

# NEW MINERAL DATA FOR THE REMAINING UNIDENTIFIED MERCURY MINERALS FROM THE CLEAR CREEK MINE, SAN BENITO COUNTY, CALIFORNIA

*Gail E. Dunning*

773 Durshire Way

Sunnyvale, California 94087

gedunning1937@gmail.com

## A BAY AREA MINERALOGISTS REPORT

### INTRODUCTION:

Since the publication of the Clear Creek mercury mine study in 2005, additional observations have been made on the remaining unknowns. Three additional unknown mercury phases have been discovered. These include two spherical samples encased within a single sample of yellow mosesite and a single, stout crystal associated with CCUK-12. This brief report presents these new observations and findings from this unique mercury deposit. Where available, photos and structure diagrams are included in the discussion. Future studies on these remaining unknowns will depend on funding and time available. To date, there have been a total of twenty one individual mercury species discovered at the Clear Creek mine. Eleven of these new species have been formally described. This total of known and unknown species may be unprecedented for any mercury mine, let alone a small mine like the Clear Creek mine. The diversity of chemical phases discovered is most unusual and makes this mine unique in the world of mercury mineralogy.

### UNDESCRIBED MINERALS:

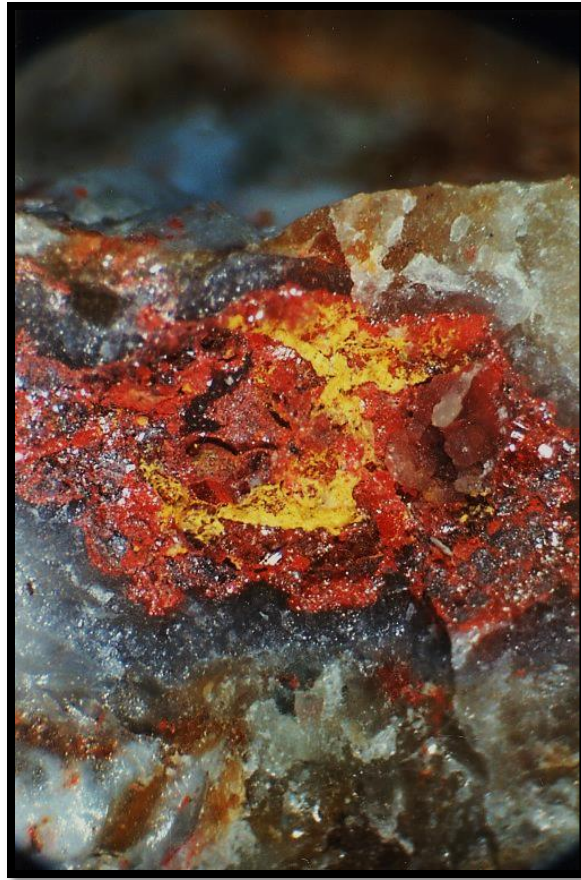
#### **CCUK-8** $\text{Hg}^{2+}\text{-CrO}_4\text{-S-nH}_2\text{O}$ ?

To date, no additional work has been performed on this mineral. Much effort has been made in obtaining a sample that contains individual crystals large enough to perform structure analysis and other important tests. So far, only micron-size crystals in crystalline aggregates and masses have been isolated. Samples that were thought to be CCUK-8 turned out to be edoylerite. The mineral is often associated with edoylerite on dull (etched) cinnabar. CCUK-8 appears by association to be one of the last mercury minerals to have formed during the chromate-rich relatively low temperature hydrothermal event. Most, if not all of the current specimens, represent a partial dehydration phase, which would indicate that the water is of a zeolitic nature, easily removed by exposure to environmental heat and low humidity of the mine area.

This mineral also has been identified from the Vaughn mine, east of Hollister, San Benito County where it occurs associated with cinnabar in a hydrothermally altered serpentinite (Dunning, 2009). Figures 1, 2 and 3 illustrate the coverage and micro size of the individual crystals.



**Figure 1.** Yellow microcrystals of CCUK-8 on a vein of cinnabar cutting a serpentinite rock. Clear Creek mine, upper workings. FOV = 30 mm.



**Figure 2.** Yellow microcrystals of CCUK-8 on cinnabar, both on quartz substrate. Clear Creek mine, upper workings. FOV = 1.8 mm.



