THE
MINERALOGY
OF
BISBEE, ARIZONA
VOLUME II

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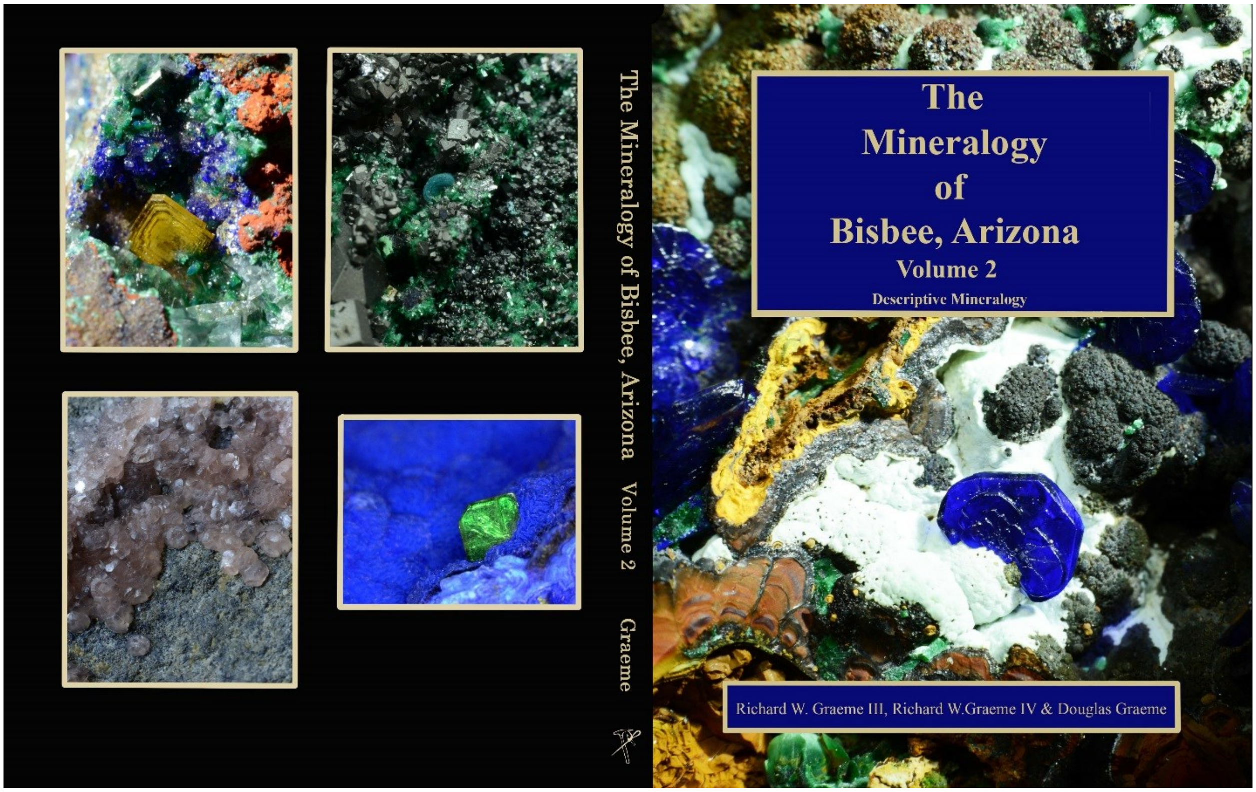
Front cover: Azurite on gibbsite and goethite with malachite, Holbrook Mine, view-9 cm. Graeme collection.

Back cover: Top left Wulfenite with azurite, calcite and malachite on hematite, Cole Mine
Top right: Claringbullite with atacamite on cuprite, Southwest Mine, 5th level, 14 stope
Bottom left, Rhodocrosite on alabandite, Junction Mine, 2300 level
Bottom right, Torbenite on Azurite, Junction Mine 770 level



INTRODUCTION TO VOLUME II:

The detailed study of the mineralogy of Bisbee, Arizona, as presented herein, is fully intended to be a comprehensive presentation of the minerals from this amazing and complex series of deposits. We have no doubt that many more species will be added over time, as other researchers recognize additional species and localities in the vast store of the many hundreds of thousands of minerals preserved in collections everywhere.

Further, it is intended that the reader access Volume I to better understand the nuances between the varying depositional environments throughout the district as well as to have the ability to put any listed species into its greater context of the minerology of this complex deposit.

However, this is a study that is different, if not unique, among overviews of the mineralogy of an area in that a great percentage is based on personal observation, experiences and the considered opinions of the authors from more than 70 years of intense study and, truly tens of thousands of hours in the field, both underground and on the surface as well the review of Bisbee minerals in collections worldwide.

Of course, the voluminous literature has been extensively reviewed in detail with a conscious effort made to own original copies of everything ever published as well as copies of the numerous important, but unpublished works in repositories wherever found. This is to assure the availability of quality reproductions of illustrations and images, as needed.

As with any such work, scores of others have contributed. The kind and generous help so freely given over these many years by innumerable miners, mine supervisors, collectors, mineralogist, geologist, engineers and museum professionals was an important, if not vital part of our ability to assemble the information presented. More on this is noted below.

Locality information:

Of great fundamental importance is the incredibly good fortune to have been born and lived in Bisbee and be deeply and fully integrated into the “Society of Old Miners”, a non-existent organization, but one of a common basis and mutual interest in sharing their stories of the past, albeit informally. This group included our own grandfather/great-grandfather who went to work underground at Bisbee in 1883. Indeed, it was through his imperfect recollections and undoubtedly embellished stories that this work ever began.

Deeply coupled with his stories, are those of dozens and dozens of other miners who worked the mines at Bisbee from the earliest of days, told to an eager youth as they enjoyed the warm Arizona sun in the small park at the General Office, this in the twilight of their years. They spoke, and often argued, of the wonders they had seen in the mines of the 1880s until after the war years, by when most had retired.

The stunning detail with which they recalled of memorable events, including the locations and descriptions of the mineralogical wonders, remains amazing to us. But then, it is commonly acknowledged that with age, we often have a more crisp and detailed memory of things from 50 years before than of yesterday. Nonetheless, because of the detail; over decades, we were able to find and explore many of the localities and environments recanted in the underground world stories of these fine men. Thus, we could put many of the specimens recovered over the near century of production into their mineralogical/geologic context as well as confirm the localities.

Staying current with what was coming out of the mines in the late 1940s and through the 1950s, and there was much, was simpler. The afternoon paper route took in all of the many bars along Brewery Gulch after shift change. These bars were often very busy mineral market places, with both sellers and buyers eager to let the paperboy see what was new and was told of from where these treasures had come. The miners fully exercised their "bragging rights" about their new rocks; a joy to hear, as the conversations often evolved into other past collecting moments.

Esker Mayberry's barber shop was the source of so much information. His barbershop was the ex-official center of the miner's side of Bisbee's collecting community. All day, every day, it was filled with men who came to admire Esker's exquisite collection, as well as have their haircut for a dollar.

Esker had an unerring eye for quality with three floor to ceiling beautiful showcases containing most of a 1,000 pieces acquired from the early 1930s until the mid-1960s. He also insisted on the provenance of each specimen he purchased – who collected it -when and where – what else was in the same area – who else owned the rock. All of this he recorded, a devoted collector well ahead of his time.

RWG III spent hundreds of hours from the late 1940s until the mid-1960s listening to Esker and his many clients discuss his wonderful treasures as well as their own. These stories were of mineral finds, often long past, as well as a running dialog of what was coming out at the moment and who had what and who was selling his current discoveries. In general, Esker allowed that three topics be discussed – Bisbee rocks, non-Bisbee rocks and deer hunting, with the latter restricted to September through November.

Further to the stories passed on by many old miners were the more technical and operational aspects of the mines. These were shared with us by both retired and active engineers and geologist from the mid-1950s on, though their individual experience frequently dated to the 1910s. Often, access or copies and sketches of field maps and observation notes from decades before, were shared by geologist, engineers and supervisors who had been the driving force behind the successful and systematic development of the many mines at Bisbee. More than a few professionals still in the employ of the company generously provided blueprint copies of the mine maps for areas long mined out, but still accessible to the adventurous. Our efforts underground began in 1948 and continued into the early 2000s, becoming better understood and more successful with time and experience.

These were the guides to our own adventures over the ensuing decades; adventures often difficult and occasionally rewarded. In no way are we suggesting that any of the mineral specimen producing areas visited contained quantities of good specimens, it simply was not the case. Indeed, it common among the miners to say *"we mined all of the ore and half of the waste."* In other words, nothing of note was left behind – that is except the geological environment along with the undesirable (to them) gangue minerals. On rare, if not very rare occasion, things of importance were found during an exploration visit to a formally specimen productive area.

And too, one of us (RWG III) had the great good fortune to work underground at Bisbee for 15 years. For 15 years, six days a week underground; first as a miner then as the Resident Geologist for the Copper Queen. To be sure, there was work to be done, but all day was spent looking at the mine walls for one reason or another.

During period as a geologist, he was responsible for saving minerals ahead of mining, a long-held policy of the company. This included the phase when the Lavender pit was expanded to the west, mining areas first exploited in the late 1880s, continuing through the 1930s. While much of the areas had been visited before during underground collecting trips, the opening of the areas with the huge pit gave an unparalleled panorama of the geology and mineralizing controls along with a deep understanding of the supergene activity, often in individual or isolated areas, which hosted a unique or very different mineral assemblage.

With the responsibility of the Resident Geologist came unfettered access to a near-century worth of mining records such as detailed maps, engineering and geological notes and in-house reports. Also, he could enter all accessible areas of the mines, so long as fundamental safety concerns were met.

It is with this foundation that we often give location information without providing a specific reference, as our personal experience is the basis. The underground world is complex and exact location was often impossible to determine, even with a map in hand. Thus, more often than not only the mine level is indicated.

Species identification:

Accurate species identification was, is and will always be an important aspect of any mineralogical study and is without doubt the area most subject to error. So often, while studying a deposit, one must take the observations of previous workers as generally valid, unless there is a compelling reason to assume otherwise. As the science of mineralogy has advanced, so much of the early date has become less distinctive. By way of example, as what was once thought to be one mineral is now considered a group such as "biotite." Does this make the early identification invalid; of course not, just less precise. Thus, we have included such reference to assure the continued availability of the information with additional data on those rare occasions, where available.

Fortunately, mineralogists are continuing to review and investigate existing species with the not too uncommon result of modification of the formula and/or questioning the validity of a species if not discrediting it all together. Again, we have continued the inclusion of the information from earlier studies for historical continuity, while amply noting current status.

Where the source of species identification came from a third party, specific note is made as to the source of the information and when received, as is commonly practiced in the science.
Now, the question of the identification as to species in this work. From the beginning in the 1950s, it was necessary to seek the opinions and advise of other knowledgeable collectors, usually untrained. The professional geologists at Bisbee, while free with their opinions, were often less knowledgeable than some of the advanced collectors. Nonetheless, within this effort are the visual identification made by some of these individuals, though largely, but not completely reconfirmed over time by further review and/or analysis.

From the mid-1950s, the University of Arizona became the preferred source for identification, but it was 100 miles distant and $3.25 (a week's earnings for a paperboy) by Greyhound. Periodically, Fritz Galbraith, then curator of the U of A Museum, would cheerfully receive a teenager with one or more boxes of newspaper wrapped "rocks" for identification. More often than not, he retained a few for closer examination. His many determinations have largely stood the test of time and reanalysis.

John Anthony, successor to Fritz, aided during the 1960s, but most of all from 1962 on there was the Phelps Dodge laboratory in Douglas, where Sid Williams and his group did latterly hundreds of X-RD analyses, including the description of graemite. When Sid went into private business, he continued to render this service, but now on a fee or specimen exchange basis.

Little has gone through our hands that was not subjected to X-RD or other means of confirmation by a qualified technician.

Additional information provided:

To further assist the reader in more fully understanding the complex mineralogy of Bisbee, several aspects of the mineral species have been added; associated mineral and recognized pseudomorphs and replacements either by the species being discussed or of the species. We have found that our purposes of study this is often helpful is both the identification and locality determination of a particular specimen. It is our hope that this additional information will assist users of this document as much as it has authors.

Mineral Data source:

For the current species status, correct spelling and mineral formula, we have relied totally on Fleischer's Glossary of Mineral Species. The most current, Back (2018) has been the most useful however, previous editions; Back, M. E., and Manddarino, J. A., (2008) and Fleischer, M. and Manddarino, J. A. (1995) have been consulted as well to follow the changes in mineral status.

THE MINERALS OF BISBEE

A

ACANTHITE Ag_2S:

This primary mineral has been recognized in one mine only and in very small amounts. However, acanthite was unquestionably more common than indicated by this limited occurrence. The historical silver grades were more than one ounce per ton in the hypogene ores most surely reflect the presence of common silver minerals such as acanthite. While other silver minerals contributed to the silver values in the ores, these other species, except for elemental silver, are far less common.

In the single recognized occurrence, acanthite was found in very small amounts as part of the siliceous hematite-hosted, mineralogically-complex fringe to the ores in the uppermost part of the Campbell orebody (Alan Criddle, personal communication, 1992).

The species noted as associated with acanthite are:

hematite
digenite
bornite
silver
wittichenite
sphalerite
djurleite
matildite
galena
gold
chalcocite

(Alan Criddle, personal communication, 1992)

aikinite
silver
iodargyrite
kettnerite
mottramite

(Sid Williams, personal communication, 1987)

OCCURRENCES:

Campbell Mine, Acanthite was noted from an unspecified level in this mine in small amounts by Sid Williams (personal communication, 1987) where it occurred as part of a complex high-bismuth mineral assemblage. Inasmuch as the acanthite recognized by Williams occurred with a very different, but still high bismuth mineral assemblage, the locality is probably different from that found by Criddle as noted below.
1600 level; Acanthite was found here as a minor constituent of a complex bismuth-rich, mineral assemblage, in a siliceous hematite matrix on the fringes of mined-out copper orebodies (Alan Criddle, personal communication, 1992).

ACTINOLITE $Ca_2Mg_{<4.5}Fe^{2+})_{>0.5}Si_8O_{22}(OH)_2$:

This mineral was formed as part of the modest contact metamorphism surrounding the Sacramento Stock complex and, to a lesser degree, the underground intrusive dikes. Actinolite was one of the more common minerals that formed in this environment (Bonillas, et al. 1916). As such, it was widely distributed as well as locally abundant.

Typically, it was found as a fibrous material or, rarely, as aggregates of minute prisms that were black to dark green in color. Compact, fine-grained impure material mixed with other similar minerals was not uncommon.

The species associated with actinolite are:

tremolite
quartz
chlorite
chalcopyrite
andradite
edenite
chlorite
grossular
epidote
diopside
wollastonite
sphalerite
pyrite
magnetite
vesuvianite
calcite
hematite
chalcocite

OCCURRENCES: Actinolite is so abundant and widely distributed that only a few of the typical occurrences are noted.

Gardner Mine, *900 level, 9 drift;* Fine, fibrous actinolite in a metamorphosed limestone was noted here by Tenney (1913).

Junction Mine, Actinolite was one of several similar minerals that formed the greenish matrix common for some of the pyritic ores.

Sacramento Mine, *1500 level;* Compact fibrous actinolite was a part of a multi-mineral replacement assemblage locally common on this level Tenney (1913).

AIKINITE $PbCuBiS_3$:

This rare hydrothermal mineral was found in very minor amounts as part of the late-stage mineralization in the Campbell orebody. Typically, aikinite was found as tiny blebs included in other sulfides.

The species noted with aikinite by Williams (personal communication, 1987), and Criddle (personal communication, 1992) are:

hematite
digenite
mottramite
kettnerite
chalcocite
djurleite
argentite
bornite
calcite
silver
chalcopyrite
pyrite
iodargyrite

OCCURRENCES:

Campbell Mine, *2200 level;* Small amounts of blackish-gray aikinite were noted from this level in a mixture of massive sulfides - chalcopyrite, bornite, chalcocite, digenite, djurleite - along with a number of minor tin-tellurium-bearing species, all in a pyrite, calcite, and hematite matrix by both Williams (personal communication, 1987) and Criddle (personal communication, 1992).

ALABANDITE $Mn^{2+}S$:

This primary mineral, while locally abundant, is apparently of limited distribution within the district. Alabandite was often associated with sphalerite, the greenish-black to black iron-rich variety, which it closely resembles. This similarity could easily have kept it from being recognized in other occurrences. In the Junction mine, alabandite was thought to be sphalerite by the stope engineers and was mined as such. Metallurgical problems in the zinc flotation circuits were caused by alabandite, forcing a closer look at the ores and the recognition of the manganese sulfide. The block of mineralization containing alabandite was left in place to avoid further problems in the mill, a boon to collectors who saved a good many samples.

Typically, alabandite occurred as a greenish-black to greenish-brown massive material in limestone or other sulfides and, often in large amounts. On exposure, alabandite invariably acquires a black to black-brown coating.

Hewett and Rove (1930) suggest that the many near-surface manganese deposits in the district may have been derived from alabandite. This was restated by Hewett and Fleischer (1960). However, no residual alabandite has ever been recognized in any of these deposits. Rasor (1939) did not consider this a problem given alabandite's readiness to oxidize. However, the authors have visited and thoroughly investigated nearly all of the near-surface Mn oxide deposits and have found no clear indications of oxidation of a sulfide, putting into question a connection between primary alabandite and the scattered Mn oxide deposits.

