Minerals from the Mojave

The Yellow Pine Mining District
John Kepper

Mammoth Mine
Sugar White

Desert View Mine
Peter B. Leavens & Jimmie D. Patton

Micro-Mineral Photography
John E. Jenkins

compiled and edited by
Robert E. Reynolds
# Minerals from the Mojave

compiled and edited by
Robert E. Reynolds

## Table of Contents

<table>
<thead>
<tr>
<th>Page</th>
<th>Title</th>
<th>Author(s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>3</td>
<td>The Yellow Pine Mining District, Goodsprings, Clark County, Nevada</td>
<td>John Kepper</td>
</tr>
<tr>
<td>15</td>
<td>The Mammoth Mine, Eastern Mojave Desert</td>
<td>Sugar White</td>
</tr>
<tr>
<td>17</td>
<td>The Desert View Mine, San Bernardino Mountains, California: A Possible Intermediate between Langban, Sweden and Franklin, New Jersey</td>
<td>Peter B. Leavens and Jimmie D. Patton</td>
</tr>
<tr>
<td>23</td>
<td>Micro-Mineral Photography</td>
<td>John E. Jenkins</td>
</tr>
</tbody>
</table>

Color photography in this volume was made possible by a generous contribution from the Southern California Chapter, Friends of Mineralogy
Minerals from the Mojave

Compiled and edited by
Robert E. Reynolds

San Bernardino County Museum Association
2024 Orange Tree Lane
Redlands, California 92374

Quarterly
Volume 47, Number 1
Spring, 2000
The Yellow Pine Mining District, Goodsprings, Clark County, Nevada

Dr. John Kepper
P. O. Box 314, Cave Creek, AZ 85327

Introduction

"If the old Nevada theory still holds good that a mining camp is no account unless it is hard to get at, then Yellow Pine is possessed of claims to distinction, for it is very difficult to access" wrote J. V. Kealy of the Yellow Pine District in the Scientific Press of September 19, 1893. Further, he said "the climate is something awful. Nothing but sharp, shiny sand and brilliant sunshine, the thermometer ranges from 90 to 120, water four cents a gallon and everything to eat, drink or use packed 50 miles through sand hub deep makes an undesirable combination. But the gold is there and lots of it." Although gold production at the Keystone Mine lived up to Kealy's claim, the district is best known today for its production of zinc and lead.

The Yellow Pine Mining District is in the southern Spring Mountain Range immediately west of Goodsprings, Clark County, Nevada, about 30 miles south of Las Vegas. The district is some 30 miles long and 10 miles wide. In the early part of the 20th century it was one of the nation's major producers of zinc. The Yellow Pine Mining District was organized in 1882. It was named after The Yellow Pine Mining Company which, in 1868, controlled a number of claims for silver and copper in an area known as Porphyry Gulch, a few miles west of Goodsprings. The earliest mining was done by Mormons who prospected for lead near Potosi Mountain. In 1856, they developed the Potosi Mine at the north end of the district. But the galena ore contained too much zinc, making the lead flaky and unusable for bullets and the operation was abandoned the following year. Mining efforts shifted to the area due west of Goodsprings in the 1880s, and copper and gold dominated production. The principle gold producer was the Keystone Mine where wire gold occurred in masses of clay-altered porphyry. To process the Keystone ore, a milling and cyanide operation was set up in the town of Sandy, just west of the Spring Mountains.

For many years the gray-white material accompanying the lead ore was considered waste rock and discarded on the mine dumps. Fortunately, T. C. Brown, an engineer from Socorro, New Mexico, visited Goodsprings in 1906 and recognized this material as similar to the zinc ores mined at Magdalena, New Mexico. The discarded rock was hydrozincite and smithsonite, the two zinc-carbonate minerals. Mixtures of hydrozincite, smithsonite, and hemimorphite (a hydrous zinc silicate) made up the zinc ore at most of the mines, but hydrozincite was the dominant one throughout the district. From 1906 to 1911 the milling process involved hand sorting to separate galena from the zinc ore. In the Los Angeles Mining Review (September 14, 1910) this milling was described as "sacking the galena product." Galena was the source of both lead and silver from the district. After 1911, the Yellow Pine Mining Company constructed a mill in Goodsprings to separate the denser lead ores from the zinc ores. The zinc product was really the tailings of the separation process. The Shenandoah mill at Sandy and the Milford Mine mill were subsequently set up to increase the production of ore for the district. Because some of the ore from the Potosi Mine was pure zinc carbonate, the owners constructed a kiln and the ore was calcined. This raised the percentage of zinc in the concentrate and reduced its weight, thus lowering freight costs. Unfortunately the presence of hemimorphite, a zinc silicate, in many of the ore zones at the Potosi and district wide, produced poor results and the practice of calcining ore was not used there again. The separation of low-grade, mixed-zinc ore and low-grade lead-zinc ore from the carbonate host was a persistent problem for the district that was never fully resolved. In addition to copper, gold, silver, lead and zinc production small amounts of cobalt, vanadium, and platinum/palladium ores were mined in the early 1900s.

Platinum and palladium-bearing ores discovered at the Boss Mine in 1914 were of great interest because these metals are not typically hosted in carbonate rocks. The excitement over this discovery led to the laying out of the town of Platina on the flats just west of the Boss Mine (Paher, 1970). By 1916, Platina had a general store, a post office, and seven houses and numerous tents to accommodate the miners. However the “boom” was over by 1918 when the owners found that the platinum-palladium could not be economically extracted from the ore. Platina quickly became a ghost town.

Concentrates were hauled by wagon to railheads some 75 miles away and shipped to Missouri or Salt Lake City for smelting and refining. The completion of the San Pedro, Los Angeles and Salt Lake Railroad to Jean, Nevada in 1906 significantly reduced the high
small mining cycles until 1952. At least five mines were operating in the 1940s to produce zinc for the strategic metal stockpile at Jean, Nevada.

**Geology**

The geology of the district is complex and the timing of the various events recorded in the rocks is still being deciphered. Much of the following information on the geology is drawn from Hewett (1931), Albritton et al (1956) and Carr (1983, 1987).

Stratified rocks in the Yellow Pine District are dominantly Paleozoic limestone and dolomite, and Mesozoic sandstone and shale, with subordinate limestone and gypsum units. The Cretaceous Lavina Wash Sequence, a succession of sandstone, conglomerate, and volcanic tuff overlying folded Triassic red beds in the upper plate of the Birdspring Thrust, is mapped in the Lavina Wash area (Carr 1980, 1987). The sequence contains boulders of volcanic rocks similar to those in the Jurassic Del Monte volcanics.

The nearest exposures of the Del Monte volcanics are in the Mescal Range, tens of miles to the south, presenting unresolved paleogeographic and structural issues (Fleck, R.J. and Reynolds, R.J., 1996). Flat-lying Tertiary (Miocene?) ash flows occur at Table Mountain in the southern part of the district. Farther south at Devil's Peak, a Miocene rhyolite plug surrounded by a narrow band of volcanoclastic sediments has been mapped. Intrusive rocks are concentrated in the central part of the district where a series of dikes and sills of granitic porphyry are exposed. The Yellow Pine sills, located in Porphyry Gulch, is perhaps the largest of the outcropping intrusions with a thickness of 780 feet. Age dates for these intrusions are early Jurassic (180 Ma, 189 MA and 190 MA, Garside et al., 1993). Minor intrusions of basalt in the central part of the district and an alignment of lamprophyre dikes (Singer, Puelz and Star Mines) south of Columbia Pass are described by Hewett (1931). The age(s) of these basic intrusions are unknown, but they indicate that the central part of the Yellow Pine District was the focus of multiple episodes of igneous activity.

The northwesterly striking, high-angle Cottonwood Fault that passes through Mountain Spring Pass marks the district's northern boundary. South of the Cottonwood Fault a sequence of northerly striking and westerly dipping thrust plates has been mapped. These thrusts dip at angles of 45 degrees and higher and ramp across the underlying stratigraphic formations. This is in contrast to the thrust pattern north of the Cottonwood Fault where the Keystone Thrust dips westward at a much lower angle. In the sequence of thrust plates in the district, the lowest structural unit is the Birdspring Thrust that extends below the overlying Contact Thrust, along the base of the east side of the southern Spring Mountains. The upper

---

**Figure 1.** Generalized geologic map of the Yellow Pine Mining District showing the locations for a few important mines. G, Goodsprings; C, Cottonwood Fault Zone; KT, Keystone Thrust; CT, Contact Thrust; GST, Green Monster-Sultan Mine Thrust; I, Ironsides Fault Zone; R, Ruth Fault Zone; P, Potosi Mine; GM, Green Monster Mine; B, Boss Mine; K, Keystone Mine; Y, Yellow Pine Mine; L-IG, Lavinia and Iron Gold Mine area; CP, Crystal Pass; M, Milford Mine; black areas are Paleozoic rocks; black dots are Mesozoic rocks; black areas are porphyry; VV, volcanic rocks. Map is modified from Longwell, et al., 1965.
plate of the Contact Thrust forms the distinctive steep, grayish limestone and dolomite cliffs south of the pass. The Keystone Thrust is exposed along the central part of the range and is structurally above the Contact. Farther west, the Green Monster/Sultan Thrust truncates structures in the underlying Keystone. Numerous secondary thrusts, associated tear faults and folds occur within each thrust block.

The most dramatic structural change is in the central part of the mining district where the north-striking Keystone thrust bends sharply to the east, resulting in a distinct east-west reentrant in the thrust pattern. The bending is to some extent accommodated by strike-slip movement along the northeast-striking Ironsides Fault, a tear fault which lies wholly within the Keystone block. Fold axes in both the Keystone and Contact thrust blocks in the area of the reentrant are also oriented east-west. Carr (1983) interprets the reentrant as resulting from the wrapping of the Keystone Thrust around an elevated structural block composed of the Contact Thrust. The structural block is bound on the east by the Ruth Fault and possibly to the south by an easterly striking high angle fault, in the vicinity of Columbia Pass, and now buried beneath the Keystone Thrust. South of the reentrant the strike of the thrust is again northerly.

Hewett (1931) and Albritton et al. (1956) felt the thrusts and associated tear faults functioned as conduits for the intrusions and that thrusting preceded the emplacement of the porphyry. If this is the case, given the Early Jurassic age dates for the porphyry, at least some of the thrusting occurred as early as Late Triassic. A second episode of thrusting appears to have happened in the Late Cretaceous as reflected in the relationship between the Keystone Thrust and the Lavina Wash Sequence in the reentrant. The shearing of the porphyry dike near the Keystone Thrust at the Keystone Mine and the truncation of this dike at its north end by the thrust likely resulted from the later thrust event.