**Figure 3.** SEM of yellow acicular CCUK-8 on cinnabar. Individual crystals range from 10 to 30 um long. FOV = 110 um.

### CCUK-12 ( $\text{Hg}_2^{2+}$ ) $\text{Hg}_{10}^{2+}\text{O}_2\text{S}_4\text{Cl}_2\text{Br}_2\text{I}_2$ ?

A single sample containing three pale green spear-shaped crystals was recovered from a single sample rock from the lower workings. These crystals occurred in a covered slanted depression, which did not allow for a good photograph or SEM image. However, with some difficulty, an EDS spectrum was obtained on one of the crystals which showed major Hg, Cl, I and Br. Small amounts of montroydite were associated with this small group of crystals. A set of pxrd data exists in addition to specific physical properties. A single crystal (2x4x25 microns) was extracted from the cavity and exposed to X-rays to determine a probable structure. The structure data was well refined to  $R = 4\%$  on a orthorhombic cell and space group of  $Pnca$ . The structure is a mixed  $\text{Hg}^+$  -  $\text{Hg}^{2+}$  phase with a large amount of anions. Figure 4 shows the apparent structure configuration of this complex mercury phase looking down the  $c$  axis. There are two bands of Hg-Hg dimers bonded to  $\text{I}^-$  anions surrounded by a parallel complex array of  $\text{Hg}^{2+}$  atoms coordinated with a group of Cl, Br, S and O anions. The above formula was extracted from the structure (Figure 4.) but still is not charge-balanced and requires four additional anion charges.

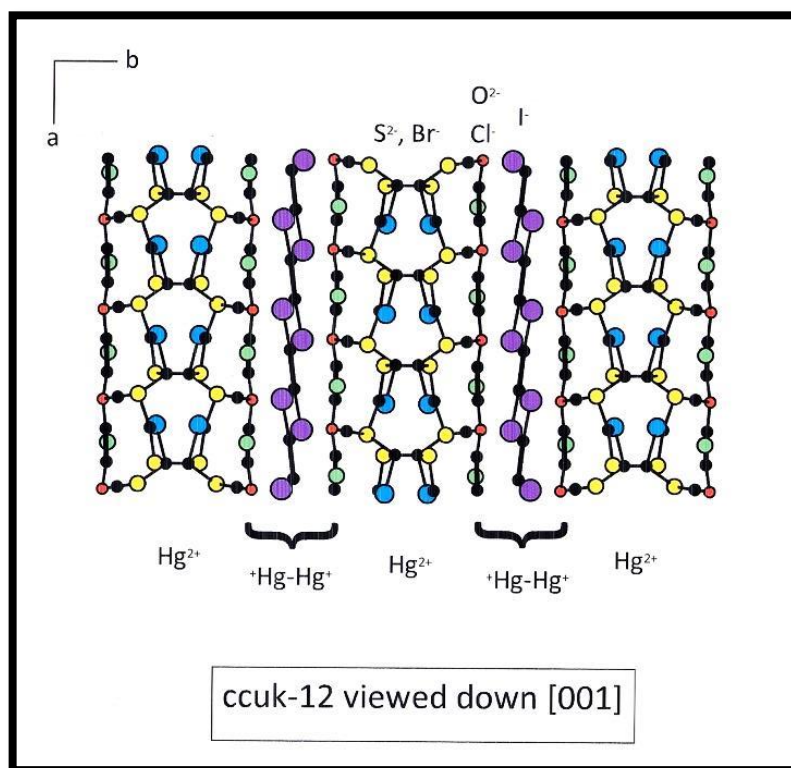


Figure 4. The structure of CCUK-12 as viewed down [001] showing the complex arrangement of anions consisting of  $\text{S}^{2-}$ ,  $\text{Br}^-$ ,  $\text{Cl}^-$ , and  $\text{O}^{2-}$  bonded on both sides by dimers of  $(\text{Hg-Hg})^{2+}$  to  $\text{I}^-$  atoms. This arrangement is quite complex and unique.