The species associated with alabandite are:

calcite

rhodochrosite

sphalerite

pyrite

OCCURRENCES:

Higgins Mine, *Tunnel level, 3 crosscut;* Alabandite was found here as minute grains disseminated in dolomitic limestone with minor rhodochrosite (Hewett and Rove, 1930).
100 level; A manganiferous dolomite on this level contained alabandite as massive material with rhodochrosite (Hewett and Rove, 1930).

Junction Mine, *2300 level;* Alabandite was abundant in a zinc stope on this level as large masses of nearly pure, green-brown, massive material with sphalerite, pyrite, and minor rhodochrosite. Many specimens of this material were recovered from this locality.

ALBITE $NaAlSi_3O_8$:

This rock-forming mineral was widely distributed in the more mafic phases of one of the intrusive units of the Sacramento Stock Complex (Bonillas, et al. 1916). It also was found in some of the underground porphyry dikes. Albite was also recognized as a minor component of a dike in the Paleozoic limestone near Mt. Martin (Tenney, 1913). Oligoclase is now considered a variety of albite, which can be referenced under “oligoclase”.

Typically, albite occurred as phenocryst to 1 cm in portions of the younger porphyry unit. These were often zoned crystals with the composition varying from sodic to calcic.

The species associated with albite are:

quartz
pyrite
orthoclase
magnetite
ilmenite
hematite
muscovite

OCCURRENCES:

The occurrence of albite in the district is essentially the same as the distribution of the noted porphyry units. However, much of the albite has been subjected to alteration, so consequently it is no longer present in many portions of these porphyries.

ALLANITE-(Ce) $Ca(Ce, REE)Al_2Fe^{2+}[Si_2O_7][SiO_4]O(OH)$:

This hydrothermal species has been found as a very minor accessory mineral in portions of the Juniper Flat granite. Allanite occurs as clusters of tiny euhedral grains. The allanite from here is slightly radioactive.

The species associated with allanite are:

quartz
orthoclase
magnetite
chlorite

OCCURRENCES:

One small area of the Juniper Flat granite contains minor allanite-(Ce) as an accessory mineral.

ALLOPHANE $Al_2O_3(SiO_2)_{1.3-2}.2.5-3H_2O$:

This species was formed during the hydrothermal alteration of intrusive units. In the Warren District, the Sacramento Stock Complex and some of the dikes in the limestone contained abundant allophane where it occurred as a hydrothermal alteration product of feldspars (Schwartz, 1947). Portions of the stock that were not well mineralized contained minor allophane as inclusions in quartz (Schwartz, 1947). Less commonly, it was found as thin, discontinuous veinlets cutting sulfides, particularly pyrite.

The species associated with allophane are:

illite
alunite
hematite
hydrobiotite
pyrite
goethite
muscovite
chalcopyrite
kaolinite
quartz

OCCURRENCES:

Campbell Mine, *3100 level;* It was found in small amounts as veinlets of compact, massive, green material in massive pyrite. Allophane from this locality has been confused with variscite, which it closely resembles. It does however, tend to crack not long after removal, thus removing the doubt about the species.

Junction Mine, *2566 level;* Allophane was common on this level in small amounts as a white to yellowish material filling small voids between pyrite crystals.

Lavender Pit Mine, *Holbrook Extension;* Small bluish masses of allophane were found in supergene hematite and/or goethite that appeared to be residual from veinlets in hypogene sulfides. This could easily be confused for chrysocolla, which it very much resembles.

Sacramento Mine, *500 level;* In specimens studied by Schwartz (1947), allophane occurred as a replacement of feldspars with kaolinite, alunite, and muscovite (sericite).

ALTAITE PbTe:

A hydrothermal mineral that was recognized as part of the multi-element, late stage mineralization in the Campbell orebody. Altaite typically was found as anhedral, tin-white inclusions to more than one cm in massive sulfides, principally pyrite.

The species associated with altaite (Criddle, personal communication, 1992) are:

cassiterite
mawsonite
sphalerite
galena
rutile
colusite
hessite
stannite
magnetite
kësterite
goldfieldite
tellurobismuthite
pyrite
stützite

OCCURRENCES:

Campbell Mine, *2100-2566 levels;* Altaite was widely distributed in small amounts in these portions of the Campbell orebody. It occurred as inclusions in massive sulfides and was associated with very minor amounts of a number of tellurium, tin, tungsten, gold, silver and bismuth minerals (Criddle, personal communication, 1992).

ALUNITE $KAl_3(SO_4)_4(OH)_6$:

This species has been recognized principally as a hydrothermal mineral that is widely distributed throughout the district. However, it also has been found to have been formed under supergene conditions in a restricted area between the Czar and Holbrook mines.

Typically, hydrothermal alunite was found in the older quartz porphyry unit of the Sacramento Stock Complex as a component of a multi-mineral alteration product of unidentified feldspars (Schwartz, 1947; Bryant and Metz, 1966)) and as a minor gangue mineral associated with the sulfides.

In the sulfide deposits, hydrothermal alunite usually occurred filling small spaces between sulfide crystal grains or as dense, compact masses that are white to gray, yellowish to brown, and greenish. Tiny rhombohedral crystals occasionally lined voids in these masses or covered the surface of the granular material. Butter, (1912) noted "Alunite has been observed by the writer in the Bisbee district, Arizona, where its occurrence seems to be similar to that at Morenci. Some analyses of the material made for the geologic department of the Copper Queen mine show it to be relatively pure alkali aluminum sulphate…")

Supergene alunite was recognized by Notman (1913) as a fairly common gangue mineral associated with the secondary ores in a restricted zone between the Czar and Holbrook mines. This alunite was typically a soft to friable, white to blue-white and/or a reddish material that was layered with other supergene gangue species. Crusts of alunite on oxide zone minerals, notably carbonates, were not uncommon, generally as a late-stage deposition, but not as a replacement crust. Supergene alunite on or with copper carbonates is frequently confused with similar-appearing chalcoalumite or gibbsite.

The species associated with alunite are:

pyrite
illite
goethite
azurite
kaolinite
quartz
magnetite
calcite
muscovite
halloysite
siderite
gibbsite
chalcopyrite
hematite
malachite
allophane

OCCURRENCES:

Cochise Deposit, Cook (1994) noted alunite veinlets in the supergene enriched zone of this deposit, north of the Dividend Fault. Samples yielded a K-Ar age of 9.0 ± 0.22 Ma

Cole Mine, *1200 level;* Large masses of a dense, compact material, very much resembling variscite occurred here in pyrite with quartz (Anthony, et al. 1995). Some of this material was polished by the local lapidaries in the late 1950s and sold as variscite.

Czar Mine, *200 level;* Tiny white crystals of alunite lining voids in massive material with kaolinite and quartz occurred here (Tenney, 1913).
200-300 levels; White to blue-white, supergene alunite as a thin, partial coating on malachite and/or azurite and goethite was relatively common from the eastern part of this level.

Gardner Mine, *800 level;* Several places on the level were noted by Tenney (1913) to have massive alunite that ranged from yellowish to red-brown as a result of iron staining.

Czar Mine, *200 level;* Tiny white crystals of alunite lining voids in massive material with kaolinite and quartz occurred here (Tenney, 1913).
200-300 levels; White, supergene alunite as a partial coating on malachite and/or azurite and goethite was relatively common from the eastern part of these levels and is often misidentified as chalcoalumite.

Denn Mine, *3100 level;* Small amounts of greenish alunite were found as veinlets in massive, granular pyrite. Here too, it closely resembled variscite.

Holbrook Mine, *300- 400 levels;* Soft, granular alunite was mixed with iron oxides in thin layers. Also*, w*hite to blue-white, supergene alunite was relatively common as a late-stage, partial coating on malachite and/or azurite and goethite from the western part of this level. One exposure, this late-stage alunite often becomes somewhat friable. This too is frequently mistaken for chalcoalumite.

Lavender Pit Mine, *Holbrook;* Large, irregular masses of compact, often granular, alunite was found mixed with or included in the supergene clays, particularly halloysite. The granular varieties frequently had a drusy surface of alunite crystals. Here too, thin white to blue-white coating on azurite, malachite and goethite just as seen in specimens from the Holbrook Mine, which had been mined by this part of the pit.

Lowell Mine, *1300 level;* Banded green and white massive alunite with kaolinite and halloysite occurred here (Tenney, 1913).

Sacramento Mine, *500 level;* Alunite was in specimens studied by Schwartz (1947) as a replacement of feldspars with kaolinite, allophane, illite, and muscovite.

ALUNOGEN $Al_2(SO_4)\cdot17H_2O$:

A single specimen in the British Museum of Natural History represents the known occurrence of alunogen in the district. This specimen, number BM 1924,609, was purchased for the museum in 1924 from Ward's Scientific Establishment by L. J. Spencer (Alan Criddle, personal communication 2001).

The genesis of this specimen of alunogen is uncertain; however, it is quite probable that it is post-mining in origin. It was during this general time frame that there was a strong interest in the post-mining minerals at Bisbee (Mitchell, 1921a, 1921b; Merwin and Posnjak, 1937) with a number of specimens collected for study as well as commercial distribution.

Alunogen occurred as compact masses of silky, fibrous crystals that ranged in color from white to pale blue to sky-blue, with the blue color imparted by associated chalcanthite. No locality information is available for the specimen other than that it is from Bisbee.

ANATASE TiO_2:

This hydrothermal species is apparently of limited distribution within the district. It occurs in small amounts where it was formed as a result of alteration of titanite.

The species associated with anatase are:

chlorite
muscovite
quartz
titanite

OCCURRENCES:

Portions of the Juniper Flat granite contain minor anatase as a result of the partial alteration of titanite (sericite-chlorite) (Sid Williams, personal communication, 1981).

ANDRADITE $Ca_3Fe_2^{3+}Si_3O_{13}$:

This hydrothermal alteration mineral is widely distributed in small amounts throughout the district. Andradite was locally associated with the modest calc-silicate alteration of the limestones, particularly that of the Abrigo formation. Most often it was observed as tiny, rounded crystals as part of an alteration assemblage and in the unoxidized, pyritic ores.

Compact granular masses of green to greenish-yellow crystals were found in several places as a component of the highly localized skarns. Crystals to 4 mm occurred lining pockets in this massive material.

The species most commonly associated with andradite are:

quartz
diopside
chlorite
grossular
pyrite
magnetite
sphalerite
tremolite
chalcopyrite

OCCURRENCES:

Gardner Mine, *900 level, 9 drift;* Nearly pure, fine-grained masses of andradite with quartz occurred here (Tenney, 1913).

1000 level; Granular masses composed of 4 mm crystals as part of skarn development were noted here by Tenney (1913).

Lowell Mine, *800 level, 806 drift;* Brown to greenish-brown, fine-grained masses of andradite occurred here as part of a skarn development adjacent to an intrusive dike (Tenney, 1913).
1000 level, 9 drift; Massive andradite with grossular, quartz, pyrite and sphalerite were noted from here by Tenney (1913). The nearby mule barn on this level contained andradite as green-brown crystals with tremolite, sphalerite, pyrite and quartz.

Sacramento Mine, *1400 level;* A stope 60 feet above the level contained abundant andradite as fractured, yellow-green massive material with magnetite filling the fractures.

ANGLESITE $PbSO_4$:

This was a common, widely distributed, supergene lead ore mineral throughout the district. Much of the lead produced before the advent of flotation recovery was from anglesite that was almost always associated with cerussite.

Typically, anglesite occurred in the oxidized portions of the many lead, lead/zinc and lead/copper deposits as an alteration product of cerussite and/or galena. Most of the anglesite was found as alteration rinds around galena or as complete replacements of galena. It was not uncommon for anglesite to have, in turn, altered to cerussite.

The species that have most commonly been found with anglesite in the district are:

galena
malachite
cerussite
hematite
leadhillite
goethite
plumbojarosite
wulfenite

OCCURRENCES:

Campbell Mine, *1800 level;* Found as poorly formed prismatic crystals to 3 cm that are gray to black in color with cerussite. Also from this level as a few, truly fine, colorless, 1 cm, spearhead-shaped crystals with exceptional leadhillite.

Gardner Mine, A common constituent of the lead ores from this mine, anglesite usually occurred as a gray, fine-grained alteration rind on galena.

Shattuck Mine, *300 level;* The supergene lead ores from the "lead cave" on this level contained important amounts of anglesite as a granular, dark gray to black material that was a replacement of galena and which was altering to cerussite.

Southwest Mine, An important ore mineral found in the majority of the lead producing orebodies associated with the silica breccias (Bonillas, et al. 1916).
3rd level; Abundant anglesite was mined from near the area close to the new Southwest Shaft as massive white to gray material, occasionally with a residual galena core.

White Tail Deer Mine, A surface cut near this mine produced massive anglesite as an alteration product of galena with cerussite (Tenney, 1913).

ANHYDRITE $CaSO_4$:

This relatively common gangue mineral was an early replacement mineral during mineralization, most frequently with later forming, chalcopyrite-dominate ores (Schumer, 2017). Typically, it was found as a minor accessory gangue mineral in the ores and in most intrusive units. Friehauf (1997) noted that anhydrite occurs as 40 m inclusions within pyrite grains (i.e. predates pyrite deposition). Hypogene anhydrite in other environments is probably far more common than the single recognized occurrence would suggest. Small amounts of anhydrite were also found as a dehydration product of post-mining gypsum in the vent for mine fire gasses.

The species associated with hypogene anhydrite in the district are:

quartz
muscovite
magnetite
pyrite
chalcopyrite
hematite
orthoclase
chlorite
gypsum
hematite

OCCURRENCES: Apart from the most common occurrence as an accessory mineral in the intrusive units and orebodies, as noted above, the below are different and interesting.

Campbell Mine, *1300 level;* Anhydrite was found on this level in the floor of a mine working in small amounts which was an alteration product of post-mining gypsum. This alteration was caused by the intense heat from a nearby sulfide mine fire.

Junction Mine, *1800 level;* Thin, discontinuous veinlets of light-brown anhydrite occurred in an altered porphyry dike with pyrite and minor chalcopyrite at this locality.

ANKERITE $CaFe^{3+}(CO^3)_2$

This hypogene species is usually quite common in mineral deposits like Bisbee, but apparently is quite rare within the district. The only reference to the occurrence of ankerite is as a gangue mineral in the very large Mountain Maid orebody in the Junction Mine near the Denn sideline (Peng, 1948). However, given ankerite's similarity to siderite and some hydrothermal calcite found at Bisbee, it is likely that other occurrences went unnoticed.

The species associated with ankerite in the district are:

calcite
muscovite
magnetite
siderite
chalcopyrite
rhodochrosite
chlorite
quartz
hematite

OCCURRENCES: A gangue or accessory mineral in an intrusive breccia composed of andesite, silicified limestone and chert, showing both unusual, rounded and angular forms (Peng, 1948)

Junction Mine, *2200, 2300, and 2433 levels;* Occurs mainly on these levels in an intrusive breccia belt about 6 feet wide adjacent to the ores in the Escabrosa limestone and is practically abundant in a fault zone with a continuous, but irregular matrix consisting of aggregates of calcite, ankerite, siderite, rhodochrosite and/ or a greenish- phyllitic material (Peng, 1948).

ANTHONYITE $Cu^{2+}(OH,Cl)_2 \cdot 3H_2O$:

This rare, typically secondary mineral has been recognized in the district in a single post-mining occurrence. The presence of anthonyite at Bisbee is one of just four known occurrences in the world (Anthony, et al. 1995).

The occurrence in the district was as a crust on crumbly pyrite near a sulfide orebody that had burned some years before and was being re-opened for mining.

The species associated with anthonyite are (Anthony, et al. 1995):

pyrite
chalcopyrite
unknown copper hydroxide

OCCURRENCES:

Cole Mine, *1300 level;* In a raise, some 40 feet above the level, anthonyite occurred as 5 mm or larger, corroded, violet crystals on crumbly pyrite. On exposure, much of the violet color is lost, leaving a pale color.

Unfortunately, only a few specimens were recovered, as the area was washed down by the miners to control dust, a standard safety procedure, before a second collecting trip could be carried out. Anthonyite is water-soluble and was dissolved.

ANTIGORITE $Mg_3Si_2O_5(OH)_4$:

This hydrothermal species is one of the more common components of the abundant “serpentine” that formed either as a contact-metamorphic or, less commonly, hydrothermal alteration product in the limestones, particularly the Martin unit. Typically, antigorite occurred as impure, compact, often-thick masses composed of small flaky or bladed crystals. While it was usually greenish, other colors including white to brown to pinkish have been observed.

The species associated with antigorite in addition to the calc-silicate minerals are:

pyrite
calcite
hematite
chalcocite
quartz
magnetite

OCCURRENCES:

Cole Mine, *1400 level;* Abundant pale green, flaky antigorite was associated with pyrite and hematite on this level.

Holbrook Mine, *500 level, 55 drift;* Banded pinkish and green layers of platy antigorite occurred here with calcite, pyrite, and hematite (Tenney, 1913).

Lowell Mine, *1300 level, 9 stope;* Green radiating plates and needle-like fibers of antigorite occurred here with pyrite and chalcocite (Tenney, 1913).

Sacramento Mine, *1300 level;* Fibrous green antigorite as an alteration of limestone was found here with pyrite and supergene chalcocite (Tenney, 1913).

Southwest Mine, *6th level;* Substantial amounts of compact green antigorite with hematite occurred in the altered limestone adjacent to the new Southwest orebody.

Spray Mine, *600 level, 46 drift;* Bladed greenish material occurred in altered limestone at this location (Tenney, 1913).

