

THE CHALLENGE MERCURY DEPOSIT, REDWOOD CITY, SAN MATEO COUNTY, CALIFORNIA

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Bay Area Mineralogists Report

The Challenge mercury deposit, Redwood City, California was discovered prior to 1863 by Mexican prospectors . Intermediate mining efforts over the years produced mainly native mercury and cinnabar before the site was converted to a housing development and city park. To date, fourteen mercury-bearing species have been identified from samples collected since its first discovery to the late 1990's. These include: cinnabar, native mercury, eglestonite, terlinguaite, wattersite, calomel, montroydite, mosesite, edgarbaileyite, kleinite(?), metacinnabar, and three undescribed species. Also, the first U.S. occurrence of tunisite was confirmed.

INTRODUCTION

The Challenge mercury deposit, also known as the Farm Hill No.2 mine, Redwood City mercury mine and the Emerald Lake mercury deposit, represents one of the smaller mercury producers situated along the Coast Ranges of California. Up to 1965, the deposit has always been known as the Redwood City mercury deposit but it is not clear what the derivation of the term "Challenge" is or when it was applied to the deposit. The locality is listed in Minerals of California as the Challenge deposit by Pemberton (1983) so the name must have been derived prior to 1980 as quoted by E. H. Bailey.

Although cinnabar had been known from the site prior to 1865, the "rediscovery" of the deposit during early 1955 created a minor "mercury boom" in the area with production of cinnabar and native mercury from the highly weathered serpentinite and silica-carbonate rocks. Numerous newspaper articles abounded with the "new discovery" and the potential of "grand riches to be made", even estimated in the millions by some people, which would be gained from the mining operations. Some even suggested that the deposit might rival those of the New Idria and New Almaden mines!

To date, there has never been a formal paper published on the mineralogical aspects of the Challenge deposit except for two short articles describing eglestonite and montroydite in 1911 by Austin F. Rogers and in 1934 by C. D. Woodhouse, respectively. The U.S. Geological Survey (Menlo Park) prepared several short file reports that were not published.

My interest in the site is the result of the several rare mercury minerals that have been identified by XRD methods from the deposit by the late Richard C. Erd, U.S. Geological Survey, retired. Several individuals, including

Dennis Sorg, Edward Oyler, Lourens Wals and Dick Erd, collected these samples. Since several of these rare mercury minerals have also been identified from the Clear Creek mine in San Benito County, I wanted to do a comparative study of the two mines to determine if any paragenetic similarities existed between the two deposits.

LOCATION

The Challenge deposit located in Sec. 36, T. 5S, R. 4W, M.D.M. near Emerald Lake, about 2 miles southwest of central Redwood City, along the area west side of Farm Hill Boulevard and east of Jefferson Avenue, San Mateo County, California. A housing development currently occupies the old mining site. Mercury mineralization was also discovered in what is now Stulsaft Park. The mineralized rocks were removed from the area in 1966. The previous mining area was leveled and is now the park recreation field.



Figures a and b. Photos of Stulsaft Park in 2008.

HISTORY

Mining History

The first reference to mercury-bearing rocks near Redwood City was recorded by Whitney (1865) following geological fieldwork conducted along the Coast Ranges, specifically the peninsula of San Francisco. The original discovery was described as on the Corte Madera Ranch near Searsville. Miners associated with the New Almaden mercury-mining effort probably noted cinnabar and native mercury earlier during prospecting in the area. It is reported that a 75-foot shaft had been dug in a vein or bed of red clay, which was reported to contain cinnabar. Assays of this material had results of three to ten percent mercury.

In 1943, Robert Stopper of the U. S. Geological Survey wrote a short report on the potential Hg reserves of the deposit. He stated that in 1941 trenching, which consisted of 11 open cuts with a maximum length of 200 feet and a depth of 10 feet, was done to determine the extent of the ore-bearing silica-carbonate rock. All exposures of the silica-carbonate rock were mineralized with cinnabar, but only about 15 tons of 3 to 5 pound ore were exposed. The limited outcrops of this rock did not allow, at that time, a rigid estimate of the total amount of ore that may be present. Because of the low grade of the exposed ore, the property did not warrant further development unless quicksilver values advance considerably beyond \$190 per flask. Records show that a small amount of mercury was produced during WWII at the Crazy Horse mine, just northeast of the present workings.

No additional references to this “find” were recorded until October 1954 when two young boys, Dennis Sorg and Richard Weiskal, “re-discovered” rocks containing cinnabar and native mercury on property owned by the Sterling Development Company, which was beginning to build a series of houses on the property. The boys contacted a Mr. H. B. Piggott of San Francisco and he and an associate, Mr. Fred Dinely, examined the find and negotiated with the property owner, Mr. Oddstad, and did some bulldozing to expose the potential ore quantity. The find got talked up to a million-dollar-a-year mine although no ore had been mined. And because outcroppings were discovered on the adjacent undeveloped city-owned Stulsaft Park, the townspeople began to dream of tax-free living with city expenses paid from the profits of a bottomless mercury mine.

Mr. Piggott reported that he took out \$25,000 worth of quicksilver in one day and later applied to the Redwood City Council for permission to mine the ore by open cut methods. As the quicksilver “discovery” lay within 40 feet of land owned by the city to be developed as a recreational park area, it was of unusual interest to the city. The Council subsequently gave Mr. Piggott permission to prospect in the proposed park area for a period of two weeks.