### CCUK-13 $[\text{Hg-Hg}]^{2+}_{16}(\text{Si}_4\text{O}_{12})_2(\text{SiO}_3)_8$

A light pink microcrystalline phase was identified on the surface of selected cinnabar samples from the lower workings. This uk, designated CCUK-13, was found associated with edgarbaileyite and montroydite. A complete set of pxrd data exists plus specific physical properties. On one sample, this pink phase is coated by schuetteite. A powder mount was made by A. Roberts and sent to Mark Cooper for structure work. The 20 micron clump gave an abundance of spots but not useful to determine any usable data. The clump was broken up and a single crystal about 5 microns was used to collect a data set. At least three different viable cells were produced after collecting the data. On one of those cells, monoclinic looking, a tentative structure was achieved in space group P1. A sensible atomic arrangement leads to a conclusive formula but the correct cell or space group are still tentative.

All of the Hg is present as  $\text{Hg}^+$  (Hg-Hg dimers). The Si is present in two forms: (1) as discrete 4-membered  $\text{Si}_4\text{O}_{12}$  ring groups; and (2) as infinite linear crankshaft  $\text{SiO}_3$  chains. Overall, the Si is split 50/50 in terms of the two types (rings and chains). An initial working formula from the data can be written as:



This arrangement would suggest a mixed ring-chain structure, the first for a mercury silicate. The structure is refined to  $R = 7\%$ , and this Hg-Si-O network is very sensible and complete. The structure has some holes in it, however as the net is neutral, the only candidate for a hole is likely to be an  $\text{H}_2\text{O}$  group. IR would have to be used to confirm this thought. Because of the very fine size of this mineral, it will be very difficult to obtain any other data from it. The final structure will have to be refined from an individual crystal on the order of 2-3 microns that is a part of a 5 micron cluster.



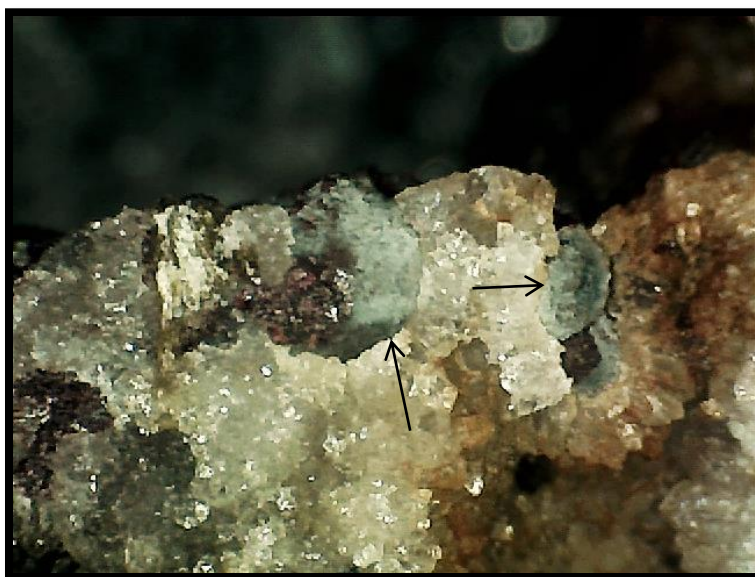
**Figure 5.** Pale pink coating of CCUK-13 on cinnabar on quartz. Clear Creek mine, lower workings. FOV = 0.57 mm x 1.2 mm.

### **CCUK-14 Hg silicate**

A second unknown silicate of mercury was discovered as a thin gray film replacing cinnabar from the lower workings. One specimen is closely associated with schuetteite. EDS of several gray coatings showed only Hg, Si and O. A powder diffraction pattern confirmed that this is a new mercury phase. Due to the extremely small grain size, no further work has been done on this unknown. No individual single crystals have been found. Aside from the Clear Creek mine, this unknown has been identified at the Picacho mine, about 3.5 km to the south, replacing cinnabar on a single quartz specimen. Later, this unknown was identified from the Vaughn mine, east of Hollister (Dunning, 2009).