ANTLERITE $Cu_3^{2+}(SO_4)(OH)_4$:

This is a widely distributed but not particularly abundant supergene mineral. Yet, some of the finest known examples of this species are from the Warren mining district.

Antlerite has marked similarity, in both appearance and mode of occurrence, to the far more common brochantite and malachite. This may well have resulted in the frequent misidentification of this species, thus, causing it to seem less common than it truly was.

Non-reactive host rocks appear to have been an important factor in the deposition of antlerite. The abundant supergene clays and iron oxides were important depositional environments as were siliceous rocks, particularly the silica breccias.

The most common form of occurrence for this mineral was as the in situ, partial to complete replacement of copper sulfides, principally chalcocite, covellite and bornite. Replacement of chalcopyrite or the very abundant cupriferous pyrite by antlerite was apparently rare.

Crusts of drusy or acicular crystals as replacement rinds on sulfides were common. Complete replacement of the sulfides by antlerite would result in porous to compact mass typically composed of small crystals.

Antlerite was frequently found as acicular crystals in the voids so common to the supergene iron oxides, particularly goethite. Here it was often associated with other secondary copper minerals, such as with cuprite and malachite the most typical. Tabular crystals to 2 cm on brochantite or fine-grained antlerite are also recognized from the district but are uncommon.

Post-mining antlerite was somewhat common as a coating on copper sulfide fragments left underground, such as material that fell from mine cars during transport. In appearance, it is essentially indistinguishable from the more common post-mining deposits of malachite or brochantite.

The species most commonly associated with antlerite are:

chalcocite
malachite
brochantite
hematite
cuprite
goethite
covellite
quartz
bornite
calcite

As noted above, antlerite has been found replacing chalcocite, covellite and bornite. However, pseudomorphs of crystals of any of these minerals by antlerite are unknown. Malachite as a pseudomorph after antlerite is known, but because of the similarity of the acicular forms common to both minerals, it is probably more common than the few recognized specimens would indicate.

OCCURRENCES:

Campbell Mine, Antlerite came from the uppermost levels of this mine as a dark green, granular material locally replacing chalcocite and covellite.
1800 level; It was found here as drusy coatings on chalcocite with anglesite and silver.

Cole Mine, *700 level, 99 stope;* It was found in small amounts at this locality as translucent, deep green, 2 cm long, needle-like crystals with cuprite on goethite.

Czar Mine, Antlerite occurred in several places in this mine as tufts of acicular crystals or blocky 4-5 mm crystals in voids in a massive cuprite or a hematite/cuprite mixture.

Holbrook Mine, Several areas contained 5 mm, blocky crystal with cuprite in voids in massive cuprite nodules.

Junction Mine, Antlerite was recognized in small amounts as a supergene replacement crust on bornite and chalcocite.

Lavender Pit Mine, *Holbrook Extension;* A few specimens were recovered with antlerite as radiating clusters of small crystals with carbonatecyanotrichite and copper on siliceous fragments.

Southwest Mine, *14 stope, 5th level;* Antlerite occurred here in small amounts as exceptionally large, well-formed prismatic crystals to 6 mm in vugs within massive cuprite and associated with minor acicular brochantite.
6th level; Small amounts occurred on this level as 1 mm crystals in vugs in cuprite with connellite.

Shattuck Mine, A small number of fine specimens with superb 2 cm tabular crystals on or encased within fine-grained, spongy antlerite were recovered here. Also, as bright, sharp crystals to 6 mm with acicular brochantite on a compact specular hematite/quartz mixture. Palache (1939a) noted dark green to black, 3 x 3.5 x 2 mm antlerite crystals on brochantite in specimens from here.

ARAGONITE $CaCO_3$:

This was an extremely abundant mineral, which was largely associated with supergene activity. The most typical mode of occurrence for aragonite was as several types of speleothems in the many oxidation caves throughout the western and southern parts of the district. Many fine specimens of this often very handsome mineral have been recovered from a number of Bisbee's mines.

Usually white to tan in color, it was not uncommon to have aragonite tinted by copper and/or iron. Coloration appears to have usually occurred as a more or less simultaneous and continuous process along with aragonite deposition. In a few instances, it is evident that later solutions colored only the surface of some aragonites.

Copper would impart hues that ranged from a pale blue-green to a pronounced aquamarine blue. This color range is distinct from similar calcite forms that have developed under like conditions, in that calcite is colored in hues of green. The smaller aragonite stalactites were often translucent, adding to the impact of the color. Coloration of aragonite by copper is a result of the presence of a dispersed second phase of a copper carbonate such as azurite along with aragonite (White, 1981). Iron left reds to browns that ranged from light tints to striking bright bands, a process that appears to have been more intermittent and less complete than was typical for copper coloration.

Often the color left by these elements was variable throughout the individual formation. Also, it was not uncommon to have iron and copper coloring different zones of the same speleothem, particularly flowstone for example.

Stalactitic forms were by far the most common occurrence of aragonite in the district and were abundant in the many oxidation caves. These were found as both stalactites and stalagmites, often in excess of several meters in length or height.

Microcrystalline to coarsely crystalline aragonite flowstone occurred as compact, often thick, colloform coverings of the floor and walls of these caves. These too were often colored similar to the other formations except that bands of copper and iron coloration, occasionally interspersed with white or colorless zones, were very common. This reflected the varying phases of the aragonite growth and coloration that occurred in the cave above. Interlayered bands of calcite commonly occurred with this type of aragonite.

Coralloidal (flos-ferri) growths of aragonite often covered large areas in these caverns, usually in the upper portions of the openings. Frequently associated with stalactites of both aragonite and calcite, these formations were usually a later stage of deposition that partially overgrew earlier forms.

Some of the flos-ferri growths were hollow for much of their length. Solid examples are known, but were uncommon. In a few instances, there is evidence of a soft, porous core material that either was an incomplete filling or had been partially removed. This was usually a corroded mixture of aragonite and a copper carbonate. In most cases, there is no indication of any core material. It is probable that flos-ferri grew as hollow tubes and that some are partially filled by later solutions.

Copper and iron often colored flos-ferri formations as well. When copper is the coloring agent, it usually throughout the whole mass, with a frequent late-stage partial veneer of more or less white aragonite or calcite. Iron coloration tended to be a surface coloration only, and often corrosive to the aragonite.

Acicular aragonite also commonly occurred in the oxidation caves and openings. This was most often as apparently oriented growths on botryoidal calcite. The aragonite crystals, while usually small and acicular, would occasionally be quite large. Chisel-shaped crystals of 5 cm on uncommonly large botryoidal calcite were occasionally found. Stalactite-like, “jackstraw” masses of 3 - 5 cm chisel- shaped crystals in masses measuring in excess of a meter were found in one cave. These delicate masses would break into several pieces when collected but would yield a number of fine specimens. Aragonite of the acicular and chisel-shaped crystal forms were almost always colorless to white. A few iron-stained examples are known, as are a very small number of copper-tinted specimens.

The rarest form of this mineral was as helical growths. These were found as randomly oriented protrusions from the walls and ceilings of several small oxidation caves. A maximum length of 18 cm has been noted. Helical forms are typically restricted to one small area of the cave and occur as individual growths or clusters, often adjacent to more typical aragonite forms.

It is worth noting that the three recognized locations for these helical growths are along the same fault. However, each of the locations is more than 100 meters from the next closest. Two of the localities are at an elevation of about 1,116 meters while the third and most prolific is at 1,148 meters.

The caves that resulted from the oxidation of the sulfide replacement deposits (oxidation caves) were ideal depositional environments for both calcite and aragonite. Typically, the calcite speleothems were much larger, far more abundant and often later in deposition than aragonite. The depositional controls forming aragonite instead of calcite under these conditions are obscure. However, it appears that higher available energy levels may have been a controlling factor. Sulfide oxidation gives off a modest, but important, amount of heat that is certainly sufficient to warm the cave atmosphere and/or the solutions that may have preferentially deposited aragonite instead of calcite.

Post-mining aragonite was of common occurrence in most of the mines. Stalactites, often coated with tiny acicular aragonite crystals, were locally abundant. In mine openings that served as main ventilation ways, the stalactite-like formations would grow into the strong airflow, nearly parallel to the mine ceiling.

Thick, massive, post-mining aragonite was noted in several places where large volumes of mine water were transferred from level to level down 100-foot raises. Ladders and other timber were often coated with 5-10 cm of aragonite by the forceful, cascading waters.

In relatively still air environments, the dripping solutions occasionally formed what the miners called "bird's nest's." These post-mining features were flattish aragonite deposits, cementing small areas of the loose rock of the mine floor with a depression where the water drops would impact. Small rock fragments in the depression would become coated with layers of aragonite and be continually moved by the dripping water, resulting in rounded, cave-pearl-like growths that roughly resembled eggs. These "bird's nest's" were usually white but bluish, copper tinted and red/brown, iron-colored examples were not uncommon. It was not uncommon for the miners to "enhance" the color development by adding a bit of the ever-present chalcanthite periodically during growth and before collecting

The species most commonly associated with aragonite are:

goethite
hematite
calcite
pyrolusite
malachite
conichalcite
rosasite
sepiolite
aurichalcite
dolomite
azurite
rosasite

Pseudomorphs of calcite and goethite after aragonite have been recognized from the district. Replacement of aragonite altering to calcite was commonly observed. In some of the speleothems, the presence of metal ions seems to have prevented the typical conversion of the metastable aragonite to the more stable calcite, a common occurrence.

OCCURRENCES: Because of the wide distribution and abundance of aragonite within the district, only a few of the more typical or unusual occurrences are noted below.

Campbell Mine, *1600-2200 levels;* Post-mining aragonite in "bird's nest" forms were found in a number of places on these levels. Many of these were up to 25 cm across and made handsome specimens. Also on the 2200 level were 2 to 3 cm thick crusts of post-mining, pale blue, reniform aragonite had been deposited on mine timbers, where large volumes of water were transferred from levels above through a raise.

Cole Mine, *800 level;* A large cave on this level contained a small number of specimens of bluish-green, acicular crystals on white botryoidal calcite.
1000 level; Fine examples of the post-mining "bird's nest" aragonite were found on this level when old workings were reopened.

Czar Mine, This large, rich mine encountered a number of often-large oxidation caves during its 60+ year productive life. Aragonite was a common mineral as speleothems in these caves.
200 level; A number of large flos-ferri specimens were recovered from this level. While many were white in color, the majority were reddish-brown. Copper-tinted examples were also found but were far less common. Bladed, colorless crystals to 1 cm across and 6 cm in length on thick iron-stained aragonite flowstone were found in one cave, but because of collecting difficulties, few were recovered.

300 level; A limited number of vivid aquamarine-blue, ribbon-like flowstone specimens in 1 cm to 2 cm thick relief on the white aragonite walls were found in a cave on this level and recovered in the 1890's.
400 level; Post-mining aragonite formed as 10 cm-thick overgrowths on mine timber at the bottom of a raise used to transfer clean mine waters under Queen Hill to this level for recovery and use.

Holbrook Mine, Many oxidation caves were also found during the operation of this mine. The majority contained aragonite in several forms and in varying amounts, but a few are noted.
100 level; A few high areas of a large cave hosted fine flos-ferri formations that were vividly colored by copper. A few had clusters of tabular calcite crystals on the top parts indicating a sub-solution depositional environment for the calcite. Striking translucent aquamarine-colored stalactites reaching 60 cm occurred in the same areas.
200 level; A large oxidation cave on this level contained fine examples of colorless to white acicular crystals on white botryoidal calcite and large flos-ferri groups.

Junction Mine, Post-mining "bird's nests" were found on several of the upper levels long after they had been closed.

Shattuck Mine, Here too, a number of oxidation caves were found during mining. Aragonite was a common mineral in most of these.
300 level; The large oxidation cave that bottomed on this level had an enormous amount of aragonite in several forms. Large areas of the cave's walls were covered by botryoidal calcite that served as a base for colorless sprays of acicular crystals of a centimeter or more. High in the cave, small patches of helictitic calcite also had centimeter long, acicular crystals deposited in an oriented fashion. Many stalactites and stalagmites as well as flowstone formations found in this immense opening were aragonite. Iron tinting of these as well as the calcite speleothems was a very common feature of this extraordinary cave.
500 level; As clusters of colorless acicular crystals on white calcite in a solution-enlarged fault along the margin of an orebody.

Southwest Mine, This extensive mine with its many oxidation caves produced the finest examples of aragonite from the district. Aragonite speleothems were a common occurrence in the vast majority of these caves.
4th level; A small cave on this level contained a few, remarkable, translucent aquamarine-blue stalactites to 35 cm in length. Also, aragonite was common as acicular crystals from 1 to 5 cm on calcite in several oxidation caves.
5th level; A small cave near the Southwest Shaft produced colorless, acicular crystals to 3 cm on remarkably white botryoidal calcite.
6th level; Unusual helical growths that spiral in screw-like fashion to a point occurred in a small cave in a body of goethite. These aragonites reached 18 cm in length and exhibited right as well as left-hand twists. Some were sprinkled with flecks of rosasite and many had partial coatings of calcite. Also from this level came aragonite as centimeter-long crystals on botryoidal calcite with aurichalcite. The portion of the New Southwest orebody on this level produced colorless 2 to 3 cm crystals oriented on exceptionally large, lustrous, botryoidal calcite.
7th level; Exceptionally fine specimens of colorless, chisel-shaped crystals to 5 cm long, usually on botryoidal calcite and frequently partially coated with dolomite, came from a cave some 25

meters above this level. Meter long" jackstraw"-like masses of 2 to 5 cm white to colorless crystals hung from the ceiling of this same small cave. A nearby cave contained substantial amounts of aragonite with an occasional specimen of 2 cm, aquamarine-blue, bladed crystals on pale green botryoidal calcite. Aragonite stalagmites and stalactites, often of very large size, were abundant throughout the level in oxidation caves.
8th level; A small oxidation cave at the top of a collapsed stope in the area of the New Southwest orebody contained fine examples of the flos ferri variety. However, because of the broken nature of the ground from collapse, only a very few specimens were recovered by the authors.

ARSENIC As:

This hypogene species is apparently quite rare within the district. The only reference to the occurrence of arsenic here is in Anthony, et al. (1995) where it is listed in the table of primary minerals at Bisbee.

ATACAMITE $Cu_2^{2+}Cl(OH)_3$:

Within the Warren mining district, this supergene species is of moderate local abundance, but is not particularly widely distributed within the district. Its similarity to other secondary copper minerals, malachite and brochantite, in particular, coupled with its similar association may well have led to confusion and misidentification, thereby limiting the number of recorded occurrences.

Most chlorine-bearing copper minerals from the district are typically associated with cuprite. Atacamite largely follows this pattern. This appears to be the result of the copper chloride, nantokite, serving as the source of chlorine. In this district, nantokite seems to occur only with cuprite.

The more typical occurrence of atacamite in the district is as small (<5 mm) acicular crystals in voids in or very near cuprite. On occasion, a second generation of atacamite has been noted in the cuprite voids that consist of a small number of 2 to 3 cm slender prismatic crystals along with the acicular crystals.

Examples of atacamite on goethite or hematite are known from here as well. These have probably formed quite close to cuprite and often the iron oxide is indeed a replacement of cuprite. Here the most common form of atacamite is as slender crystals or mats of crystals usually less than 5 mm in length. However, fine specimens with stout, prismatic crystals in excess of 1 cm have, on one occasion, been found in voids in hematite rinds on massive cuprite. The hematite was a replacement of the massive cuprite.

The species most often found with atacamite are:

cuprite
goethite
hematite
malachite
paratacamite
linarite
nantokite
chrysocolla
tenorite
clinoatacamite
connellite
spangolite

brochantite

Sharp, well formed, pseudomorphs of malachite after small atacamite crystals have been noted from the district. However, if these pseudomorphs were not seen in the context of being associated with nearby atacamite, they would be difficult to recognize as such, given their similarity to other, common malachite forms.

OCCURRENCES:

Cole Mine, *700 level, 110 stope;* Atacamite came from here as a few fine specimens of 2 mm needle-like crystals in radiating clusters on hematite with large (> 1 cm) cuprite crystals.

Czar Mine, Blocky crystals of atacamite to 5 mm on chrysocolla with cuprite came from here. Also, atacamite was found in this mine as radiating fibrous crystals completely filling voids in massive cuprite/hematite, occasionally with connellite.

Juniper Flat: Atacamite was recognized here as a minor accessory mineral in some of the mineralized gold bearing quartz veins with brochantite, linarite, paratacamite, and malachite (Rob Bowell, personal communication 2004).

Shattuck Mine, *400 level;* Atacamite was found here as very small crystals on siliceous hematite.

Southwest Mine, *14 stope, 5th level;* This locality produced a small number of extremely fine specimens of atacamite in several different forms. The most impressive of these was as dark green, stout, prismatic crystals to 1.4 cm in length with hopper-growth terminations, on a base of light green acicular atacamite in hematite. Also, found here were clusters of needle-like crystals up to 3 cm in length in vugs with often-large cuprite crystals. Thirdly, as light green acicular crystals that provide a base for other atacamite crystals or for large cuprite crystals.

AUGITE $(Ca,Mg,Fe^{2+})_2Si_{,2}O_6$:

This primary rock-forming mineral has been recognized by Bonillas, et al. (1916) as a constituent of two minor dikes in the district. These dikes are both an olivine and augite diabase in nature. One is pre-Cambrian and the other is post-Paleozoic (Bonillas, et al. 1916). The pre-Cambrian dike is folded into the Pinal schist while the post- cuts the Paleozoic limestones.

In the pre-Cambrian dike, augite is found as coarse granular aggregates, while the other dike contains augite as tiny grains (Bonillas, et al. 1916).

