riffled discharge launder to the waste dump. The writer panned a good 'prospect' from some of this discharged pulp. Without doubt this jig can perform an economic service in such a place when given a fair chance, as it has proven a profitable installation on gold dredges[16] in California and on tin dredges in Alaska. With the one table as at first installed, an average of 500–600 pounds of concentrate was made per 24 hours, assaying 20% mercury; and retorted in 2–12″ pipe retorts, 225 pounds being charged per 8 hours. This plant was driven by a 16 h. p. Western gas engine. Later, a 'D' retort was installed, with a condenser system consisting of a 6″ pipe, two wooden boxes, 2′ x 3′ x 6′ and

[16]Eddy, L. H., Jigs on a California dredge; Eng. & Min. Jour., vol. 101, pp. 207–208, Jan. 29, 1916.

2′ x 3′ x 4′ and a small blower. Manzanita, madrone, and oak are the available fuels.

An undercurrent grizzly 5′ long, with ¾″ opening is placed in the launder line of the plant on the Manzanita dump, to reject the coarser material; but no revolving screen was used as at the other plant. The Neill jig and two tables were driven by a 5 h. p. Standard, distillate engine. In the ravine below the Manzanita dump, the lessees had, in February, 1916, three men working with rockers, concentrating material which the rains had washed down from the dump. A fair amount of cinnabar was thus recovered.

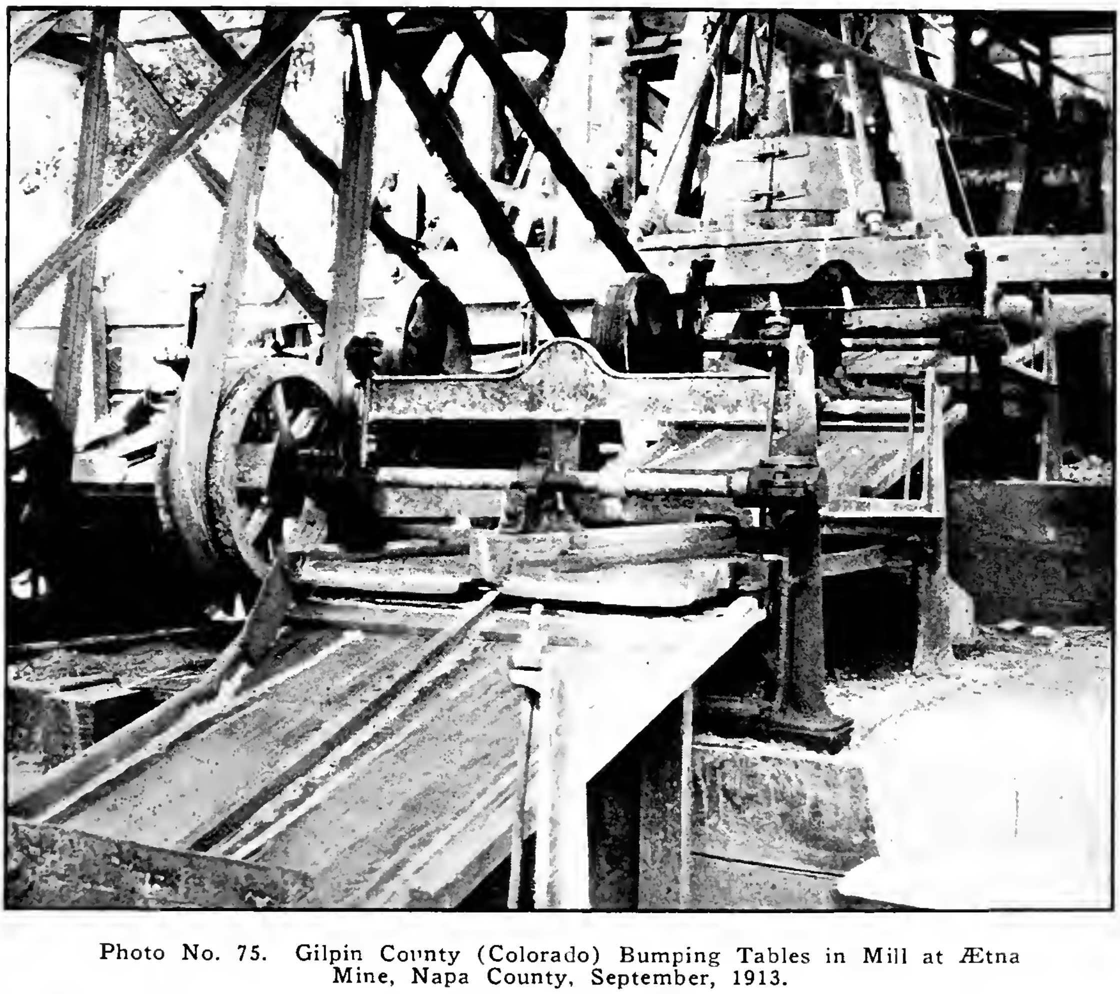


Photo No. 75. Gilpin County (Colorado) Bumping Tables in Mill at Ætna Mine, Napa County, September, 1913.

As the Oat Hill mine dumps have lain out in the weather for some years, the erosion of winter rains has naturally concentrated considerable material from them into the gravels of James Creek and its tributary ravines below the dumps. **Lindblom Bros.**, leasing on land on James Creek, owned by Mrs. M. Patten, with two rockers were able to make 30–40 pounds of concentrates per 8-hour day. This yielded 30%–40% mercury in a retort consisting of two 4″ pipes. In 1915 and 1916 there were several others operating similarly, in a small way with rockers, farther down on James Creek, near Aetna Springs. Among these were: A. Marro, Joe Paulishich, Bert and Henry Wells.

At the **Wall Street** mine, Lake County, when visited by the writer[17] in 1913, there was a small Chilean mill and two homemade table-concentrators said to have a capacity to handle 3½ tons of ore per day. More recently (September, 1917), the owner reports that he has a small-size Deister concentrator. Some of the soft ore is concentrated, but the hard one is retorted direct.

