THE SULFUR HOLE

CALICO DISTRICT, SAN BERNARDINO COUNTY

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The Sulfur Hole was discovered in the 1880's by local borax miners who were searching for a possible source of agricultural sulfur. The deposit is the type locality for krausite, and has produced an attractive suite of colorful, well-crystallized, hydrous sulfate minerals including coquimbite, halotrichite, krausite, metavoltine, potassium alum, quenstedtite, römerite and voltaite. Associated minerals include botryogen, copiapite, anhydrite, gypsum, melanterite, marcasite and sulfur.

INTRODUCTION

The Sulfur Hole has long been known by California collectors as a source of rare hydrous iron-potassium-aluminum sulfate minerals. These minerals occur in a columnar pipe that formed from hot, ascending, iron-bearing acidic fluids acting on the underlying volcanic rocks. Fine crystallized specimens of coquimbite, krausite, metavoltine, quenstedtite and voltaite have been collected there and the potassium-iron sulfate krausite was first described as a new mineral from this locality. Potassium alum, also new to the locality, has recently been found as small, brilliant octahedral crystals.

Although the Sulfur Hole locality is well known to serious, older collectors, its remote location and lack of identifying landmarks have hindered the study of the locality. The site is located on the south wall of Mule Canyon in a shallow, unobtrusive cleft against the wall with only a faint trail leading to it. The area is north of the old borax claims near the site of the town of Borate in the Calico Hills and about 4 miles northeast of Yermo, San Bernardino County in the SE¼ of the SE¼ of Section 18, T10N, R2E, San Bernardino Meridian, or at 34° 57' N, 116° 49' W. The cleft containing the Sulfur Hole is not readily apparent and the sulfates are not normally exposed at the surface to mark the locality. To collect requires digging down to the sulfate body through the accumulated debris.
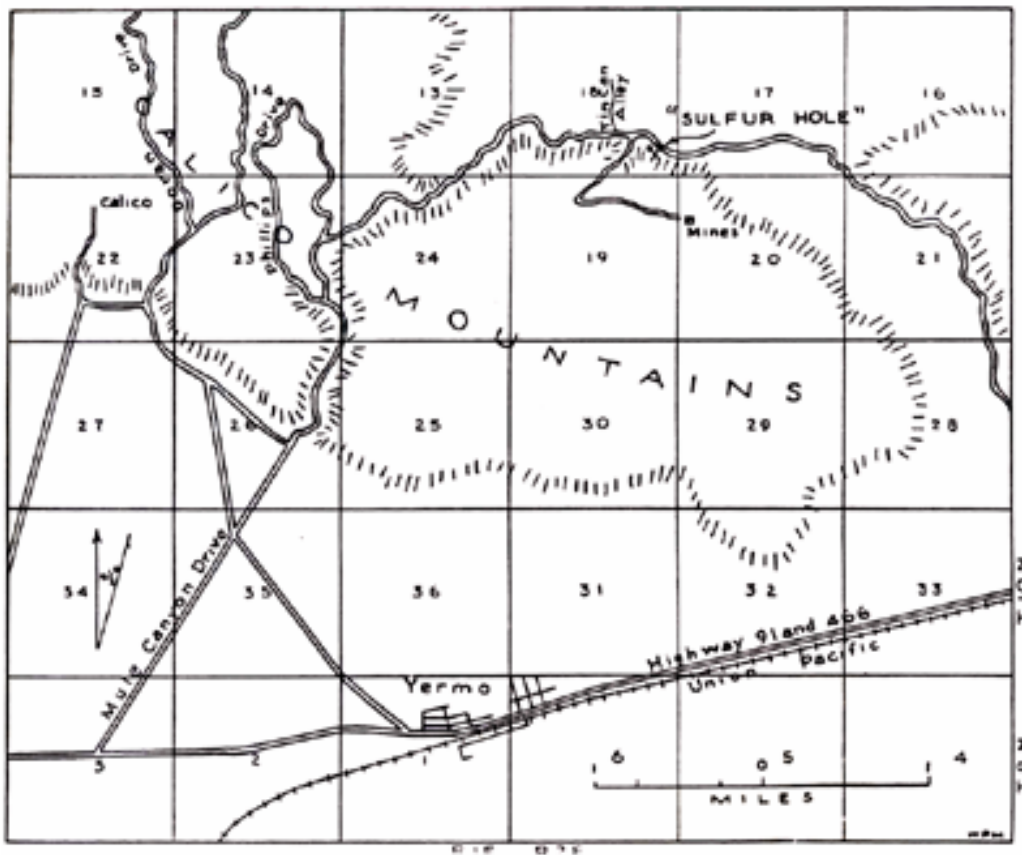

Figure 1. Map showing the location of the Sulfur Hole in the Calico Mountains, San Bernardino County, California (after Moller, 1963a).

AREA HISTORY

The first mining in the area began in the 1860's with the discovery of rich silver ores in the hills above the small town of Calico. Calico quickly became a major silver producer and remained so for over

20 years. As the silver rush faded and the mines went into decline, prospectors searched the nearby lower hills for other profitable mineral deposits.