Age of the Mineralization

Detailed mine mapping shows that both the intrusions (e.g., sills and dikes at the Yellow Pine Mine) and structures (e.g., Principal Thrust at the Potosi Mine) acted as permeability barriers to ore-bearing fluids. Ore zones at the above mines terminate against such boundaries. The ore bodies appear to be post-intrusion and therefore post-Early Jurassic. Most workers in the district attribute the ores to a late hydrothermal phase following the intrusion of the porphyry. The dikes and the sills may represent the higher portions of a deeply buried porphyry system. An additional reason for associating the ores with the emplacement of the porphyry is the zoning of metals and the distribution of the intrusions. Virtually all of the outcrops of porphyry and the gold, silver, copper, cobalt, vanadium and platinum/palladium ores occur primarily in the central part of the district, within or close to the reentrant in the Keystone Thrust. Minor occurrences of these metals, where ore fluids were guided by the major thrusts, are found outside of the reentrant.

Additional support for a pre-Late Cretaceous age for the mineralization comes from the copper-bearing garnet-diopside skarn at the Iron Gold Mine, located in the eastern part of the reentrant. The skarn is juxtaposed to the Lavina Mine porphyry; the only intrusion in the district with sulfide bearing quartz veins. Contacts between the porphyry and the skarn are covered and the cause and effect relationship between them inferred. The skarn developed in one of the thinly laminated carbonates typical of the Banded Mountain Member of the Bonanza King Formation. According to Burchfiel et al. (1988), this stratigraphic unit is commonly found at the sole of the major thrusts. These metamorphosed Cambrian rocks are probably at the basal part of the Contact Thrust, which, along with the adjacent porphyry, are now incorporated in a fault slice carried up along the Ruth Mine Fault. From present exposures we cannot determine the structural relationships between the skarn, porphyry, and the Contact Thrust. Either both the skarn and the porphyry are in the upper plate of the thrust or the intrusion was emplaced across the thrust contact. If the Lavina Mine porphyry is part of the early Jurassic magmatism, then the copper-bearing skarn may be indicative of a contemporaneous mineralizing event. However, if the thrust cuts both the skarn and the porphyry, then the copper mineralization could be older than Late Triassic. Carr’s mapping (Carr, 1983) shows that the Ruth Fault barely offsets the Keystone Thrust in the area of the reentrant. This indicates most of the movement on this fault system occurred before the emplacement of the Keystone (pre-Late Cretaceous) and favors a Jurassic or older date for the skarn mineralization and, by extension, the formation of the ores throughout the district.

If, as postulated, the ores and porphyry sills and dikes were emplaced in the higher portions of a deeply buried porphyry system, then it is curious that the total and derivative magnetic maps for Nevada (Hildenbrand and Kucks, 1988a,b) give no indication of such a system beneath the Spring Mountains. Either the system is highly altered and gives no magnetic signature or perhaps thrusting or other regional faulting has detached ores and intrusions from a magmatic source located farther to the west.

Age of the Oxidation

The dating of the oxidation of the ore deposits is somewhat constrained by scattered exposures of
Miocene (?) volcanic and conglomerate units that unconformably overlie structures, including ore-bearing faults, in the district. The latitic and andesitic flows, tuffs and breccias at Table Mountain, south of Goodsprings, rest on an erosion surface that truncates mineralized faults north of the Deadman Canyon area. Outcrops of cobbles and boulder conglomerate, mapped as the Early Alluvium by Hewett, contain clasts of limestone, dolostone and quartzite. As noted by Hewett, the quartzite appears to be from Precambrian formations not exposed in the central and southern Spring Mountains. The stratigraphic relationship between the volcanics and the conglomerates in the Spring Mountains is unknown. However, these units may be equivalent to Miocene quartzite-bearing fanglomerates and associated volcanic rocks described in the Kingston Range area, just to the west of the district in California (McMackin and Prave, 1991). The southern Spring Mountains were probably at least partly buried beneath Miocene fan deposits derived from sources to the west. Subsequent erosion has removed most of this Miocene cover. In the district the oxide zone either developed beneath the sub-Miocene unconformity or formed during the period when the southern Spring Mountains were exhumed and the Miocene fan deposits eroded. The depth and extent of the oxide zone reflect a deep water table combined with sufficient infiltration of the available rainfall, along an extensive fracture system, to thoroughly oxidize the primary sulfides. The depth to the water table may have been partly a function of elevation of the range.

Structural and Stratigraphic Controls on the Localization of Ore

There are over seventy (70) mines in the Yellow Pine District in addition to a number of prospect pits, short exploration adits and shafts. Combinations of structure and stratigraphy appear to have controlled the movement of mineralizing fluids and the concentration of ore into discrete zones. For detailed descriptions of the ore bodies and maps of the mines the reader should consult Hewett (1931) and Albritton et al. (1956).

Mineralization in the porphyry is uncommon and most of the ore is hosted in the Devonian and Mississippian carbonates. Thrusts and the associated secondary structures formed the "plumbing system" for the ore fluids. Since the dolomites of the Cambrian Bonanza King Formation typically occur at the sole of the main thrusts, it is puzzling that this unit is rarely mineralized. One possible reason for this may be that the Bonanza King was dolomitized prior to the intrusion of the porphyry and the emplacement of the ores. Dolomite in the Bonanza King is stratigraphic in the sense that individual units can be mapped throughout the district as well as regionally. It may have formed by diagenetic dolomitization during the Cambrian and be unrelated to Mesozoic or later events. In contrast, dolomite in the overlying Paleozoic units is much more erratic in its distribution. Stratigraphic units, such as the Ironsides Member of the Sultan Limestone (Devonian) or the Bullion, Anchor or Yellow Pine Members of the Monte Cristo Formation, are limestone in one local section and dolomite in the adjacent one. Dolomite in the ore bodies is typically light colored and coarsely grained, and often occurs in banded breccia zones or as bands of bedding parallel white dolomite (zebra stripping). According to Hewett (1931) and Albritton et al. (1956) these coarsely crystalline dolomites preceded the deposition of the primary sulfides. Typically, ore occurs in the dolomite in preference to the adjacent limestone beds. The pre-ore stratigraphic dolomite in the Cambrian units may have been less permeable than the structurally prepared zones in the overlying limestone units. Dolomitizing fluids, which preceded the ore solutions, moved through the plumbing system and concentrated in the fractured limestone beds.

In detail, permeability differences played a significant role in the distribution of ore bodies at each of the mines. Permeability barriers are represented by the porphyry sills and dikes, by the basal shales and sandstones of the Birdspring Formation, and by clay gouge developed along some fault zones. The Yellow Pine and Prarie Flower ore bodies are localized in the Yellow Pine Member of the Monte Cristo Formation beneath either the Yellow Pine Sill or the basal shales of the overlying Birdspring Formation. The Como Dike, in the northern portion of the Yellow Pine Mine, functioned as a lateral barrier to the ore fluids. At the Potosi Mine, ore zones back on clay gouge in the Principal Thrust or, locally, beneath the basal shales of the Birdspring. Albritton et al. (1956), again at the Yellow Pine Mine, demonstrated that strike slip movement along sinuous, high angle faults created zones of intense fracturing and the localization of ore. Similar reasoning applies to the Boss Mine where strike slip movement along sinuous northeast striking faults (Ironsides Fault Zone) contributed to fracturing and the formation of ore bodies. Using the Ironsides Fault Zone in this way is not inconsistent with a pre-Late Cretaceous age for the mineralization if the fault zone is made up of older faults reactivated during thrusting. The Boss is particularly interesting in that intersecting northeast and northwest striking mineralized faults probably provided the conduits for the introduction of hydrothermal fluids. Ore bodies in the Milford Mine #3 (Kepper, 1995, unpublished mapping) illustrate how the mechanical properties of individual rock units influence permeability. A high angle, south dipping (70°) fault brings the thinly bedded, cherty dolomites in the Anchor Member on
the north side up against the massive dolomite of the Bullion Member. The dip of the fault decreases to an angle close to the 30 degree dip of the beds where it crosses the Anchor and the thinly bedded dolomite is highly fractured. Most of the ore is in the Anchor with minor amounts in the massive Bullion.

To date the only significant mineralization of the granitic porphyry is at the Keystone Mine where clay-altered porphyry contains gold. The porphyry was emplaced as a dike in the Banded Mountain Member of the Bonanza King Formation, just above the Keystone Thrust. The dike is truncated at its north end by the thrust. Quartz veinlets containing proustite and pyrrargyrite were reported to occur in the Lavina Mine porphyry (Hewett, 1931). In the Crystal Pass area a highly silicified porphyry dike and the adjacent recrystallized dolomite contain an abundance of secondary silver minerals such as chlorargyrite and argentite that may be indicative of precursor silver-bearing sulfosalts in the intrusive body.

**Primary Ore Mineralogy**

Because most of the deposits are thoroughly oxidized to various secondary minerals, the nature of the primary minerals is poorly known. The primary copper mineral is chalcocylrite, typically rimmed by secondary chalcocite. These two sulfides were probably the chief sources of the copper production. Small quantities of bornite are reported by Hewett (1931). Additional sulfide minerals noted by Hewett include tennantite, proustite, stibnite and cinnabar. Limonite pseudomorphic after pyrite is common throughout the district, although the volume of pyrite in the primary assemblage appears to vary considerably within and between ore bodies. Galena and sphalerite are the primary sulfides for the lead-zinc mines.

Jedwab (1999a, 1998 and 1999, pers. com) has been working on oxygenated platinum group metals (PGM) from localities in Africa, Europe, and South America and is currently conducting studies on such material from Goodsprings. Samples from the Boss, Azurite, Oro Amigo, Blue Jay and Kirby mines are part of the study. Isolated grains of individual mineral species within bituminous matrices are analyzed down to 35 angstroms using SEM and EMP methods. The bitumen derived from the carbonaceous limestone host migrated into the ore zone during hydrothermal mineralization. The bituminous matrix from the Boss Mine samples contains elevated amounts of palladium, platinum, gold and mercury. Sulfide grains identified in the bitumen to date include: pyrite, galena, arsenopyrite, bornite, covellite, pyrrhotite, argentite, bismuthinite, and cinnabar. Single grains of potarite (Pt, Pd, Au Hg) and gold (including mercurian gold), considered primary minerals, occur in the bitumin and as inclusions in quartz.

Secondary minerals associated with the bituminous matrix include chalcocite, cinnabar, florencite-Nd, plumbojarosite, argentojarosite, hydromium-jarosite, arseniosiderite and some unidentified bismuth oxychloride species. Knopf (1915b) reported anatase crystals from the platinum/palladium bearing siliceous material and this has been confirmed by Jedwab. P. Hlava (1999, pers. com) reported a chromium-bearing hematite as inclusions in smoky quartz crystals within vugs of the silicified ore from the Boss.