At the **Ætna** mine, Napa County, Bror Soderhjelm, lessee, built a concentration plant, which when visited by the writer[18] in September, 1913, was

"equipped with a Dodge crusher, Griffin mill and six Gilpin County bumping tables, (see Photo No. 75) the whole being operated by a 40 h.p. distillate engine. It was observed that the Griffin mill made a considerable proportion of slimes. The Gilpin County bumpers seemed to collect most of the coarser cinnabar, but lost the fines. As already pointed out, it is very important to avoid sliming of cinnabar, as it is extremely friable. The use of a common power unit for both crushers and concentrators is also objectionable for effective concentration, on account of the variations of speed caused by the rock breaker. Having discussed these points with Mr. Soderhjelm at the time above noted he writes, under date of January 23, 1914, that he has taken out four of the bumpers and put one New Standard (Llewellyn Iron Works, Los Angeles) table in their place, 'but the Standard table had too much to do; so I have ordered another, and if that is not enough I will have some more of the same kind, as the Standard seems to take kindly to the slime.' Also, the concentrators are now being driven by a separate 5 h.p. engine. Ore from the surface cuts is soft and clayey while that from underground is in part hard and siliceous. The capacity of the mill is stated to be 64 tons per eight hours. An 18-mesh screen is used on the Griffin mill. The concentrates are reduced in two 'D' retorts, arranged with both a fan and a water-jet for draught. In the same letter above quoted: 'I found that lime was not so good as charcoal with air in the retort, and I have to use lots of it too, besides shaking it up two or three times.'"

Soderhjelm continued operating this property, treating material both from the mine and certain of the old dumps, until some time in 1915, when the lease was taken over by other parties, with A. A. Gibson as superintendent. The Soderhjelm table tailings had been impounded on account of the slimed cinnabar contained. A sample from these tailings was utilized by the writer during some of the tests described elsewhere herein (see p. 287, *ante*).

At the time of the writer's visit to the Aetna mine in February, 1916, the crushing plant was not in use, but some of the concentrators were in operation. Two Colorado bumpers and one New Standard table had been transferred to the '#7 Silver Bow' dump, the material being ground-sluiced to them through riffled launders and an undercurrent. At the Washington dump about ¼ mile below, they were sluicing through riffled launders and an undercurrent to an Eccleston slime concentrator. The deck of this table was covered with a rubber plate having fine, molded riffles. It was driven by a 2 h. p. Aermotor gas engine, and was producing, per 8-hour day, 600 lb. of middlings yielding 2% mercury and 50 lb. of concentrates yielding up to 60% mercury. These products after drying were retorted with sorted ore from the mine. As at Oat Hill, it was impracticable to determine the percentage of extraction made by the concentrators, because the material

[17]Bradley, W. W., Mines & mineral res. of Colusa, et al. counties: Cal. State Min. Bur., chapters of State Mineralogist's Report, 1913–1914, p. 67, 1915; also in Report XIV, p. 239, 1916.

[18]*Op. cit.*, pp. 111–114; also in Report XIV, pp. 283–286.

was ground-sluiced from the dumps, making difficult even a reasonable estimation of the weights handled. Only the weights of concentrates and resulting quicksilver, and its final cost per flask produced were readily determinable. Even this was usually not recorded. R. P. Newcomb at the Oat Hill mine figured that he could produce quicksilver there at a cost of $10 per flask; but his was an unusually favorable case.

Since the rehabilitation and resumed operation of the 60-ton Scott furnace at the Ætna mine, the past year [1917], concentration has been discontinued by the present operators.

Among some other, smaller operators in the Colusa-Lake-Napa-Sonoma district, who have been concentrating quicksilver ores during the past two years, the following are noted:

At the **Twin Peaks** mine, near the Oat Hill mine, Napa County, for a time in 1916, material from the dumps was concentrated on one New Standard table.

At the **Great Western** mine, Lake County, the Royal Development Co. operated for a time in 1916 on dump material with one New Standard table, since removed to the Big Injun mine west of Middletown.

At the **Great Eastern** mine, Sonoma County, concentration was tried for a short time with a Gates machine in 1916, but only the coarser sulphide was recovered, the slimed cinnabar remaining in suspension and lost with the tailings. The ore was apparently ground too fine.

At the **Big Injun** mine, Lake County, there is one New Standard table (formerly at the Great Western mine), which was employed on low-grade ore during the winter of 1916–1917 while the water supply was sufficient. The addition of a revolving screen has since been made to the equipment. The ore contains native quicksilver as well as cinnabar, in soft serpentine. The concentrates are retorted with high grade ore.

A few flasks of quicksilver, each, were made in 1916, utilizing concentration, at the **Wilbur Hill** mine, Colusa County, adjoining the Manzanita; at the **Baker** mine, Lake County; by **O. W. Boeseke** in Los Priestos district, Santa Barbara County; and at the **Rattlesnake** mine, Sonoma County, the ore of this last-named mine carrying largely native quicksilver.

At the **Bella Union** mine, Napa County, in 1916, a Deister table was tried by the Rutherford Mining Co., but it saved only the coarser cinnabar. Then a K & K flotation machine was installed, the fine grinding being done with a Hendy ball mill, 3′ diam. x 3′ long. Flotation is stated to have saved the slimed cinnabar from the pulp, well; but the coarser particles escaped. Later, two Deister-Overstrom tables were used in conjunction with the flotation machine, to recover the coarse cinnabar. The oil was mixed with the pulp between the ball-mill, and flotation unit, in a box having the form of an inverted pyramid. With this arrangement operations were continued for only a short time; but the writer is not informed as to the reasons for the cessation. Some statements relative to this ore are given under the head of flotation tests, elsewhere herein.[19]

At the **Cloverdale** mine, Sonoma County, early in 1916, an experimental concentration plant was in operation for a time, using a New Standard table. Screens of ¼ inch and 10-mesh were used and the oversize was re-crushed in high-speed rolls. It is stated that the results were favorable, but for certain financial reasons a larger plant was not installed.

At the **Bullion** mine near Middletown, Lake County, in the spring of 1917, a few flasks of quicksilver were obtained from concentration with hand rockers working on old dump material.

At the **Barton** mine, Oak Bar, Siskiyou County, in 1916, under the superintendence of Wm. Forstner, concentration was tried for a time, using tables and burlap. On account of a considerable proportion of the cinnabar being in the form of 'paint,' Forstner states[20] that they were able to obtain only 50% extraction, on material running ¾ lb. quicksilver per cubic yard. The burlap caught some of the fine, crystalline cinnabar, but not the paint.

At the **Kings** mine, Kings County, during a portion of 1915-1916, a concentrating mill was in operation, equipped with a Huntington mill and an Isbell table. The ore[21] is principally of soft serpentine and shale with some sandstone, and carries native quicksilver in addition to cinnabar. The concentrates were reduced with the regular ore charge in the 10-ton Scott furnace. The writer is not informed as to the outcome of the concentration work, but he noted on a recent visit (September, 1917) to the mine, that the Isbell table had been taken away.

At the **Oceanic** mine in San Luis Obispo County, Murray Innes built a small concentration mill in 1914 to handle wet ore from some of the old mine fills, and which he operated up to early in 1916 when he bonded the property to E. A. Clark, et al, of New York. This plant was described by Herberlein[22] and by Logan.[23] According to the latter's description:

"The concentration plant consists of a 3½' Huntington mill and Deister table. It was originally installed for the purpose of handling wet ores and does this nicely.