An office memorandum sent to Mr. Bailey at the Geological Survey states that Mr. Piggott shipped 500 tons of ore the first week of mining (recovered 169 flasks) and 650 tons in the second week (200 flasks recovered). This ore averaged 24 lbs mercury per ton of ore. By July 26 he had shipped 5000 tons of ore. The low-grade ore went to the Palo Alto Mining and Smelting Company of San Jose and the higher-grade ore to a retort in Cloverdale, a trip of about 142 miles. Despite the extensive mining operation including several trucks, a “steam shovel” and a tracked front loader, there has not been a mining claim recorded for the site nor any formal mining permits acquired. The philosophy appears to have been, “mine now, get rich and deal with the paperwork later.” To further complicate the situation, the property is not zoned for mining, only residential. All of this “hasty mining efforts” have caused a lot of questions to be raised by the Redwood City Council, especially the city attorney.



*Figure 1. Dennis Sorg & Richard Weiskal, discoverers of mercury-containing rocks at the Redwood City site.
(Courtesy of the Redwood City Tribune, September 30, 1955)*



*Figure 2. Mining operations during September 1955 at the Redwood City mercury deposit.
(Courtesy of the San Francisco Chronicle, September 25, 1955).*

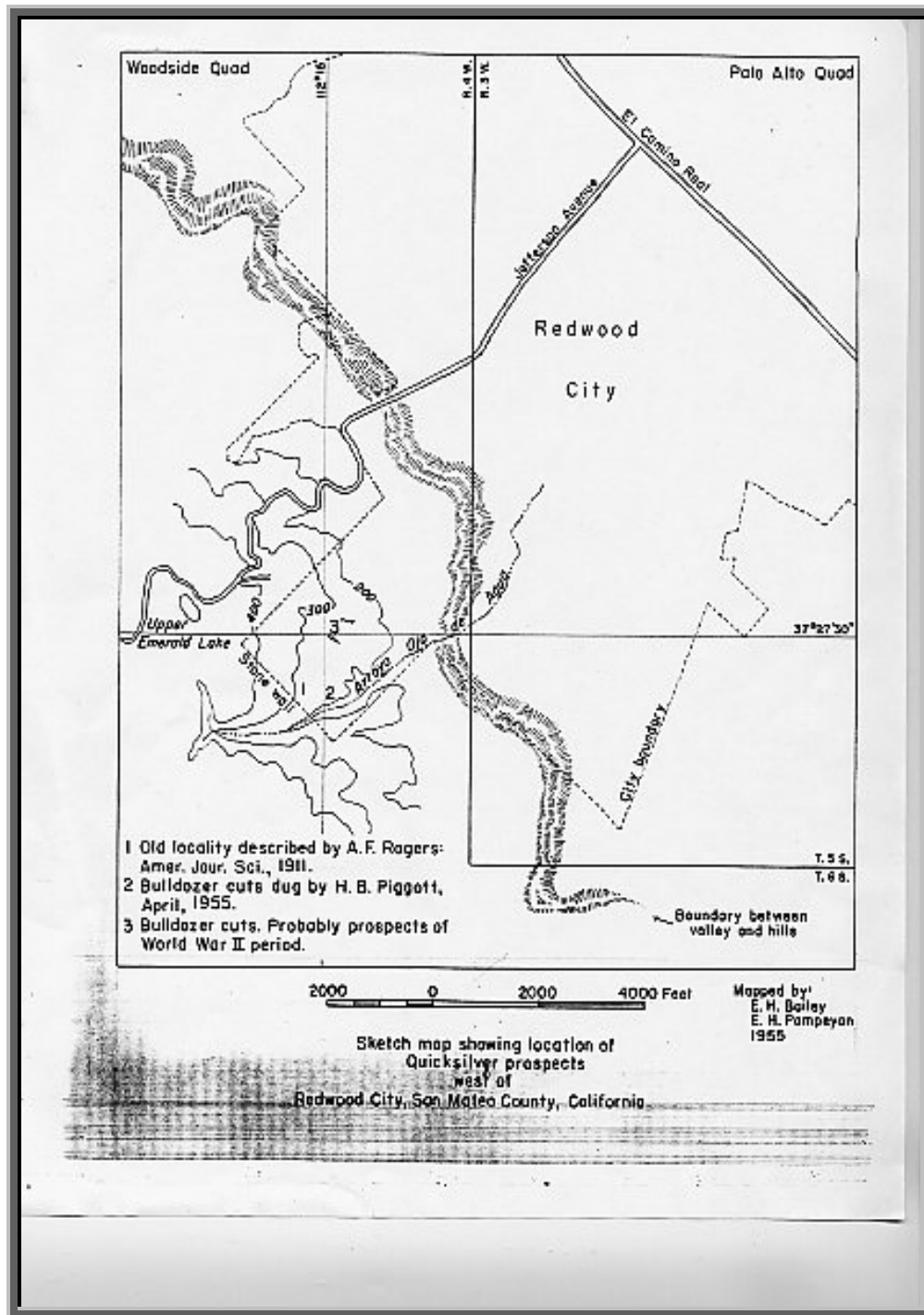


Figure 3. Map of the Redwood City mercury deposit showing the exploratory pits dug during 1941 and 1955 (after Bailey and Pampeyan, 1955).