The colemanite deposits at Borate in the Calico Hills were discovered in 1883, and although these deposits were neither as large nor as rich as the famed Death Valley borax deposits, they were able to successfully compete with them because of the primitive transportation system used in Death Valley. Because of their proximity to the railroad shipping point at Dagget, the colemanite ores of Borate did not require the use of the famed "20 mule team" wagons that the Death Valley ores used and therefore, the small coyote-hole diggings could be profitably worked. When the railroad reached Death Valley, the Borate colemanite ores became comparatively more expensive to produce and, as the easily mined ore had been removed, production at Borate declined until only a handful of miners remained.

After the end of World War I, interest in the area was rekindled and William F. Foshag of the U. S. National Museum examined the area as part of his study of the colemanite deposits of California. The borax deposits were still being worked in a desultory manner and local prospectors told Foshag of the unusual "Sulfur Hole" nearby. Foshag visited the locality and described the unusual mineralogy of the occurrence, including the new potassium-iron sulfate, *krausite* (Foshag, 1931).

Figure 2.   **Camp scene at the Sulfur Hole on November 25, 1961. The collecting area is the dark excavation at the center of the photo.**

GEOLOGY

The Calico Mountains form a rugged landscape of steep slopes supporting sparse vegetation with volcanic flows creating bold outcrops of hard, resistant material. They are composed of a series of Miocene sedimentary beds that are underlain by andesites and rhyolite tuffs. These sedimentary rocks have been entirely eroded away in the western portion of the area and the exposed multicolored volcanic

rocks gave the district it's name, Calico, after the multicolored fabric. The eastern portion of the district is covered by remnants of the sediments consisting of a series of sandstones, shales, marls and algal limestones that rest on the basement volcanic rocks. These sediments were originally deposited in a fresh-water lake environment.

Figure 3. *Gail Dunning (left) and Dwight Weber (right), both in their much younger years, examining specimens of sulfate minerals collected at the Sulfur Hole, December 20, 1959.*

Deposits formed containing nodules of colemenite associated with ulexite, celestine and strontianite. Lower in the series a squence of chert and shale beds were deposited and sediments were partially silicified. The difference in metamorphism is apparently due to the porosity of the individual beds. Foshag (1922) found no apparent connection between the lower, more silicic beds and the upper borate-bearing limestones and marls. The relationship between the deposition of the sulfates in the shales and the colemanite bodies found in the marly limestones is not known.

The geology of the volcanic, volcanocastic to sedimentary series in the Calico Mountains has been discussed in detail (Dibblee, 1970; Erwin and Gardner, 1940; McCulloh, 1965; Schuiling, 1999). Recent work (Reynolds and Woodburne, 2001) indicates that the deposition sequence included a massive stromatolite layer, three brown, platy limestones, and a persistent bed of borax and strontium minerals. The section at Borate correlates with the section in the Mud Hills that corresponds to an age of 16 to 17 million years, with the borate and strontium-minerals being no younger than 15.5 million years. The section at Borate is overlain by gravity slides of siliceous andesitic breccia that dates to 17 million years (B. Wilson personal communication, 2001). Fossils in the sedimentary section of the Calico Mountains also suggest an earlier Barstovian Land Mammal Age (LMA) from the early middle Miocene. A large three-toed horse, *Merychippus*, is present (Dibblee, 1970) and tracks of early proboscidenas, restricted to younger than 16.3 million years in western North America, have been found in Little Borate Canyon (Reynolds and Woodburne, 2001).

Resting conformably on the agglomerates are arkosic sandstone, argillaceous shales and hard, banded cherts. They are particularly apparent at the Sulfur Hole where the rocks surrounding the zone of sulfate deposition are chert members. Immediately above the chert are beds of dense arkosic sanstone and shale overlain by pale yellow tuff and a little thinly bedded shale.

The Miocene sediments with silica and borates have been folded compressionally along a west-northwest axis. This compression folding took place in response to rising andesite domes in the northern Calico Mountains and in response to gravity-slide deposits that slid southward over the unconformity on top of the compressed Miocene sediments.

Ground water percolation that produced the various sulfate minerals has been controlled along two local fractures zones. The initial movement was along a fracture zone perpendicular to the strike of the sediments and vertical to the bedding planes. The surface exposure of this fault is partially covered, but it may be observed approximately 70 meters east of the Sulfur Hole, where bedding changes abruptly from nearly perpendicular, as exhibited at the hole, to approximately horizontal with only a moderate dip southward. The second generation of deformation was a fault parallel to the bedding planes that produced a vertical displacement of unknown magnitude. Small fracture zones and drag folds may be observed in the vicinity of the Sulfur Hole.