Quartz is the most common species associated with augite in these occurrences.

OCCURRENCES:

The occurrence of augite in the district appears to be restricted to the two intrusive units noted above.

AURICHALCITE $(Zn,Cu^{2+})_5(CO_3)_2(OH)_6$:

Bisbee has long been recognized as one of the premier localities for this lovely and delicate supergene mineral. A great many fine specimens have been recovered from several of the mines in the district.

While locally abundant, it is decidedly much less common than the copper carbonates - malachite or azurite, but more abundant than rosasite, the copper zinc carbonate. The more prolific localities for aurichalcite seem to be restricted to the zone between the Copper Queen and Shattuck mines in an area often referred to as the Queen, Southwest and Shattuck blocks that include the Copper Queen, Czar, Holbrook, Southwest, Uncle Sam and Shattuck mines.

The most common mode of occurrence for this species was as a partial covering of the walls or as a lining of voids in the lower parts of a small number of oxidation caves. The bottoms of the oxidation caves were almost always a chaotic mass of boulders of iron oxides and/or limestone, often mixed with calcite. In the caves that contained aurichalcite, many of the voids between the boulders were lined with this mineral. This is probably the type of occurrence noted by Kunz (1885) when he described it as "in beautiful tubes lining cavities."

Boxwork voids in the iron oxides, both in the caves and the orebodies, were also a common depositional site for aurichalcite. Often, however, the amount of aurichalcite deposited was modest, resulting in either a partial covering of the void surfaces or scattered tufts of acicular crystals. Large volumes of this type of material were mined as ore from several places (Bateman, et al. 1914).

The crusts of aurichalcite from the cave/boulder environment were typically composed of densely packed, acicular crystals oriented perpendicular to the growth surface and parallel to subparallel to each other. Crystal length was seldom in excess of a centimeter, with half that length far more common. Boxwork voids in the iron oxides more often contained aurichalcite as scattered tufts of delicate acicular crystals or as randomly oriented growths. Rarely, compact, radiating, acicular crystals formed small, reniform masses in the boxwork voids. Crystal size is usually less than 5 mm in the former instances but up to 6 cm in the latter.

Post-mining aurichalcite was observed forming over the period of just a few days along with azurite and malachite. The aurichalcite was formed from a thin jellylike mass running into an open space and drying in a 30-cm wide goethite seam bounded by limestone (Tenney, 1913).

The mineral species most often associated with aurichalcite are:

goethite
hemimorphite
smithsonite
calcite
hematite
copper
azurite
rosasite
pyrolusite
malachite
dioptase
chrysocolla

What appear to be pseudomorphs of goethite after aurichalcite have been found on the "A" level of the Uncle Sam mine, while at the nearby Shattuck mine dioptase formed as rough epimorphs after aurichalcite. Chrysocolla pseudomorphs after aurichalcite have been found several places in the Southwest mine. Also, a few casts of aurichalcite after tabular gypsum variety selenite crystals were found in the Southwest mine. Replacement of acicular malachite by aurichalcite has been noted as well.

OCCURRENCES:

Cole Mine, *1200 level, 26-J stope*; This single stope produced what are probably among Bisbee's finest aurichalcite. It was found as compact, radiating, banded crystal masses with reniform surfaces in boxwork voids. Crystal lengths reached 6 cm and were up to 1 mm thick. Some of the specimens were not attached to the matrix while others were secure and partially overgrown with calcite. Hemimorphite with crystals to 2 cm was a commonly associated species.

Copper Queen Mine, Aurichalcite was reported in this mine as occurring "in beautiful tubes lining cavities" (Kunz, 1885). This was most probably in the void spaces between boulders in the bottom of an oxidation cave. Also, aurichalcite came from here as clusters of uncommonly large (2 to 4 mm) tabular crystals on pale yellow smithsonite with azurite and an unidentified manganese oxide.

Czar Mine, Aurichalcite is known from here by specimens from an unspecified level as uncommonly large tabular crystals of 2 mm wide by 5 mm long on goethite.
200 level, 27-1 stope; It came from here in large amounts as fibrous crystals on goethite and pyrolusite (Tenney, 1913).
400 level; Aurichalcite was noted from here by Bateman, et al. (1914).

Holbrook Mine, *100 level;* Minor amounts of aurichalcite were noted here as 5 mm spheroids and tufts on goethite and/or calcite in a large oxidation cave.

Lowell Mine, A zone of oxidation near the shaft that ran from the 200 level to the 600 level contained important amounts of aurichalcite with malachite on pyrolusite and goethite (Tenney, 1913). Copper was also associated with aurichalcite on the 400 level (Tenney, 1913).

Shattuck Mine, It occurred here in moderate amounts as fibrous crystals to 5 cm on hematite-stained silica fragments with later dioptase that had formed at the expense of the aurichalcite. Calcite and malachite are also associated with aurichalcite from here. A few of the specimens from here are quite spectacular with centimeter thick aurichalcite lining voids between malachite and dioptase.

Southwest Mine, *3rd level;* Aurichalcite was common on this level as 5 mm spheroids on goethite completely encased in radiating clusters of colorless hemimorphite crystals.
4th level, 2 stope; On the 5th floor of this stope (44 feet above the level), Tenney (1913) noted the formation of post-mining aurichalcite along with azurite, malachite, and what appeared to be chrysocolla.

5th level; It occurred here in large amounts on this level as a partial crust of 7 mm acicular crystals on often-large limestone fragments. Also, a few stalactitic growths of very compact aurichalcite were found here associated with the more typical, acicular form. This occurrence is in a collapse breccia and specimens of more than a meter across were produced. A substantial amount of lace-like calcite was also in this breccia, some of which was colored by enclosing the earlier aurichalcite. Some alteration of aurichalcite to chrysocolla was observed at this locality.
6th level; Abundant here as thick, luxurious coatings of acicular crystals, to 2 cm in length, on altered manganiferous limestone. This occurrence is in the lower portions of an oxidation cave as well as in the underlying orebody and is associated with botryoidal calcite and, less frequently, aragonite.

Uncle Sam Mine, *"A" level;* Aurichalcite was locally abundant here as randomly oriented clusters of 5 mm acicular crystals on goethite boxwork with rosasite and hemimorphite in a meter-wide fault zone.
"B" level; It was found on this level as areas of up to 1.25 meters of 1 cm crystals covering several parts of the walls of a small oxidation cave that was above a copper/zinc orebody.

AUSTINITE $CaZn(AsO_4)(OH)$:

This is a mineral of supergene origin and is quite rare in the district, having been recognized at only one locality. However, at this single locality, it has been found as both typical austinite and as a cuprian variety.

The minerals associated with austinite are:

quartz pyrolusite

OCCURRENCES:

Southwest Mine, *7th level;* A small open cut on the surface near the Hendricks Gulch portal to this level contained a few specimens that had a crust of 0.1 mm tan to colorless crystals on silica breccia fragments. These crystals were partially overgrown by 0.25 mm gray-green to deep green crystals of cuprian-austinite. Pyrolusite was associated with this occurrence.

AZURITE $Cu_3^{2+}(CO_3)_2(OH)_2$:

This widely distributed secondary mineral made Bisbee famous as a producer of fine mineral specimens very soon after the discovery of the Atlanta and Southwest orebodies in the mid to late 1880s. Numerous superb azurite specimens were found and, most importantly, preserved. Some of the finest known examples of this lovely mineral for the time were from here (English, 1890). Good to fine specimens of azurite are known from all of the economically successful mines in the district, in a wide range of habits and forms, as well as varying hues of light blue to nearly black. Azurite was also sufficiently abundant in a number of the mines to constitute an important ore mineral.

The most common form of azurite in the area's mines was not as fine specimens, but as large masses of very impure, often-earthy material typically mixed with goethite and/or a combination of manganese oxides. This soft azurite was formed as a replacement of the residual, often granulated, limestone following the initial supergene reactions and the formation of the oxides.

This earthy material was also found as an incomplete filling within boxwork structures that were frequently very soft themselves. Azurite/iron oxide/manganese oxide deposits of this type were derived from very low to low-grade copper sulfides where the high iron/high acid development controlled the system. Frequently, much of this azurite was partially altered to malachite.

Azurite as a partial to complete replacement of limestone was the second most common occurrence for this mineral. Here, the source was somewhat higher-grade sulfides. The solutions derived from the oxidation of these followed fractures and bedding planes replacing the limestone with impure though compact azurite, some of which was replaced by earthy, impure black chrysocolla as later solutions reacted with the azurite. Some alteration to malachite was also common. The replacement of the limestone seldom exceeded a meter beyond an individual fracture. However, multiple, often parallel channels were available, resulting in layers of limestone interspersed with the layers of azurite of varying purity. Fossil brachiopods, crinoids and corals were occasionally replaced by azurite under these conditions as the fossils were typically already replaced by calcite, which reacted readily, if not preferentially, with the copper-rich solutions. This type of occurrence, while interesting, seldom yielded recognizable replacements, but rather centimeter-sized blue masses. However, Bateman, et al. (1916) noted one occurrence of well-preserved fossil features in azurite replacements.

Azurite deposition in voids appears to have occurred under two often-fluctuating environments, open air and sub-solution conditions. The classic, banded, reniform material formed in an open-air environment. Post-mining occurrences coupled with features preserved in this compact material strongly suggest a gelatinous origin. Thus, as could be expected, this type of azurite was found on the bottom of the voids and to a much lesser degree in thinner layers along the sides of open spaces.

All crystalline azurite, including the drusy material appears to have a sub-solution origin. Deposition in this environment commonly covered all sides of the open space in a more-or-less even fashion. As previously noted, the environments seem to have often fluctuated between open air and sub-solution as fluid levels changed. Accordingly, it is not uncommon to see a crystalline veneer over otherwise massive, banded azurite as well as the reverse.

Drusy, sub-solution azurite coverings of earlier minerals such as malachite, goethite and open-air-deposited azurite are common as well. In these instances, the underlying shape is often retained giving the impression that the azurite actually developed in this form. Stalactites are an example of such a feature. Azurite stalactites from Bisbee appear to always be a sub-solution deposition of azurite on preexisting stalactites of earlier minerals such as malachite, goethite, gibbsite and rarely, calcite.

Boxwork structures of iron oxides, particular goethite, and less often malachite, were a common host for azurite deposition. The many, often large, open spaces and abundantly available carbonate provided an ideal environment for almost all forms to develop. Relatively thin, botryoidal to drusy crusts, covering or partially covering many of the available surfaces, were common in these voids.

In some areas, the azurite was deposited so heavily on a malachite boxwork that the resulting material was nearly solid azurite and malachite. Masses of up to 8 tons of this type were found. The azurite in these instances was frequently decidedly lighter in color than is typical. This may have been a result of a very modest amount of zinc being included in the azurite. Typically, the malachite under the azurite was also very pale for the same reason.

Pisolitic azurites, with spheres to 1.5 cm (Mitchell 1920b), often drusy, as well as small crystal clusters, rosette-like in appearance, were frequently found as sub-solution deposits on malachite boxwork. These were usually a scattering of the azurite forms on the malachite. Specimens of this type approaching a meter across were recovered from the western part of the district.

Crystals of all sizes and habits were often deposited on the surfaces of the voids formed in the boxwork environment as well. In the case of large azurite crystals, malachite was far less common as the base for deposition. In almost all cases, the base was either goethite or hematite. It was in this type of environment that the best of Bisbee’s crystalline azurites were formed.

Almost without exception, Bisbee azurite crystals of any size greater than 2 cm and on an iron oxide matrix are, in reality, oriented, parallel, second-generation overgrowths of azurite on malachite pseudomorphs after azurite. This characteristic was noted by Schwartz and Park (1932). Palache and Lewis (1927) commented on a single occurrence of azurite with the second-generation, parallel overgrowths, which they thought to be the exception, not the rule, but the reverse is the true case. With some crystals, this feature is quite obvious, but not with most. Many of these crystals give the appearance of being partially altered to malachite. However, a close examination of the interface between the underlying malachite and the azurite will reveal depositional features such as crystal faces with an almost corroded look, a feature of the volume reduction that is part of the alteration of azurite to malachite. It is this overgrowth feature, which accounts for the uncommon, very blue color of most large azurite crystals from Bisbee.

Azurite was also found as bright, often composite, crystals up to 1 cm on isolated masses of lustrous, compact, acicular malachite. The depositional environment for these was sub-solution in small open spaces within a very soft iron or manganese oxide. Most of the irregularly shaped malachite was covered by the oxides, thus, restricting the azurite deposition to the exposed surface, which was typically small when compared to the overall mass.

Rosettes of azurite - aggregates of intergrown pseudorhombohedral or blocky crystals, which formed free-floating and unattached to a matrix - are well known from Bisbee. These are near symmetrical to spherical to irregular masses in form. There is little doubt that the best azurite “roses” from Bisbee are the finest known. A number of locations throughout the district produced rosettes of varying size and quality, but only one area yielded the truly classic examples, the Dividend fault zone in the Czar and Holbrook mine areas.

The depositional environment is similar in all instances for the formation of roses as well as the blocky crystal masses occasionally found with them. Steeply dipping fault zones with at least one limestone wall is where these azurites were formed. These faults are filled with soft, clay-like material for at least several meters in width. The clays were obviously quite plastic and largely non-reactive to the copper-bearing solutions at the time of azurite formation. The roses developed within the clays, but always at or very near a carbonate source, usually residual rock flour in the fault gouge. Rosette size, distribution and density within the fault zone were clearly a function of the available carbonate and thus, the derived CO_2.

Other less common modes of occurrence for azurite are as a direct, in situ alteration product of copper sulfides. Chalcocite has frequently been observed with an alteration rind of azurite. On occasion, the alteration of chalcocite to azurite was complete - resulting in largely featureless masses. Small azurite crystals were rarely formed along the outside of these pieces. Bornite, and, to a much lesser degree, chalcopyrite has been found with thin veneers of azurite, which was a result of in-place alteration. Massive cuprite has been reported as altering to azurite in the Junction mine (Mitchell, 1920b) and the Shattuck mine (Bateman, et al. 1914). This same alteration has also been observed by the author in the Cole mine as well and is probably not of uncommon occurrence within the district.

Post-mining azurite was found in a few locations as bright blue to dark blue crusts on limestone. When forming, it was a thin gelatinous layer over previous, hardened material. Tenney (1913) observed the formation of post-mining azurite along with malachite, aurichalcite, and what appeared to be chrysocolla in a matter of just a few days. The solutions were jelly-like and ran into voids in goethite and dried. Typically, post-mining azurite was near sulfides high in copper content, which were altering because of the surface conditions introduced by mining. In one instance, the time between the exposure of the sulfides and the formation of a 1 cm-thick crust of azurite was approximately 25 years.

Many of the gangue and other supergene minerals have been found with azurite, but the most frequently occurring are:

goethite
hematite
cuprite
malachite
smithsonite
cerussite
chalcocite
tenorite
copper
pyrolusite

A limited number of mineral species have been found as pseudomorphs after azurite. In all instances except where the pseudomorph is malachite or, in some instances, chalcoalumite after azurite, the apparent pseudomorph after azurite is almost certainly a replacement of an earlier, intermediate malachite pseudomorph after azurite. The species from the district that are known as pseudomorphs after azurite are malachite, chrysocolla, copper, rosasite, goethite, chalcoalumite and siderite.

No distinct pseudomorphs of azurite after other species are known from the district. However, azurite has been found as what appeared to be a replacement of chatoyant malachite. But, because of the strong similarity in form and lack of crystal definition, the presence of a pseudomorph could not be confirmed. Azurite replacing massive cuprite was often observed. As noted above, Bateman, et al. (1912) recognized azurite as a replacement of massive cuprite on the 200 level of the Shattuck mine as did Mitchell (1920b) at a location in the Junction mine, but no crystals have been recognized as pseudomorphs of azurite after cuprite.

OCCURRENCES:

Campbell Mine, *1800 level;* The Campbell fault zone contained azurite rosettes on this level. While they reached up to 10 cm in size, they were not nearly the quality of those from the Czar/Holbrook areas. These Campbell fault roses were often lighter in color than those from other areas were and, in many instances, show a late-stage period of azurite deposition on an earlier corroded, azurite core. Hematite-rich, clay-like materials were the host of these roses and it is frequently impossible to completely remove the red clay from the specimen. This level also had an extension of the 105-C stope from the level below, thus, similar specimens to those noted below were produced.
1900 level, 105-C stope; This stope produced many fine crystallized azurite specimens as groups and as single crystals to 20 cm. For the most part, the larger crystals from here are composite crystals, with numerous parallel to subparallel growths forming the larger crystal. All of the crystals give the appearance of altering to malachite, but they are invariably second-generation azurite overgrowths of variable thickness on earlier malachite pseudomorphs after azurite.

Malachite pseudomorphs after azurite were uncommonly abundant in this orebody, but only a relatively small number had the second-generation azurite overgrowth and these were localized. In the distance of less than a meter, these pseudomorphs transitioned from all one generation of azurite totally replaced by malachite to crystals with a second-generation azurite overgrowth to crystals with an overgrowth of malachite that was not a replacement of azurite. Thick, near impermeable, hematitic clays seem to have controlled solution movement as well as CO_2 levels. Cerussite as twinned crystals is a commonly associated mineral with the azurite from this location. Malachite, hematite and hematite-stained silica fragments are also found with these azurites. There is little doubt in the minds of the authors that these azurite crystals, including the second-generation overgrowths were pre-Cretaceous in formation.