[19]See p. 316, *ante*.
[20]Conversation with the writer.
[21]Bradley, W. W., et al. Mines & mineral res. of Fresno et al. counties; chapters of State Mineralogist's report, 1913-1914, Cal. State Min. Bur., p. 103, 1915; also in Report XIV, p. 529, 1916.
[22]Heberlein, C. A., The mining and reduction of quicksilver ore at the Oceanic mine, Cambria, Cal.: Am. Inst. Min. Eng., Bull. 98, p. 499, February, 1915; also in Trans. vol. LI, p. 112.
[23]Logan, C. A., et al. Mines and mineral res. of Monterey et al. counties; chapters of State Mineralogist's report, 1915-1916, Cal. State Min. Bur., p. 122, 1917.

but at present is being used to increase the capacity of the furnace. It handles 15 tons in 24 hours and yields a twenty-to-one concentrate which contains an average of 80% of the values so that its product adds the equivalent of 12 tons daily to the furnace capacity. The ore is crushed to 14-mesh and does not slime appreciably because of the friable nature of the gangue, which releases the small cinnabar crystals easily. The owner does not claim to be attempting a close recovery with this little plant, but aims rather to make a rough concentrate. The concentrates are sun dried in summer, but for winter, a dryer was being evolved at the time of the writer's visit, which utilized the hot exhaust of the distillate engine. This is later reported to be satisfactory. The concentrates are fed into the furnace daily with the ore, not however all at once.

* * * * * * *

"The figures given below for concentration costs apply to conditions as they existed in November, 1915.

Concentration Costs.

Wages of 3 millmen at $2.50 per day	$7 50
Cost of power (estimated, basis $25 h.p.-year), 21 h.p. at .068	1 43
Total cost to concentrate 15 tons daily	$8 93
Cost per ton	$0 597

"This figure has little significance when it is borne in mind that 3 millmen could take care of a tonnage several times as great with only a slight added expense for power."

Heberlein[24] states that:

"Some experiments have been made lately [February, 1915] with the flotation process on quicksilver ores, but it is hardly probable that this process ever will find application for the good reasons: (1) The fine grinding alone would cost as much as the ordinary furnace process; and (2) the oil sticking to the concentrates would distill over in the retort and severely impair the quicksilver which would have to be especially cleansed of its coating of oil."

The writer has shown elsewhere herein[25] that this last-mentioned objection apparently does not so work out in practice. So small an amount of oil is required to bring about flotation of the cinnabar, that an inappreciable quantity seems to stick to the concentrates.

This small concentration mill was replaced in 1916 by Clark et al, with a larger plant calculated to handle 300 tons of ore per day. It was equipped with ball mills, various classifiers, and both sand and slime tables. The ball mills ground the ore so fine that a considerable proportion of the cinnabar was slimed and lost via the tail-race. Innes resumed the management of the property in the spring of 1917, and both concentration plants have since been dismantled. All ore from the mine now is treated by two 50-ton Scott furnaces.

At the **New Idria** mine, San Benito County, in December, 1915, two New Standard concentrating tables were installed[26]

"between the grizzlies and the No. 1 (fine-ore) furnace. The fine ore, after passing through the grizzly, is fed onto a shaking screen of 8-mesh, the coarser material going direct to the Scott furnace and the through product to the concentrators. In two 8-hour shifts these two machines were (December, 1915), handling a total of 36 tons of ore, and making 4½ tons of a concentrate carrying approximately 6%–7% mercury, from an original ore of about 0.5% mercury. By thus eliminating the very fine material from the ore which has a tendency to interfere with the furnace draught and to hold back the volatilization of the quicksilver, the capacity of the Scott furnace has been raised to about 75 tons daily. On account of the large percentage of fines coming from the mine, some of this ore was being added to the coarse-ore furnace charge. Naturally this interfered in a more marked degree with the capacities of the two coarse-ore furnaces than the extreme fines did with the Scott. The elimination of practically 32 tons daily of the extreme fines by concentration has thus relieved the No. 2 and No. 3 furnaces of fine ore, giving them also, freer action and increased capacity. The concentrates after drying are charged with ore to the Scott furnace."

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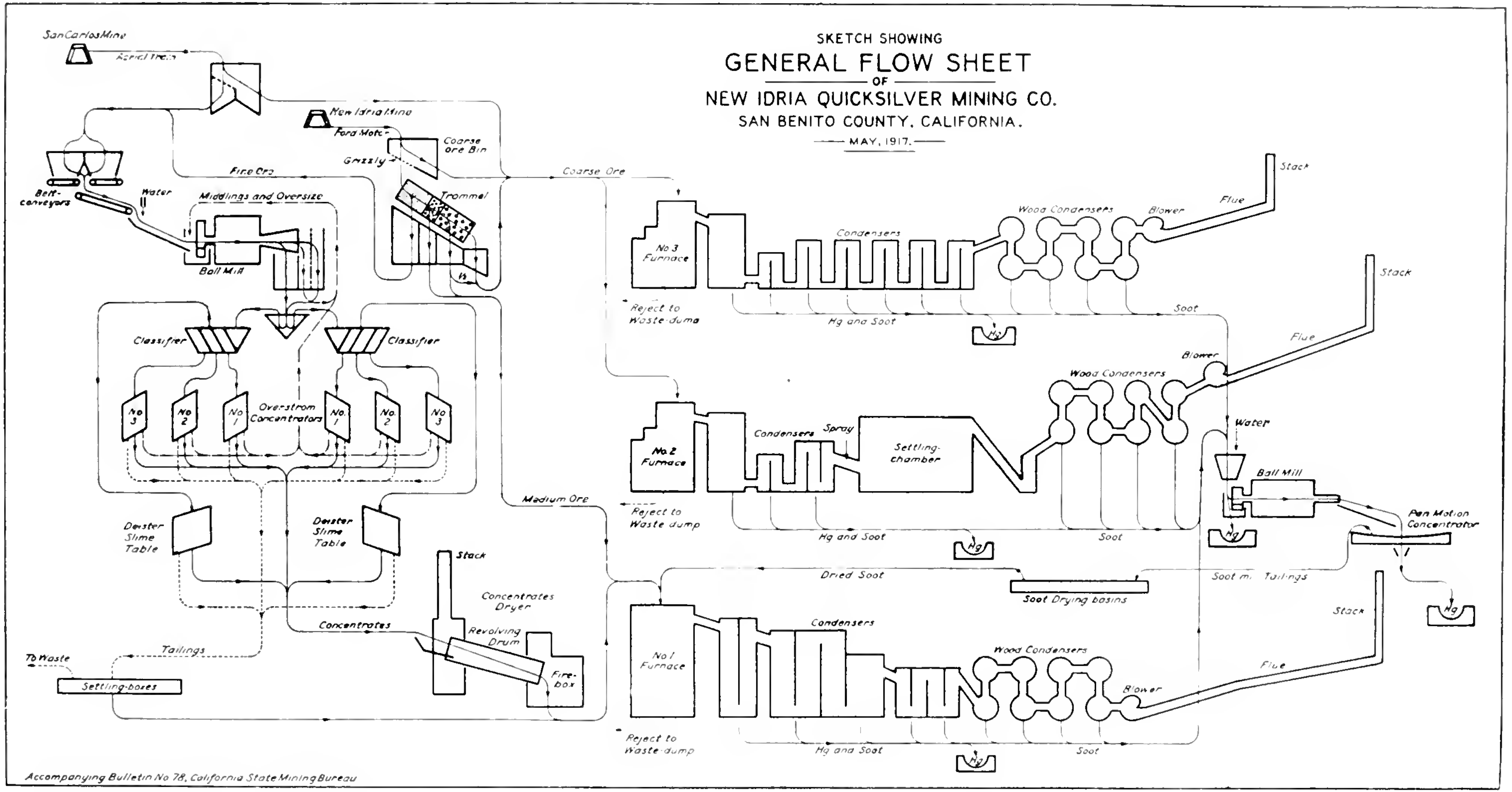
[24]*Op. cit.*, p. 499.