The sulfates at the Sulfur Hole were formed as a result of low-temperature aqueous, acidic, sulfate-bearing solutions that percolated through the hot volcanic rocks and attacked existing iron sulfides. These solutions were rich in ferrous and ferric iron and also contained leeched magnesium, potassium, sodium and aluminum from the underlying rock formations. The fault provided a fracture system that allowed the upward migration of these heated, highly acidic iron-rich solutions. Changes in temperature, pressure and pH resulted in the formation of the various sulfate minerals.
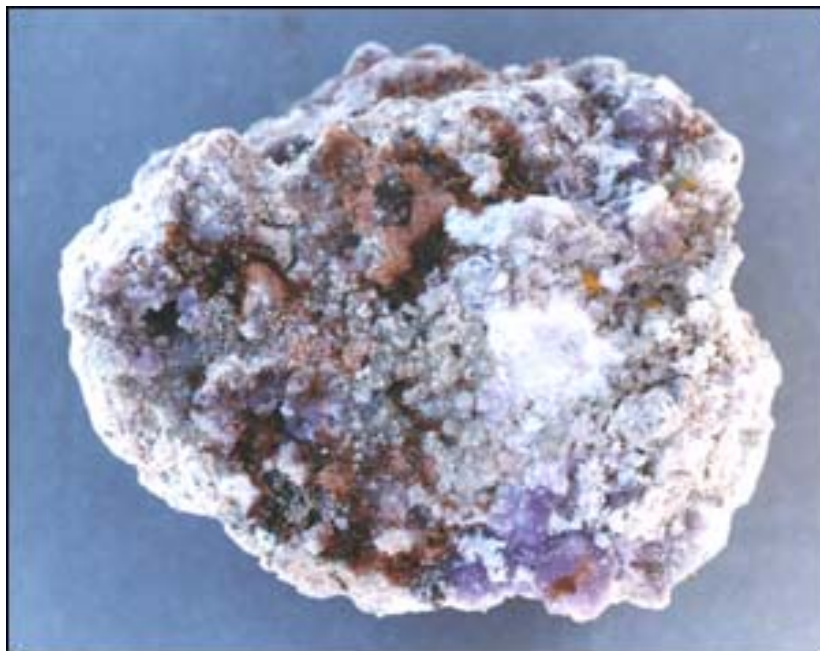

Figure 4. **A 5 x 7-cm specimen from the transition zone showing the typical sulfate assemblage (purple coquimbite, brown römerite, gray-green krausite, and sugary-white coquimbite).**

DESCRIPTION OF THE SULFUR HOLE

The sulfates occur in pod-like masses up to several meters across in an area of fractured shale that is cemented by white granular coquimbite. It is interesting to note that the sulfates in this deposit show a zoning pattern and that the material the authors found shows a similar pattern to that mentioned by Foshag (1931) in his original paper. Foshag estimated the original thickness of the exposed sulfates to be less than 3 meters and noted that the minerals were roughly zoned, with massive coquimbite occupying the footwall and grading into sugary granular coquimbite, while the hanging wall was composed of a mixed group of iron sulfates that became more acidic toward the bottom edge of the deposit.

The major portion of the sulfate mass is composed of granular white coquimbite and this may make up to half of the pod volume. The coquimbite varies in texture from a dense, white, fine-grained material near the footwall to a more coarse-grained sugary material near the center of the pod. The fine-grained coquimbite frequently shows shrinkage cracks and these are commonly lined with yellow-green to gray-green krausite crystals associated with occasional patches of golden yellow metavoltine.

The most interesting of these zones for the collector is the transition zone between the coquimbite and the acidic iron sulfate zone where colorful well-crystallized specimens typically occurred. This transition zone varies considerably in thickness and is entirely absent in some areas. Specimens have often been found in a base of granular, sugary white coquimbite that commonly contains large crystals of purple coquimbite, green krausite, reddish brown römerite, golden yellow metavoltine and white fibrous halotrichite. Many of the rarer minerals were formed in this zone in cavities between the römerite and coquimbite crystals.

The acidic iron sulfate zone near the footwall is also variable in thickness and is composed mainly of a mixture of melanterite, halotrichite, voltaite and römerite. The most abundant mineral in this zone is römerite and granular friable masses of rough römerite crystals over 10 cm thick have been found. Melanterite and halotrichite veinlets commonly cut these römerite masses and occur as white to pale green fibrous veinlets. Pockets are not common in this zone but voids occur in the coarsely crystalline römerite. They commonly contain other acidic sulfates, and voltaite also occurs in this area, both as massive material and as well-crystallized masses of black cubic crystals.

At the base of the acidic sulfate zone a thin discontinuous layer of loose friable sandy shale fragments was found. It was impossible to determine the extent of this layer but its absence of fines indicates that it is extremely porous. Sulfates are rare in this layer and composed mainly of minute feathery crystalline aggregates of melanterite and gypsum. Embedded in this layer are small masses of potash alum. Much of this material is massive but occasional pockets showed well-formed brilliant octahedral crystals.

MINERALS

Alunite (?) $K_2Al_6(SO_4)_4(OH)_{12}$

Alunite was reported by Foshag (1922) as being relatively abundant at the Sulfur Hole, occurring as white granular masses near the hanging wall. Material resembling that described by Foshag was collected by the senior authors and was found to contain only iron and sulfate. A microscopic examination revealed only granular aggregates composed of minute bipyramidal crystals of coquimbite. Alunite was not found during the present study. X-ray diffraction analysis also showed that samples previously reported to be alunite by Moller (1963a,b) are actually coquimbite. To date no alunite has been identified from any samples collected at the Sulfur Hole.

Anhydrite $CaSO_4$

Foshag (1931) reported anhydrite associated with gypsum in the upper section of the Sulfur Hole. It probably formed as a dehydration product of gypsum.

Botryogen $MgFe^{3+}(SO_4)_2(OH)\cdot 7H_2O$

   Rare, brick-red, minute botryoidal groups of botryogen occur on sugary coquimbite. Only a few samples have been found to contain botryogen and it is probably the least abundant mineral present. It was identified by its color, radiating structure and EDS spectrum.