**Figure 6.** Gray coating (center) of ccuk-14 on cinnabar from the Clear Creek mine, lower workings. FOV = 0.6 mm.

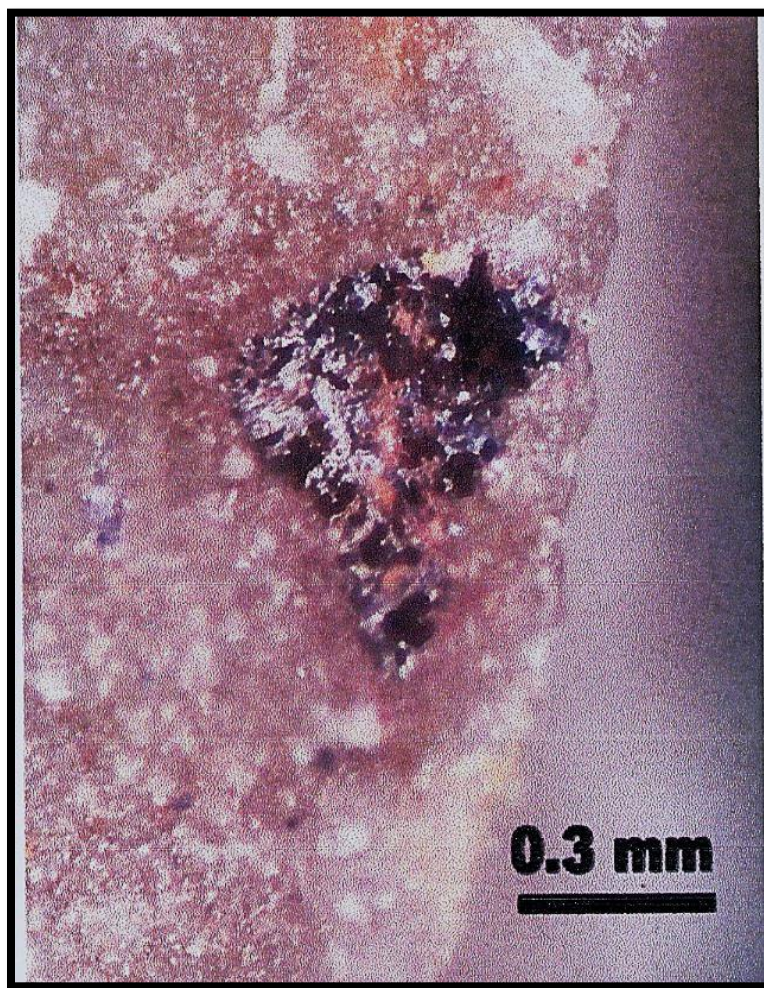


**Figure 7.** Gray coating of CCUK-14 on two inclusions of cinnabar in quartz from the Picacho mine, San Benito County. FOV = 7 mm.



**CCUK-15**  $\text{Hg}^+_{10}\text{Hg}^{2+}_3\text{O}_6\text{I}_2(\text{Cl},\text{Br})_2$

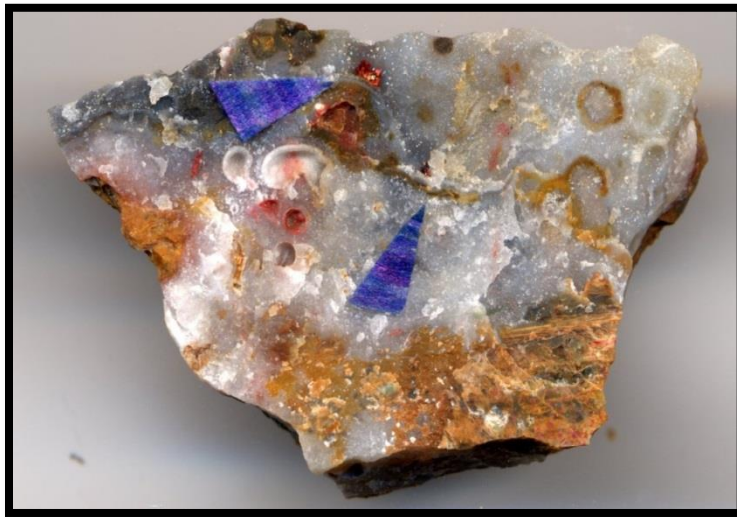
CCUK-15 is a very rare mixed valence mercury oxy-halide that occurs as an inclusion within aurivilliusite (Roberts et al., 2004). Both minerals are closely associated with liquid mercury, cinnabar and edgarbaileyite on quartz. In general, ccuk-15 most closely resembles a metallic sulfide or sulphosalt in appearance. It is opaque with a metallic luster, brittle, has an uneven fracture and is non-fluorescent under both long-and shortwave ultraviolet light. The provisional formula is based on quantitative EMPA performed during the description of aurivilliusite. To date, no additional work has been done on this rare complex mercury phase.