Cole Mine, *800 level;* A major fault zone near the interior shaft on this level was mined for an ore that was almost entirely made up of small free-floating azurite masses. While most were soft or poorly formed, a number that were good rosette specimens have survived. Typically, these are 5 cm or less in size and associated with and/or partially altered to malachite. Fossil brachiopod fragments are found imbedded in or attached to many of the specimens from here. A few of the rosettes were well-formed, deep blue, and with very glassy surfaces. These are distinct from the far superior Czar/Holbrook roses, in that the crystals which form the rose pattern, are smaller and more numerous, resulting in a more spheroidal shape.
1000 level; Sharp, bladed, light blue crystals on a goethite/hematite boxwork were found on this level.
1200 level, 141-F stope; Azurite was the principal ore in this stope and was abundant as deep blue crystals to 7 mm and crystalline spheroids to 1 cm with malachite and, rarely, 0.5 –to 1 mm yellow smithsonite crystals as a partial overgrowth. Some of the spheroids were lighter blue in color as a result of a partial, somewhat porous late-stage deposition of azurite. Dense goethite with small, close spaced boxwork patterns was the matrix for these specimens.

1400 level; A stope on this level that was operating at the time of final closure mined an ore, which was largely an azurite replacement of fossil brachiopods (Atrypa reticularis). Very few of these replacements were of specimen quality however, as most were quite soft. Thus, few survived collecting.

Copper Queen Mine, Very little azurite was actually mined from the original Copper Queen orebody and the few confirmed specimens seen by the authors are of modest size and quality. The attribution of specimens to the Copper Queen was a result of the Copper Queen Consolidated Mining Company owning all of the operating mines, except the Copper Prince, until 1902.

2nd level-4th level; The Atlanta and Southwest orebodies extended between these levels and produced most of the azurite that made this small mine famous in the mid-1880s until the closure of the Copper Queen mine in 1888. These same ores were mined through the newer, more efficient Czar mine to maximize hoisting capacity, thus identical specimens were produced by both mines and are indistinguishable.

Azurite was found as clusters of bright, large, tabular crystals to 11.5 cm on goethite with minor apparent malachite. However, as is typical, these are actually second-generation overgrowths on malachite pseudomorphs after azurite. The uncommonly bright blue color of these pieces is a result of the thin veneer of azurite. Other areas of the same orebodies produced a great many specimens of bright, tabular crystals from 1 to 4.5 cm on goethite. Many of these were recovered as thin crusts, often with stalactitic forms. These specimens are invariably associated with abundant, tiny cuprite octahedrons that are coated or rarely, completely altered to malachite.

Deep blue to near-black botryoidal azurite formed with drusy surfaces and associated with malachite were also produced in this part of the mine. Also from these areas came lovely specimens where the azurite was deposited as a thin, bright crust of tiny, tabular crystals on uncommonly chatoyant malachite.

Czar Mine, This mine was the most prolific in the district as far as azurite was concerned, producing thousands of specimens. Most of the Atlanta and Southwest orebodies, first mined through the Copper Queen were exploited by this nearby, more efficient mine after workings from it reached the area in 1884. Because of this, many of the Copper Queen-type specimens were actually mined from the Czar. It is impossible to detail all of the important occurrences in this mine, much less the many, many lesser ones. Please keep this in mind as you look for a specific occurrence.
100 level; The footwall of the Dividend fault zone produced many pockets of up to 20 cm lined with drusy azurite and some malachite, which is often lightly goethite stained.
200 level - 400 level; The plastic clays from the Divided fault zone contained many free-floating, glassy, deep blue rosettes and similar groups of blocky crystals. These areas continued into the nearby Holbrook mine. Because of very difficult mining conditions, this area was mined several times, each producing more azurite roses. A few of these specimens were up to 16 cm across. There can be little doubt that these roses are the world's finest.
200 level; Deep to medium blue botryoidal azurite, often with malachite and some with drusy surfaces, were abundant at the edges of some of the orebodies on this level in the Belle Isle claim. Often these masses were up to 6 cm thick with varying hues of blue common on the same

specimen. Occasionally banded, chatoyant patterns on their sides suggesting a replacement of malachite can be found and are exceptional for lapidary applications. Valiant, in 1897, noted that more than 2,000 pounds of material had been sent to Denver for polishing.

A number of specimens of azurite with pseudorhombohedral/pseudocubic crystal forms also came from this level. These had bright crystals to 1 cm covering a thin, hard goethite boxwork. This level also produced azurite as plates of intergrown, brilliant tabular crystals to 1.5 cm that are similar in appearance to rosettes. The large block in the American Museum of Natural History was mined in 1891 from this area (Tombstone Epitaph, 1891), (Chicago Daily Tribune, 1893), (American Museum Journal, 1914).

In 1895, the greatest azurite find the world has ever seen was made from this level, when a relatively small cave completely lined with crystalline azurite was found as an extension of the Southwest Orebody, where mining had started some ten years earlier. It was described to one of the authors as *"A room, not too big, perhaps 50 feet in curved length and 20 feet high and 15 or so feet wide. The walls were all manner of irregular lumps of black azurite dotted with malachite. From the back* [ceiling] *hung limonite stalactites with azurite crystals here and there on them. The floor was mostly a thin crust of blue (azurite) on malachite (Graeme, 1981).*
The cave occurred in massive, impure goethite on the edge of this very large orebody with the opening most probably formed along a marginal, oxidation subsidence related crack. Multiple periods of supergene activity can be seen in the study of a selection of specimens from here, which show azurite deposition first, then alteration of the azurite to malachite, along with local malachite deposition, then minor goethite deposition, followed by azurite deposition and, lastly, minor cuprite deposition, much of which is at least partially altered to malachite.

Also, much of the malachite had a light coating or staining of goethite on the exposed surfaces and reflected minor corrosion by the iron-rich solutions as well. Broken faces of the malachite from here combined a degree of luster and chatoyancy not seen elsewhere. Azurite in this exceptional cave occurred in several forms, much as spherical clusters of tabular crystals in grape-like groupings on goethite and/or goethite stained malachite and sprinkled with tiny, malachite coated cuprite octahedrons. Hundreds, if not thousands of fine and often very large azurite specimens were collected from this cave. Numerous specimens exceeding 50 centimeters across from this locality are in collections worldwide, while fine smaller pieces are relatively abundant and highly treasured by their owners. Additionally, from this same area came numerous specimens with clusters of intergrown tabular crystals, which formed open spheroids to 1 cm on goethite, or often on malachite.
300 level; Huge masses weighing many tons of azurite and malachite with what appeared to be psilomelane and lesser amounts of goethite were found in the stopes on and above this level. Voids in these masses frequently contained stalactites of azurite and/or malachite as well as distinct solution level lines indicated by the deposition of malachite or azurite of a different form and/or hue. Here too, varying shades of blue were common on the same specimen.
400 level; The area on this level between the Holbrook and the Czar mines produced pisolitic azurite on malachite boxwork, often as very large specimens. The azurite was usually dark blue and drusy, covering much of the malachite and reflecting the underlying boxwork pattern.

Gardner Mine, *600 level, 37-2 stope;* Fine azurite crystals with malachite cores were noted from here by Tenney (1913). These were undoubtedly the typical second-generation overgrowths. This is most probably the source of the fine second-generation azurite overgrowths on bladed malachite pseudomorphs after azurite discussed by Palache and Lewis (1927). Stevens (1911) notes this was the deepest level of the Copper Queen's mines at the time and similar specimens are known to have come from here.

Holbrook Mine, This was a prolific mine which produced a vast number of fine azurite specimens.
200 level - 400 level; The clay zones along the Dividend fault and the supergene alteration clays near the Sacramento Stock Complex continued well into the Holbrook mine area. These areas produced exceptionally fine azurite rosettes identical to those from the nearby Czar mine.
200 level; Drusy azurite with acicular malachite and malachite pseudomorphs after tiny azurite crystals were found lining voids in goethite boxwork lined first with wad.
300 level; This level yielded a great many specimens of light blue azurite with delicate velvety surfaces partially overgrown on pale (zincian) malachite. Boxwork forms are typical. Some examples have a late stage coating of acicular malachite.
400 level; Thick masses of boxwork azurite with many of the voids lined with bright spheroidal clusters of crystals were found on this level. Many of these specimens contain abundant white siliceous fragments including numerous fossil fragments, remnants of the replaced limestone. Also, from this level came a number of specimens of pisolitic azurite in boxwork forms. These often had a somewhat friable medium blue azurite over a much lighter blue azurite. The light blue azurite is usually exposed by a partial loss of the delicate overgrowth. Some specimens have been "enhanced" by the complete or partial mechanical removal of the friable azurite, leaving the lighter blue as often handsome forms.
500 level; Blocky azurite crystals to 1 cm alongside malachite pseudomorphs after these same crystal forms were found in limited numbers on this level. When found, the unaltered azurite was coated with a black clay-like material that protected it from alteration. A thick, compact wad was the matrix for these specimens.
600 level; A limited number of 5 cm bladed azurite crystals on goethite were found on this level. As is typical for large crystals, these are actually second-generation overgrowths on malachite pseudomorphs after azurite. Occasionally the pseudomorphs were partially coated with a thin veneer of a dark brown/black material. These coated areas were not overgrown by the later azurite.

Higgins Mine, *Tunnel level;* The main Higgins orebody on this level mined azurite as an important part of its ores. From this orebody came a number of specimens with azurite in crystallized, half-spheroids covering goethite boxwork. A small number of the voids in this material were lined with bright blue azurite that served as a base for clusters of acicular malachite tufts.

Irish Mag Mine, *850 level;* A fault zone on this level produced azurite roses to 12 cm, many of which show some alteration to malachite. These are typically dull to only slightly lustrous and often have minor siliceous fragments included.
1050 level; Lustrous, 2 cm tabular crystals on goethite came from this level.

Junction Mine, It is highly probable that all of the copper carbonates that occurred from the 900 level and above are pre-Cretaceous in age.

770 level, shaft station; In March of 1905, the shaft penetrated a zone of azurite and malachite in a soft manganese oxide assaying 22% copper (Calumet & Arizona, 1905) at this level. The discovery was not a surprise, as exploration diamond drilling from the surface had cut the ores before the shaft was sunk. Indeed, it was this successful drilling effort that caused the Junction shaft to be located at this site (C& A 1904)

Here the copper carbonates were found as isolated masses of azurite or azurite and malachite. Most of the azurite at this locality occurred as bright blue, but not lustrous, overgrowths or pisolitic forms on irregular shaped malachite. Also, from this area came thin crusts of malachite on wad with a boxwork form that was decorated with scattered, bright blue azurite specks. Some of the other azurites from here were small, light blue, but dull, rosette-like forms often contain fossil fragments.

770 level, 20 crosscut - 900 level; The large, high-grade orebody first found in this crosscut in 1921 extended from near the 900 level to 90 feet above the 770 level (Engineering & Mining Journal, 1921; Calumet & Arizona, 1922, 1925, 1927). Masses of malachite up to 10 cm thick with partial overgrowths of bright blue azurite occurred in this orebody. Many of these specimens were quite large in size reaching a meter and weighing up to 50 kilograms and reminiscent of the very early classics in size and quality.

A number of exceptionally handsome specimens of bright blue botryoidal azurite with a compact radiating, fibrous internal pattern to 10 cm thick came from this area. The surface of these specimens typically was of 2 to 4 mm tabular crystals as well as with scattered sheaf-like clusters of 1 cm crystals parallel to the surface. The base of these azurites was a friable wad and/or pale yellow to gray, dry-bone type smithsonite. Minor hydrozincite is common as white specks or blotches on the azurite surfaces. The slice of an azurite/malachite stalactite on the US postage stamp issued in 1992 is from this occurrence. For reasons unknown to the authors, more than a few of these specimens have been mislabeled as coming from Morenci in spite of the recorded provenance in many museum collections at the time of acquisition.

1000 level; Mitchell (1920b) noted the occurrence of modified monoclinic crystals of 2.5 cm or more from an unspecified level in this mine. However, near identical specimens were found on the 1200 level of the nearby Sacramento Mine, which would be the 1000 level of the Junction.

Lavender Pit Mine, *Holbrook Extension;* This area of the pit mined much of the original Holbrook mine area. As might be expected, a number of specimens similar those from the Holbrook were produced. Boulders of boxwork azurite with drusy linings of the voids were common. Many of these had siliceous fragments in the azurite. Attractive crystal clusters and spheroids of azurite on yellow, boxwork smithsonite were found here early in 1970. Large masses of azurite and malachite that occasionally exceeded a ton were found along the margins of old stopes. These were boxwork forms with partial pisolitic azurite overgrowths as well as rosette-like clusters on velvet malachite. Pseudo-orthorhombic azurite crystals to 2 cm, often with malachite pseudomorphs after azurite of a different form, were found in voids in hard siliceous hematite boulders. In one area, hematitic clays contained thousands of small, spheroidal azurites with only minor crystal definition reflected on the surface. These typically were a centimeter or less in diameter, but examples to more than 3 cm were found by the authors.

Night Hawk Mine, *650 level;* An orebody more than 30 meters across consisting of mostly azurite was mined on this level (Mining & Scientific Press, 1927). Elsing, (1921), calculated more than 9,000 tons of ore at a copper grade of 10% in this stope with azurite as the principal ore mineral.

Sacramento Mine, This mine produced the best crystals of azurite from the district.
1200 level - 1400 level; A series of stopes on a single tabular orebody along the southeast porphyry/limestone contact yielded a small number of exceptional specimens. These were lustrous, pyramidal crystals to 15 cm as singles or as small groups in vugs in a siliceous goethite/hematite matrix. Many of the voids were lined with delicate acicular malachite crystals as well. Often the crystals appeared to be altering to malachite, but on examination prove to be the typical second-generation of azurite oriented on sharp malachite pseudomorphs after azurite.
1200 level; Clusters of tabular azurite crystals to 5 cm with a later, unidentified manganese oxide, were found in voids in soft goethite boulders on this level. As is typical for the district, the crystals were a second-generation of azurite oriented on malachite pseudomorphs after azurite. The covering by the later azurite was not always complete giving an appearance of alteration. The edges of an old stope on this level visited in the late 1960s contained boxwork that had voids to 20 cm lined with drusy azurite crystals. Other voids were lined with acicular malachite that usually had scattered 4 to 6 mm azurite crystals. Ocherous hematite was associated with these specimens. A few specimens with stalactitic azurite were collected from here as well with the stalactite forms actually subaqueous azurite overgrowths on pre-existing malachite stalactites.

Shattuck Mine, Azurite as an earthy replacement of limestone was an important ore at this mine.
200 level; Noted from here by Bateman, et al. (1914) as a replacement of cuprite.
45 raise; Azurite was abundant in this working as large masses composed of 2 to 4 mm crystals on malachite and/or goethite boxwork. Stalactitic azurite forms as overgrowths on malachite or goethite stalactites were not uncommon here.
400 level; This level produced fine specimens to 25 cm that were dark, reniform masses with a highly crystalline surface and later malachite.

Southwest Mine, Azurite was an important ore mineral in this mine during its productive life. It was usually found as very impure, earthy replacements of limestone or as scattered patches with malachite in a hematite/goethite mixture.
3rd level; An area of post-mining azurite more than a meter across was forming on the wall and floor of a crosscut on this level in 1997. It was a quite delicate material nearly a centimeter thick, deep blue in color, with a drusy surface.
4th level, 2 stope; Post-mining azurite was forming in the voids in a 30 cm-wide goethite seam along with malachite and aurichalcite (Tenney, 1913).
5th level, 14 stope; Patches of massive azurite were found here with malachite and cuprite in goethite. Elsewhere on this level, specimens of azurite were found as tight, sheaflike clusters of bladed crystals to 4 cm, which were partially altered to malachite.
6th level; The new Southwest orebody on this level produced a few bright drusy specimens to 20 cm across. A fault at the margin of this same orebody produced a limited number of small, bright rosettes.

Wolverine number 2 Mine, This mine exploited ores that were a continuation of the Shattuck deposits, mining azurite that had replaced limestone. While this material was typically soft and earthy, a few vugs of 5 mm crystals were found.

B

Bandylite: $CuB(OH)_4Cl$:

This rare mineral has been noted in small amounts in specimens from a single locality. It was a minor part of a complex, secondary mineral assemblage

The species associate with bandylite are:

cuprite
claringbullite
atacamite
connellite
clinoatacamite

OCCURRENCES:

Southwest Mine: *5th level, 14 stope;* Very minor amounts of pale-blue bandylite was noted at the interface between massive cuprite and claringbullite crystals (Bob Downs, personal communication, 2010). Atacamite, clinoatacamite, paratacamite and minor connellite were recognized on the same specimens.

BARLOWITE $Cu_4FBr(OH)_6$:

This very rare secondary mineral has been recognized in single specimen from one locality within the district. Its similarity in color and occurrence to the more common, yet still rare connellite/ buttgenbachite and likasite may have caused other examples to be overlooked. It occurred as an extremely minor component of a very diverse and complex assemblage in cuprite nodules.

The species associated with barlowite are:

cuprite
malachite
brochantite
goethite

OCCURRENCES:

Southwest Mine, *5th level, 14 stope,* Barlowite was noted from this locality as part of a complex supergene assemblage, in very minor amounts. It occurred as bright blue, 1-2 mm, tabular crystals in voids in cuprite nodules with brochantite, and malachite. Identification is based upon unit cell determination and SEM-EDS chemistry. A sample is preserved in the RRUFF library at the University of Arizona as number 20055. (Marcus J. Origlieri, personal communication, 2018).