Copiapite $Fe^{2+}Fe^{3+}_4(SO_4)_6(OH)_2\cdot 20H_2O$

   Copiapite occurs in the aureole surrounding the sulfate body and is locally abundant within the sulfate mass. It is yellowish green to yellow brown and occurs as small patches in cavities in coquimbite in the transition zone, often associated with römerite. Copiapite is commonly associated with seams of gypsum and occurs as thin yellow coatings on it.

Figure 5.   **Purple coquimbite crystals associated with halotrichite (acicular white) and römerite (dark brown), embedded in sugary-white coquimbite. Field of view is 2 cm.**

Coquimbite $Fe^{2+}Fe^{3+}_4(SO_4)_3\cdot 9H_2O$

   Coquimbite is the most abundant mineral present in the Sulfur Hole and probably comprises almost 80% of the sulfates present. It forms the major portion of the vein filling material and occurs as colorless to pale lilac-colored granular masses up to 30 cm thick. Microscopic examination of this granular material reveals that it is composed principally of minute colorless bipyramidal crystals associated with scattered small anhedral masses of coquimbite. The most common crystal forms present are the pyramid $\{10\bar{1}1\}$

associated with a secondary prism $\{10\bar{1}0\}$ face. The crystals occasionally show the development of (0001) and $\{11\bar{2}0\}$ faces but these are not common.

   Near the transition zone larger coquimbite crystals occur and purple masses of equant crystals up to 2 cm across are relatively common. Most of the larger crystals are blocky in outline but occasional crystals that show the typical hexagonal bipyramid are also found. Although the larger crystals commonly show a blocky form and resemble overgrowths, paracoquimbite has not been identified from the site. Specimens of sulfate rock from the transition zone can be quite attractive and colorful with the large purple coquimbite crystals, bright yellow metavoltine, green krausite crystals and red-brown römerite crystals embedded in a white granular coquimbite groundmass.
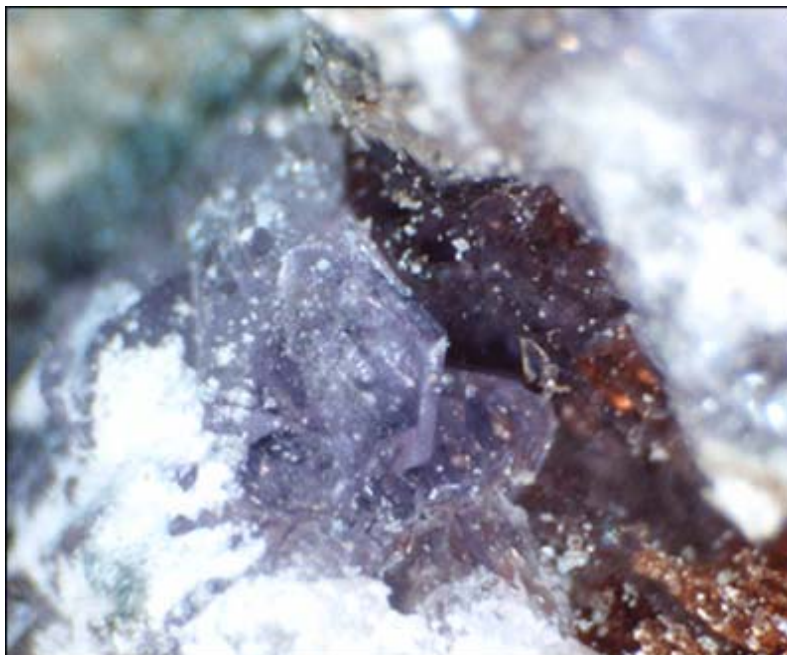

Figure 6. **Typical blocky purple coquimbite crystals, to 7 mm, associated with brown römerite in fine-grained coquimbite.**

Fibroferrite(?) $Fe^{3+}(SO_4)(OH)^. 5H_2O$
   Fibroferrite was reported as occurring at the locality by Foshag (1922). The fibroferrite reported by Moller (1963a) was re-examined by X-ray diffraction analysis and found to be halotrichite admixed with copiapite. To date no fibroferrite has been identified from the samples collected at the Sulfur Hole.

Gypsum $CaSO_4^. 2H_2O$
   Gypsum occurs as isolated masses and veins of satin spar gypsum in the edge of the high iron sulfate zone near the footwall, associated with copiapite. The gypsum is colorless to white, fibrous and can be up to 3 cm thick. The gypsum layers are commonly encrusted with massive yellow copiapite and fracture faces are often corroded. The gypsum shows a pale yellow fluorescence and may show a yellow phosphorescence under shortwave ultraviolet light.