The bituminous material from the Azurite Mine contains an unusual suite of minerals including auriferous tocornalite (Ag, Hg I), eucairite (Cu, Ag Se) and either moschellandsbergite or schachnerite (isometric and hexagonal forms respectively of AgHg). These minerals are associated with native silver and iodargyrite. No platinum, palladium, cinnabar or plumbojarosite occur in the Azurite

### Table 1: Minerals Reported from the Yellow Pine District

<table>
<thead>
<tr>
<th>Mineral Type</th>
<th>Symbol</th>
<th>Quartz</th>
<th>Byssolite</th>
<th>Galena</th>
<th>Sphalerite</th>
<th>Chalcopyrite</th>
<th>Bornite</th>
<th>Arsenopyrite</th>
<th>Pyrrhotite</th>
<th>Pyrite</th>
<th>Iodargyrite</th>
<th>Silver</th>
<th>Pyrochlorite</th>
<th>Proustite</th>
<th>Azurite</th>
<th>Gold</th>
<th>Chalcocite</th>
<th>Native Silver</th>
<th>Native Gold</th>
</tr>
</thead>
<tbody>
<tr>
<td>Primary Ore Minerals</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

* *mineral species new to Nevada

---

samples.

Sphalerite from the Potosi Mine is typically a medium to dark brown color and occurs as distinct rounded crystals up to ½ inch in size. The sphalerite crystals are tetrahedrons modified by dodecahedral faces. These crystals line the edges of white calcite-filled open-space cavities in breccia zones. Sphalerite also occurs as disseminations and as crystalline masses in the gray, dolomite host rock. Similar sphalerite appears on the mine dumps at Milford #1 and at the Green Monster Mine. Masses of galena, some as crude cubic crystals, are enclosed in the sphalerite and the hydrozincite ore at the Potosi. Sphalerite veinlets cutting across galena indicate that the latter formed first. Small amounts of finely crystalline pyrite occur in the carbonate matrix surrounding the galena and sphalerite. Takahashi (1960) reported greenockite (cadmium sulfide) associated with the sphalerite at the Potosi Mine.

The granitic porphyry is of mineralogical interest because it is the source of well formed orthoclase crystals up to two inches in length. Orthoclase weathers easily out of the rock and crystals are collected by picking through the soil above a rock exposure. Drugman (1938) and Gilmour (1961) describe single and twinned crystals from the Crystal Pass area, just southeast of Goodsprings. Carlsbad twins are the most abundant, but Baveno and Manebach twins are present. Plate 1 in Drugman’s paper contains excellent illustrations of all of these including various combinations of twins. The porphyry exposures at the Yellow Pine Mine and near the Lavina Mine are also sources of fine crystals.

Small vugs lined with sharp, millimeter size, golden brown to grayish brown andradite occur in the garnet-diopside skarn at the Iron Gold Mine. The garnets are dodecahedrons and dodecahedrons modified by trapezohedrons. There is some retrograde metamorphism represented because the diopside, in places, is altered to actinolite. Chalcopyrite is present in minor amounts and millimeter size grains with a bluish fluorescence, probably scheelite, are also in the skarn. Small, octahedrons of magnetite are present in the skarn at the Iron Gold and in a recrystallized dolomite near the Monarch Mine, south of Crystal Pass.

Secondary Minerals in the Supergene Zone

Weathering of a primary sulfide ore body by reaction with downward percolating oxygenated water results in a vertical zoning of secondary minerals described as the supergene zone. The general structure of the supergene zone consists of a gossan at the surface followed by a leached subzone, an oxide subzone and an enriched subzone at and just below the water table. In the Yellow Pine District the two upper zones may have largely been removed by erosion subsequent to the development of the supergene environment. The oxide subzone is well developed and is the source of most of the metal production throughout the district. There is no evidence of an enriched zone of secondary sulfides for two reasons. First, the host rocks for the primary ore are carbonates which create an alkaline environment unfavorable for the formation of the chief secondary copper sulfide, chalcocite. Secondly, copper is immobilized in the oxide zone in the form of secondary carbonates and oxides reducing the availability of copper to form an enriched sulfide zone below the water table. The two primary lead and zinc sulfide minerals, sphalerite and galena, do not react to form secondary sulfides of zinc or lead. Most of the lead...
released in the supergene weathering process combines with available sulphate, carbonate, arsenate, phosphate, or vanadate to form secondary minerals in the oxide subzone. Due to the low solubility of galena, much of this primary mineral remains in the ore bodies surrounded by secondary ores. Sphalerite is relatively soluble and zinc is either removed by groundwater or becomes trapped in the oxide subzone as one of the zinc-bearing carbonate minerals.

The dominant mineral in the oxide subzone at most of the mines is goethite which ranges in color from yellow-orange, yellow brown, dark brown to black iridescent material. Yellow-orange goethite occurs as finely grained, porous, often powdery material. The darker brown to black goethite typically forms hard, cellular or boxwork masses resembling clinkers from a furnace. The hard nature of this material is the result of silification or the addition of silica to the iron oxyhydroxide. At the Milford #1 Mine a shiny material composed of a hydrous iron silicate (hisingerite) forms irregularly shaped shells and botryoidal crusts lining the cellular openings in the goethite. One of the characteristics of goethite, important to the mineralogy of the oxide subzone, is its ability to absorb metals initially leached from the primary minerals. These absorbed metals, under the right conditions, are later released to become constituents in the secondary minerals. Secondary iron oxide also occurs in the district as hematite.

Minerals in the Copper-bearing Oxide Subzone

With the exception of the Blue Jay Mine, copper minerals belonging to the oxide subzone, although common, are not spectacularly developed. The dominant oxide subzone copper minerals are tenorite, malachite, and chrysocolla. Tenorite occurs as black to dark, reddish-black lustrous material typically rimmed with malachite or laced with veinlets of the same mineral. Malachite appears as clusters of stubby prismatic to acicular dark green crystals lining opening in the boxwork goethite. The most interesting occurrence of malachite is at the Blue Jay Mine where malachite pseudomorphic after azurite crystals in the 1 to 5 cm range are found. Sky blue to greenish blue chrysocolla is abundant at a number of the mines. It occurs in disseminated or veinlet form. Chryocolla pseudomorphic after prismatic malachite occurs at the Boss Mine. Dioptase occurs as millimeter size, greenish blue prismatic crystals at both the Blue Jay and Green Monster Mines. Other oxide subzone copper minerals identified in the district include aurichalcite, rosasite, brochantite, libethnite, nissonite, conichalcite, galilite, and turquoise. The aurichalcite is present as radiating sprays of acicular, light blue crystals. Masses of aurichalcite up to 5 pounds were taken at the Yellow Pine Mine (Hewett, 1931). It is present at both the copper mines and the lead-zinc mines. Rosasite forms bluish green globular arrays of crystals, principally in the lead-zinc mines. Nissonite, a new mineral for Nevada, was recognized in 1996 at the Boss Mine where this rare copper phosphate forms diamond-shaped plates of light blue crystals. The first occurrence in Nevada of galilite, a green, globular copper silicate mineral, is also at the Boss Mine. Green, globular arrays of needle-like crystals of the copper arsenate conichalcite were identified by P. Adams (1998) at the Singer Mine.

One of the most intriguing comments by Hewett (1931) is the reported occurrence of linarite crystals up to 4 inches in length from the Yellow Pine Mine. The whereabouts of such material is presently un-
Gypsum does not appear to be common in the oxidized copper ores. This may result from intense silicification at the time of the primary mineralization that would, in turn, reduce the availability of calcium during the subsequent oxidation. Jedwab (1999) noted tiny granules of native iridium in gypsum from the Boss Mine. Barite (calcium sulfate) occurs as minor vein fillings at a few of the copper mines.

**Minerals in the Lead-Zinc Oxide subzone**

Oxidation at the lead-zinc ore bodies has resulted in a wide spectrum of secondary minerals. The two primary minerals, sphalerite and galena, respond quite differently to conditions in the oxide zone. Sphalerite is much more soluble than galena and, in most of the mines, masses of galena are surrounded by secondary zinc minerals. The chief secondary zinc mineral is the hydrated zinc carbonate, hydrozincite. Although hydrozincite is normally colorless to white, it may be colored by various trace elements (largely iron or manganese) leading to shades of brown, pink and purple. At the Milford #1 Mine white to brown hydrozincite forms thin, highly contorted laminae in the host dolomite. The pattern is similar to rhythmic liesegang banding found in iron-bearing weathered sandstones. The pattern is attributed here to the interdiffusion of zinc from the ore fluids and carbonate from the host rock source at a millimeter scale. Clear, flattened, paper-thin crystals of hydrozincite lining the interior of cavities in massive hydrozincite are not uncommon (Kepper, 1995). This mineral has a striking bright blue fluorescence.

Two other secondary zinc ores of importance are hemimorphite (hydrated zinc silicate) and smithsonite, a zinc carbonate. Smithsonite is another of the zinc carbonates that is widespread in the district, but is subordinate in quantity to the hydrozincite. At the Milford #1 Mine smithsonite occurs as white, botryoidal masses of fine radiating needles, often as the initial lining in a vug or cavity in the host dolomite. Rhombs of white smithsonite, attached to thin acicular prisms of hemimorphite and millimeter-size scalenohedrons of pale pink smithsonite have been identified optically from samples collected at the Yellow Pine Mine. Takahashi (1960), from his study of the lead-zinc mineralization in the district, determined that hydrozincite ore bodies were typical of the higher levels and smithsonite the lower ones. Hewett (1931) made a similar observation at the Yellow Pine Mine, one of the largest and deepest of the zinc producers. Ore specimens show smithsonite followed by hydrozincite lining the walls of vugs and of bedding-parallel openings. Central portions of these openings often contain clear crystals of hemimorphite; which, generally, was the last of the zinc ore minerals to form.

At Milford #1 and #3 Mines (Kepper, 1995),

---

**Figure:** Hydrozincite and hemimorphite, field of view 8 mm. Yellow Pine Mine, Goodsprings. S. White photo.
hemimorphite shows a great variation in habit. The earliest hemimorphite replaces the host dolomite. In openings in breccias or vugs in the host dolomite hemimorphite forms sheets of flattened sheafs of very platy, clear crystals precipitated along the walls of the openings. A later hemimorphite forms singles and small clusters of water clear stubby prismatic crystals either perched on the sheaf hemimorphite or as solitary crystals on goethite and hisingerite in cellular openings. These solitary hemimorphite crystals occasionally show a hopper structure resulting from rapid growth of the crystal faces in the {001} zone relative to the faces on the termination. The latest hemimorphite occurs as small acicular prisms perched on the earlier stubby ones. In the breccia zone at the 100 level in Milford #1, where the hemimorphite is associated with plattnerite, the hemimorphite is strongly etched and partially replaced by hydrozincite. This seems to reflect high pH and strongly oxidizing conditions. Willemite, another zinc silicate, is rare but was recognized by Takahashi (1960) and later by Adams (1998) at the Singer mine. Willemite clusters occur in goethite at the 100 level of the Milford #3 Mine. It has a distinctive hexagonal prismatic form and a yellow-green fluorescence.