[25]See p. 305, *ante*.

[26]Bradley, W. W., et al. Mines and mineral res. of Monterey et al. counties; Chapters of State Mineralogist's report, 1915–1916, Cal. State Min. Bur., p. 73, 1917.


SKETCH SHOWING
GENERAL FLOW SHEET
OF
NEW IDRIA QUICKSILVER MINING CO.
SAN BENITO COUNTY, CALIFORNIA.
MAY, 1917.
San Carlos Mine
New Idria Mine
Coarse ore Bin
Grizzly
Trommel
Belt-conveyors
Water
Middlings and Oversize
Fine Ore
Ball Mill
Classifier
Classifier
Overstrom Concentrators
No 3
No 2
No 1
No 1
No 2
No 3
Deister Slime Table
Deister Slime Table
Stack
Concentrates Dryer
Revolving Drum
Fire-box
Concentrates
Tailings
To Waste
Settling-boxes
Coarse Ore
Medium Ore
No 3 Furnace
No 2 Furnace
No 1 Furnace
Reject to Waste-dump
Reject to Waste dump
Reject to Waste-dump
Condensers
Condensers
Condensers
Spray
Settling-chamber
Wood Condensers
Wood Condensers
Wood Condensers
Blower
Blower
Blower
Flue
Flue
Flue
Stack
Stack
Stack
Hg and Soot
Hg and Soot
Hg and Soot
Soot
Soot
Soot
Hg
Dried Soot
Soot Drying basins
Water
Ball Mill
Pan Motion Concentrator
Tailings
Accompanying Bulletin No 78, California State Mining Bureau

Since the above was written, the plant and practice at New Idria have been improved and expanded materially. The accompanying flow-sheet (see Plate XLII) indicates the part that concentration is at present playing at this the largest producing quicksilver mine in the Western Hemisphere. The drawing gives the flow-sheet, as of May, 1917. Though there have been some changes of details, since, this will give a good, general idea of the New Idria practice, quite recently. It is stated that before the ball-mill was added, a New Standard table handling screened 8-mesh fines from the San Carlos only, showed less slimed cinnabar in the tailings than since. The underground workings of this company are divided into two groups; designated the New Idria, and the San Carlos, respectively. The reduction plant is stationed at the former (see Photo No. 21, *ante*), while the latter is connected with it by an aerial tram 2 miles in length. Two-thirds of the grizzly (1″) fines from the San Carlos, and the — ⅛″ screen-house fines from the New Idria go to the concentration mill. From the mill ore-bin there are 4 caterpillar feeders with three speeds each, which mix the San Carlos-New Idria ores in the desired proportions and deliver onto a belt conveyor. This, in turn discharges into a launder where a stream of water carries the pulp into the ball-mill center-feed. The ball-mill also has a scoop-feed for picking up the returned middlings and trommel oversize. When visited by the writer, October 2, 1917, preparations were being made to add a Richards' pulsator-jig to take the — ⅛″ feed from the screen-house trommel instead of this feed running through the launder. A hutch-concentrate will there be taken out, while the ball-mill trommel oversize and the jig-tailing will go direct to the center-feed of the mill. The scoop-feed will continue to pick up the returned middlings. This arrangement is expected to prevent sliming in the ball-mill of those particles of cinnabar which are sufficiently broken and clean to concentrate in the jig.

The grinding unit is an Allis-Chalmers ball granulator, 7′ diam. x 5′ long, with screen-grating of ⅛″ maximum size (one-half on $\frac{1}{16}$″ and one-half on ⅛″). A manganese-steel cascade lining is used, with chrome-steel balls (4″ diameter at start; when worn down to 1½″ they were taken out and used in the soot mill[27]). The consumption of balls is ½ pound per ton of ore ground. The ball-mill is driven by a 100 h. p. Fairbanks-Morse, type Y, semi-Diesel, 2-cylinder upright engine. There is a short trommel on the ball-mill discharge.

From the ball-mill trommel, the undersize pulp passes through a 6-compartment Richards pulsator-classifier (a second one will be added shortly, and the feed divided, as the one, alone, is crowded, handling 160 tons per day), with a 1 m. m. screen; the product of each of the

[27]See p. 276, *ante*.

6 spigots goes to a separate Deister-Overstrom double-deck table, the six tables being driven by a 20 h. p. Fairbanks-Morse, type Y, semi-diesel engine. The amount of the middlings is regulated by the width of the 'cut', and they are returned by a bucket elevator to the ball-mill for regrinding. An improved extraction is obtained since the Richards' classifier has been installed. The slime tables noted on the flow-sheet have been cut out since adding the classifier.

The concentrates averaging 13% mercury are transported in solid-bottom, hopper, end-dump steel cars to a special rotary drier installed above the Scott fine-ore furnace. This rotary drier is 2′ 9″ inside diameter, 20′ long, set on a grade of 1′ in the 20′, and driven at 8 r. p. m. by a 4 h. p. gas engine. The temperature is kept at 50° C., being recorded by a Brown electric pyrometer. The dried concentrates are discharged into a bin from which they are fed to the Scott furnace, at the rate of 8 shovelfuls each time the furnace is charged.

The mill engines consume 4 bbl. of Calol Fuel Oil, 22°–24° B. per day, which costs approximately $1.60 per bbl. (large contracts) at Mendota, and about $3.40 per bbl. at the mine.