Figure 7. **Bipyramidal coquimbite crystal associated with krausite on massive coquimbite. Crystal is 1.7 mm.**
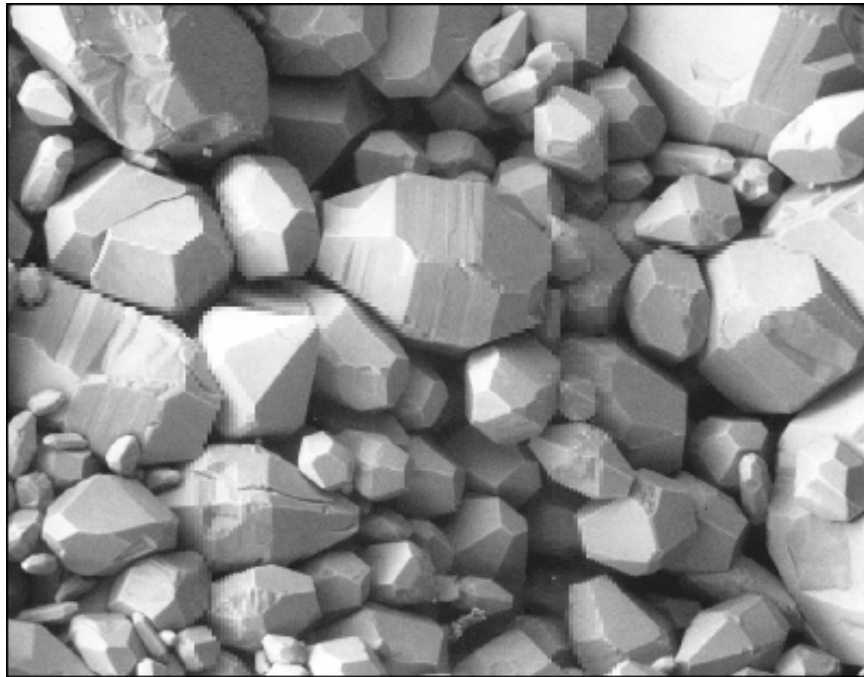

Figure 8. **SEM photo of sugary white coquimbite crystals showing the bipyramidal habit. Size range of the crystals is 10 to 100 microns.**

Figure 9.　**White fibrous halotrichite and brown römerite, 5 cm.**

Halotrichite　　$Fe^{2+}Al_2(SO_4)_4 \cdot 22H_2O$

Halotrichite is relatively common in the more acidic rock near the footwall where it forms white fibrous veins associated with melanterite. The veins cut coarsely crystalline granular masses of römerite and are commonly intergrown with melanterite. Occasionally it is found as delicate tufts of acicular crystals in cavities associated with römerite and voltaite crystals. Halotrichite veins commonly grade into massive apple-green melanterite, and intergrowths of fibrous halotrichite and melanterite are occasionally found.

Jarosite (?)　　$K_2Fe_6(SO_4)_4(OH)_{12}$

Jarosite was reported from the Sulfur Hole by Foshag (1922) as yellow coatings of minute crystals. Material resembling that described by Foshag was collected by the authors and was found to contain iron, potassium and sulfate. X-ray diffraction analysis identified the minute yellow crystals as metavoltine. To date no jarosite has been identified from the samples collected at the Sulfur Hole.

Krausite　　$KFe^{3+}(SO_4)_2 \cdot H_2O$

Krausite is relatively abundant in the transition zone and in the granular coquimbite near it. It occurs as groups of pale green to yellow-green, short, equant crystals in shrinkage cracks and as discrete masses embayed by coquimbite. It commonly covers areas as large as several cm across and almost always occurs as small monoclinic crystals with the terminating faces showing, presenting an almost octagonal outline. In the transition zone crystals may be associated with lilac-colored coquimbite and reddish brown römerite. The largest crystals of krausite occur in the transition zone and single crystals up to 7 mm across

have been found embedded in granular white coquimbite. The larger crystal faces are not as brilliant as the smaller crystals and often appear to have been etched. This is the type locality for krausite described by Foshag (1931).

Figure 11. **Blocky krausite crystals to 8.4 mm associated with golden metavoltine.**

Figure 10. **Dark green krausite crystals to 4 cm (center) surrounded by purple coquimbite, golden metavoltine, and white acicular halotrichite on fine-grained coquimbite.**

Marcasite FeS_2

Marcasite has been noted as small patches and grains on the rock that encloses the sulfate mass near the footwall. It generally shows a greenish yellow color and a botryoidal surface. No marcasite has been noted in the sulfate mass and only a few specimens were found.

Melanterite $FeSO_4 \cdot 7H_2O$

Melanterite is only found in the mass of acidic iron sulfates that formed near the footwall. Melanterite occurs as small irregular grains and as veins of fibrous crystals that range in color from pale green to white, commonly intergrown with halotrichite. The green color disappears as the specimens dehydrate. Veins of fibrous melanterite up to 1 cm thick and a meter long have been found cutting the römerite and voltaite and were presumably among the last minerals to form.

Metavoltine $K_2Na_6Fe^{2+}Fe^{3+}_6(SO_4)_{12}O_2 \cdot 18H_2O$

Metavoltine is locally abundant at the Sulfur Hole and has been found as areas of scale-like, bright golden yellow crystals that have the {010} form dominant. This material is most abundant in thin shrinkage cracks in the granular coquimbite, especiallyt near the upper portion of the coquimbite body in the more fine-grained material. Whereas krausite is commonly closely associated with the metavoltine, the shrinkage cracks containing metavoltine generally show no other species. Metavoltine is presumed to have been one of the last minerals to form.

Figure 12. Typical specimen, 7 x 9 cm, showing a golden metavoltine vein in fine-grained coquimbite.

Figure 13. Yellow-orange metavoltine crystals showing hexagonal outlines. Field of view is 1.5 mm.

Figure 14. Metavoltine crystals to 50 microns showing the stacked hexagonal plates (SEM photo).