On January 16, 1956 the mill and mine site were visited by Roscoe Smith, Hal Stager and Edgar Bailey. Their report states the following: "A 40 ton Herreshoff furnace is located south of the gypsum plant at Port Redwood City. The furnace was moved from the McAdoo property, Bottle Creek District, Nevada and operated by a Mr. Tripolay. He had been in production for six months, treated 30-40 tons per day and recovered about 80 flasks a month and had a total production of about 500 flasks. He also stated that Buckman's furnace recovered about 600 flasks. Most of the ore was mined several months ago and stockpiled on the flat by the furnace. Calcines are

dumped into an arm of the bay by the plant. The ore grade is 5.5 lb/ton. It was first thought to be better. The plant is up for sale although there is still considerable ore piled beside it. There was apparently no great profit.”

The mining area was also described: “The old lower cut seemingly exhausted and abandoned and partly filled by road fill. A new cut up the hill about 300 yards is being mined by power shovel. Ore is all in messy, sheared and altered serpentine. There is no structure to the rock. Some silica-carbonate rock in altered lumps in the serpentine. This has quartz veinlets with some native mercury and seems similar to the material that yielded the montroydite and oxychlorides first reported on by Rogers. Ore zone dips east a bit steeper than the hill and is about 5 feet thick. I have no ideas as to why it is there; could even be localized along the sole of an old landslide. Grade being mined is reported to be 4 pounds which seems about right.”

For the two young discoverers of the first find, Richard Weiskal and Dennis Sorg, Mr. Oddstad, the owner of the land, gave them a “finders check” for \$1500 for their discovery in 1954. Feeling somewhat “cheated” over their discovery, the two boys sued for more and finally came out with an additional \$4500, half of which went to attorney fees. The remainder, \$3750, they split.

Not to be outdone by their previous discovery, Dennis Sorg and his partner prospector, Richard Weiskal, now geologists, discovered two pods of rich mercury ore in Redwood City’s Stulsaft Park. The new deposit is easily accessible and is located about 200 feet from Farm Hill Boulevard right in the middle of a park service road. It is only 100 feet from the largest original mine pit which now is a turfed area. Ironically, it is located right where the job shack for the old mining operation was located. Preliminary trenching produced mercury ore values estimated at \$200,000. However, no records exist of any ore produced after this “second find.”

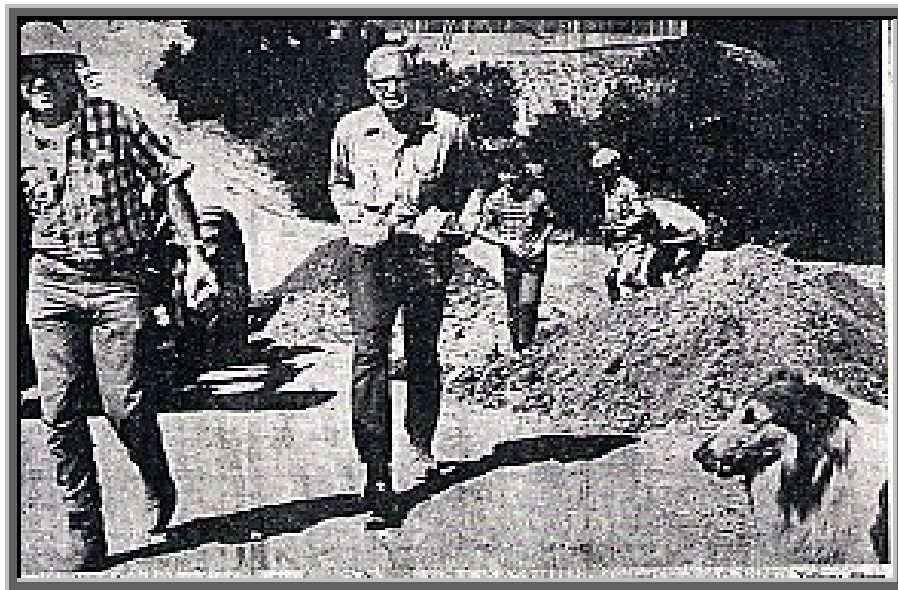


Figure 4. Dennis Sorg and Richard Weiskal recovering mercury-bearing samples from a trench in Stulsaft park during their “second” discovery in 1966. (Courtesy of the Redwood City Tribune, June 1966)

Collecting History

Prior to 1911, Austin F. Rogers, professor at Stanford University, received some specimens from a quicksilver prospect in San Mateo County, that were brought to his attention by Mr. W. R. Nobs, a mining student at Stanford University. These pale-brown siliceous samples contained cinnabar, native mercury, calomel and an unknown yellow mineral, which was identified as one of the oxychlorides of mercury known previously from the Terlingua, Texas deposits. Subsequent chemical and optical tests concluded that this yellow mineral was eglestonite.

Noting the identification of eglestonite by Dr. Rogers, Mr. C. D. Woodhouse, a mining engineer working at the Champion mine, near Laws, Inyo County, visited the Redwood City site prior to 1934 in search of specimen material. While working on a new section of the vein about a foot below the surface, he noted groups of small, red, acicular crystals floating on drops of native mercury and in some instances lining small vugs containing dolomite crystals. These acicular crystals were later examined under the microscope and proved to be montroydite, which prior to this date, had only been reported from the Terlingua, Texas mercury mines. Mr. Woodhouse had also noted a greenish-yellow powder in some vugs that suggested the mercury oxychloride, terlinguaite, however insufficient material was present at that time to perform conclusive tests.