The mill heads are sampled at the conveyor-belt discharge, weight being determined by a moisture sample and the car tally. The car tally is checked weekly with a 1 cu. ft. box. Since this practice has been adopted it has been found that former tonnages were overestimated. The tailings are sampled automatically in the tail-race. The concentrates are sampled by hand at the furnace-car loading chute, after drying. Screen analyses show that the cinnabar lost in the tailings is mainly in the extreme fines (— 100 mesh), and in the unreleased (+ 20 mesh) material.

The soot-mill operation at the New Idria plant is one of concentration, but is described[28] elsewhere herein, under the discussion of soot treatment.

In the spring of 1917, a series of experiments were carried out with flotation at New Idria. With the mill heads assaying 14 pounds (0.7%) mercury per ton, table concentration was reducing the tailings to a 4-pound assay value. Flotation, alone, did not give as good a result as the tables, alone; but combined, the tailings assays were reduced to 3 pounds of quicksilver. A combination of 1 part pine-tar oil and 2 parts mineral oil were used. The Minerals Separation company demanded as royalty for use of the flotation process, $1.50 per flask on the *entire output of the mine*, though less than 50% of the ore goes to the mill, and of that, only the slimed portion would have been treated by flotation. As this was considered unreasonable, flotation was dropped from consideration.

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[28]See p. 275, *ante*.

At the **New Almaden** mine, Santa Clara County, both table concentration and flotation were tried in 1916–1917, but had just been discontinued at the time of the writer's visit in September, 1917. In June, 1916, a concentration plant consisting of a ball-mill and a Deister-Overstrom table was in operation at the old Randol dump, but later moved to another part of the property, as the quicksilver values in the dump material were spotted and too low for commercial work. On June 15th, with the plant running smoothly and apparently doing good work, samples taken every half-hour for 5 hours assayed as follows: Heads 0.03% mercury; tails 0.015%; middlings 0.03%; concentrates 1.16%. The ore treated in the 5 hours amounted to 20 cars of 15½ cu. ft. each. There was occasionally a very little native quicksilver, which was caught by amalgamation on a piece of tin at the concentrate-discharge end of the table.

Following that, concentration plants were placed in operation at the Day tunnel and at the Senator mine which is at the north end of the New Almaden property. These plants consisted of crushers, ball-mills and Deister-Overstrom tables. The concentrates were roasted mixed with ore, in the Herreschoff[29] furnace installed at the Senator. Electric motors furnished the power. In the Day tunnel mill, below the jaw crusher was a 6′ x 5′ Allis-Chalmers ball-mill in closed circuit with a Dorr Simplex classifier. The grinding was regulated so that approximately 87% of the pulp passed 60 mesh. The overflow from the classifier passed through 4 Callow flotation cells, and then to 1 double-deck Deister-Overstrom table. The table was not only crowded (120 tons per 24 hr.) but was compelled to handle an unclassified feed. A 12′ diam. x 6′ high, Dorr settler dewatered the concentrates, followed by a 6′ diam. x 4′ Oliver filter. The concentrates were handled by motor truck to the Herreschoff furnace. It is stated that the heads sample averaged 0.23% mercury; that the tailings could have been brought down to 0.03% mercury by finer grinding; that the equipment and practice could have been improved so that an extraction of over 80% could have been obtained; but that it cost from $80–$85 per flask (including furnace reduction of the concentrates) to produce the metal, as against $45–$50 per flask by careful sorting and regulation of the ore feeding direct to the furnace. Fine grinding was the expensive part of the process. The ore being largely a hard and tough, silicified serpentine, the steel-liner and ball consumption was high. There is no ochre in the ore, but considerable slime from the serpentine. Screen analyses showed cinnabar in the flotation tailings on the —80 and —100-mesh 'chats'.

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[29] See p. 250, *ante*.

The flotation plant at the Senator had 3 Callow cells and a Deister-Overstrom table; and at first used two 4′ x 4′ ball-mills. These latter were replaced by a 4½′ x 6′ Marcy mill. The flotation concentrates proved to be messy stuff (see Photo No. 76) to handle, and not the easiest thing to dry for convenient feeding to the furnace. According to R. S. Lewis[30] others have found the handling of flotation concentrates far from being an 'unalloyed pleasure.' After passing through the flotation cell, the pulp passed directly to the tables with-

Photo No. 76. Flotation Concentrates drying in the sun, at the Senator Mine of New Almaden Company, Santa Clara County.

out further classification or dewatering. Some experiments were tried with dewatering at the Senator plant, but with only slight success, it is stated.

There was, however, a concentration plant of another sort in operation at the Hacienda of the New Almaden Company, at the time of the writer's visit. The ground underneath the site of the old intermittent adobe furnaces, and of two of the older Scott furnaces and their condensers, was being excavated to bedrock, a depth of 25′ to 30′. This earth, sand and gravel is well-sprinkled with dissemi-

[30] Lewis, R. S., The disposal of flotation products: Min. & Sci. Press, vol. 114, pp. 473-481, April 7, 1917.

nated globules of quicksilver,[31] which had worked their way down from the furnaces during the years of operation here. The material is hoisted and transported by an Alaska-carrier cable, having a bucket of 1 ton capacity. From 50 to 100 buckets per day are hoisted, the men working on a bonus system. The bucket dumps into a bin (see Photo No. 77) from which the material is fed to a revolving screen with ¾-inch round holes.* The —¾″ material then passes to a 'log washer' (having a screw conveyor); then, successively, through a