Figure 15. **Clear octahedrons of potassium alum. Field of view is 4 mm.**

Potassium Alum $KAl(SO_4)_2 \cdot 12H_2O$

   Potassium alum was noted as occurring in a thin, black, extremely porous and friable layer at the base of the footwall of the Sulfur Hole. A few small rounded nodules that contain small cavities lined with brilliant octahedral crystals were found. This material proved to be a potassium aluminum sulfate with only minute amounts of iron present. Potassium alum has not been previously reported from this locality.
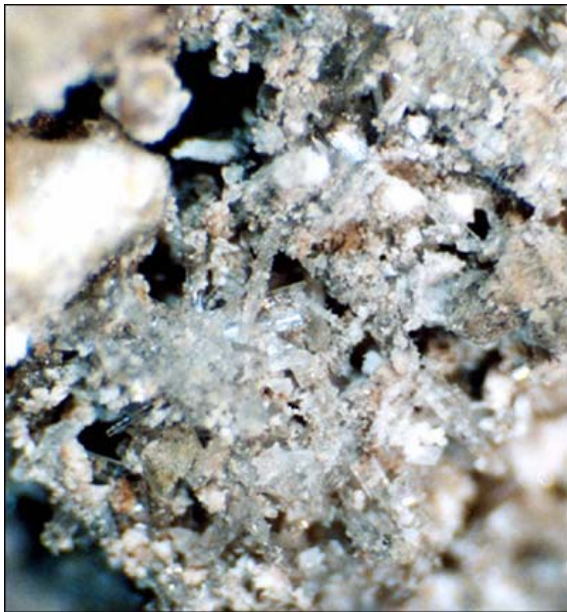

Figure 16. **Typical surface showing colorless to pale pink, jack-straw crystals of quenstedtite. Field of view is 4 mm.**

Figure 17. **Enlargement of Figure 16 showing the acicular habit of quenstedtite associated with golden metavoltine and clear, blocky krausite. Crystal length is 0.5 mm.**

Quenstedtite $Fe^{3+}_2(SO_4)_3 \cdot 10H_2O$

Quenstedtite was first identified from the Sulfur Hole by Weber and Graal (1975) and must be considered one of the rarest of the minerals found there. It has been found only on the acidic sulfates deposited near the footwall. Quenstedtite occurs as jackstraw groups of minute, colorless to pale pink triclinic crystals and usually occurs as monomineralic groups of crystals in cavities of römerite.
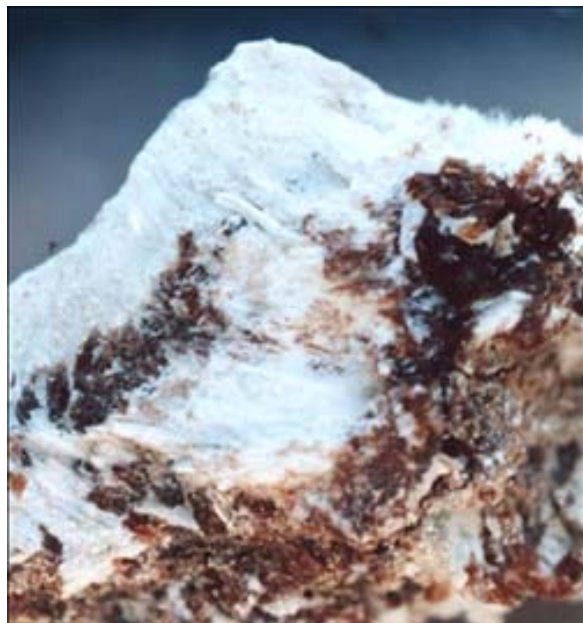

Figure 18. **Sample of dark brown römerite associated with white fibrous halotrichite. Width is 3 cm.**

Figure 19. **Typical specimen, 2 x 5 cm, of dark brown römerite with white fibrous halotrichite.**

Römerite $Fe^{2+}Fe^{3+}_2(SO_4)_4 \cdot 14H_2O$

Römerite is relatively abundant in the area of the footwall and large masses of friable, reddish brown crystals can be found. The römerite is often cut by veins of green melanterite and white fibrous halotrichite containing small cubic crystals of black voltaite. Römerite rarely forms good crystals but is most often found as granular masses of elongated anhedral crystals.

Sulfur S

Sulfur is not common in the mineral assemblage at the Sulfur Hole. It occurs as thin, pale yellow crusts associated with white granular coquimbite and krausite. It appears to have been one of the last minerals formed and is known from only a few specimens. Sulfur occurs as pale yellow granular masses coating other sulfate minerals.

Voltaite $K_2Fe^{2+}_5Fe^{3+}_4(SO_4)_{12} \cdot 18H_2O$

Voltaite is relatively common close to the footwall of the Sulfur Hole where more acidic conditions exist. It commonly occurs in association with römerite and melanterite as black patches and well-formed cubic crystals. These crystals may reach 5 mm across and normally are brilliant cubes with no modifying faces. The römerite-melanterite-voltaite sulfate complex is the least stable of the sulfate assemblages and commonly occurs as a crumbly mass. It is interesting to note that the cube is the dominant form at this locality whereas the octahedron commonly forms in acidic sulfate assemblages from post-mining sulfate deposition.