Mr. Woodhouse noted the associated mercury minerals in the deposit including eglestonite in cubic, dodecahedral, and acicular malformed crystals and also as crusts coating dolomite; calomel in masses of small colorless euhedral crystals, native mercury in drops along seams and vugs in the vein and cinnabar in subhedral crystals and crusts.

GEOLOGY

Geological descriptions of the area have been described by Bailey and Pampeyan (1955) and Stopper (1943). The local geology consists of an intrusive serpentinite, derived from the alteration of both peridotite and pyroxenite and covers 90 percent of the mapped area. It is composed mainly of antigorite cut by thin seams of chrysotile; magnetite, chromite, and magnesite are also present in small amounts. In general, exposures of the rock are weathered, but most of the serpentinite appears to be unusually massive and nearly devoid of slickensides.

Small lenses of sandstone and chert are engulfed in the serpentinite. The sandstone, which is massive and buff colored on weathered surfaces, is composed of sub-rounded well-sorted grains of quartz, feldspar, muscovite, and small fragments of black and brown shale; it appears similar to sandstone of the Chico formation of Cretaceous age. The cherts are massive, red, green, blue, and yellow; and are similar to the chert of the Franciscan formation of Jurassic age.

Locally silica-carbonate rock, which is of importance as it is the host for the mercury minerals, has been formed from the serpentinite. The silica-carbonate rock is mainly composed of chalcedonic quartz, but is traversed by veinlets of calcite and dolomite. The carbonate veinlets, which amount to less than 10 percent of the rock, are cut by later quartz veinlets, and a still later generation of quartz traverses these seams. Small amounts of magnetite and chromite, present as residual mineral, indicate the derivation of the rock from serpentinite. Close to the silica-carbonate bodies, the serpentinite has been slightly silicified, and is more altered than is the surrounding serpentinite.

The mercury minerals are, for the most part, confined to the silica-carbonate rock, and are the last minerals introduced into this complex rock. In order of abundance are native mercury, cinnabar, calomel, eglestonite and montroydite, and all occur in seams and crevices in the rock. Because of the soft nature of the weathered

serpentinite rock, much cinnabar was deposited in it also. Most of the cinnabar is of the “paint” variety, but crystals of cinnabar formed small incrustations in cavities and along fracture surfaces.

MINERALOGY

Besides the accessory minerals normally encountered in serpentinite, the silica-carbonate replacement rocks host a number of rare mercury-bearing minerals along seams and fractures. Two of these minerals, wattersite and edgarbaileyite, are quite unique to only a few mines. Wattersite has been previously found only at the Clear Creek mine, San Benito County while edgarbaileyite has been found at select California, Nevada, Arkansas and Texas localities. In addition, three undescribed, and quite rare minerals have been noted in samples recovered. These rare minerals prompted our documentation of the small but important mercury deposit. Unfortunately, only about thirty small samples were made available for this study, which were a part of the late Edward Oyler collection.

Mercury Minerals

Calomel Hg_2Cl_2

Calomel was first noted by Rogers (1911) from the deposit in samples submitted by Mr. Nobs, a mining student at Stanford University. It occurs as massive to subhedral to euhedral crystals along veins in the weathered silica-carbonate rock. It is best identified by its red fluorescence under SWUV light. Along parts of these veins small pockets occur that are lined with massive montroydite with small globules of native mercury. Associated minerals include dolomite and calcite.



Figure 5. Vein of calomel with associated dolomite and calcite. FOV = 16mm

Cinnabar HgS

Bright red cinnabar occurs as subhedral crystals and crusts along fracture surfaces of the weathered serpentinite and filling fractures associated with quartz, calcite and dolomite. None of the cinnabar examined shows any effects of etching, so often encountered in the ores at the Clear Creek mine. Crystals along the quartz veins show a stout to slender prismatic [1010] habit.



Figure 6. Flattened cinnabar crystals along a quartz vein in the silica-carbonate rock. FOV = 16mm



Figure 7. Vein cavity showing complex cinnabar crystals with quartz. FOV = 7mm.



Figure 8. Higher magnification of previous photo showing parallel growth of crystals. FOV = 3mm.

Edgarbaileyite $\text{Hg}_6^+\text{Si}_2\text{O}_7$

Richard. C. Erd, using XRD methods from a single sample collected by the late Edward Oyler in 1990, identified Edgarbaileyite. It has been described as a green, massive material associated with quartz. This is the fourth recorded California locality for this rare mineral, the others being the Socrates mine, Alpine mine and the Clear Creek mine. On the same specimen a single euhedral grain of tunisite was identified.