BARYTE $BaSO_4$:

This common species is locally abundant as a hypogene mineral in many of the near surface manganese deposits (Ransome, 1920). In these occurrences, baryte was found as veins, masses and nest of tabular crystals in the manganese oxides (Palache and Shannon, 1920; Taber and Schaller, 1930). In the manganese deposits, baryte was typically found as a white to gray, massive material, often with surficial iron staining, which was highly fractured, possibly by mining. Vein-like features of baryte cutting the manganese oxides were up to 6 cm in thickness. Isolated lumps up to a meter in size were not uncommon in the oxides. Tabular crystals to 5 cm were found in clusters with the intercrystal space filled by hard manganese oxides or silicates.

Less commonly, baryte was also a minor constituent of the gangue assemblage in the hydrothermal sulfide vein deposits (Anthony, et al. 1995). Baryte has also been found as several, small hydrothermal deposits in surface outcrops on the eastern edge of the district. In these occurrences, are in Cretaceous rock units and associated with compact specular hematite and not manganese ores, as is so typical elsewhere in the district.

The species associated with baryte are:

braunite
chlorite
hematite
pyrolusite
magnetite
mottramite
psilomelane
malachite
pyrite
conichalcite
azurite
quartz

OCCURRENCES: Because of the wide distribution of this mineral, only the most important of these are noted below.

Higgins Mine, *Twilight claim;* The large manganese deposit on this claim contained baryte as white to gray veins, or masses (Ransome, 1920), and as clusters of poorly formed crystals to 10 cm in size completely encased in hard manganese ores.

Junction Mine, *2100 level;* Baryte to 2 cm. in thickness with a thin veneer of quartz occurred in vugs adjacent to ores in a single stope here. It was typically massive with a limited number of 3-5 mm. colorless crystals in voids.

Lavender Pit Mine, *Holbrook;* A few specimens with baryte as golden-yellow blades on azurite and malachite were recovered from this part of the pit. Hematite and an unidentified clay-like mineral were associated with the specimens.

Portage Lake Mine, A surface outcrop near this small mine on the eastern edge of the district contained baryte as white, tabular crystals to 1 cm encased in compact specular hematite.

Old Warren Mine, An outcrop near this unproductive mine contained small masses of white to pink baryte in an impure hematite. This was in the post-ore Glance conglomerate.

BAYLDONITE $Cu_3PbO\ (AsO_3OH)_2(OH)_2$:

A secondary mineral of limited distribution within the district. The lead, copper/lead and lead/zinc orebodies associated with the silica breccias in both the Southwest and Shattuck mine areas were a source of a number of unusual lead minerals including bayldonite.

The minerals associated with bayldonite are:

calcite
mimetite
hemimorphite
galena
malachite
hematite
anglesite
descloizite

OCCURRENCES:

Specimen number 21,475 in the collection of the American Museum of Natural History is from an unrecorded mine in the district, but the Southwest mine is probably the source. The specimen consists of calcite crystals coated by druses of yellow-green bayldonite.

Kentucky tunnel; The dump at this prospect on the south side of Escabrosa ridge contained a number of pieces of oxidizing galena in vuggy quartz. In this material bayldonite occurred as tiny green crystals associated with mimetite, descloizite, hemimorphite, anglesite, as well as quartz and galena.

Shattuck Mine, *200 level; Tiny* yellow-green crystals of bayldonite occurred here with malachite and mimetite on hematite.

Southwest Mine, *6th level; Specimens* found on the dumps of this level contained bayldonite as spongy linings of a resinous, greenish-yellow material in small voids in a silica breccia with minor colorless calcite.

BAYLEYITE $Mg_2(UO_2)(CO_3)_3\cdot 18H_2O$:

This secondary mineral is most uncommon in the district, having been recognized at a single locality. This only locality for bayleyite was in a fault zone that was highly radioactive. Examination of the zone for possible sources of the radioactivity yielded only bayleyite.

The minerals found with bayleyite at its single occurrence were:

calcite
gypsum
epsomite

OCCURRENCES:

Cole Mine, *800 level;* Bayleyite occurred as patches of bright yellow crusts on a limestone fault gouge with minor calcite. Both gypsum and minor epsomite were also noted in the fault zone but were not directly on any of the specimens collected.

BEAVERITE-Cu $Pb(^{+},Fe_{2}^{3+} Cu)(SO_{4})_{2}(OH)_{6}$:

This secondary mineral is moderately abundant at the one recognized locality. The lead, lead/copper, and lead/zinc deposits associated with the silica breccias in the Southwest mine area produced a number of unusual minerals including beaverite-Cu. Given the nondescript appearance of beaverite-Cu, it is probable that it has been confused with other similarly appearing lead or copper minerals.

The minerals associated with beaverite-Cu in the district are:

plumbojarosite
calcite
quartz
malachite

OCCURRENCES:

Southwest Mine, *6th level;* Beaverite-Cu was plentiful as earthy, yellow masses intimately associated with plumbojarosite, which it closely resembles, in a silica breccia-hosted lead/copper orebody on this level. Abundant calcite and modest amounts of malachite were associated with the beaverite-Cu /plumbojarosite mixture.

BEUDANTITE $PbFe_{3}^{3+}(As_{0.5}S_{0.5}O_{4})_{2} OH)_{6}$:

This is a locally abundant secondary mineral with limited distribution within the district. The lead, lead/zinc, and copper/lead orebodies associated with the silica breccias in the Southwest mine area were the source of several unusual mineral species including beudantite.

The other species associated with beudantite are:

goethite
quartz
hematite
calcite
plumbojarosite
mimetite

OCCURRENCES:

Atlanta Claim, A small, un-named surface prospect from the very early days on this claim had tiny amounts of weathered beudantite on goethite.

Crazy Horse Pete Mine, Minor amounts of beudantite were noted in vugs in goethite chunks on the dump of this small lessor operation.

Kentucky Tunnel; Specimens from the dump of this nonproductive prospect contained small amounts of beudantite as tiny, apple green crystals on quartz with mimetite.

Southwest Mine, *3rd level;* Beudantite was common on this level in the lead stopes near the Southwest shaft as yellow-brown, 0.5 mm, pseudocubic crystals on goethite and compact specular hematite with minor calcite.

6th level; This mineral was abundant in a lead stope that surfaced in Hendricks Gulch as tiny apple green, pseudocubic crystals with plumbojarosite and calcite in a calcite-cemented breccia. Also, from another part of this level as a drusy crust of brownish crystals on hematite-colored, silica-breccia fragments.

BIANCHITE $ZnSO_4 \cdot 6H_2O$:

This mineral has only been recognized in post-mining occurrences in the district. As with most such minerals, it is probable that bianchite also formed as part of the supergene process but was not noted. Typically, bianchite formed as a white to yellowish-white efflorescence on mine openings or on broken zinc sulfide ores left underground.

The species associated with bianchite are:

sphalerite
pyrite
goslarite
melanterite

OCCURRENCES:

Campbell Mine, *2000 level;* Bianchite was common in one stope on this level as a white crust on low-grade, broken, iron-rich sphalerite along with goslarite. Pyrite and minor chalcocite were associated with the sphalerite.

Junction Mine, *1600 level;* A small number of white to colorless 1 cm stalactites of bianchite were forming in the mine openings below a long-abandoned zinc stope on this level. Pyrite was associated with the remaining sphalerite in the stope.

Southwest Mine, *6th level;* Minor amounts of bianchite formed along the high pyrite fringes of a small, bedding-controlled sphalerite replacement deposit in a crosscut as pale yellowish material. Some melanterite had formed in this fringe area as well.

BÍLINITE $Fe^{2+}Fe_2^{3+}(SO_4)_4 \cdot 22H_2O$:

This uncommon species has only been recognized in post-mining occurrences. Typically, bílinite was found as a fibrous crust on corroded, decomposing, massive pyrite. Other than pyrite, no additional species were noted with bílinite. This lack of other associated species, particularly other sulfates, is somewhat unusual.

OCCURRENCES:

Higgins Mine, *100 level - 200 level;* A sulfide stope near the steeply inclined interior shaft of this mine extended from well above the 100 level and almost to the 200 level and contained abundant massive pyrite that was in various stages of decomposition. Locally, a thick, gummy botryoidal crust of white to tan, fibrous bílinite was found in patches to 10 cm on and forming at the expense of the pyrite.

BINDHEIMITE (?) $Pb_2Sb_2O_6(O,OH)$:

The validity of bindheimite as a valid species is questioned by Back (2018). It has been included here for completeness; to allow for the work of previous studies to remain available. This secondary mineral is of very limited distribution in the district. Typically found in small amounts with other supergene minerals.

The species associated with bindheimite are:

chalcocite
malachite

OCCURRENCES:

Campbell Mine, *1800 level;* A few specimens of chalcocite with small amounts of malachite collected in the very early 1970's had scattered whitish, wart-like bindheimite on both the chalcocite and malachite.

"BIOTITE" $K(Mg,Fe^{2+})_3(Al,Fe^{3+})SiO_{10}(OH,F)_2$:

Biotite is now a series name used to describe any of the series of dark micas including phlogopite, siderophyllite and eastonite, and is therefore no longer to be regarded as a species name. It is included here for the sake of completeness only, as the exact member of the series is typically not noted in the early papers referenced herein.

This common rock-forming mineral is widely distributed in the intrusive units throughout the district. "Biotite" is an important constituent of the porphyry intrusive units that are part of the Sacramento Stock Complex.

Typically, "biotite" occurred in the porphyries as euhedral crystals to several millimeters across. In the Juniper Flat granite, "biotite" occurs in small amounts as tiny crystals enclosed in quartz or rarely in feldspars (Ransome, 1904).

In the porphyry units of the Sacramento Stock complex, most of the "biotite" has been altered to varying degrees. This alteration ranges from bleaching to complete replacement. Muscovite (sericite), chlorite, epidote and kaolinite have all been noted replacing "biotite" (Schwartz, 1958).

The species most commonly associated with "biotite" are:

quartz
muscovite
orthoclase
microcline
plagioclase

OCCURRENCES:

The occurrence of "biotite" is largely the same as the distribution of the intrusive units noted above.

“BISBEEITE” $CuSiO_3$ H_2O:

While this is not considered a valid species, the available information is still provided inasmuch as Bisbee is the type locality for this secondary mineral of questionable validity (Oosterwyck-Gastuche, 1967). *The information provided herein is to be considered for reference only, allowing for the work of earlier researches to remain available.*

It is worth noting that the work recently carried out which, once again, raised the issue of validity was done on material from localities other than Bisbee, a practice that is unwise. It is notable that Laurent and Pierrot (1962) investigated the type material from Bisbee along with material from several African localities and it was determined to be a valid, distinct species.

As with several of the copper silicates found in the district, bisbeeite is from the silica breccias in the Shattuck mine area. This is the only known locality for bisbeeite in the district. Even here, it was a very rare mineral with only a small number of specimens recovered.

Bisbeeite occurred as an alteration of shattuckite. It was found as pale blue to bluish-white, acicular crystals in vugs in both the breccia and shattuckite.

The species associated with bisbeeite are:

shattuckite
quartz
malachite
hematite

Pseudomorphs of chrysocolla after bisbeeite are suspected, but unrecognizable largely because bisbeeite occurs as a pseudomorph after shattuckite and, as such, any pseudomorph after bisbeeite would appear to be after shattuckite or even the malachite originally replaced by the shattuckite.

OCCURRENCES:

Shattuck Mine, *200 level*, *174 prospect;* Bisbeeite was described from here as bluish-white pseudomorphs after acicular shattuckite crystals (Schaller, 1915).

BISMITE Bi_2O_3:

This is a supergene mineral formed by the alteration of other bismuth minerals, particularly elemental bismuth. Typically, bismite was found in small amounts in the upper portions of the Campbell orebody as thin rinds on or replacements of hypogene bismuth minerals.

The species associated with bismite (Alan Criddle, personal communication, 1992) are:

wittichenite
copper
chalcopyrite
bismuth
cuprite
galena
sphalerite
covellite
acanthite
chalcocite
silver
stromeyerite

bornite
jalpaite
djurleite
hematite

OCCURRENCES:

Campbell Mine, *1600 level;* Small amounts of bismite were recognized replacing bismuth minerals in samples from here that were in a complex mineral assemblage hosted by a siliceous hematite (Alan Criddle, personal communication, 1992).

BISMUTH Bi:

Elemental bismuth is a hypogene mineral of apparent very limited distribution within the district. It occurred in small amounts as part of a complex bismuth/silver-rich mineral assemblage. The matrix was silicified hematite.

The species associated with bismuth are (Alan Criddle, personal communication, 1992):

wittichenite
spionkopite
silver
galena
digenite
bismite
djurleite
bismuthinite
bornite
acanthite
sphalerite
chalcopyrite
gold
stromeyerite
chalcocite
covellite
emplectite
jalpaite

It is worth noting that the associated chalcocite and wittichenite contained 6% and 7% silver respectively.

OCCURRENCES:

Campbell Mine, *1600 level;* Bismuth was noted in samples from here as silver-white blebs to 5 mm in a bismuth/silver-rich, complex mineral assemblage (Alan Criddle, personal communication, 1992).

BISMUTHINITE Bi_2S_3:

A hypogene mineral that was found in a single mine and then only in small amounts. Bismuthinite occurred as microcrystalline inclusions in a very complex bismuth/silver rich mineral assemblage. The matrix was a silicified hematite (Alan Criddle, personal communication, 1992).

The species associated with bismuthinite are (Alan Criddle, personal communication, 1992):

wittichenite
djurleite
spionkopite
galena
bismite
chalcopyrite
bismuth
bornite
sphalerite
covellite
gold
stromeyerite
chalcocite
silver
emplectite
jalpaite

digenite	acanthite

It is worth noting that the associated chalcocite and wittichenite contained 6% and 7% silver respectively.

OCCURRENCES:

Campbell Mine, *1600 level;* Bismuthinite was noted in small amounts in a complex mineral assemblage on this level (Alan Criddle, personal communication, 1992).

BISMUTITE $(BiO)_2CO_3$:

This supergene mineral has been found in limited amounts at a single locality. Bismutite was noted as a replacement of aikinite that was part of a complex mineral assemblage (Sid Williams, personal communication, 1992).

The species associated with bismutite are (Sid Williams, personal communication, 1992):

quartz	hematite	aikinite

Bismutite was noted by Sid Williams (personal communication, 1992) as pseudomorphs after prismatic aikinite crystals.

OCCURRENCES:

Campbell Mine, Bismutite was found in specimens from here in small amounts as pseudomorphs after prismatic crystals of aikinite in a quartz-hematite matrix by Sid Williams (personal communication, 1992).

BIXBYITE $(Mn^{3+},Fe^{3+})_2O_3$:

This species is considered to be of hypogene origin by Hewett and Fleischer (1960). In the Warren district, bixbyite occurred in small amounts at a single locality. It is probable that bixbyite is more abundant and more widely distributed than the only recognized locality would indicate, given the rough similarity of bixbyite to other species.

OCCURRENCES:

Shattuck Mine, 500 *level;* Bixbyite was found on this level in small amounts as nearly pure, coarse-grained masses (Sid Williams, personal communication, 1981).

BOGDANOVITE $(Au,Te,Pb)_3(Cu,Fe)$:

The genesis of this rare mineral is somewhat uncertain at the single occurrence in the district. At the type locality, bogdanovite was of supergene origin (Spiridonov and Chvileva, 1979), however, the Bisbee occurrence appears to be hypogene. Here, bogdanovite was found as clusters of small grains in pyrite crystals (Sid Williams, personal communication, 1987).

The species associated with bogdanovite in the district are:

- chalcopyrite
- pyrite
- quartz

OCCURRENCES:

Campbell Mine, This species was noted from here by Sid Williams (personal communication, 1987) as clusters of small, bronze-colored grains in pyrite crystals with chalcopyrite and quartz.

BÖHMITE AlO(OH):

The occurrences of böhmite in the Warren district appear to be of supergene origin. It was a constituent of the abundant, widespread and often complex mixtures of supergene clays and clay-like minerals, particularly those in and adjacent to the Sacramento Stock Complex/meta-limestone contact zone.

It was formed by the reaction of the altered limestones, intrusive dikes, and the stock, with the supergene-derived fluids (Ransome, 1904). Böhmite was also found associated with the supergene ores in the limestone replacement deposits as a constituent of the low-grade cores. Usually, it was found as impure masses that ranged from whitish to yellowish to brown to reddish. Often, it was associated with finely-divided hematite and/or goethite that served as coloring agents. Disseminated böhmite was also common as minute blebs in mixed, supergene clays and clay-like minerals. These too were invariably iron stained by the ubiquitous oxides.

The species associated with böhmite are:

- gibbsite
- hematite
- cuprite
- kaolinite
- illite
- azurite
- halloysite
- goethite
- malachite
- diopside
- copper
- dickite

OCCURRENCES: Given the wide distribution and nondescript appearance of böhmite, only a few of the more important localities will be noted.

Czar Mine, Portions of many of the large, rich, secondary orebodies in this mine contained abundant böhmite as a constituent of the barren “ledge matter” of Douglas (1900).

Lavender Pit Mine, *Holbrook Extension;* Large amounts of böhmite occurred in this part of the pit as a supergene alteration product of the meta-limestones as well as portions of the stock. Here, it was found as part of the mineralogically complex, alteration clays associated with the supergene ores that were so abundant in this area.