Figure 20. **Typical 1-cm specimen of voltaite showing the black cubic form associated with brown römerite and halotrichite.**
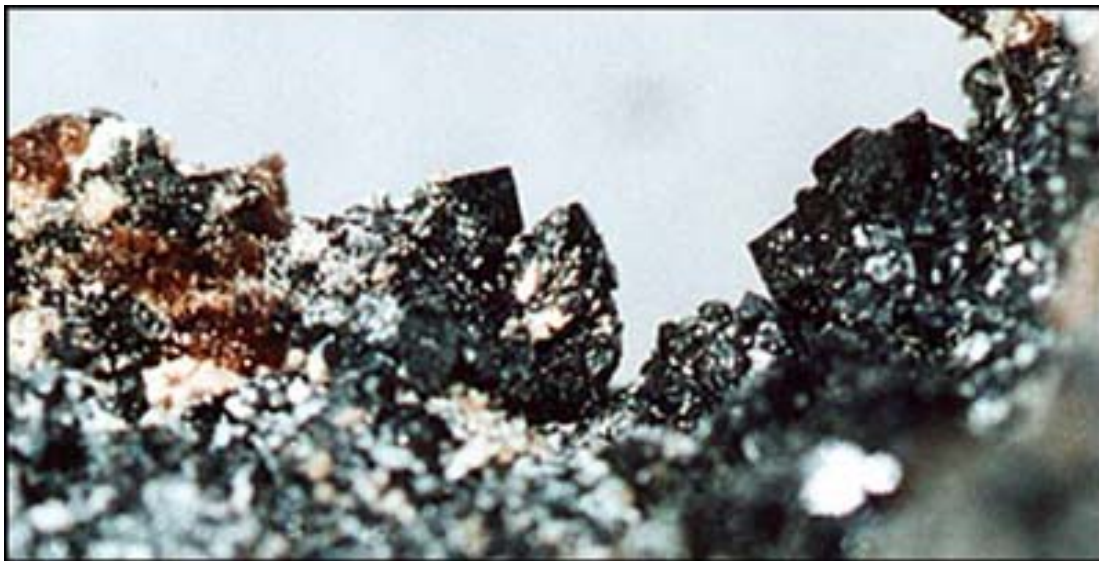

Figure 21. **Voltaite specimen showing 2-mm cubic crystals (center top) associ-aited with brown römerite (left).**

Table 1. Minerals from the Sulfur Hole, San Bernardino County, California

Anhydrite	$CaSO_4$	**Melanterite**	$FeSO_4{\cdot}7H_2O$
Botryogen	$MgFe(SO_4)_2(OH){\cdot}7H_2O$	**Metavoltine**	$K_2Na_6FeFe_6(SO_4)_{12}O_2{\cdot}18H_2O$
Copiapite	$FeFe_4(SO_4)_6(OH)_2{\cdot}20H_2O$	**Potassium Alum**	$KAl(SO_4){\cdot}12H_2O$
Coquimbite	$Fe_2(SO_4)_3{\cdot}9H_2O$	**Quenstedtite**	$Fe_2(SO_4)_3{\cdot}10H_2O$
Gypsum	$CaSO_4{\cdot}2H_2O$	**Römerite**	$FeFe_2(SO_4)_4{\cdot}14H_2O$
Halotrichite	$FeAl_{12}(SO_4)_4{\cdot}22H_2O$	**Sulfur**	S
Krausite	$KFe(SO_4)_2{\cdot}H_2O$	**Voltaite**	$K_2Fe_3Fe_4(SO_4)_{12}{\cdot}18H_2O$
Marcasite	FeS_2		

COLLECTING

At present no restrictions are placed on entry to the area and it appears to be under the control of the Bureau of Land Management. Collecting at the Sulfur Hole is mainly a question of finding the locality and digging out the accumulated debris. This will produce a hole several feet deep and often requires removing slabs of the shale beds that have fallen into the sulfate body over the years. At best it is dry and dusty work, but if you are lucky enough to find a pocket of sulfates the work is definitely worth the effort.

The Sulfur Hole does strange things to people. On our second visit (by JFC and GED) we had driven for over 400 miles that day, arrived at dusk and had a hasty dinner after setting up camp. After dark we walked up to the locality, ostensibly to leave our tools for the following morning. We started digging and shortly found a thin vein of massive coquimbite that we followed down to a good pocket of mixed sulfates, which produced many fine transition-zone specimens of coquimbite, krausite, römerite and the other sulfates the locality is famous for. We finished up about 4 a.m., covered with sulfate dust and in possession of some of the nicest coquimbite and krausite specimens we had ever seen from the locality.