Eglestonite $\text{Hg}_6^{1+}\text{Cl}_3\text{O}(\text{OH})$

Eglestonite was first discovered from the Challenge deposit on samples submitted to Dr. Austin Rogers prior to 1911 by Mr. Nobs, a mining student at Stanford University (Rogers, 1911). The eglestonite occurs in a pale-brown siliceous material in serpentinite. The crystals examined are quite small, the largest being about 0.5 mm in diameter. The luster is adamantine, and color varies from yellow or orange-yellow to brownish-yellow. Optical measurements identified the following forms: $a\{100\}$, $d\{110\}$, $o\{111\}$, and $n\{211\}$. Four distinct habits were recognized. The most common type of crystal form is that with dominant cube, modified by the dodecahedron and very small faces of the trapezohedron $\{211\}$. The second type is dominated by the octahedron with prominent cube faces and narrow dodecahedrons. The third type shows the dominant dodecahedral habit with narrow trapezohedral $\{211\}$ faces. The fourth type shows acicular crystals proved to be distorted dodecahedrons with striations parallel to the intersection edges.

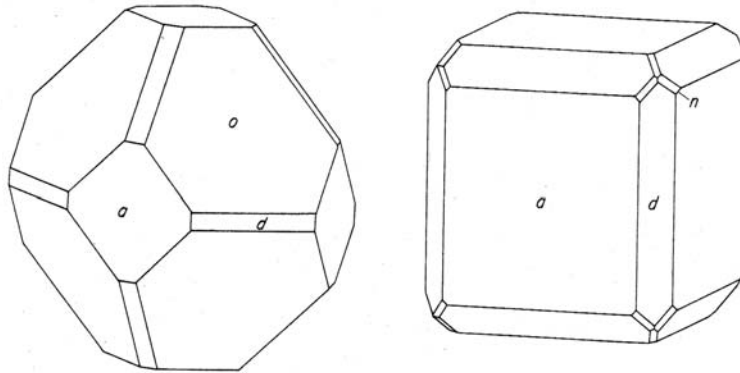


Figure 9. Eglestonite crystal forms from the Challenge mercury deposit. (After Rogers, 1911).

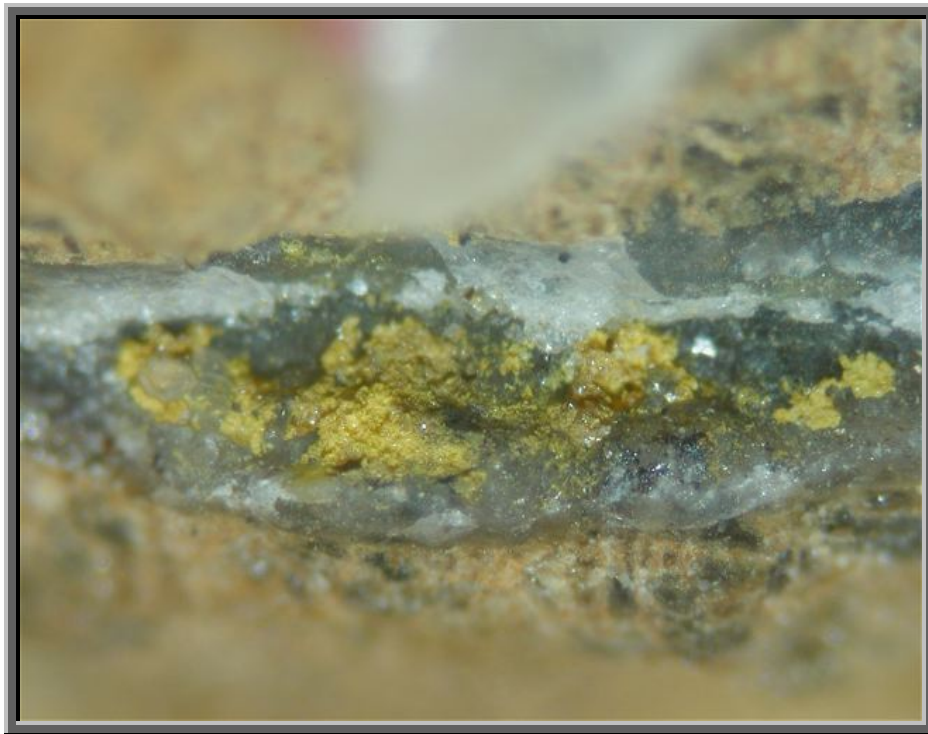


Figure 10. Thin quartz vein containing subhedral to anhedral eglestonite in an elongated cavity. FOV = 5mm



Figure 11. Quartz cavity lined with subhedral to anhedral eglestonite. FOV = 10mm.



Figure 12. Cavity filled with subhedral eglestonite crystals and masses. FOV = 10mm.



Figure 13. Cavity filled with subhedral eglestonite crystals and masses. FOV = 10mm.

Kleinite (?) $4[\text{Hg}_2\text{NCl}]\cdot\text{Hg}(\text{SO}_4, \text{Cl})\cdot\text{H}_2\text{O}$

A small sample collected during 1990 containing a massive orange-yellow material that was tentatively identified as kleinite-like using XRD methods by R. C. Erd. No further tests were performed on the specimen.

Mercury Hg

Native mercury occurred throughout the deposit associated with cinnabar as free droplets in the weathered serpentinite and filling voids in quartz veinlets cutting the silica-carbonate rock where it is associated with montroydite and eglestonite.



Figure 14. Globules of native mercury in quartz cavity. FOV = 5mm.



Figure 15. Masses of native mercury associated with rare red montroydite. FOV = 5mm.

Metacinnabar HgS

Metacinnabar occurs as black, shiny anhedral grains and thin coatings associated with cinnabar along fracture surfaces in the weathered silica-carbonate rock. It was identified by XRD methods.