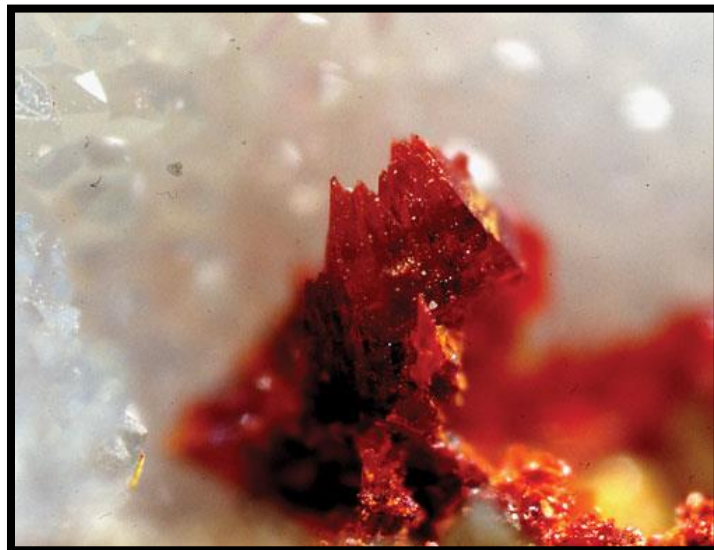
*Figure 8. Area showing aurivilliusite on quartz containing an inclusion of CCUK-15, Clear Creek mine, lower workings.*

**CCUK-18**  $\text{Hg}_2\text{N}(\text{I},\text{Cl})\cdot\text{H}_2\text{O}$ , the probable I analogue of mosesite.

During the course of sample examination from the Clear Creek mine, several small samples were noted that showed a mineral with an unusual deep red color. An X-ray diffraction data set closely resembles that of mosesite but chemically rich in I by EDS analysis. It is mostly formed on quartz. A set of physical properties has been documented by A. Roberts and is with M. Cooper.

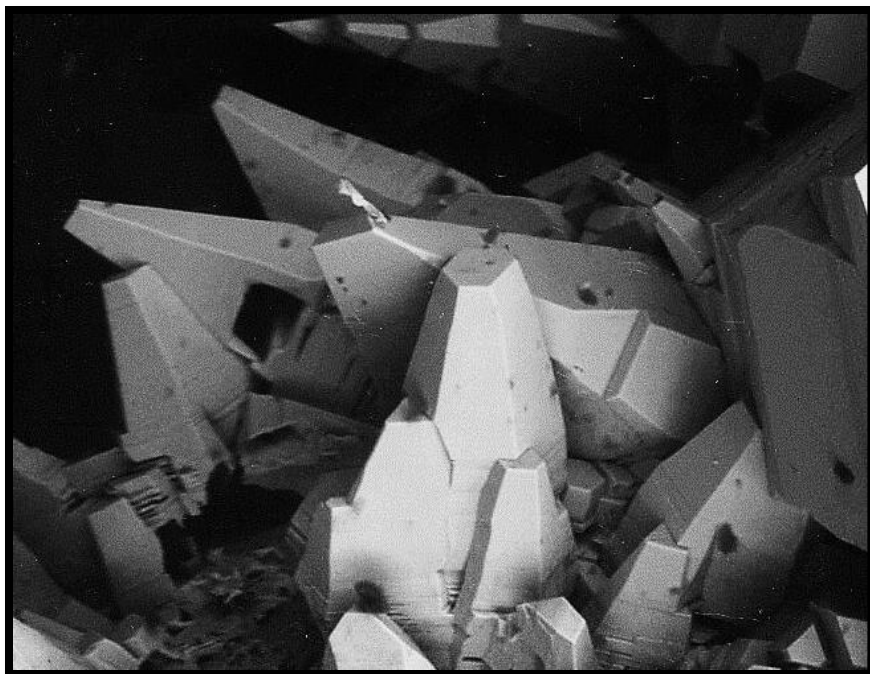


**Figure 9.** Sample of a quartz seam showing two locations containing groups of CCUK-18 crystals (at end of arrows). FOV = 50 mm.