Preservation of Specimens

The sulfate minerals from this locality appear to be relatively stable, with the exception of the acidic sulfate mineral assemblage that occurs near the footwall. Specimens collected by one of us (JFC) 40 years ago and stored in plastic boxes show little deterioration. While this may be true of most specimens from the Sulfur Hole, some of the minerals are sensitive to humidity and will hydrate and deteriorate unless carefully stored. Exposure to either low or high humidity will allow the minerals found in the more acidic footwall zone (römerite, voltaite, melanterite) to literally dissolve in their own water of crystallization or crumble into a fine-grained powder. In extreme cases storing the specimens with desiccants has proved successful and coating the surface with acrylic resins has also proved successful, although doing so will change the luster of the crystal faces. Under normal conditions, storage in a sealed plastic box will suffice, but the survivability of the acidic footwall minerals is best guaranteed in a sealed glass jar.
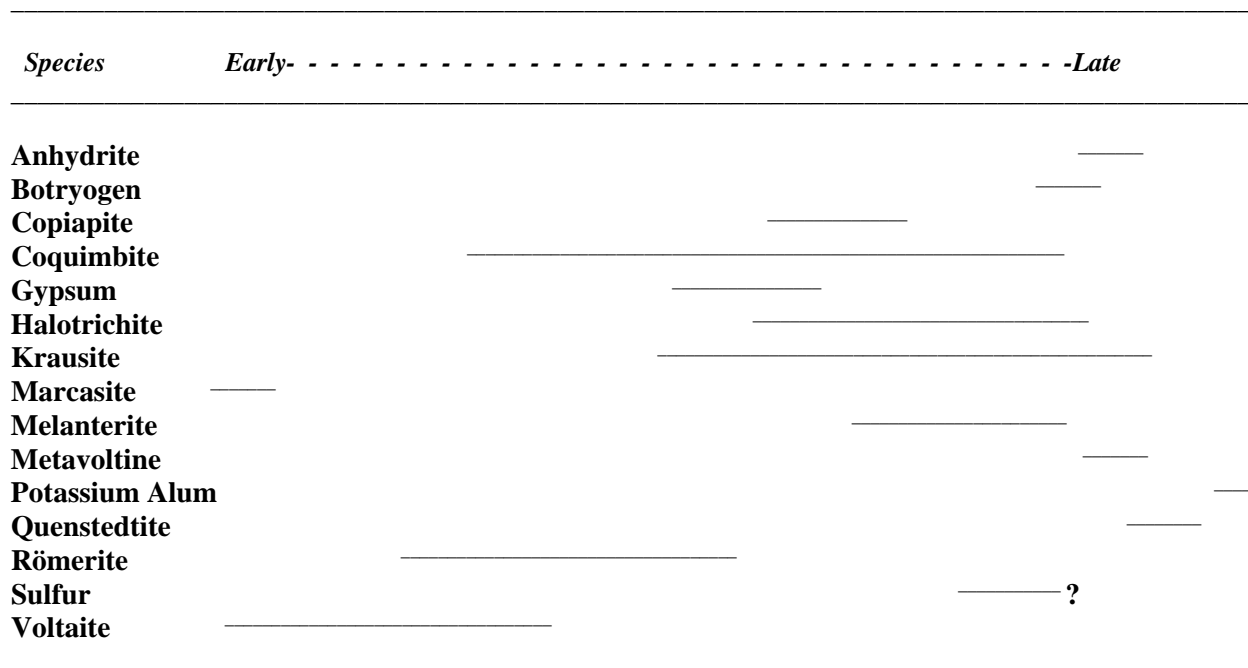
Associated Minerals in the Area

The old borax mines in the area contain several minerals of interest to the collector. Colemanite forms friable masses, and crystal-lined geodes are relatively common. The geodes reach several feet in diameter and are commonly lined with well-formed colemanite crystals up to several inches across. The colemanite is often associated with colorless to pale blue celestine prisms and occurs on a groundmass of pale yellow strontianite, making for attractive specimens. The prospects also produce well-crystallized gypsum specimens that show a characteristic flattened form. These specimens frequently show a pale yellow fluorescence under short wave ultraviolet light and often phosphoresce white.

PARAGENESIS

While no direct paragenesis of the sulfates present can be definitely established, the zoned nature, associations and chemistry of the deposit allow an apparent paragenetic relationship to be suggested. Examination of specimens has supported this hypothesis, however there is considerable species overlap. The more acidic species were among the earlier sulfates to form while the less acidic coquimbite assemblage formed later in the system's history. The apparent relationship of the sulfate minerals is shown in Figure 22.

Figure 22. **Paragenetic timeline for the formation of the sulfate minerals at the Sulfur Hole.**

Species	Early- -Late
Anhydrite	————
Botryogen	————
Copiapite	—————
Coquimbite	————————————————————————
Gypsum	—————
Halotrichite	—————————————
Krausite	————————————————————
Marcasite	———
Melanterite	—————————
Metavoltine	————
Potassium Alum	——
Quenstedtite	————
Römerite	———————————
Sulfur	————?
Voltaite	———————————

DISCUSSION

Foshag's original description of the Sulfur Hole included mention of alunite, fibroferrite and jarosite as minerals occurring at the locality. Alunite was considered to be abundant and fibroferrite and jarosite were said to be an important part of the mineral suite. The authors of the current study, however, were unable to find any specimens of these minerals in the material they collected, despite the fact that many of the samples resemble the descriptions of these minerals given by Foshag. Botryogen, copiapite, gypsum, haliotrichite, krausite, marcasite, melanterite, metavoltine, potassium alum, quenstedtite, römerite, sulfur and voltaite were verified by either X-ray diffraction analysis (WPM) or EDS (GED) methods and their occurrence at the Sulfur Hole has been confirmed. Material previously identified as alunite, fibroferrite and jarosite was restudied. The so-called alunite and fibroferrite were found to be fine-grained coquimbite, and halotrichite stained by copiapite, respectively, and the yellow crystals of the so-called jarosite proved to be metavoltine. Foshag (1931), in his original description of the locality, does not describe the methods used to identify these minerals and merely mentions them as being present. No authenticated samples of these three minerals from the Sulfur Hole are known to exist. In light of the present investigation, the existence of alunite, fibroferrite and jarosite at the Sulfur Hole must be considered questionable.

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