BOOTHITE $CuSO_4 \cdot 7H_2O$:

Boothite has been recognized in the district in a single post-mining occurrence with other post-mining minerals. As with the majority of post-mining species found here, there is little doubt that it occurred as part of the supergene process but was not recognized. Also, because of its strong similarity to other post-mining minerals, particularly cuprian-melanterite and chalcanthite, it is reasonable to assume that boothite was not recognized and is more common than the single occurrence would indicate.

At this one locality, boothite formed as the result of decomposition of copper-bearing pyrite in a humid environment. It was most commonly found as light blue, silky, fibrous to acicular tufts with copiapite and melanterite. Granular masses of small crystals of boothite also occurred in this same area and were also associated with melanterite and copiapite.

The species associated with boothite are:

pyrite	melanterite	copiapite	chalcanthite

OCCURRENCES:

Southwest Mine, *7th level;* A stope on this level, which had been developed in massive chalcopyrite/pyrite and was near the Wolverine interior shaft, contained small amounts of boothite. Here it occurred as intergrown masses of centimeter to three-centimeter-wide clusters of radiating, acicular crystals with a fibrous center. It also occurred as small, granular masses composed of 1 to 2 mm crystals.

BORNITE Cu_5FeS_4:

This was one of the most abundant and economically important ore minerals in the district. It was widely distributed, often in very substantial amounts, in all of the productive mines of the district. Bornite was largely formed under hypogene conditions, but supergene bornite was not altogether uncommon.

Hypogene bornite was almost always found as massive material of varying purity mixed with other sulfides, typically chalcocite, pyrite and chalcopyrite. Large masses of pure bornite were rare, and even in hand-sized pieces pure specimens were uncommon. However, sulfide masses where bornite was the dominant ore mineral were thousands to tens of thousands of tons in size. Massive, hypogene bornite occurred from extremely fine-grained material to very coarse, even subhedral to euhedral masses. Less commonly, it was found as veinlets and infillings in shattered, massive pyrite as well as replacement rinds on and in fractured pyrite crystals.

The presence of supergene bornite at Bisbee has been noted in several separate studies -- Graton and Murdoch (1913), Bonillas, et al. (1916), as well as Schwartz and Park (1932). It appears to have been restricted to the interface of the supergene copper sulfide alteration with the hypogene copper sulfides and was considered a transitional phase (Bonillas, et al. 1916). Supergene alteration of chalcopyrite is believed by Graton and Murdoch (1913) as well as Schwartz and Park (1932) to have been the source of this type of bornite.

Supergene bornite is often very difficult, if not impossible, to distinguish from the hypogene material. It was typically noted replacing chalcopyrite and mixed with other, apparently unaltered, hypogene sulfides or other supergene sulfides such as chalcocite. Like its hypogene counterpart, supergene bornite textures range from very fine-grained to a coarse material, often reflecting the replaced mineral. With continued supergene activity, bornite alters to chalcocite.

The species associated with bornite include most of the hypogene and early supergene species found in the district. Among the more common are:

- chalcocite
- quartz
- galena
- chalcopyrite
- sphalerite
- pyrite
- hematite
- tennantite
- magnetite
- tetrahedrite

OCCURRENCES: Because of the widespread distribution and the typical lack of distinction for bornite throughout the district, only a few notable localities are listed below.

Campbell Mine, The Campbell orebody from the 1600 level to below the 2000 level contained incredible masses of bornite, of hypogene and to a much lesser degree supergene origin and, mixed with chalcocite, chalcopyrite, and pyrite. Bornite was also found in important quantities throughout most of this mine.
2566 level; Porous, often-granular masses of usually poorly-formed crystals were found along the edge of a massive pyrite body on this level. Several specimens of modified cubic crystals to 8 mm were recovered from this occurrence.

Cole Mine, *1400 level, 39-A stope;* This was the locality for fine dodecahedral bornite crystals to 6 mm on a massive pyrite/bornite matrix. A small number of these specimens contained elemental gold with a very few having the gold oriented on the bornite crystal faces.

Junction Mine, The most attractive massive bornite in the district came from this mine. Several stopes on different levels produced highly colorful, coarse-grained bornite with centimeter-sized inclusions of chalcopyrite. Supergene bornite was noted from this mine (Graton and Murdoch, 1913).

BOTALLACKITE $Cu_2^{2+}Cl(OH)_3$:

This is a rare mineral of secondary origin. Only a very small number of specimens from Bisbee are known.

As is typical of the majority of the copper-chlorine minerals from the district, botallackite is found associated with cuprite. This is probably because of availability of both copper and chlorine through the alteration of nantokite, which appears to have occurred only with cuprite. Botallackite occurs here as minute, pale blue blades in voids in cuprite.

The minerals associated with botallackite are:

atacamite
paratacamite
cuprite
clinoatacamite

OCCURRENCES:

Southwest Mine, *5th level*, *14 stope;* Tiny, pale blue to blue-green, tabular crystals of botallackite were found in voids in massive cuprite at this locality as were small patches of drusy crust of botallackite on fractures, also in cuprite. It was also associated with atacamite, paratacamite and clinoatacamite.

BOTRYOGEN $MgFe^{3+}(SO_4)_2(OH)_3$:

This mineral was found both in supergene and post-mining occurrences, usually in small amounts. It is reasonable to assume that botryogen was more common, particularly as a secondary mineral, than the limited, recognized occurrences would indicate.

In post-mining occurrences, botryogen formed as a crust on pyritic limestone along with other similar sulfates. In the supergene occurrence, it formed as a thin, spotty crust along fractures in non-reactive rocks with other iron sulfates.

The species associated with botryogen are:

copiapite
rhomboclase
pyrite
coquimbite
quartz
jarosite

OCCURRENCES:

Campbell Mine, *1600 level;* Attractive specimens of orange botryogen coating rhomboclase and coquimbite were found as a part of a multi-mineral crust in a high pyrite area on this level.
2200 level; This species was locally abundant on this level as a post-mining mineral occurring as red-orange to orange, crystalline crusts associated with other sulfates, particularly copiapite, on pyritic limestone.

Higgins Mine, *Tunnel level;* Botryogen was common in the sulfide area of this level as a thin, orange, spotty crust on silica-breccia fragments and lining fractures in these fragments. Copiapite and abundant jarosite were associated with botryogen at this locality.

BRAUNITE $Mn^{2+}Mn_6^{3+}SiO_{12}$:

This supergene mineral was abundant and widely distributed throughout the district as the principal ore mineral in many of the near-surface manganese deposits mined during the 1916-1918 period.

In these deposits, braunite occurred as large, compact, but impure masses, often many tens of tons in weight. Generally, in these occurrences, braunite was hard and compact, often with a granular texture and associated with other secondary manganese oxides. Distinct pyramidal crystals were common, particularly in voids and near the contact with the hosting limestones.

Hewett and Rove (1930) and Hewett and Fleischer (1960) believe that the braunite in the near-surface deposits at Bisbee was derived from the supergene alteration of alabandite as well as minor rhodochrosite. However, no residual alabandite or rhodochrosite has been noted in any of the deposits containing braunite. Rasor (1939) in his study of similar deposits near Tombstone, did not consider this a problem given the readiness of alabandite to oxidize. The authors are not completely convinced that supergene altered alabandite was the source of braunite at any of the manganese deposits, as there are none of the typical features common to sulfide oxidation. However, an alternate source is not obvious either.

The species associated with braunite are:

calcite
groutite
neltnerite
goethite
manganite
baryte
braunite II
malachite
conichalcite
hematite
tilasite
mottramite
pyrolusite
hausmannite
romanèchite

OCCURRENCES: Because of the widespread nature of braunite in the near surface deposits, only those areas of special interest are noted below.

Briggs Mine, *1300 level;* Braunite was noted from here by Tenney (1913) as hard, compact, granular masses with "psilomelane."

Higgins Mine, Twilight *claim;* Immense amounts of massive, granular braunite were mined from this area. A small number of crystallized specimens with 3 to 5 mm pyramidal forms were found at the limestone contact. Baryte, conichalcite, as well as minor mottramite were associated with braunite at this locality, as were several manganese and iron oxides.

Number 4 claim; This relatively large manganese mine contained substantial amounts of braunite as hard, compact masses. Small pyramidal crystals were occasionally found in vugs. Hausmannite, pyrolusite and romanèchite were associated with braunite at this locality.

White Tail Deer Mine, A surface outcrop very near this mine produced braunite crystals to 2.5 cm with cores of braunite II. These were associated with minor neltnerite (Sid Williams, personal communication, 1987).

BRAUNITE II $Ca(Mn,Fe)_{14}^{3+}SiO_{24}$: **(?)**

The status of braunite II as a distinct and valid species is in question as of this writing. Depending on the reference, braunite-II is either compositionally the same as braunite but with a doubled "c" cell parameter or a calcian-ferrian variety (16.3% Fe_2O_3, 4.3% CaO) of braunite. The information provided herein is to be considered for reference only, allowing for the work of earlier researches to remain available.

This supergene mineral was undoubtedly more abundant and widely distributed than the single locality would indicate. Because this is a recently described species, none of the early workers studying the manganese deposits would have noted its presence.

The mode of occurrence for braunite II was as cores of braunite crystals with neltnerite. Anthony, et al. (1995) suggests that these three species are independent and stable phases.

The species associated with braunite II are (Sid Williams, personal communication, 1987):

braunite
neltnerite
cryptomelane
coronadite
hübnerite

OCCURRENCES:

White Tail Deer Mine, A surface outcrop near this mine produced braunite II as cores of large (2.5 cm) braunite crystals. Tiny grains of coronadite and hübnerite were noted as inclusions in the braunite II (Sid Williams, personal communication, 1987).

BROCHANTITE $Cu_4^{2+}(SO_4)(OH)_6$:

This was a widely distributed, often abundant supergene mineral, so much so that it served as an important ore. Bisbee has produced the finest known examples of this relatively common mineral.

Post-mining brochantite was frequently found as a soft, often pulverulent, coating on copper sulfide fragments, notably bornite, left underground such as material that fell from mine cars during transport.

Because of the common nature of this mineral, a number of other supergene and some hypogene species are associated with brochantite. The more common or important are:

chalcocite
azurite
chalcopyrite
goethite
bornite
hematite
malachite
cyanotrichite
chlorargyrite
calcite
antlerite
pyrolusite
connellite
bromargyrite
silver
cuprite
copper
covellite
quartz
jarosite

Malachite is a very common alteration product of brochantite. Faithful pseudomorphs of malachite after brochantite up to 5 cm were not rare. Other replacements of brochantite are, in reality, pseudomorphs after the malachite that originally replaced the brochantite. Both goethite and chrysocolla have been recognized as pseudomorphs of this type.

Brochantite, as previously noted, is often found replacing copper-bearing sulfides. The more common are chalcocite, covellite, and bornite, but no pseudomorphs of brochantite after any of these minerals have been noted.

OCCURRENCES:

Czar Mine, Several locations in this mine produced brochantite as compact masses of course, radiating 5 cm crystals with minor ocherous hematite. Brochantite was also found as discrete, irregular masses of coarse “jackstraw” crystals in soft iron/manganese oxides. Also, from here are examples of brochantite as large spongy masses of tiny, medium green crystals and as partial replacements of massive chalcocite. Nest of acicular brochantite crystals lining, if not filling, voids in massive cuprite were common here.

Holbrook Mine, Prismatic crystals to 4 mm with cuprite and malachite came from this mine. Also, found here as acicular to prismatic centimeter-long crystals, often completely filling voids in massive hematite/goethite and associated with later azurite and malachite.

Irish Mag Mine, Specimens from here were recovered with the brochantite as clusters of prismatic crystals to 8 mm on hematite with acicular malachite.
850 level; Noted from this level and associated with cuprite, copper, and malachite by Ransome (1904).

Junction Mine, Brochantite was common in the upper levels of this mine as a soft, earthy to compact, fibrous or drusy material, often lining fractures in massive copper sulfides. This brochantite was formed as partial to complete replacement of chalcocite.

Juniper Flat: Brochantite was recognized here as a minor accessory mineral in some of the mineralized gold bearing quartz veins with atacamite, paratacamite, and malachite (Rob Bowell, personal communication 2004).

Lavender Pit Mine, *Holbrook Extension;* This area of the pit contained small amounts as 4 mm prismatic crystals on a thin crust of compact acicular brochantite that is in turn on a matrix of hard, compact goethite associated with cyanotrichite. Also found here as 5 mm tabular, pseudohexagonal crystals with malachite on goethite and in voids in goethite as loose, 5 mm spheroids composed of prismatic crystals in subparallel orientation.

Sacramento Pit Mine, *5420 level;* Tenney (1913) noted brochantite, with minor chalcocite, as dark green to green-black crystals on fractures in the ore zone. This was almost certainly brochantite replacing chalcocite.

Shattuck Mine, This relatively small mine produced most of the Bisbee brochantite now found in collections. It occurred as lustrous, jackstraw masses of large prismatic crystal that are undoubtedly the finest examples of this mineral ever found. Additionally, brochantite came from here as needle-like and slender to stout, striated, prismatic crystals, occasionally associated with tabular antlerite (Palache1939a, 1939b). Also, found here as free or loosely attached tabular crystals in voids within bunches of prismatic brochantite crystals.
300 level; A great many specimens of brochantite came from this level as intergrown "jackstraw" masses, often of large size, that were composed of superb, brilliant crystals to 8 cm x 6 mm x 6 mm. These specimens are usually associated with varying amounts of jarosite, specular hematite and small, white to brown siliceous fragments. Hundreds of pieces of this material were saved during mining.

Southwest Mine, *4th level;* Minor brochantite occurred here as inclusions of compact, fibrous material in massive cuprite often rimming connellite. Also, spherical aggregates to several centimeters composed of small prismatic crystals came from this level. Here, too, it is typically associated with specular hematite.

Uncle Sam Mine, "*N" level;* An unusual occurrence for brochantite was at this locality where it was found as large volumes of a sand-like material composed of 0.5 mm or smaller, free-floating crystals mixed with loose specular hematite and some quartz. Also, from this mine are "jackstraw" crystal masses that are essentially indistinguishable from those produced from the more prolific, adjacent Shattuck mine. However, more of the brochantite from here was altered to malachite to varying degrees including complete replacement.

BROMARGYRITE AgBr:

A secondary mineral of apparent limited distribution, bromargyrite was almost certainly more common in this silver-rich district than the limited recognized occurrences would suggest. At the Shattuck occurrence, it was locally abundant, so much so that it constituted an important part of the ore value when this mine was reopened in a search for precious metals in the late 1970s.

The species found associated with bromargyrite are:

silver
quartz
hematite
plattnerite
cuprite
malachite
murdochite
cerussite

Bromargyrite has been recognized as pseudomorphs after silver.

OCCURRENCES:

Cole Mine, *700 level, 99 stope;* A limited number of specimens were found where bromargyrite occurred as 1 to 2 mm, sharp, lemon-yellow, jewel-like crystals on brilliant 2 mm to 3 mm cuprite crystals in small vugs within massive cuprite. Minor malachite was associated with these specimens.

Shattuck Mine, *300 level;* Bromargyrite was an important economic mineral in the "lead cave" orebody on this level, as yellow, waxy crusts on rock fragments with the cerussite ores. At the margin of this stope, it was found as partial to complete replacements of silver, including distinct pseudomorphs, on siliceous fragments and as 1 mm, well-formed, modified cubic crystals. The species found with bromargyrite here were tiny crystals of specular hematite as well as minor plattnerite and murdochite. In all cases, the material from here was greenish-yellow in color.

BROOKITE TiO_2:

This hypogene species is only referenced as occurring here by Anthony, et al. (1995) where it is listed in the table of Rock-forming, Gangue, and Alteration minerals at Bisbee.

BRUCITE $Mg(OH)_2$:

This hydrothermal alteration species has been noted in a single locality within the district. Brucite was recognized in very small amounts as tiny tabular crystals that were formed as a result of the alteration of Martin limestone.

The species associated with brucite are:

quartz
kaolinite
goethite
copper

OCCURRENCES:

Czar Mine, *300 level, 93 drift;* Tenney (1913) noted tiny, pale green crystals of brucite with chalcedonic quartz, kaolinite, and elemental copper in samples from here.

BUTTGENBACHITE $Cu_{19}Cl_4(NO_3)_2(OH)_{32}\cdot 2H_2O$:

This secondary species is apparently uncommon in the district; however, it will prove be more common than the few confirmed occurrences would suggest. It was first identified by Hibbs, et al. (2002, 2003) in a specimen from the Cole Mine, which previously was believed to be connellite. Subsequent investigation by others has identified it in specimens from different mines and there is good reason to believe that more will be recognized in specimens from here. A point of concern for many is "what is the source of nitrogen at the depths where some of the buttgenbachite occurs. Nitrogen and/or nitrates are uncommon in these types of deposits, an organic sources seems probable, but at these depths; perhaps the bacteria that is necessary for sulfide oxidation is the source. A question that needs much more study.

The occurrence of buttgenbachite is very similar to connellite in that it appears to always be associated with cuprite, as are so many of the rare copper/chlorine species. It is one of only a few nitrate-containing minerals recognized at Bisbee and occurs here as azure-blue clusters of small radiating crystals to 5 mm in massive cuprite that are visually undisguisable from connellite.

At Bisbee, the species associated with buttgenbachite are:

cuprite
tenorite
malachite
chrysocolla
goethite
hematite
brochantite

OCCURRENCES:

Cole Mine, Buttgenbachite was identified in a sample from this mine, which had previously been identified as connellite (Hibbs, et al. 2002, 2003).

Copper Queen Mine, *Meyer's Tunnel level;* This area of the Copper Queen was mined in the 1930s by lessees, but minor amounts of cuprite were left behind, in which were small scattered nest of small, acicular buttgenbachite crystals. Murdochite was associated with this cuprite as a late-stage deposit on the massive cuprite as was calcite.