**Figure 10.** Red crystals of I-rich mosesite (CCUK-18) on quartz. Clear creek mine, lower workings. FOV = 0.7 mm.

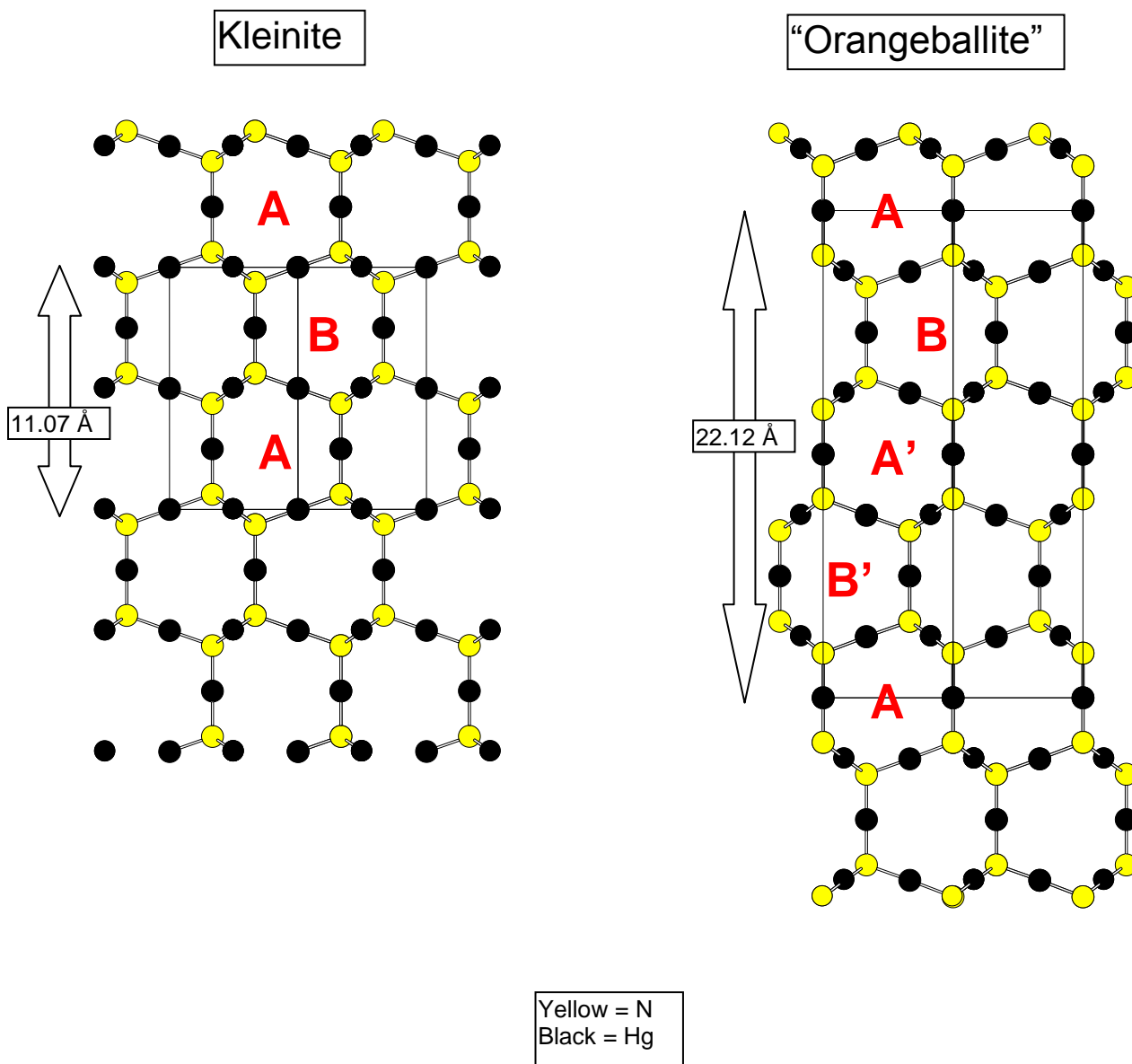




**Figure 11.** SEM photomicrograph of individual CCUK-18 dark red crystals showing the {100} pinacoidal face and either the {114} or {116} pyramidal forms.