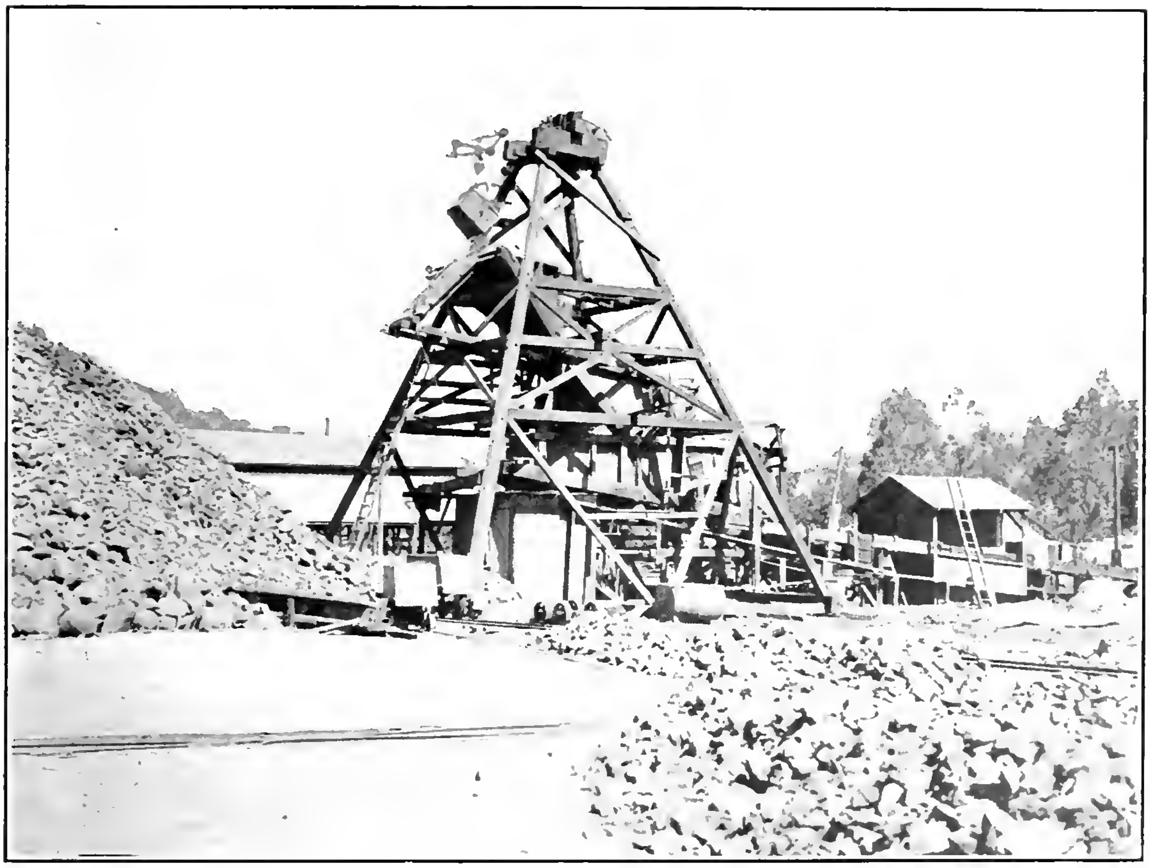

Photo No. 77. Gravel-washing plant for recovering metallic quicksilver from material excavated from old furnace sites, at Hacienda of New Almaden Company, Santa Clara County.

riffled launder; a Richards pulsator-riffle (Hungarian riffles with a pulsator compartment); and finally through another riffled launder. This has proved to be quite an effective plant for the material being handled. Even the bin at the head had to be made mercury tight with provision for drawing it off as considerable quicksilver settles out there when the bucket is dumped. The larger boulders are hand-sorted out, in the pit, and dumped to one side of the washing plant.

At the **Guadalupe** mine, Santa Clara County, a concentrating plant of 50 tons daily capacity was built in the winter of 1916–1917, and

[31]See Photo No. 50, *ante*.

*Since the above was written, owing to the material becoming lower grade, a small hydraulic giant sluices it to a sump, whence it is raised by a centrifugal pump to the launders.

started operating in February on material from the old mine dumps. The mill is on the bank of the creek, alongside of the dumps. The ore is trammed by hand and dumped into an underground pocket from which it is hoisted by a skip to the mill bin. Crushing is done in a 3′ x 4′ Hendy ball-mill, with 20-mesh screen discharge, from which the pulp passes through a Dorr Simplex classifier. The coarse product goes to 2 Wilfley sand tables, and the fines to a #5 Deister and a Deister-Overstrom table. The concentrates are stated to assay 8%–10% mercury as only a roughing operation is attempted. Considerable slimes are made. The concentrates are reduced in the fine-ore furnaces.

At the **Harrison** mine, Yolo County, under bond to January Jones, a concentration mill was being built in July, 1917, when visited by Mr. Emile Huguenin of the staff of the State Mining Bureau; and from whose notes the following data are taken. The mill is to have a capacity of 150 tons of ore daily; and is equipped with crushers, ball-mill, Wilfley tables for the sand, and Deister concentrators for the slime. It is expected to begin operation of the mill after the fall rains provide a water supply. Meanwhile, ore from the mine was being hand-sorted and retorted.

At the **Sulphur Bank** mine, under bond to the Sulphur Bank Association, preparations are being made to concentrate the extensive dumps of many years' accumulation. Practically all of the dumps in sight (see Photo No. 10, *ante*), and some over the hill on the north side have concentratable values. A steam-shovel will be utilized for excavating the material, and motor-trucks for transportation to the mill bins, as it will be necessary to haul it up to one-third of a mile in distance and raise to an elevation above the mill-site. When visited by the writer in September, 1917, a plant serving as a test unit had been in operation several weeks. The main difficulties encountered here, not only in concentrating, but in assaying, retorting or furnacing, are all due to the excess of free sulphur. A sample of concentrates assaying 15% mercury, showed on analysis a content of over 20% native, free sulphur. Table tailings from the same run showed 15% free sulphur. No provision had as yet been made in this test-unit for crushing or grinding the feed. Of 500 tons excavated, daily, 300 tons of the coarser material was eliminated by the grizzly; and the revolving screen ($\frac{1}{8}$ inch opening) took out 75 tons from the remainder, leaving 125 tons daily to be handled by the 4 Deister-Overstrom tables. There were two Challenge ore feeders below the ore-bin chutes. The revolving screen was 16′ long x 42″ diam., made of single-crimped wire, the whole plant being driven by a 15 h. p. gas engine. Water is pumped against 85′ head, from Clear Lake to two wooden tanks

(6,000 and 10,000 gal.) above the mill, by a triplex, geared Gould pump, 100-gal. per min., driven by a 10 h. p. Type Y, Fairbanks-Morse, semi-Diesel engine burning 24° B. fuel oil. Another, 200-gal. pump will later be added.

As the tables were at first operated on this ore, the concentrates and middlings were rather crowded together, and considerable native sulphur was mixed with both. Though a cleaner concentrate was obtained than later, it was at the expense of extraction, as cinnabar in the middlings was crowded over into the tailings. By flattening the grade of the table and changing the wash-water feed, the products were spread out more, and showed the following order at the concentrate end: a bright red streak of cinnabar; a bright-yellow streak of fairly clean native sulphur; a mixed streak of sulphur, cinnabar and some middlings; middlings, containing in addition to some cinnabar and sulphur, the coarser particles of the white leached basalt. Finer crushing will probably eliminate the last-named. It is expected that later another table may be added to clean the middlings and to make a fairly clean sulphur product.

The assays given herewith, show the improvement in extraction with the change of practice, and the relative changes in assay values of the products. The percentage of extraction is calculated on the basis of the following equation:

$$\text{Recovery} = \frac{100\ b\ (a\text{-}c)}{a\ (b\text{-}c)},$$ where a = head assay; b = concentrate assay; c = tailings assay. This gives a slightly higher result than the 'indicated extraction' based on the simple proportion of tails assay: heads assay, subtracted from 100.