Figure 16. Vein of metacinnabar associated with cinnabar in silica-carbonate rock. FOV = 10mm.

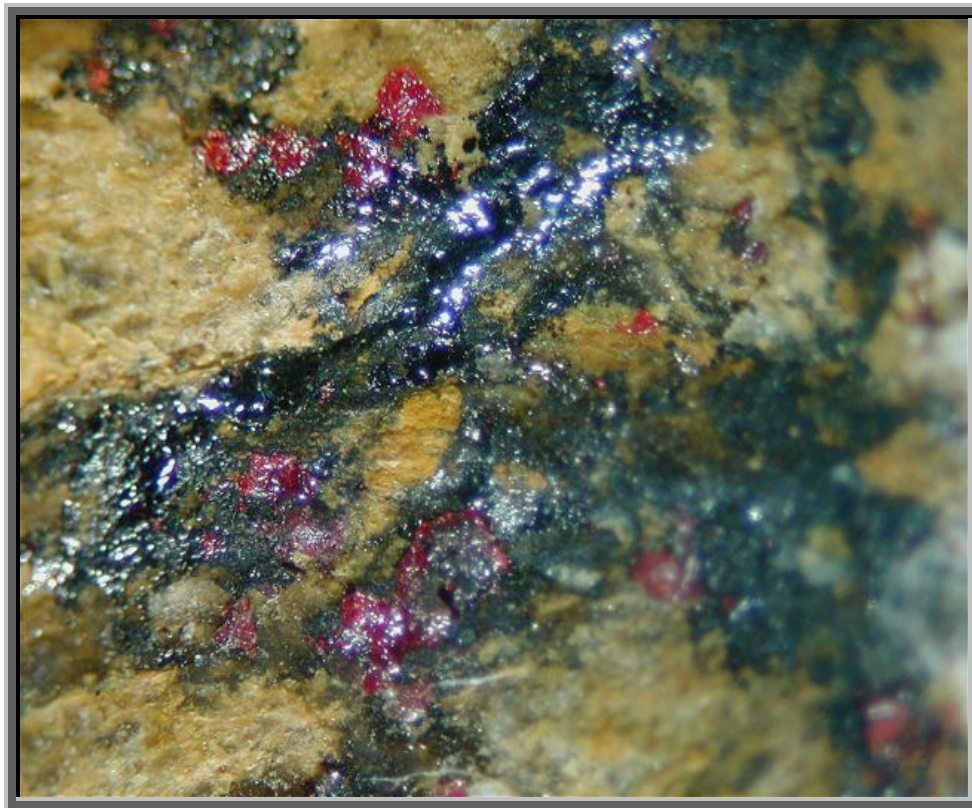


Figure 17. Higher magnification showing the metacinnabar vein with cinnabar. FOV = 6mm.

Montroydite HgO

Montroydite was first noted by Woodhouse (1934) on samples he collected from the rocks at the Redwood City site. These orange-red crystals that were observed floating on drops of native mercury, proved to be the first California occurrence of this mineral. Two forms of crystals were observed on the samples studied: (1) long, subhedral, prismatic forms varying in length from sub millimeter to about 2 mm and terminated at one end only and (2) malformed and bent crystals having a worm-like appearance. These unusual forms are striated, uneven and show no terminations. In some cases the crystals are so bent that they assume U-shaped forms. These bent forms were determined to be the result of bend-gliding, as described by Mügge (1898) and Buerger (1930). Other minerals such as stibnite, kyanite and gypsum show the same behavior after bending.

Mosesite $\text{Hg}_2^{2+}\text{N}(\text{Cl}, \text{SO}_4) \cdot \text{H}_2\text{O}$

Mosesite has been identified by XRD methods as yellow-orange to yellow-green fine-grained material and spheroids in quartz cavities from a sample collected by Dennis Sorg during early 1965.

Terlinguaite $\text{Hg}^1\text{Hg}^{2+}\text{OCl}$

Terlinguaite was identified by XRD methods from a single sample collected by Dennis Sorg. This sample contained a yellow powder in a quartz cavity. Also on this sample were several yellow-green spheroids and coatings that were also identified as terlinguaite. The mineral is considered to be quite rare in the mineralized zone.

Tiemannite HgSe

Tiemannite was identified by XRD methods in samples containing black metacinnabar associated with cinnabar along fracture surfaces in the weathered silica-carbonate rock.

Wattersite $\text{Hg}_4\text{Hg}^{2+}(\text{CrO}_4)\text{O}_2$

The second occurrence of wattersite was confirmed by XRD methods. The wattersite occurs as brilliant, black prismatic crystals on quartz and is associated with native mercury and hydrocarbons. This sample was collected by the late Edward Oyler in 1990 and is the second recorded occurrence for this very rare mineral.

Unidentified Hg-bearing Species**CDUK-1** Trigonal dimorph of HgO (?)

A sample collected by Mr. Edward Oyler in 1990 contained several reddish-orange spherules partially coated by a brownish-black crust. Two XRD patterns of this reddish-orange material agree with the data for PDF 11-584, the trigonal dimorph of HgO. However, insufficient material was remaining to conduct further testing. No crystals were noted which could be used for a structure evaluation. The average observed *d*-spacings in Å and relative intensities calculated from two films of this material gave: 3.10 (50), 2.92 (100), 2.89 (60), 2.52 (100), 2.11(30), 1.786 (50), 1.778 (50), 1.522 (80), and 1.459 (50).