The oxidation of sulfides results in at least an initially high sulfate concentration in the vadose water. Because of the availability of calcium from the carbonate host, gypsum is an early sulfate mineral at some of the lead-zinc mines. At the Potosi Mine, polished slabs of primary ore show small amounts of gypsum forming boxworks along cleavages and fractures in sphalerite (Takahashi, 1960). Samples from the Potosi show veinlets of clear gypsum extending across the sulfide and the host rock. In one specimen the walls of the veinlet are lined with gypsum and the interior of the vein contains hydrozincite. Masses of white gypsum crystals mixed with hematite occur on the dump at the Milford #1 Mine.

Anglesite, lead sulfate, is present in limited amounts at a few of the mines. It typically is a gray to grayish brown, resinous to vitreous material rimming galena. Much of the initial anglesite was replaced by the lead carbonate, cerussite, because of the abundance of carbonate anion. Excellent micro-crystals of anglesite are found at the Potosi and Contact Mines. These are typically water clear, sometimes slightly wine-colored crystals lining vugs in galena or developed along cleavages in galena.

The most common secondary lead mineral in the district is cerussite. Cerussite forms gray to nearly black resinous to vitreous rims and nodular replacements of galena. Clusters of clear to white or slightly yellow, well formed stubby to elongated prismatic crystals occur in the vicinity of galena at many of the mines. Hematite often forms a dark reddish brown to black coating on these cerussite crystals. Elbow and rare cyclic twins of cerussite occur at the Milford #1 Mine and the Yellow Pine Mine. A complex single crystal of cerussite from the Milford #1 Mine shows multiple stages of growth (SEM, Back Scatter Mode, Hlava, 1994, pers. com). Paragenetic studies on Milford Mine samples show that cerussite is replaced by mimetite/pyromorphite or by wulfenite. Bladed, dark gray crystals of cerussite up to a centimeter in length appear on the dumps at the Yellow Pine.

Pyromorphite, the lead phosphate, and mimetite, lead arsenate, occur in small amounts at most of the lead-zinc mines. Excellent prismatic crystals of the lead vanadate, vanadinite, have been collected at the Ruth Mine. White calcan pyromorphite is common throughout the district. This calcian pyromorphite ranges from stubby prismatic hexagonal prisms to very thin needles. Yellow and green pyromorphites occur in prismatic forms, but in some case form steep, tapering dipyramidal forms (Milford and Singer Mines).

SEM images of yellow, pyromorphite crusts by P. Hlava illustrate dipyramidal pyromorphite crystals from the Milford #1 Mine with small “cauliflower” shaped lumps of mimetite attached to the crystal faces. Back-scattered SEM (P. Hlava) of bright orange crusts associated with cerussite rims on galena at the Milford #1 show zoned hexagonal prisms consisting of an arsenate dominated (mimetite) core and phosphate dominated exterior (pyromorphite). Excellent prismatic green and yellow pyromorphites were reported.
from the Root Mine by Hewett (1931). EMP analysis
(John McCormack, UNR, 1998, pers.com.) indicates
that this material is mimetite with elevated concentra-
tions of phosphate. McCormack also noted the
possible occurrence of heliophyllite, a rare oxychloride
of lead and arsenic, within the yellow, pyromorphite
crusts from Milford #1 Mine. Goethite pseudomor-
phic after mimetite or pyromorphite in the form of
thin, hollow prismatic shells occurs at several of the
mines.

Vanadinite crystals from the Ruth Mine are sharp,
brownish red to golden brown hexagonal prisms with
pinacoidal terminations on a matrix of finely crystal-
line light brown to yellow chervetite or on a black
motttramite. Some of the vanadinites are zoned along
the c axis with alternating brownish red and golden
brown zones. Vanadates are also present as the
minerals descliozite and motttramite. Descliozite
occurs as brownish black flattened dipyrical crystals
and motttramite as yellow green, olive green and black
avrusts. Jedwab (pers. com. 1999) noted that some of
the Boss Mine motttramite contains bismuth. Lustrous
dark green microcrystals of motttramite are present at
the Whale Mine.

The chromate mineral, fornacite, occurs as yellow-
ish green crystals at the Yellow Pine (S. White, pers.
comm) and as wedge-shaped plates, both as single
crystals and as twins, at the Singer Mine (Adams,
1998). Fornacite forms wedge to chisel-shaped olive
green crystals associated with chlorargyrite, pyromor-
phite, and wulfenite at the silver prospect near Crystal
Pass and as thin crusts of crystals on dolomite at the
Alice Mine. A grayish pink platy mineral perched on
orange wulfenite and consisting dominantly of zinc
and chromium was collected by J. Kepper in 1994
from the dump at the Milford #3 Mine. It was
subsequently found in situ on the 100 level at Milford
#3 and in minor amounts on the 100 level at Milford
#1. This mineral is currently under investigation at the
University of Nevada-Reno.

Wulfenite (lead molybdate) is one of the most
interesting minerals found in the Yellow Pine District.
It has been identified at the Milford #1 and #3 Mines
(Kepper, 1995), the Mobile Mine, Whale Mine,
Yellow Pine/Praire Flower Mines, Ruth Mine, Green
Monster Mine and Potosi Mine. Wulfenites from the
Mobile and Whale mine are yellowish gray, and
typically quite platy. Probably the largest wulfenites
from the district occur at the Mobile where the crystal
plates are slightly larger than a centimeter. At the
Ruth, bright reddish-orange, tabular to stubby
pyramidal wulfenite associated with motttramite and
vanadinite was once found in abundance. Unusual,
needle-like yellow-gray to pale brown wulfenite
associated with hemimorphite occurs in samples from
the Potosi Mine. Milford #3 Mine has produced
wulfenite from the upper adit. This wulfenite consists
of grayish yellow, paper-thin, square plates, often in
the range of 5 to 1.5 mm. However, of all of these
occurrences, the Milford #1 Mine by far shows the
greater variety in form and color for wulfenite at any
of the mines (Kepper, 1998). Martin Crane, University
of Western Sydney, Nepean, Australia, is currently
studying wulfenites from the district, and elsewhere,
for trace element controls on the development of
variation in crystal forms.

At the Milford Mines, the dimensions of these
wulfenites are normally in the 2 millimeter or less
range, but single crystals up to a centimeter do occur.
In the 100 level stope at the Milford #1 Mine,
wulfenite occurs as translucent, lemon yellow, paper-
thin plates with the familiar "stop sign" morphology
attached to dark brown shells of hisingerite lining
 cavities in cellular goethite. Small, clear hemimorphite
crystals attach to the edges of these wulfenites.
Orange, square to rectangular tabular wulfenite also
appears in the 100 level specimens. Rarely, zoning
occurs in these crystals as a distinct orange-red center.
Some of these crystals are clearly wulfenite twins
because of the presence of a pronounced reentrant
structure developed along the composition plane
(Hurlbut, 1955). In the same stope, barrel-shaped,
steep pyramidal tab to pale orange wulfenites are
perched on colorless hemimorphite that has been
partially replaced by hydrozincite. Black needles of the
lead oxide mineral platnerite occur as overgrowths on
the etched surface of these pyramidal crystals. These
barrel-shaped crystals are deeply etched along the c
crystallographic axis and in some cases the crystal is
actually a shell of wulfenite with the interior leached
away. Translucent honey-brown, rarely yellow-green,
wulfenite displaying first and second order pyramidal
forms in combination with pedions, line cellular
openings in goethite in a few specimens from the 100
level.

The 200 level stope at Milford #1 contains an
abundance of grayish yellow, platy, layered wulfenite
associated with platnerite developed along a silicified
west dipping fault zone. This wulfenite (Kepper,
1998) shows multiple cycles of precipitation and
dissolution. Platnerite occurs as radiating sprays of
fine black needles attached directly to plates of
wulfenite or as inclusions within some of the wulfenite
layers. These black needles are also found perched on
calcareous fine silt to clay size sediment coatings on
the positive pedion. Sediment coatings also appear to
occur within the layered structure of individual
wulfenites. The negative pedion (based on etch
figures) shows a series of small pyramidal crystals in
parallel growth. Parallel growth is indicated by parallel
reflections from the first order pyramidal faces and by
fine striations (steps between the first and second
order pyramidal faces) which are continuous from layer
to layer across the sides of the crystals. Each wulfenite
plate is a single crystal structure represented by a series of small crystals in parallel growth. A few wulfenites show the small pyramidal crystal growth on opposite sides and represent twinned crystals.

These platy wulfenite crystals show deep square etch pits characteristic of the negative pedon (Hurlbut, 1955) on one surface. Removal of the sediment layer on the opposite surface of the crystal exposes shallow hopper structures typical of the positive pedon.

Preferential deposition of the sediment on the positive pedon may reflect a piezoelectric effect related to the non-centric symmetry of wulfenite. The sediment coating(s) suggest that the water table may have periodically risen to allow fine sediment to accumulate on the pedon surface. Growth and dissolution (etching) of the wulfenite oscillated, perhaps with the position of the water table. Takahashi's work suggests that wulfenite might not be stable under the highly oxidizing conditions favorable to the formation of plattnerite and etching cycles may equate to times when plattnerite was formed.

Calcite, aragonite, and dolomite as secondary minerals are well represented throughout the district. Aragonite occurs as pale brown to white finely crystalline, banded material associated with post-ore solution-precipitation processes. This banded aragonite serves as the base for centimeter-long clear to white bladed prisms of aragonite. The aragonite has a yellow-green fluorescence. Excellent examples occur at the Potosi, Oro Amigo, Prairie Flower and Milford mines. Calcite appears as clear to white rhombohedrons perforated on earlier secondary copper, lead or zinc minerals. These rhombs are combinations of positive and negative rhombohedrons, are occasionally sharp, but are often rounded in appearance with step-growth patterns on each face. At Milford #3 the calcite is zoned with white cores and a clear exterior. Flattened rhombs or "nailhead" calcite up to several centimeters also occur in the district. Scalenohedral forms are more rare, but have also been recognized. Dolomite appears as sharp, clear rhombohedrons perched on the edges of acicular hemimorphite crystals at Milford #3 Mine.