Date	Sample	Per cent Hg.	Pounds Hg. per ton	Per cent recovery
8/23/17	Mill heads	2.44	48.8	
8/23/17	Tailings	1.44	28.8	43.4
8/23/17	Concentrates (forenoon)	25.1	502.0	
8/23/17	Concentrates (afternoon)	28.0	560.0	
8/24/17	Heads	2.5	50.0	
8/24/17	Tailings	1.52	30.4	42.6
8/24/17	Concentrates	24.5	490.0	
9/ 1/17	Heads	2.04	40.8	
9/ 1/17	Tailings	0.40	8.0	82.6
9/ 1/17	Concentrates	14.8	296.0	

Screen analyses show most of the mercury lost in the tailings to be in the fines. For the present, the concentrates are being retorted, along with debris from the old Scott furnaces and condensers. The concentrates are spread out on a concrete floor to dry, after which lime is added in the proportion of 1 lb. to each pound (±) of free sulphur contained. The large amount of sulphur present has a strong affinity for the iron of the retorts; and various expedients have been tried for overcoming it. With a larger plant in operation after the present test-unit has served its purpose, some other form of furnace will no doubt be used, as retorts are of too limited capacity, and the labor cost-per-ton for operating them is high.

ESTIMATES OF CONCENTRATION COSTS.

To say with any definiteness beforehand what a given process will cost is not a simple matter. Costs vary widely with equipment, character of ore, labor, and other local conditions. So few mines that have tried concentration on quicksilver ores have kept an accurate or any account of expenditures, that it is difficult to give any exact figures. From a comparison of cost data on mills handling other ores, it is reasonable to estimate that, with average conditions obtaining in the California quicksilver districts, table concentration can be conducted at cost figures between 50¢ and $1.25 per ton, including crushing and table operations, labor, supplies and repairs. Richards[1] gives actual concentration costs in certain stamp-mills of: $1.00 per ton with a 95-ton per day mill; $0.92 per ton on a 175-ton capacity; and $0.28 on a 700-ton daily capacity. Rolls will do better work on quicksilver ores, and probably be cheaper than stamps. Water required will amount to from 5–8 tons (1200 to 1900 gal.) per ton of ore, depending largely on the nature of the ore.

With concentration by flotation, operating costs will be somewhat higher on account of the cost of finer grinding. From the experience at New Almaden[2] it would appear evident that, where sliming is necessary to release the cinnabar, such treatment can not compete with the Scott furnace; even though it yield a somewhat higher recovery. Cost data have been published in a number of recent instances for flotation plants. Simons[3] gives the following for the Timber Butte mill, Montana, treating 450 tons daily of a complex copper-lead-zinc-pyrite ore and making several products:

"Treatment costs have averaged between $2 and $2.25 per ton of ore passed through the mill. This covers labor, power, water, supplies, repairs, and general expenses, but not interest on investment and depreciation."

In the mill of the Consolidated Arizona Smelting Co.,[4] at Humboldt, Arizona, treating 240 tons per day, of copper ore:

"The total cost of concentration, including coarse crushing and flotation royalty, is slightly over $1 per ton. In September [1915] it was $1.03. Exclusive of royalty, the cost of the flotation part of the treatment has been 27¢ per ton during a period of six months. The cost for oil is 2.8¢ per pound on a consumption of a little less than one pound of oil per ton of crude ore. The power consumed by the flotation machine [Minerals Separation] is 32.7 kw. per 24 hours."

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[1]Richards, R. H.: Ore Dressing, vol. II, pp. 1129, 1133; 1905.
[2]See p. 243, *ante*.
[3]Simons, Theodore, The concentrator of the Timber Butte Milling Co., Butte, Mont.: Am. Inst. Min. Eng., Bull. Sept. 1915, p. 1307.
[4]Unsigned, Flotation at Humboldt, Arizona: Min. & Sci. Press, vol. 112, p. 41, Jan. 8, 1916. "Précis of an article appearing in Metall. & Chem. Eng., Dec. 1, 1915."

At Copperopolis, California, on copper ore, using Callow cells, Robbins[5] gives the following data:

"Operating costs. These are shown by the following figures taken at random from the company's books, representing actual costs for the week ending July 7, 1916:

"Power, 181 h.p. per day, at 0.825c per kw. hr.	$191 25
Operating labor, 70 shifts, at $3.25	228 75
Superintendence, repair and extra labor	137 48
Supplies of all kinds	132 40
	$689 88

"On a normal tonnage of 192 per day, this is equivalent to 51.4¢ per ton."

REDUCTION OF CONCENTRATES.

The concentrates being obtained, have yet to be roasted to get the final, desired product,—metallic quicksilver. Retorts are of limited capacity, but if used, the concentrates are likely to require some stirring to prevent packing on account of their high specific gravity, especially if assaying between 10% and 40% mercury. At higher values than 40%, the sulphide should be self-burning and leave but little residue. However, it is rarely ever economic to produce such a high-grade concentrate. A small furnace of the Scott type could be used, with a narrower shaft and narrow shelf-slit; such as was in use for treating soot at the New Idria mine for some years until the recent installation of the soot concentration mill. This was suggested by the writer[6] in a recent report on the quicksilver mines of Lake County. Here again we have the fuel combustion products mixed with the quicksilver vapor, and the attendant condensing difficulties. Some form of a rotary roaster may be adapted, similar to the concentrate drier now in use at New Idria; or a small-size unit of the Wedge muffle-fired type of mechanically-rabbled furnace. This last-named would have the advantage of the retort principle of keeping the quicksilver vapors apart from the products of fuel combustion. The Landers retort[7] would also have this same advantage, but in view of recent experience at Sulphur Bank, it is doubtful if any form of cast-iron retort would last long when handling concentrates, on account of the sulphur matteing with the iron.

[5]Robbins, H. R., Flotation at the Calaveras Copper—a simple flow-sheet: Min. & Sci. Press, vol. 113, p. 772, Nov. 25, 1916.

[6]Bradley, W. W., Mines and mineral resources of Colusa et al. counties, chapters of State Mineralogist's report, 1913-1914, Cal. State Min. Bur. p. 56, 1915; also in Report XIV, p. 228, 1916.

[7]See p. 218, *ante*.

ADVANTAGES OF THE ALKALINE SULPHIDE SOLUTION METHOD.

The most striking and attractive advantage of this method is that it obviates the necessity for an expensive furnace installation, on those ores which are amenable to it. With the exception of heavily ochreous ores, practically all quicksilver ores can be handled by it. In some cases where extreme fine-grinding would be required to give the solution contact with the mercury minerals, the cost will doubtless be too high in comparison with Scott furnace treatment. For most ores, grinding need not be finer than — 80 or — 100 mesh. The plant installation should not cost over one-half that of a Scott plant, as the standard cyaniding equipment (but without agitators) can be utilized. This can be done for under $500 per ton-day capacity.