### **CCUK-19 “orangeballite” $\text{Hg}^{2+}\text{N-Cl}$ ?**

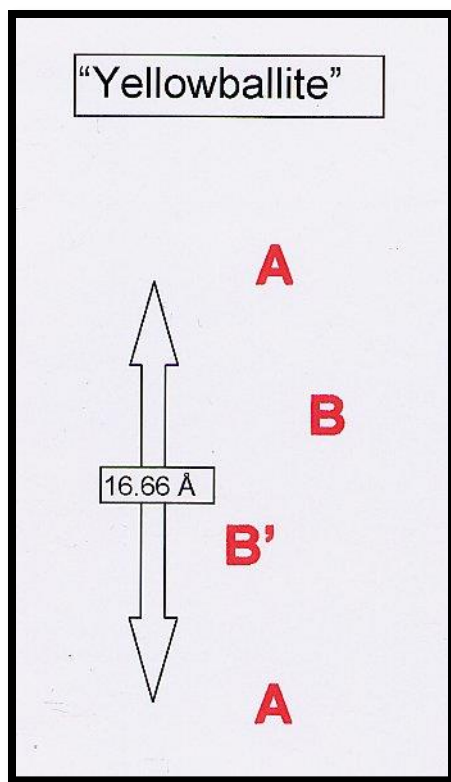
A sample of yellow mosesite was submitted to Mark Cooper as a “standard” of mosesite from the Clear Creek mine. Upon examination of the small sample with a sharp instrument, a small, orange spherical object fell out of the principal sample. Subsequent X-ray data indicated that this orange phase has a Hg-N-Cl composition. X-ray structure data confirms that the phase has very close similarities with kienite except the c value is larger by a factor of two. A comparison is shown in Figure 12 showing the difference between the c values of kienite and CCUK-19. The original yellow mosesite sample contains considerable liquid mercury. It is believed that subsequent fluid activity altered a sphere of mercury and turned it into the phase named “orangeballite”.



**Figure 12.** Comparison of the structures between kleinite and “orangeballite” showing a doubling of the c value of the unit cell.

### CCUK-20 “yellowballite” $\text{Hg}^{2+}$ -N-Cl ?

During the examination of the yellow mosesite sample, a single yellow spherical ball was also discovered associated with the above-described “orangeballite” sample. In comparison, it is several factors smaller in diameter. A set of data was gathered and compared to both kleinite and “orangeballite”; the c value was determined to be 16.66Å. The partial structure data is represented by the following Figure 13. No further work has been done on determining the elements of this phase, although it would likely contain  $\text{Hg}^{2+}$ , N, and  $\text{Cl}^-$  and be consistent with CCUK-19. It is also suspected that this phase resulted from an alteration of a small sphere of liquid mercury embedded in mosesite.



**Figure 13.** A partial structural diagram for the rare unknown, “yellowballite”.

#### **CCUK-21** Brown xl with ccuk-12

During the examination of the small specimen containing several crystals of CCUK-12, a deep orange-brown colored stout prism was discovered. The crystal was mounted for unit cell data. The following table compares the known crystallographic data for several mercury phases to CCUK-21.

**Table 1. Comparison of crystallographic data for several mercury phases.**

Mineral	Crystal System	Cell dimensions	Space Group
CCUK-21	Orthorhombic	a=6.80 b=44.61 c=11.61	C
“Orangeballite”	Hexagonal	a=6.80 c=22.12	P6 <sub>3</sub> /mmc
Terlinguacreekite	Orthorhombic	a=6.74 b=25.53 c=5.53	I
Comancheite	Orthorhombic	a=18.41 b=21.33 c=6.70	Pnnm
Kleinite	Hexagonal	a=6.76 c=11.07	P6 <sub>3</sub> /mmc
“Yellowballite”	Hexagonal	a=6 c=16.66	P?

To date, no further data has been collected on this single crystal to determine the chemistry of it. Its close association with CCUK-12, a mixed mercury sulphide-oxide-halide, it would be unusual that it is a nitride of mercury. Structural data would determine the actual element composition of this very rare phase.



## CONCLUSIONS:

This additional data has brought the study of mercury mineralogy a few steps closer to understanding this complex group of minerals from the Clear Creek mine. Despite the dearth of available material and the micron-size of individual crystals, important additional data has been achieved on this group of unknown mercury minerals. As time and support become available in the near future, additional studies to define these remaining unknowns will continue. To date, a total of 21 individual mercury phases have been identified from this small mercury deposit. Its uniqueness is unparalleled in the known mercury deposits worldwide.

The current study of mercury mineralogy of the McDermitt mine, Humboldt County, Nevada has demonstrated a parallel set of new mercury phases associated with a different host environment, with a total of 13 potential new mercury phases now under study.

## REFERENCES:

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