Unpublished reconnaissance reports prepared for the Atomic Energy Commission in the 1950s, during the nationwide search for uranium resources, include descriptions of several mines in the Yellow Pine District. Some of these reports are stamped with the acronym SOM, the code word for uranium. This is an artifact of the days when the uranium search was under the Manhattan Project and anything related to development of the atomic bomb was secret (Chenoweth, 1998). Kasolite, hydrous lead uranium silicate, and dumontite, hydrous lead uranium phosphate, were collected in one of the adits at the Green Monster Mine during this survey work (unpublished reports and Albritton et al., 1965). Excalibur Minerals illustrated a specimen (on their Photo CD, 1999) with an orange yellow crust of dumontite on a brown kasolite. Millimeter-size bright yellow sprays of radiating acicular crystals of boltwoodite (hydrous potassium uranium silicate) were found at the Green Monster by Dick Thomssen (S. White, pers. com.) and bright yellow, platy kasolite crystals nestled within clusters of aurichalcite occur in a few of the dump samples from the same mine.

Conclusion

The potential for the discovery of mineral species new to Nevada or simply entirely new species is very high for the Yellow Pine District. Given the long list of trace metals available throughout the district, the geochemical potential for new or unusual species is there. The district has not attracted large numbers of collectors because, although most of the mines or at least the mine dumps are accessible, the individual mineral species tend to be in the millimeter or less size range. Mineral identification requires initial microscope work followed by x-ray, EDS and SEM analysis to make the mineral determinations. Nonetheless, serious collectors, with the support of professional mineralogists, will continue to be rewarded and the list of mineral species from the Yellow Pine District will lengthen over time.

References

Burichfeil, B. C., and G. A. Davis, 1988, Mesozoic thrust faults and Cenozoic low-angle normal faults, eastern Spring Mountains, Nevada and Clark Mountain thrust complex, California; in This Extended Land, Field Trip Guidebook, Geological Society of America, Cordilleran Section meeting, Las Vegas, Nevada; pp. 87–106.
Fleck, R. J. and R. E. Reynolds, 1996, Mesozoic stratigraphic units of the eastern Mescal range, southeastern California; in R. E. Reynolds and J Reynolds (eds), Punctuated Chaos in the Northeastern Mojave Desert; San Bernardino County Museum Quarterly, vol. 43, Nos 1 and 2, pp. 49–54.


Hildenbrand, T. G., and R. P. Kucks, 1988a, Total intensity magnetic anomaly map of Nevada; Nevada Bureau of Mines and Geology, Map 93A.

__, 1988b, Filtered magnetic anomaly maps of Nevada; Nevada Bureau of Mines and Geology, Map 93B.


Takahasi, T., 1960, Supergene alteration of zinc and lead deposits in limestone; Economic geology, vol 55, No. 6, pp. 1084 – 1114.

Von Bargen, D., 1999, Nevada Gold, Silver, and Copper deposits and their minerals; Rocks and Minerals, v.74, No.6, pp. 405-414
Yellow Pine District

Wulfenite, 2 mm crystal. Milford #1 Mine, 100 level, Goodsprings. J. Keper photo.

Wulfenite, 5 mm crystal. Milford #1 Mine, Goodsprings. J. Keper photo.

Wulfenite, largest crystal 1.5 mm. Milford #1 Mine, 200 level, Goodsprings. J. Keper photo.

Vanadinite, zoned, 1 mm crystal. Ruth Mine, Goodsprings. W. Lombardo photo.

Smithsonite rhombs on acicular hemimorphite; field of view 2 mm. Yellow Pine Mine, Goodsprings. S. White photo.

Cerussite twin, 0.75 mm crystal. Milford #1 Mine, Goodsprings. J. Keper photo.
Cerussite, 3 mm crystal. Potosi Mine, Goodsprings. J. Kepper photo.

Belwoodite, field of view 8 mm. Green Monster Mine, Goodsprings. S. White photo.

Nissonite, 2 mm clusters. Boss Mine, Goodsprings. J. Kepper photo.

Mimetite, field of view 5 mm. Prairie Flower Mine, Goodsprings. S. White photo.

Philippinegite, Mammoth Mine. S. White photo.

Carnegie, Mammoth Mine. S. White photo.

Rosasite, Mammoth Mine. S. White photo.
Micro-Mineral Photography

Olivine and quartz, Leiser Ray Mine, San Bernardino County, CA. J. E. Jenkins photo.

Hidalgoite a/f. mimetite, cuprite, Molonk Mine, San Bernardino County, CA. J. E. Jenkins photo.

Japan twin quartz and conichalcite. Gold Hill, Utah. J. E. Jenkins photo.

Scorodite, Gold Hill, Utah. J. E. Jenkins photo.

Pharmacosiderite, Gold Hill, Utah. J. E. Jenkins photo.

Quartz, Hope-New Method Mine, San Bernardino County, CA. J. E. Jenkins photo.
Vanadinite, Tonopah Ranch, Maricopa County, AZ. J. E. Jenkins photo.

Selenite, Mule Canyon, Calico Mountains, San Bernardino County, CA. J. E. Jenkins photo.

Carnellite after mimetite coated with heudunite, Mohawk Mine, San Bernardino County, CA. J. E. Jenkins photo.

Wulfenite and cerussite, Wendon, AZ. J. E. Jenkins photo.

Boulangerite rhombo, Mohawk Mine, San Bernardino County, CA. J. E. Jenkins photo.
The Mammoth Mine, Clark Mountain, San Bernardino County, California

Sugar White
Research Associate, San Bernardino County Museum, Redlands, CA 92374

The Mammoth Mine is located in Section 10, Township 17 N, Range 12 E on the north face of a foothill of Clark Mountain, nine miles north of Interstate 15. The dumps are readily visible from the east/west trending power line road. Research through several publications — California Division of Mines and Geology journals, lists of copper deposits in California and various mineral yearbooks — found only one mention of a Mammoth Mine in this location: Geological Survey Professional Paper 275 by D. E. Hewett. He described the structural geology of the mine:

A tear fault, along which schistose granite gneiss is thrust over the basal section of the Cambrian system, trends northeast just north of the mine. The longest tunnel explores the contact of the Noonday dolomite on this gneiss.

The mine was worked by the original owner, W. D. McQuen, from 1906-1929, primarily for copper. Approximately 100 tons of ore were mined between 1916 and 1918, but from 1918 to 1929 only 38 tons were processed. Gold and silver were minimal.

At the time the Clark Mountain area was examined for anomalous radioactivity by geologists of the USGS and the Atomic Energy Commission in 1948, the mine name had been changed to the Jeep No. 2 Claim (USGS Special Report 49, “Radioactive Deposits in California” by Walker, Lovering, and Stevens). It was owned by Albert Schmidt and W. R. Johns of Valley Wells, California and leased to Manning Briggs and Associates. Special Report 49 describes the deposit:

bedrock exposed in the area consists of dolomite limestone enclosed by quartzite, phyllite, and schist of pre-Cambrian age. Carnotite occurs with oxidized copper, lead, zinc, and manganese minerals in small replacement bodies and along veins in the limestone ... The richest sample collected from the property contained 0.41 percent equivalent uranium.

A limited underground inspection of the mine workings by this author revealed nothing remaining of the original ore body. Hewett speculates that it consisted of pyrite, chalcopryite, and quartz.

The name FRO I & 2 has been spray painted on the wall of the main tunnel as well as is the date 7-7-79 suggesting that the mine was claimed and renamed once again. Today, the Mammoth Mine is within the Mojave Desert Preserve.

Hewett lists the minerals malachite, azurite, chrysocolla, aurichalcite, alunite, limonite and quartz. This author also found adamanite, conichalcite, jarosite, cuprite, rosasite, hemimorphite, carbonate fluorapatite (the most common mineral from the dump material), carnocite in crystals up to 0.8 mm, philipsburgite, and carbonate cyanotrichite. All minerals in this list were found on the dump with the exception of carbonate cyanotrichite which was found in the mine.

The identification of the last three minerals was accomplished by Dr. William Wise of the University of California Santa Barbara. This mine is the only reported location for carbonate cyanotrichite in southern California and the only reported location for philipsburgite in California.
The Desert View Mine, San Bernardino Mountains, California: A Possible Intermediate between Langban, Sweden and Franklin, New Jersey

Peter B. Leavens and Jimmie D. Patton
Department of Geology, University of Delaware, Newark, DE 19716

Introduction
The Desert View Mine is a small prospect in Paleozone marble in the San Bernardino Mountains, northwest of Fawnskin, California. Paul (1986) noted that the rocks of the mine include the minerals franklinite, ideally ZnFe$_2$O$_4$, hetaerolite, ZnMn$_2$O$_4$, willemite, Zn$_2$SiO$_4$, and zincite, ZnO, an assemblage usually considered unique to the famous Fe-Zn-Mn deposits at Franklin and Sterling Hill, New Jersey. However, the deposit has not been studied in any detail; this is a preliminary report of our current investigation.

Franklin and Sterling Hill and, we believe, the Desert View as well, are members of a small group of oxide-rich deposits of marine-exhalative origin, modified by subsequent metamorphism (Fronde1 and Baum, 1974; Johnson, Rye, and Skinner, 1990). This group also includes the iron and manganese oxide deposits at Langban and elsewhere in the Bergslagen district of Sweden (Moore, 1970) and the manganese deposits of the California Coast Ranges (Huebner and Flohr, 1991). Each of these other deposits has some notable differences in the details of their geochemistry and mineralogy, but all are Precambrian in age, all have undergone regional metamorphism, and all are embedded in marble. The Desert View deposit is distinctive in being Cambrian in age (Brown, 1986), in being associated with platform or miogeosynclinal carbonates of a non-rift environment, and in having been subjected only to low pressure, contact metamorphism. However, as discussed below, it appears to be geochemically intermediate between the Franklin and Langban deposits.

Geologic Setting
The Desert View Mine is situated in the San Bernardino Mountains about five km (three miles) northwest of the town of Fawnskin, California. It is within the boundaries of the San Bernardino National Forest, in steep, brushy desert, at an elevation of about 2300 m (7600 feet), near the crest of the mountains. It is accessible by steep, narrow, unpaved roads passable by four-wheel drive vehicle. A number of small prospects and mines dot the terrain. The northeast slope of the mountains is being quarried extensively for lime.

The major rocks of the area are intrusive granodiorites of the Southern California batholith of Cenozoic age. Brown (personal communication) mapped the rocks around the mine. Contact-metamorphosed sedimentary rocks occupy small roof pendants, no more than a few hundred meters across, in the intrusions; these rocks can be correlated with Paleozone cratonic to miogeosynclinal sedimentary rocks of the Mojave Desert to the east (Brown, 1986). The metasedimentary rocks are complexly folded and faulted. The Desert View Mine lies in the middle Cambrian Bonanza King Dolomite, which has been metamorphosed to wollastonite grade in the vicinity of the mine. The mine consists of a few dozen square feet of surface workings in the exposed part of the ore body, and a horizontal tunnel, or adit, about 15 m long, which was intended to intersect the ore at depth, but failed.