With this system, it is not necessary to wait months or even weeks after installation before metal can be put on the market. Such a plant is quicker to install than furnaces, and once in operation, clean quicksilver is ready for bottling in 3 or 4 days at the outside. The time of contact required of the ore and solution is very short. By grinding 'in solution', the solvent will have done its work by the time the pulp reaches the filters, without the necessity of any intermediate agitators. The possible recovery is high, approaching 100% of the metallic content of the ore. This last-named item will offset the somewhat higher operating cost as compared with furnace practice.

CONCLUSIONS.

With some of the conclusions summarized in a recent paper by Landers,[1] the author is, in the main, in accord:

"Extractions as high as 86% have been obtained by crushing and tabling the ore, but there are undoubtedly some ores in which the cinnabar occurs in an almost amorphous state, where the extraction by tabling alone can not be brought much above 60 to 70%. Careful tests have indicated that the losses here occur almost entirely in the fines that are apparently in suspension in the pulp and as flotation results have shown that, so far as cinnabar is concerned, it can be successfully applied only to the fines, no doubt a total extraction of over 90% can in most cases be economically obtained. Other sulphides, notably pyrite, are almost always present in cinnabar ores, and this pyrite can be concentrated out with the cinnabar, proving a valuable addition to the succeeding furnace operation and cutting down the amount of fuel necessary to smelt the ore. Concentration has one other great advantage, which is that it elimates the asphaltum products and other carbonaceous materials that are nearly always found in the ores and are among the chief sources of difficulty in the proper collection of the mercury after smelting. It might be well to mention here that all fire methods of reducing cinnabar call for subsequent condensation of the mercury vapors and that any hydrocarbon distillates that may be condensed with the vapors add greatly to the difficulty of collecting the metallic mercury.

"Briefly, such concentrators as have been installed recently consist of rock crushers, ball mills and various types of tables. Jigs have been tried in one place and no doubt should be given a more general trial elsewhere. The coarser the concentrate that can be made, the more favorable it is for roasting in the furnace, and if retorts are excepted, none of the present furnaces would work very long on typical flotation concentrates.

* * * * * * *

"A thorough knowledge of the losses, mechanical and metallurgical conditions leads one to forecast that the future will either bring out a successful wet method for reducing mercurial ores or will develop the wet concentration of these ores until a saving in excess of 90% will be made on a commercial scale. Furnacing of the ores will probably always be the cheapest in per ton costs on tonnages greater than 25 per day and on ores in excess of 1% mercury content. The losses sustained in treating low-grade ores in furnaces will in all probability be greater than that of wet concentration plus a proper retorting of the concentrates.

"Mines having large investments in furnace plants will continue to use them up to capacity, but will build concentrating plants for their lowest-grade ores, mixing the resulting concentrates with the ore going to the furnace. The low per-ton cost of a concentrating plant together with its necessary retorts will probably preclude the erection of more large furnaces, although in the case of the installation of a large concentrator the quantity of concentrates obtained will necessitate the construction of some type of furnace with greater capacity than can be secured from retorts. This will bring in mechanical furnaces having little or no application of external heat, the concentrates containing sufficient sulphur to provide their own fuel. Such a condition would be ideal for the distillation of mercury, as the volume of furnace gases with attendant vapor loss could be kept down to a minimum. The price of mercury may influence the choice of process."

The ultimate decision between a straight furnace reduction, or concentration and roasting of concentrates will be a matter of comparative costs coupled with comparative extractions. The initial installation of a Scott fine-ore furnace unit is high (including condensers, etc., $1000 per ton-day capacity. We know of instances where the cost has been materially less than this figure, but they are the exception rather than the rule); the extraction is ordinarily low (in the majority of cases probably not over 75%); the cost of operation is low (50¢ to 75¢ per ton for large units, economically managed, though this does not include high-cost repairs, interest or depreciation on the high initial installation capital). A table concentration plant of equal capacity will require approximately one-fifth the initial capital expenditure, and a correspondingly lower depreciation charge; properly designed and operated, it should give 25% to 30% higher extrac-

[1] Landers, W. H., The smelting of quicksilver ores: Eng. & Min. Jour., vol. 102, pp. 630–633, Oct. 7, 1916.

tion; but the operating cost, on account of finer crushing, will be 30% to 50% higher. An alkaline-solution plant will require less than one-half the initial capital expenditure of a furnace plant and yield practically a complete extraction. These points will have to be determined upon for each individual property.

In this connection, while calling attention to the subject of capital expenditure, it is apropros to state that the items of amortization, depreciation and interest are too often omitted from consideration in cost data. Their inclusion is vital in a consideration of the proper plant and treatment for a quicksilver ore.

The writer is of the opinion that either concentration or the alkaline sulphide solution method can be economically adopted at some quicksilver properties, depending on the nature of the ore and gangue associations; but it does not appear that they are likely to any considerable extent to displace the Scott furnace. Concentration may also serve as an adjunct to some existing furnace plants, to increase their capacity, as is at present being done at New Idria.

PART III.

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*Trinity County	----
*Tuolumne County	----
Yuba County	.25
Register of Oil Wells (with map), Los Angeles City	.35

‡Write for price-list.

OTHER MAPS.

	Price
*California, Showing Mineral Deposits (50x60 in.)—	
Mounted	$1.50
Forest Reserves in California—	
Mounted	.50
Unmounted	.30
*Mineral and Relief Map of California	----
El Dorado County, Showing Boundaries of National Forests	.20
Madera County, Showing Boundaries of National Forests	.20
Placer County, Showing Boundaries of National Forests	.20
Shasta County, Showing Boundaries of National Forests	.20
Sierra County, Showing Boundaries of National Forests	.20
Siskiyou County, Showing Boundaries of National Forests	.20
Trinity County, Showing Boundaries of National Forests	.45
Tuolumne County, Showing Boundaries of National Forests	.20
*Mother Lode Region	----
Desert Region of Southern California	.10
Minaret Region, Madera County	.20
Copper Deposits in California	.05
Calaveras County	.25
Plumas County	.25
Tuolumne County	.25
Geological Map of California (mounted)—50x60 inches	2.50

DETERMINATION OF MINERAL SAMPLES.

Samples (limited to three at one time) of any mineral found in the state may be sent to the Bureau for identification, and the same will be classified free of charge. No samples will be determined if received from points outside the state. It must be understood that no assays or quantitative determinations will be made. Samples should be in lump form if possible, and marked plainly with name of sender on outside of package, etc. No samples will be received unless delivery charges are prepaid. A letter should accompany sample, giving locality where mineral was found and the nature of the information desired.

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