The structure of the artificial phase is similar to that of cinnabar. Two types of chains exist: Hg-O-Hg and O-Hg-O with a distance between the chains of 2.79 Å.

CDUK-2 $\text{Hg}^{2+}\text{Cl}_2\cdot 3\text{HgO}$ (?)

The brownish-black crust observed coating the reddish-orange spherules on sample CCUK-1 gave an XRD pattern having a good match for $\text{HgCl}_2\cdot 3\text{HgO}$, as described in the PDF 1-0456. This is the first occurrence of an Hg (II) chloride-oxide in nature. Insufficient material was available for further study. The observed *d*-spacings in Å and relative intensities for this material are: 5.83 (25), 3.96 (100), 3.25 (50) 2.93 (75), 2.70 (100), 2.59 (25), 1.793 (25), 1.643 (20), and 1.57 (20).

CDUK-3 $\text{Hg}_2^{2+}(\text{CO}_3)(\text{OH})_2$ (?)

On the same sample that the wattersite was identified, a bright-yellow powdery material was noted that gave a powder diffraction pattern identical with the material noted as a “scum” on surfaces of the native mercury. The strong diffraction lines and overall data appearance suggest that the material may be a carbonate and similar to the general formula for the rosasite group. However, insufficient material was available to conduct further tests. The average observed *d*-spacings for two films in Å for this material are: 6.1, 5.2, 4.66, 3.53, 3.03, 3.11, 2.60, 2.33, 2.09, 1.80, and 1.61. No relative intensities were reported for this data set. A similar surface coating has been observed on native mercury samples from the Clear Creek mine but insufficient material was available for further tests.

Associated Minerals**Calcite** CaCO_3

Calcite veins associated with dolomite cut the silica-carbonate rock and are later cut by quartz veins.

Dolomite $\text{CaMg}(\text{CO}_3)_2$

Subhedral to euhedral dolomite occurs along fractures in the silica-carbonate rock associated with calcite, calomel, native mercury, montroydite and quartz.

Undifferentiated Hydrocarbons

Within the quartz veins cutting the weathered serpentinite are pods containing liquid petroleum. Attempts to analyze this material have resulted in no specific compounds. Peabody and Einaudi (1992) have described similar

natural petroleum products at the Culver-Baer deposit, Mayacmas District, Sonoma County, California. They have described this petroleum product as a mixture of polycyclic aromatic hydrocarbons.

Magnesiochromite MgCr_2O_4

Minute euhedral grains of magnesiochromite are common throughout the silicified serpentinite in the deposit. There has been no halo of alteration noted on any of the samples examined, suggesting the intermediate mineral, eskolaite, which has been noted at the Clear Creek mine (Dunning, et al. 2005).

Magnetite Fe_3O_4

Stopper (1943) noted small amounts of magnetite associated with chromite or magnesiochromite and magnesite in the altered serpentinite.

Quartz SiO_2

Thin seams of quartz occur associated with many of the mercury-bearing minerals in the deposit. It is often associated with native mercury.

Tunisite $\text{NaCa}_2\text{Al}_4(\text{CO}_3)_4(\text{OH})_8\text{Cl}$

A specimen collected by Edward Oyler in 1990 was submitted for evaluation. A single spear-shaped, clear crystal plate about 150 microns in maximum dimension was noted in a cavity. The X-ray powder pattern matched that for the rare mineral, tunisite. It is believed that this discovery is the first U.S. occurrence for this mineral. The mode of formation is unusual when compared to other reported occurrences from Tunisia, Ukraine and France. It is surmised that the tunisite formed by a rare calcite neutralization of an Al-rich, acidic, saline brine.

PARAGENESIS

General Sample Description

The number of samples available for study and their poor quality restricted the paragenetic picture for this small mercury deposit. These study samples, about thirty, were recovered in 1990 after mining operations had ceased and came from isolated rocks exposed in the city park area by Richard Erd and Edward Oyler. No samples were available from the original mining operations conducted in 1955-56 or during additional field exploration during 1965. The majority of samples examined showed a highly weathered appearance and are light brown in color and friable. Several small samples were found to be representative of "normal" silica-carbonate rock, composed mainly of quartz or chalcedonic veins. Textural signatures of the replaced serpentinite often seen in other deposits are nearly obliterated by the extensive weathering.

Paragenetic Sequence

Carbonate-rich veins composed of calcite and dolomite cut the friable host rock. Episodes of fracturing followed by quartz/chalcedonic-rich intrusions cut these carbonate-rich veins. A later generation of fracturing followed by quartz-rich fluids cut these prior veins. Mercury minerals are confined to both the friable low-grade partially replaced serpentinite (cinnabar and metacinnabar) and the complex quartz cross-veins (cinnabar, native mercury, eglestonite, terlinguaite, montroydite). The majority of the cinnabar observed is confined to slip surfaces and cavities within the weathered low-grade serpentinite rock. No surface dissolution effects have been observed of the cinnabar in samples examined, as it is quite shiny. Several samples of bright cinnabar as subhedral to euhedral flattened crystals occur along quartz seams and are quite attractive. Marginal intrusion of cinnabar into the weathered serpentinite is common with discontinuous coatings and void fillings.