The black outcrop of the ore body is about 15 m across and about 7 m high, dipping W at about 75°. It appears to be one to two m thick. It stands out prominently from the surrounding white marble. The deposit is a well-known fluorescent mineral locality and has been heavily collected, and there is an extensive apron of rubble spreading out at the base of the outcrop of the ore. Brown (personal communication) mapped “iron-rich skarn” outcropping for a distance of about 100m, more than observed by JP during a visit to the mine in July, 1998.

Previous Work
Paul (1986) described some of the minerals of the mine and reported several mineral assemblages, including hetaerolite (ZnMn$_2$O$_4$) + zincite + quartz with associated willemite + calcite, magnetite ss + andradite + willemite + epidote + quartz, and calcite + grossular + wollastonite + altered Mg silicate. He identified hetaerolite as the most abundant metal oxide, and proposed a complex origin for the deposit involving deposition of Mn oxide in a shallow water setting, high temperature contact metamorphism to
form the grossular + wollastonite assemblage, contact metasomatism by solutions saturated with zinc sulfide which reacted with the manganese oxides to produce the hematolite, and later stage retrograde reactions to form the other mineral assemblages.

**Current Work**

In the summer of 1998 a suite of 60 samples was collected by JP from the ore body and surrounding marble, and a sketch map made of their locations (Figure 1). Other samples were collected from the loose rubble around the outcrop. The samples were examined in the laboratory with shortwave ultraviolet illumination to determine the distribution and intensity of red fluorescence of calcite; intensity of fluorescence depends on the Mn content of the calcite (Palache, 1928). Ultraviolet illumination was also used to find wollastonite, which fluoresces yellow, and willemite, which fluoresces green. Most samples were subjected to x-ray diffraction analysis, using a computer-controlled diffractometer and analytical software, to determine the minerals present (Table 1).

EDAX analysis was performed on selected samples to provide compositional information; however, polished sections were not prepared, so the results are only qualitative. A dozen thin sections of the texturally and mineralogically complex samples were prepared for transmitted-light polarized-light microscopy (PLM). Fine-grained, isotropic, crystallophatic fabrics predominate, indicating equilibrium crystallization with little deformation.

The most abundant ore mineral assemblage in the samples collected is hematite +/- magnetite +/- quartz; some samples are predominately quartz, despite their dark color in hand sample. The hematite rock is black, dense, and fine-grained; several samples have dark green films of andradite garnet coating fracture surfaces. The rock weathers rusty, which would provide a means of identification in future field work. hematite rock appears to compose most of the surface outcrop of the ore body (Figure 1). Associated with the hematite rock are masses of andradite garnet skarn, with minor non-fluorescent calcite. Hetaerolite is apparently much more restricted in its distribution; only one sample (22) was in the collected suite, from the base of the outcrop (Figure 1). This sample appears to be pure hetaerolite, with just a few grains of fluorescent willemite, but without the zinc + quartz reported by Paul (1986). It is dense, dark to brownish black, and weathers to sooty Mn oxides; this difference in weathering distinguishes it from the hematite rock. Associated with the hetaerolite rock is mineralized marble containing fluorescent, manganese calcite, minor willemite, and trace zincite. Minor barite and rhodonite were also identified by EDAX analysis in one sample. The intensity of fluorescence in calcite varies with distance from the ore, and in particular with distance from the hetaerolite ore, suggesting that there is a Mn halo in the marble surrounding the ore body (Figure 1).

Skarns containing fluorescent calcite, wollastonite, grossular, and in one sample vesuvianite occur at the periphery of the ore. If some limits can be put on the pressure of metamorphism, then the compositions and associations of these minerals could be used to help interpret PT-X conditions of metamorphism, using the methodology and reaction curves developed by Valley et al. (1985) and by Bowman (1998).

**Discussion**

Despite the location of the deposit in a roof pendant and the proximity of the granodiorite, the iron-rich portions of the Desert View deposit do not have the characteristics of metasomatic, iron-rich skarns typified by the deposits in southeastern Pennsylvania (Lapham and Gray, 1973; Spencer, 1908.) The Pennsylvania deposits are coarse and variably grained, have abundant magnetite and rare hematite, and contain accessory sulfides. Quartz is rare or absent in the massive ore. The Desert View deposit is fine grained, hematite is more abundant than magnetite, quartz is abundant in some samples, and sulfides are absent. Paul’s (1986) proposal of a hybrid exhalative-contact metasomatic origin for the Desert View deposit also is not necessary; it can be more simply explained as a purely exhalative deposit, an analog of the Franklin/Sterling and the Langban-type deposits.
Figure 1A: Desert View Prospect.
Outcrops are outlined. Predominant minerals: FeOx: hematite/quartz; Cc: calcite. Numbers identify location of samples. Type size indicates intensity of calcite fluorescence:

Figure 1B: Desert View Prospect, Plan View

Calcite Outcrops
FeOx Outcrops

Number indicates location of calcite samples. Type size indicates intensity of calcite fluorescence, e.g., 55 little to none; 55 pale; 55 moderate; 55 strong.
These deposits are composed largely of iron and manganese oxides, but their differences are as great as their similarities. At Franklin/Sterling, zinc was a major component of the ores, and iron, zinc, and manganese were found together, predominately in the mineral frankinite, a Zn-Fe-Mn spinel of complex composition (Leavens and Nelen, 1990). Iron is predominately trivalent and manganese divalent in frankinite; Leavens (1988) suggested that this close association indicated that the iron had been deposited originally as oxides and hydroxides, and the zinc and manganese as carbonates and silicates, under conditions of buffered or restricted $f_{O_2}$ in a rift environment. At Langban (Moore, 1970), iron and manganese ores are separated but in proximity, with manganese ores above iron ores. Manganese, like iron, is predominately trivalent. This could be explained by deposition in an ocean-floor environment in equilibrium with ocean water; the higher oxidation potential of manganese would cause it to be deposited after iron, as trivalent and quadrivalent oxides.

The Desert View deposit appears to have the distinct separation of iron and manganese minerals characteristic of the Langban-type deposits, but it contains a number of minerals characteristic of Franklin/Sterling Hill: frankinite, hetaerolite, willemite, and zincite, none of which are reported from Langban (Moore, 1970). Hetaerolite is particularly significant: it was originally described from Sterling Hill (Palache, 1935) as a secondary mineral formed by the weathering of frankinite ore; the iron from the frankinite formed associated ferric oxides and hydroxides. Hetaerolite was subsequently detected in one high-temperature ore sample from Franklin by Leavens and Nelen (1990), who interpreted it as primary exhalative hetaerolite which had survived the granulate-grade metamorphism of the Franklin deposit. If this model is correct, the massive hetaerolite at the Desert View could have been an original mineral of the exhalative ore. Zincite and willemite can be generated in a number of ways by metamorphism of appropriate sedimentary precursors (Leavens, 1988); in the chemically simplest (although not necessarily correct) way, zincite (ZnO) would form from the decarbonation of smithsonite (ZnCO$_3$) and willemite (ZnSiO$_4$) from the dehydration of hemimorphite (Zn$_2$Si$_2$O$_5$(OH)$_4$); both smithsonite and hemimorphite are common minerals in secondary, weathered zinc deposits.

The Buckeye manganese deposit in the California Coast Ranges southeast of San Francisco has been studied intensively by Huebner and Flohr (1990). It contains banded ores rich in manganese carbonates, oxides, and rhodochrosite, MnCO$_3$. Iron minerals are absent. The host rocks are turbidites and cherts. The Buckeye is similar to other bedded manganese deposits (Huebner, 1976), but is different from the Desert View in geologic setting and especially in lacking associated iron oxides. The greatest similarities between the Buckeye and the Desert View are that they both contain manganese minerals and both are believed to be of marine exhalative origin. Huebner (1976) makes two points that may bear on the difference in mineralogy of the two deposits: (1) hausmannite, MnMn$_2$O$_7$, is stable under conditions where hematite and magnetite coexist, but (2) manganese is normally separated from iron in sedimentary deposits because of the greater solubility of manganese in acid waters. However, exhalative waters in a carbonate environment would be buffered to slightly alkaline conditions more rapidly than waters in a non-carbonate environment, such as the siliciclastic environment around the Buckeye. Deposition of manganese would be much more rapid in the carbonate environment, and the iron and manganese minerals could be associated. This model may explain why Franklin, Sterling Hill, Langban, and the Desert View, all in carbonate rocks, contain both iron and manganese minerals.

A substantial problem with the exhalative model for the origin of the Desert View deposit is a source for the iron, manganese, and especially zinc to form the deposit in a quiet continental shelf environment. There is little hope of determining such a source, as much of the earlier geology of the area has been obliterated by the intrusion of granite. However, the deposit does fit the exhalative model in structure and mineralogy. More work is needed to find the full extent of the ores, determine the distribution of iron and manganese minerals, and decipher the geologic history of the Desert View deposit, but chemically and, we believe, genetically it is an intermediate between the Langban and the Franklin/Sterling deposits.

**Acknowledgements**

Billy P. Glass and Paulus B. Moore made a number of helpful content and editorial suggestions. We appreciate their help.

**References Cited**


Micro-Mineral Photography

John Jenkins
Research Associate, San Bernardino County Museum, Redlands CA 92374

Introduction

Many collectors of micro-minerals would like to photograph their better specimens but are hesitant to undertake such a seemingly complicated and expensive endeavor. However, recent advances in camera technology have made photomacrography almost as simple as ordinary photography, and it need not be terribly expensive.

There probably are as many variations in equipment and techniques as there are photographers. The experienced photographer will not agree with everything in this article; however, the information contained herein is recommended for the beginner. After gaining some experience, one may want to make some changes.

Most people interested in minerals and natural history have a camera, a binocular microscope, or both. This article will guide your photographic efforts using equipment you may already have.

Great satisfaction can be derived from micro-mineral photography. A good set of slides is the most satisfactory way to show your tiny minerals to a group of friends, and you probably will be called upon to give slide presentations to various groups. Many will be surprised at your ability to photograph an area of perhaps one-eighth to one-quarter inch. All will marvel at the beauty of the minerals.

Surprisingly, most micro-minerals should be photographed at only five to ten times life size (width of field approximately one-quarter to one-eighth of an inch). The slide projector is the main source of magnification.

There are two schools of thought on what this type of work should be called. Some insist that any photograph taken through the microscope should be called a photomicrograph, and one taken through a bellows should be called a photomacrograph. Others maintain that magnification, by either means, from life size to ten times life size should be called photomacrography, while anything over ten times life size should be called photomicrography. Microphotography is the opposite, in which large objects are photographed on small film (such as documents on microfilm). In common usage, macrophotography is often substituted for photomacrography. Although the two words have opposite meanings, it is generally understood that photomacrography is meant.