Also along the calcite-dolomite veins, moderate amounts of calomel formed as minute crystals and euhedral grains and coatings. Native mercury was quite common in some sections of the deposit and formed the principal mercury ore. Along some quartz veins examined, native mercury occurs filling vugs and is associated with thick liquid hydrocarbons. Montroydite has formed from the oxidation of the native mercury and has completely replaced it in some vein sites. In other voids, montroydite forms dark reddish-orange elongated crystals on surfaces of the native mercury. Minor eglestonite and terlinguaite occur in conjunction with cinnabar and metacinnabar but formed later by the action of chloride-rich fluids.

The very rare minerals wattersite, edgarbaileyite and the three un-described mercury-bearing minerals would suggest that the fluid conditions were locally near neutral to slightly acidic. Wattersite and edgarbaileyite are stable near neutral conditions with a moderate Eh and are quite localized in the deposit, with only one sample of each identified to date.

The oxychlorides eglestonite and terlinguaite are stable within the range of pH of 4 to 5. The lack of a green halo of oxidation surrounding the magnesiochromite grains, as is quite common at Clear Creek, would indicate that the pH did not reach moderately high values, although some did locally oxidized to form the very rare wattersite. This condition is also shown by the absence of edoylerite and ccuk-8 (a hydrous mercuric sulfide-chromate) and also by no visible surface dissolution of cinnabar in the ore samples examined. The lack of moderate montroydite in the ores except associated with native mercury in confined voids within quartz would also confirm that the pH remained slightly acidic where montroydite is not stable. The veins of carbonates in the ores acted to neutralize some of the acid and kept the pH slightly acidic to neutral.

The moderate amount of native mercury in the deposit would suggest that it is the product of early reduction and may have been introduced in conjunction with the petroleum products along the quartz veins and associated margins of the weathered serpentinite. The disproportionation of cinnabar would also yield native mercury and sulfate ions.

The single sample of edgarbaileyite identified would also suggest that fluid conditions favorable for its formation remained more acidic than required for its general stability. At Clear Creek native mercury, edgarbaileyite, wattersite and montroydite are often found together along voids in the quartz veins. At the Challenge deposit, this is not the case and it is presumed that the lack of moderate carbonate minerals in the mercury host rock prevented many of the rare minerals to form by allowing the pH to be somewhat less than 4.

Table 1 below shows a “best guess” for the paragenetic sequence for the mercury deposition at the Challenge deposit. Without additional material to work with, the placement is solely based on the results of the extensive study of the Clear Creek mine paragenesis, where many hundreds of samples were examined. Table 2 shows the relative distribution of mercury minerals at the Challenge deposit and was based on the few study samples examined.

Table 1. Paragenetic timeline for the Challenge deposit, Redwood City, California.

| <i>Mineral</i> | <i>Early</i> | <i>Late</i> |
|----------------|--------------|-------------|
| Quartz | ————— | ————— |
| Dolomite | ————— | |
| Calcite | ————— | |
| Cinnabar | | ————— |
| Metacinnabar | | ————— |
| Mercury | | —————? |
| Wattersite | | |
| Edgarbaileyite | | ————— |
| Calomel | | ————— |
| Montroydite | | ————— |
| Terlinguaite | | ————— |
| Eglestonite | | ————— |
| Mosesite | | ————— |
| Kleinite | | ————— |
| CDUK-1 | | ————— |
| CDUK-2 | | ————— |
| CDUK-3 | | ————— |

Table 2. **Rarity of minerals from the Challenge deposit, Redwood City, California.**

| <i>Mineral</i> | <i>Composition</i> | <i>Rarity</i> |
|----------------------------|--|------------------|
| Mercury Minerals | | |
| Cinnabar | HgS | Common |
| Calomel | Hg ₂ Cl ₂ | Uncommon |
| Edgarbaileyite | Hg ₆ Si ₂ O ₇ | Very Rare |
| Eglestonite | Hg ₆ Cl ₃ O(OH) | Rare |
| Kleinite (?) | 4[Hg ₂ NCl].Hg(SO ₄ ,Cl).H ₂ O | Very Rare |
| Mosesite | Hg ₂ N(Cl).H ₂ O | Very Rare |
| Wattersite | Hg ₄ Hg(CrO ₄)O ₂ | Very Rare |
| Terlinguaite | HgHgOCl | Very Rare |
| Mercury | Hg | Common |
| Metacinnabar | HgS | Common |
| Montroydite | HgO | Very Rare |
| CDUK-1 | HgO | Very Rare |
| CDUK-2 | Hg ²⁺ Cl ₂ ·3HgO (?) | Very Rare |
| CDUK-3 | Hg ₂ (CO ₃)(OH) ₂ (?) | Very Rare |
| Associated Minerals | | |
| Calcite | CaCO ₃ | Common |
| Dolomite | CaMg(CO ₃) ₂ | Common |
| Magnesiochromite | MgCr ₂ O ₄ | Common |
| Hydrocarbons | Various aromatic compounds | Uncommon to rare |
| Magnetite | Fe ₃ O ₄ | Uncommon |
| Quartz | SiO ₂ | Common |
| Tunisite | NaCa ₂ Al ₄ (CO ₃) ₄ (OH) ₈ Cl | Very Rare |

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