The Camera

The single lens reflex (SLR) camera is the only type that will be considered here. The camera may be used with a bellows or may be mounted on a microscope. An aperture priority automatic is the preferred type. When a shutter priority automatic is used, it must be set in the manual mode. Special light meters are available for manually controlled timing, but the meter would cost about as much as the camera bodies to be described later, and are not as convenient to use.

Manual timing can be done by trial and error. If good records are kept, one can soon determine rather closely the proper exposures. Depending on the intensity of the light and the amount of magnification, it may take several seconds for a proper exposure.

If you own a good SLR camera it can be used for photomacrography although it may lack some convenient features. If, however, you are considering the purchase of a new camera, you would be well advised to study the specifications of as many models as possible. The manufacturers are constantly trying to improve their products and it is hard to keep up with the latest innovations. A good camera is expensive, but there is a lot of competition among dealers, so shop around for the best price. Decide on the make and model and then make several phone calls; you may be surprised at the possible savings.

If the camera is to be used for photomacrography, the following features are very desirable.

- The focusing screen should be easily interchangeable. Most cameras are equipped with a split image or similar focusing screen and the center part will black out in the very low light level encountered at the magnification used for photographing micro-minerals. However, the focusing may be done through any part of the screen that is not blacked out. Even then it is difficult to see well enough to focus properly. Cameras with the interchangeable feature can be equipped with a macro screen.

Focusing is much easier and more accurate with the bright macro screen.

- The camera should be automatic and capable of the aperture priority mode; that is, you set the lens opening to the desired F-stop and the camera automatically determines the proper exposure time. The camera must be capable of several seconds of automatic exposure time; otherwise, you must set the camera on manual and guess at the time. Some popular cameras lack the long exposure capability.
• Off the film (OTF) metering is desirable for photomacrography. OTF metering is very accurate because it computes the total amount of light that reaches the film while the shutter is open. Most cameras meter all of the light that enters the camera, including the light that enters through the focusing screen, and they set the exposure before the shutter opens. On long exposures, therefore, the screen must be covered to prevent false timing (underexposure).

• Typically, SLR cameras record a greater area on the film than can be seen through the viewfinder. If the difference is several percentage points, unwanted areas may appear on the finished product. Ideally, 97 percent of the image to be recorded should be seen through the viewfinder. The slide mount will cover about 3 percent of the picture. Thus, when the slide is projected, the area shown will be almost exactly what was seen through the viewfinder.

The Olympus company apparently was the first to offer cameras with all of the above features; however, the new models have become very expensive. Some models of Canon and some models of Nikon now have these features and may be a much better buy.

If it is absolutely necessary that you understand how to use your particular camera. The instructions will be found in the booklet that came with the camera. Study it carefully. When using the proper camera, photomac- rography is as simple as normal photography except that the focus is extremely critical because of the very shallow depth of field.

The previously described equipment is modestly priced, but excellent photographs can be obtained with it. The average lens has a higher resolution than ASA 160 film so there is no advantage in using a high priced macro lens unless a finer grain film is used. Also, the camera and lens can be used for normal photography.

Photography Through the Microscope

If you have a collection of micro-minerals, you probably have a low power binocular microscope. If you also have a good SLR camera, it would cost very little to get started taking pictures of your minerals. All that is needed is an adapter to connect the camera to one of the eye-pieces of the microscope. No camera lens is used since the optics of the microscope serve as the lens. The adapter is not expensive but it will not fit the microscope without modification. The adapters are made for monocular microscopes which usually have a smaller eye-piece.

The adapter may be modified by sawing off the tube that fits over the eye-piece and substituting a tube of the proper size. The tube may be made of either plastic water pipe or a metal pipe. The end that slips over the eye-piece must be slotted on opposite sides so that a rigid, light-tight fit will result when a hose clamp is tightened around it. The tube can be fastened to the adapter with epoxy cement. All inside surfaces should be painted flat black.

Some microscopes have a third ocular, a “phototube,” which is intended to be used with a camera. The adapter should fit this tube without modification. The image is reversed in the third ocular; therefore, the photograph will have a reverse image, but that is not objectionable for mineral photography since the angles of the crystal faces remain the same.

The rated magnification of the microscope is not the magnification that will be recorded by the camera. The magnification will be determined by the equipment used. If the microscope is set at ten power and the camera is mounted directly to the adapter, the magnification may be on the order of two or three times life-size. A set of extension tubes placed between the microscope and camera increases the magnification considerably. For best results, the microscope should be set at low power and extension tubes used to increase the magnification. To determine the magnification, focus on a millimeter scale. Note the width of the field in mm. The opening in the slide mount is 35 mm, so divide 35 by the width seen in the viewfinder.

A cable shutter release is necessary for photomacra- grophy to prevent shaking the camera. The equipment should be placed on a sturdy table away from vibrations caused by household appliances and shaky floors. The slight vibration from the open- ing shutter, when used with a cable release, will have no effect when the exposure is of several seconds duration. However, a continual vibration will certainly caused a blurred picture.

Many fuzzy pictures are blamed on vibration when, in fact, the cause was improper focus. Improper focus can be due to causes other than careless focusing. Make sure that the mechanism of the microscope has enough tension to carry the added weight of the camera without creeping downward while the shutter is open. The focusing screen is designed for normal eyesight so some of us must wear corrective glasses to focus properly. The macro focusing screen is designed
to indicate if vision correction is needed. Also, a dirty or fogged lens will cause a spotted or unclear picture.

Excellent photographs can be obtained with either monocular or binocular microscopes, but a microscope is not as versatile as a bellows and camera lens.

**Photography With Camera and Bellows**

The purpose of the bellows is to increase the distance between the film and the lens. The greater the distance, the greater the magnification with a given lens. While extension tubes could be used for that purpose, the bellows affords a much easier method of changing the magnification. To change magnification when only tubes are used, sections of tube must be added or removed. The bellows allows an infinite rate of change between the fully closed and the fully open positions. If more magnification is required than that afforded by the bellows alone, extension tubes may be added without affecting the operation of the bellows.

The bellows, whether new or used, should be the double rail type. Used bellows can sometimes be found at camera stores and pawn shops. Most bellows can be attached to most cameras by using one or more adapter rings. Well stocked camera stores carry a good assortment of rings, or will order them for you.

The bellows unit has a mounting surface with a threaded hole which allows the unit to be mounted on a tripod or copy stand. The camera/bellows unit works best if mounted in a vertical position when photographing micro-minerals. A copy stand is perhaps the best device for holding the unit in that position.

A copy stand may be purchased, or one can be made using 3/4 inch iron pipe and fittings mounted on a piece of plywood with a pipe flange. A mounting plate from an old tripod can be attached to the pipe to hold the camera/bellows unit. The base of the stand should be fitted with three feet to give it stability even when placed on a slightly uneven surface.

**The Lens**

Most wide angle and normal lenses, if they are in good condition and if the aperture can be set for manual control, are suitable for photomacrography. The 28 mm wide angle lens is perhaps the most useful. Special macro lenses are available for the experienced photographer.

Lenses other than macro lenses must be mounted in reverse position. Reversing the lens increases the magnification to some extent but, most important, it increases the quality of the picture. Reversing rings are available to fit most lenses. They screw into the front of the lens like a filter. It may be necessary to use one or more adapter rings along with the reversing ring to connect the lens to the bellows.

Lenses are available in a wide range of focal lengths. In normal photography, the longer focal length lens produces a smaller field of view and a larger image. In photomacrography, however, the shorter the focal length, the smaller the field of view and the greater the magnification with a given bellows extension.

Zoom lenses are not suitable for photomacrography. A teleconverter lens used in conjunction with a reversed normal or wide angle lens will degrade the picture and should not be used. Macro lenses of less than 20 mm focal length should not be used by the beginner as the working distance is so short that there is danger of contact between the lens and specimen when focusing. This could crush the specimen that you are trying to capture and preserve through photography. The lens could also be damaged.

**Focusing**

When using a normal or wide angle lens in reversed position, the lens must be set at infinity for greatest resolution. Focusing is not possible by adjusting the lens when it is mounted backwards. Limited focusing is possible by adjusting the length of the bellows, but any change in length changes the rate of magnification. Focusing must be done by moving either the specimen or camera/bellows unit.

The double rail bellows has one rail for changing the length of the bellows and another rail for moving the unit back and forth. It is difficult to focus precisely by moving the bellows unit. A device for moving the specimen is much more satisfactory.

A laboratory jack mounted on the base of the copy stand is an efficient focusing mechanism. Various sizes of “lab jacks” can be purchased from scientific supply stores. The jack works on the principle of an automobile scissors jack.

In photomacrography the depth of field is very shallow. The greater the magnification, the less depth of field. Careful focusing is of utmost importance. One should focus with the aperture wide open,
allowing the maximum amount of light to reach the viewfinder for ease of viewing. At that setting the depth of field is tissue paper thin. The very thin depth of field allows for a more precise focus. Focus on the highest part of the specimen that must show clearly in the picture. When properly in focus, advance the film and re-focus, if necessary, since something may have moved. Then stop the lens down to F-11 or F-16. Note that the depth of field increases markedly as the aperture is stopped down. When more depth of field is required, it may be necessary to reduce the magnification and re-focus. F-16 is the preferred setting as it seems to be the best compromise between depth of field and sharpness. Numbers lower than F-11 and higher than F-16 are not recommended.

After you have gained experience in focusing as previously described, you may want to focus slightly below the highest point of interest. When the diaphragm is stopped down after focusing, the depth of field increases in front of, and to the rear of, the original point of focus, but increases about twice as much to the rear.

A diaphragm setting of F-11 produces a slightly sharper image than F-16. However, the depth of field is reduced. When it is desirable to have the background out of focus to highlight a certain area, F-8 is sometimes used. Experimentation with these settings should not be done until one becomes adept at photomicrography.

**Film and Light**

Daylight film such as *Kodachrome 64*, when used in mid-morning or mid-afternoon sunlight, will perhaps produce the truest color obtainable. Since it is often inconvenient to wait for a calm sunny day, most photomicrography is done indoors with the aid of incandescent light. Daylight film is totally unsuitable for use indoors unless the proper filter is used. Some films are balanced for incandescent light, with *Ektachrome 160* (tungsten) being perhaps the best for the beginner.

The above films are for color transparencies. *Kodak Royal Gold*, ASA 25 and ASA 100, are both excellent films for color prints. Because they are balanced for daylight, a filter is necessary when using incandescent light. These films are recommended when enlargements, such as 8x10s, are made.

Two filters can be used with incandescent light and daylight film: 80-A and 80-B. Although 80-A is recommended for most incandescent light, 80-B may be better for the long exposures used in photomicrography. The filters are not expensive: it would be wise to try both to see which is most suitable for your needs. Filters may not be available to fit your lens, but they can be glued to a ring that fits or can even be taped to your lens.

The lower the ASA number, the sharper the image. Although *Ektachrome 160* is recommended for the beginner, *Professional Ektachrome 50* (tungsten) will produce slightly sharper pictures with the average lens and should be experimented with after gaining some experience with the ASA 160.

A Leitz or Zeiss macro lens may be the highest quality lens available. When used with *Kodachrome 40* (tungsten) or *Kodachrome 24* (daylight), the increased sharpness is noticeable. *Kodachrome 40* is a very fine grained film which produces excellent sharpness. However, exposure of more than three seconds may cause a color shift and it is therefore not recommended for use with the usual lighting.

*Always* use two or more sources of light, one closer or brighter than the other, to prevent harsh shadows. Never use two types of light, such as a clear bulb and a blue one, or incandescent and fluorescent. When photographing in sunlight, a mirror or an aluminum reflector should be used for fill in light to tone down or eliminate shadows.

Two microscope lamps give sufficient light. A low voltage, high intensity lamp may be substituted for one microscope lamp, or three high intensity lamps will illuminate quite well. The high intensity lamps give a good light without too much heat. Some microscope lamps produce so much heat that care must be taken to keep them far enough from the specimen to prevent heat damage.

Perhaps the best source of light is a quartz halogen lamp with the light directed through bifurcated fiber optics (two bundles of optical fiber joined at the lamp end). This lamp produces enough light for use with *Kodachrome 40*. The light from the fiber optics is cold so the light may be placed as close to the specimen as desired without fear of damaging it with heat. A word of caution: strange as it may seem, it is possible for the light to be too intense for some specimens. The problem is caused by reflections and refraction from within the specimen. This can be overcome by placing the light farther from the specimen.

Flare or reflection can be a problem if the specimen is mounted in an unpainted plastic box. All boxes, either clear or black, should be completely coated inside with flat black paint. Even though the box may not be in the field of view, light reflecting from it will sometimes strike the lens causing a foggy picture which may be mistaken for improper focusing. The glossy bottom of an unpainted box will sometimes reflect the image of the iris diaphragm. The flare and/or reflection may not be noticed in the viewfinder but will certainly register on the film.

The angle at which the light strikes the specimen is very important. After you have composed the picture and focused properly, check the lighting. The lights
may need to be raised or lowered, or moved to the side, to show the specimen to the best advantage.

When it is impossible to light the specimen without one or more of the crystals mirroring the light, diffused light should be used. Diffusing material is available at camera stores. However, a white handkerchief or facial tissue placed between the lamps and the specimen will do quite well.

**Exposure**

The exposure time is determined by five factors:

- the speed of the film (ASA number)
- the F-stop
- the intensity of the illumination
- the rate of magnification, and
- the intensity of the color of the specimen.

The average exposure time with the described bellows unit using ASA 160 film, one microscope lamp and one high-intensity lamp, is between five and ten seconds.

Most photography experts recommend that you bracket the shots for optimum results. Bracketing involves taking three exposures of the specimen — one at the indicated setting, one slightly overexposed, and one slightly underexposed. On manually timed exposures, bracket your best guess with perhaps two seconds over and two seconds under, depending on the intensity of the illumination. Experience will soon enable you to estimate the proper timing. If the camera has OTF metering, bracketing is seldom needed. However, bracketing is almost mandatory to assure success when photographing a borrowed specimen and it is your only chance to photograph it.

When photographing a tiny colorless or light-colored crystal on a dark background, the frame should be underexposed, because even an accurate OTF center-weighted meter reads the entire area, causing the light area to be overexposed at the normal setting. A small dark mineral on a light background should be overexposed for the same reason. The crystal must be properly exposed regardless of the background.

The automatic camera can be adjusted for over or under exposure by changing the ASA setting. For instance, when using film with an ASA rating of 160, set the dial higher (perhaps 320) for underexposure, or lower (somewhere between 64 and 100) for overexposure. Always remember to re-set the ASA dial to match the film speed before continuing. Experience, if good records are kept, will quickly teach you when and how much over or under exposure is needed.

---

**The Subject**

An outstanding specimen may or may not be photogenic. When viewing a specimen through a binocular microscope it is seen in three dimensions; however, the camera records it in two dimensions, which can make a great difference in appearance. Especially as a beginner, select specimens with good form and color, and with crystals that contrast well with the matrix. Regardless of how rare and interesting a specimen may be, if it is not photogenic the photograph will not be satisfactory.

The composition of the picture is as important in photomacrophotography as it is in a scenic photo. The specimen should be placed under the microscope for primary orientation, then viewed through the camera for final composition. Turn and tilt the specimen until the best possible orientation is obtained. The specimen should be mounted in a micro-mount box for protection and maneuverability. Most often, the specimen must be tilted. Therefore, a device for holding it in any position is needed (Figure 3). Some modeling clay placed under one edge of the box will work if nothing else is available.

Several styles of holders can be made which allow the specimen to be held in any position. A hemisphere and cup may be the most satisfactory. One-half of a small hollow rubber ball, or the large end of a plastic Easter egg can be filled with fiberglass resins or with patching material, such as Fixall or Rock Hawk Water Putty, to make the hemisphere. Make a depression in the flat part of the hemisphere by wrapping a micro-mount box with two or three layers of masking tape and pressing the box one-eighth of an inch or more into the uncured filler. After the filler has hardened, remove the box and tape. Smooth the top of the hemisphere and coat it with flat black paint. The cup can be made of a short (5/8-inch) length of plastic or
metal pipe — a plastic pill bottle can be cut to proper length with a fine-toothed hacksaw to make the cup. The hemisphere and cup are used to orient the specimen for photography when using either the microscope or bellows system. The height of the lab jack can be adjusted to bring the specimen into focus when using the bellows system.

**Helpful Hints**

The first view of your pictures will be very exciting and you may tend to overlook or minimize any faults. After the excitement subsides, go over them critically. If you find it hard to criticize your own handiwork, pretend that you are judging a competitive exhibit. Use the following criteria to try to determine what went wrong with those that are not up to par:

1. Was the specimen photogenic?
2. Was the specimen properly oriented?
3. Was the specimen in focus?
4. Did some reflected light strike the lens?
5. Was the proper F-stop used?
6. Did something shift position while the shutter was open?
7. Was there vibration?
8. Was the camera set in the aperture priority mode?
9. Was the magnification too little or too great?
10. Is the color true?

If the color is not true, the film and lighting may not have been compatible. Over or under exposure will cause poor color rendition. Occasionally, an extra long exposure will cause a color shift even though the exposure time was correct. Lastly, it seems that some specimens simply will not register correctly, regardless of anything that can be done.

It has been said that the key difference between a professional and an amateur is that the professional takes many photos and shows only his best, while the amateur takes few and shows them all. So take the hint: show only your best photos and never draw attention to any shortcomings. A short presentation is usually better than a long one. Ideally, the program should end before the audience wants it to!

**Conclusion**

Photomacrography need not be limited to micro-minerals. Possibilities for beautiful and interesting photographs are limited only by one's imagination. Time spent with the microscope searching for subjects can be very rewarding. Tiny blooms of some grasses and weeds are surprisingly photogenic. Individual parts of larger flowers, including the pollen, are interesting. Tiny insects and parts of larger ones are also possibilities.

**Bibliography**

ABCs of Practical Close-up Photography: John Kohout.
San Bernardino County Museum Association
Information for Authors

The San Bernardino County Museum Association publishes articles and monographs on subjects pertaining to the cultural and natural history of San Bernardino County and surrounding regions. We welcome submissions of such manuscripts.

**Subject Matter:** articles and monographs pertaining to San Bernardino County, inland southern California, and surrounding regions, in history, anthropology, archaeology, paleontology, mineralogy, zoology, botany, ornithology, and related disciplines. Manuscripts considered for *Quarterly* publication should be written toward the well-educated non-specialist. Technical research will also be considered for publication. All manuscripts should reflect original work which furthers knowledge in their fields.

**Format:** Two clear copies of the manuscript must be submitted to the Editorial Board with a letter of transmittal requesting that the manuscript be considered for publication and that it is not presently under consideration elsewhere. Manuscripts should be typewritten, double-spaced, on one side only of 8.5 x 11" paper. Ample margins should be allowed for editing comments. The first page should contain the title and author(s) name, address, telephone number and E-mail address, if applicable. The author’s last name and page number should appear at the top of each following page. Include COPIES of figures, tables, and photographs. Do not send original photographs or figures with your initial submission.

**Style:** Authors should follow the standards for footnotes, citations, headings, and other conventions as applicable to their discipline. The Editorial Board suggests the following:

- Anthropology/Archaeology: Society of American Archaeology (American Antiquity)
- History: American Historical Association (American Historical Review)
- Geology: Geological Society of America (Bulletin)
- Paleontology: Society of Vertebrate Paleontology (Journal)
- Biological Sciences: American Institute of Biological Sciences (eg., Journal of Entomology)

Authors should be aware of and avoid inappropriate gender-biased language. The Editor is available for consultation of matters of style, format, and procedures.

**Review:** Manuscripts will be considered by the Editorial Board of the Museum Association Publications Committee, and will be reviewed by outside experts. Manuscripts may be accepted, provisionally accepted, or be found unsuitable for publication by the Association. Provisional acceptance may include suggestions for revisions. Very lengthy or profusely-illustrated monographs that are otherwise acceptable for publication may require outside funding to help defray publishing costs. Manuscripts will be copy edited after acceptance.

**Attachments:** If photographs are used, originals or equivalents will be required. Photographs should be black-and-white or color prints, of good quality and contrast. Figures and drawings should be in India ink or equivalent on white paper or PMTs. Captions should be submitted on separate pages, double-spaced, and referenced to their accompanying figures. Photographs should be marked lightly in pencil on the back border with the author’s name and figure number. Authors are encouraged to submit accepted manuscripts on DOS-compatible disks or Zip disks in addition to paper copy. Please contact the editor regarding electronic submission of manuscripts and figures.

**Responsibilities:** The author has the primary responsibility for the correctness and reasonableness of his or her information, arguments, and presentation. In submitting a manuscript for consideration, the author assures the Editorial Board that the manuscript is an original work and does not infringe upon the rights of previous authors or publishers.

Address queries and manuscripts to:
The Editor
San Bernardino County Museum Association
2024 Orange Tree Lane, Redlands CA 92374
or query by E-mail: jreynold@empirenet.com
Upper left: Wulfenite, 5 mm crystal. Mobile Mine, Goodsprings. S. White photo.
Upper right: Wulfenite and lummerauerite, 2 mm crystal. Milford #1 Mine, Goodsprings. J. Kepper photo.
Lower left: Azurite, 2 mm crystals. Yellow Pine Mine, Goodsprings. S. White photo.
Lower right: Fornacite, 1 mm cluster. Yellow Pine Mine, Goodsprings. S. White photo.