Czar Mine, A single specimen of massive cuprite from an undocumented level in this mine contained buttgenbachite in very small amounts as tight clusters of radiating crystals.

Lowell Mine; Several specimens labeled as connellite from this mine have been shown to be buttgenbachite. It occurred as radiating, bright blue masses in massive cuprite with brochantite, tenorite and malachite.

C

CALAVERITE $AuTe_2$:

This hypogene species has only been recognized in small amounts at a single locality. Here, it was a part of a tin-rich, complex mineral assemblage in sphalerite, galena, and chalcopyrite ores. Calaverite occurred as microscopic, compound inclusions in these ore minerals (Alan Criddle, personal communication, 1992).

The species associated with calaverite are (Alan Criddle, personal communication, 1992):

sphalerite
tetrahedrite
colusite
sylvanite
gold
galena
bornite
Mawsonite
krennerite
hematite
chalcopyrite
covellite
kiddcreekite
petzite
rutile
tennantite
stannoidite
altaite
kostovite
pyrite

Sid Williams (personal communication, 1987) noted these additional species with calaverite:

rhodostannite	melonite	volynskite

OCCURRENCES:

Campbell Mine, *2200 level;* Calaverite was noted in specimens from this level by Sid Williams (personal communication, 1987) in a pyrite-sphalerite matrix as a microscopic phase with rhodostannite, melonite, volynskite, galena, and altaite.
2300 level, 124 stope; Alan Criddle observed calaverite in samples from this location where it occurred as rare inclusions in the sulfide ore minerals as a part of a complex, late-stage mineralizing event (Alan Criddle, personal communication, 1992).

CALCITE $CaCO_3$:

In its various forms, calcite is one of the most abundant minerals within the district. Obviously, it is most common as the principal constituent of the limestones that are so prolific throughout the area. Calcite is also common as veins of hydrothermal origin that cut all rock types, most commonly the ore-hosting limestones. These veins occasionally contained crystal-filled pockets. Alteration introduced substantial amounts of manganese, which along with bleaching and recrystallization of some of the limestones, created abundant manganiferous calcite (Schwartz, 1959). Here, too, pockets were occasionally found with lightly tinted pinkish crystals.

However, it is the calcite that accompanied the widespread supergene activity for which Bisbee is so noted. The most common form is as calcite speleothems in the many caves formed by the oxidation of the sulfide replacement bodies in the hosting limestones. One very distinctive feature of some of the calcite from Bisbee's' caves was coloration. The salts of copper and iron individually or, occasionally together, tinted many of the speleothems (Ransome, 1904a).

But the calcite for which Bisbee is best known was that found within the oxidized orebodies. Its frequent association with the usually colorful supergene copper and copper/zinc minerals is the reason for its fame. Malachite is the most common associate with this type of calcite, but the reality is that there not a great many of these classics in the world. The most spectacular specimens of this association are a result of the inclusion of or simultaneous deposition of substantial amounts of acicular malachite within otherwise colorless calcite. All degrees of green coloration resulted from this type of growth with some specimens only partially colored.

Chalcotrichite, the acicular variety of cuprite, was also occasionally included in calcite as it grew. This gave a striking, bright red calcite, often mixed with colorless crystals. These are far less common than the malachite colored specimens. Also, aurichalcite was similarly included in calcite but these are rare at Bisbee. And too, the calcite with included aurichalcite was typically less transparent, resulting in a less pleasing effect.

A great many calcites were associated with the ores that were colored by iron and manganese oxides, giving muted shades of red-browns to browns to black-brown. This coloration resulted from the inclusion of the oxide or, less commonly, a thin veneer of one of these oxides on otherwise colorless calcite followed by a later generation of calcite.

Fluorescence was a feature common to much of Bisbee's calcite. The often-intense degree of fluorescence of this material has not been widely recognized. Green, red, and red-orange are the colors most often seen from fluorescent material.

Post-mining calcite was also common in the majority of the mines. Small stalactites and thin flowstone coatings occurred in many of the workings. Thick, travertine-like calcite formed in many of the ditches and wooden flumes used to channel the often-heavy water flows in the eastern part of the district. This calcite was frequently tinted a light green to brown.

The vast majority of minerals, both primary and secondary, from the district are recognized as being associated with calcite.

Calcite has been recognized as pseudomorphs after aragonite. The following minerals have been noted as pseudomorphs after calcite:

goethite
siderite
hematite
malachite
copper
azurite
quartz
cerussite

OCCURRENCES:

Campbell Mine, *1600-1900 levels;* Colorless, often-complex crystals came from the oxidized portions of the Campbell orebody on these levels. The matrix was typically a somewhat spongy, siliceous goethite.
1800 level; A large pocket in a crosscut connecting the Campbell with both the Junction and Dallas mines produced numerous groups of translucent, white, tabular crystals that ranging from 5 to 10 cm across on a matrix of yellowish stained, somewhat granular quartz-rich, goethite matrix.
2200 level; East of the Campbell fault, a meter-wide watercourse was open for 20 meters in length and 10 meters in height; this was lined with amber to light tan scalenohedrons that were from 7 to 10 cm in size.
2566 level; A spectacular cave-like pocket some 26 meters above the level and adjacent to a lead-zinc stope contained large amounts of calcite as 1 cm, tabular, pseudohexagonal crystals. These were randomly oriented overgrowths on thin goethite stalactites, as coatings on boxwork plates, and as coverings on all of the walls, floor, and ceiling of the opening. Most of these were thinly coated by goethite and partially overgrown by a subsequent generation of calcite. These specimens are commonly highly fluorescent with a brilliant red to red-orange color. Also, from this level and near another lead-zinc stope came colorless to slightly manganiferous, modified, often twinned rhombohedrons to 7 cm, randomly scattered on a base of colorless 1 cm rhombohedrons. Additionally, from near this stope, calcite occurred as large plates of complex crystals, ranging from 2 to 5 cm, on a goethite-stained silica boxwork. The crystals range from nearly colorless to white but are often iridescent as a result of an almost imperceptibly thin coating of goethite. Workings on this level also produced calcite as colorless, slightly elongated rhombohedrons to complex crystals on a dark, porous goethite boxwork.

Unfortunately, in spite of the many hundreds of specimens collected from the several localities on the 2566 level, few are free of damage. Calcite was under-appreciated in general, and all too often little, if any care was given during collecting and even less care given to the specimens after collecting. Many ended up in gardens as decoration.

2700 level; The Denn sideline area on this level hosted a number of hydrothermal openings that were lined with complex calcite crystals. A thin veneer of goethite and, occasionally, a later generation of colorless calcite coated many of these specimens.

Cole Mine, *500 level;* A crosscut on this level near the Powell Shaft contained a pocket of calcite as groups of sharp, colorless scalenohedrons to 4 cm.

800 level; Calcite speleothems, including some green-tinted stalactites, were abundant in several oxidation caves on this level. Also, from this level came a number of specimens with small tabular crystals on thin malachite veneers on goethite.

1000 level; An unusual occurrence for calcite was on this level that consisted of small, equant, colorless calcite crystals over tiny, bright cuprite octahedrons with scattered azurite crystals on the calcite.

1200 level to 1400 level; A wide variety of forms and associations were produced from the orebody that was mined by the 26-J (1200 level), 26-K (1300 level) and 26-L (1400 level) stopes. Groups of tabular, colorless crystals to several centimeters came from the upper part of 26-J stope, many of which were partial overgrowths on aurichalcite, rosasite, and hemimorphite. The lower portions of this and the upper parts of 26-K yielded a number of specimens where calcite occurred as modified white rhombohedrons on spongy, malachite replacements of copper. Black rhombohedrons of calcite to 1 cm with malachite and tiny djurleite crystal came from this stope as well.

Copper Queen Mine, Several small oxidation caves were found in this mine during its short life, which contained speleothems tinted by copper and/or iron. Modified scalenohedrons with inclusions of fibrous malachite were not uncommon in this mine.

Open cut level to "B" level; Calcite was abundant in this part of the Copper Queen as noted by Wendt (1887a) and Douglas (1899 and 1900). For the most part, it occurred as colorless to white complex crystals lining the many voids in massive malachite. Stalactites of malachite in these openings were coated by calcite as well (Wendt, 1887b).

Czar Mine, A great many highly decorated caves were hit during the operation of this mine. A photograph of a very large example of one of these openings is in Douglas (1900). It is probable that the exceptional calcite group described by Hovey (1899) came from this mine, as similar examples were later found by the authors in the same breccia system, but higher, in the Southwest mine.

200 level; As small, colorless, complex crystals partially overgrowing spongy copper. The encased copper is typically bright. Rarely as 5 to 10 mm colorless crystals overgrown on copper that is altered to cuprite variety chalcotrichite, forming striking, brilliant red groups to 25 cm across.

300 level; As groups of unusual, complex crystals with individuals to 10 cm in length. These were colorless to pale amber in color. Also, from this level were copper- and iron-tinted stalactites up to 3 meters long and also as remarkable, pure white botryoidal masses.

400 level; Extraordinary, bright red, chalcotrichite colored crystals to one centimeter in cluster were found in a small stope, some 6 meters above the level. These are the best of this type from Bisbee. Also, this same stope yielded fine examples of copper both on and included within centimeter sized, complex crystals, with the included copper remaining bright while that not protected by the calcite were dark.

Dallas Mine, *1400 level;* As small, colorless crystals overgrown on bright copper.

Denn Mine, *1700 level;* Found in small amounts as clusters of elongated water-clear crystals on copper.

Holbrook Mine, Calcite was abundant in the many oxidation caves in this mine as well as in the orebodies.
100 level; A large oxidation cave produced a number of forms, including spike-like tan crystals to 10 cm, branching groups of tan to colorless rhombohedrons with included malachite fibers, and exceptionally intense copper-tinted stalactites and helictites.

Shattuck Mine, *200 level;* From a large oxidation cave as exceptional helictite groups to 25 cm and as copper/iron-colored stalactite to 3 meters. Also from this level as small handsome crystals with inclusions of coarse malachite crystals and spheroids of fibrous shattuckite.
300 level; As gray lustrous crystals that have inclusions of sandy cerussite.
700 level; A small cave at the margin of a massive hematite body contained clusters of highly colored, red-brown spiny crystals to 7 cm along one wall.

Southwest Mine, The many oxidation caves in this extensive mine produced a large number of specimens as did the porous silica breccias. Most of the calcite with inclusions of fibrous malachite specimens from Bisbee came from this mine.
4th level; As cream-colored tabular crystals on similarly colored botryoidal material. Also noted as copper-tinted stalactites containing a high percentage of malachite and helictites. Bateman, et al. (1914) noted that one large cave on this level contained a "frothy" calcite with flecks and fibrous crystals of malachite that the miners said grew after the cave was opened, something Bateman doubted. Recent examination of this cave by the authors (1997) showed that the calcite was actually being dissolved, thus, the "frothy" appearance, with the formerly encased malachite exposed.
5th level; Large groups of delicate lace-like crystals were found in a limestone collapse breccia, some of which were associated with aurichalcite. Also from this level as thin, curved, composite crystals to 10 cm sprinkled with colorless 5 mm tabular crystals. Several areas on this level were the source of fine examples of calcite with inclusions of fibrous malachite.
6th level; Several varieties of plumbian calcite came from the lead stopes on this level. Most were rough, brown to yellowish clusters of complex, 1 cm crystals. Less common were small groups of lustrous 5mm pseudohexagonal, tabular crystals on a crust of calcite covering aurichalcite. Another area produced branching clusters of colorless complex crystals as overgrowths on typical speleothems. Some of these contained scattered 0.5 mm plattnerite crystals as inclusions. Numerous specimens consisting of 2 cm white to tan rhombohedrons were found in many of the voids revealed by the collapse of the New Southwest orebody. Also, from this level were groups of red-brown to tan rhombohedral and /or scalenohedral crystals to 20 cm at the interface of a silica breccia and the Martin limestone.
7th level; Some of the most unusual calcites from the district were found just above this level in openings in the large silica breccias adjacent to the New Southwest orebody. These were

irregularly curved, coiled, and randomly twisted composite individuals. Typically, a pocket would contain one or two of these unusual individuals, while the rest of the calcite displaying normal forms. An irregularly alternating, stacking of positive and negative rhombohedral crystals may well explain these unusual forms. A small number of 2 cm black/brown scalenohedral crystals were found here as well.
Uncommonly large and lustrous examples of botryoidal forms were found in the area of the New Southwest orebody. The individual bulb-like forms were up to 7 cm with a satiny luster. Nearby, white saddle-shaped crystals to 5 cm with razor-sharp edges were found.

CALEDONITE $Pb_5Cu_2(CO_3)(SO_4)_3(OH)_6$

Caledonite is an uncommon supergene mineral in the Bisbee area. As is typical for this species, it formed as an alteration of galena.

The minerals recognized as being associated with caledonite are:

galena
cerussite
anglesite
brochantite

OCCURRENCES:

Southwest Mine, *6th level;* This species was found in specimens from this level as 0.25 mm transparent, blue-green, bladed crystals on galena with anglesite, cerussite, and brochantite.

CANFIELDITE Ag_8SnS_6:

This hydrothermal mineral is apparently of limited distribution in the district. It was found in one location as inclusions in pyrite by Sid Williams (personal communication, 1981).

The species associated with canfieldite are (Sid Williams personal communication, 1981):

pyrite
stannoidite
altaite

OCCURRENCES:

Campbell Mine, *2200 level;* Noted in specimens from here by Sid Williams (personal communication, 1981) as interstitial growths in pyrite with stannoidite and altaite.

CARBONATECYANOTRICHITE $Cu^{2+}_4Al_2(CO_3,SO_4)(OH)_{12}\ 2H_2O$:

This is a secondary mineral that is uncommon within the district.

The most typical occurrence of carbonate-cyanotrichite is as small tufts of pale blue, acicular crystals on azurite. In this case, it appears to have formed at the expense of the underlying azurite as the azurite crystals exhibit minor corrosion. The azurite was the likely source of copper and perhaps the carbonate as well. Both may have been remobilized by what were probably modest amounts of aluminum-bearing sulfate solutions.

Carbonate-cyanotrichite also occurred as tiny, radiating acicular crystals on copper. Here, too, the carbonate-cyanotrichite was formed at the expense of the earlier copper.

The minerals recognized as associating with carbonate-cyanotrichite are:

azurite
goethite
quartz
copper
antlerite

OCCURRENCES:

Holbrook Mine; Delicate pale blue, acicular crystals of carbonate-cyanotrichite were a patchy covering of azurite in boxwork form.

Lavender Pit Mine, *Holbrook Extension;* Tiny acicular crystals of carbonate-cyanotrichite on copper, along with minor antlerite on fracture planes, in mineralized siliceous breccia fragments, occurred in a section of this part of the pit.

CASSITERITE SnO_2:

This hydrothermal mineral is almost certainly far more common and more widely distributed than the few confirmed occurrences in the district would suggest. Cassiterite occurred in small amounts as tiny grains in the sulfide ores, often with other tin minerals. In at least one instance, cassiterite appears to have survived supergene alteration and remained as a relic in massive cuprite.

Schumer (2017) noted the replacement of cassiterite during the sulfidation of Sn and W to make the accessory sulfides of these phases (stannoidite, tungstenite, etc.) in place of earlier cassiterite and scheelite.

The species associated with cassiterite are (Alan Criddle, personal communication, 1992):

rutile
stannite
aikinite
petzite
kiddcreekite
roscoelite
quartz
bornite
magnetite
mawsonite
hessite
altaite
kësterite
sphalerite
wittichenite
pyrite
colusite
stützite
calaverite
covellite
silver
volynskite
calcite
galena
“wolframite”
gold
sylvanite
chalcocite
nolanite

In the supergene environment where, cassiterite was found, the following species were present:

cuprite	hematite	malachite

OCCURRENCES:

Campbell Mine, Alan Criddle (personal communication, 1992) noted minor cassiterite as part of a complex mineral assemblage in specimens from both the 2100 and 2200 levels, as well as several stopes on the 2300 level, and from a locality on the 2566 level.

Cole Mine, *1300 level;* A small number of specimens of a massive pyrite-bornite-chalcocite mixture contained inclusions of tiny cassiterite grains.

Southwest Mine, *5th level, 14 stope;* Microscopic, anhedral grains of cassiterite were found in a massive cuprite/hematite mixture that was also host to a wide variety of rare supergene minerals. It is highly probable that this cassiterite was a relic of the inclusions in the original sulfides.

CELADONITE $K Fe^{3+}(Mg,Fe^{2+})Si_4O_{10}(OH)_2$:

Anthony, et al. (1995) noted this hydrothermal alteration species as occurring in the district. It is in the list of rock-forming, alteration, and gangue minerals at Bisbee. However, no information regarding the mode of occurrence or the area where it occurred is provided.

CERUSSITE $PbCO_3$:

This was a common, widely distributed, and economically important ore mineral in a number of the mines, largely in the western portion of the district. As a point of interest, cerussite was the first ore mineral discovered in the Mule Mountains, a find that eventually led to the discovery of the nearby copper deposits.

While common, cerussite was seldom found as desirable specimens. The most typical occurrence was as massive gray to whitish, compact to spongy, material that formed as a direct, in situ replacement of galena. Remnant cores of anglesite grading into galena were often found with this type of cerussite. Large volumes of this kind of material were mined at Bisbee.

Less often, cerussite was found as a loose, granular, almost sand-like material. This type of occurrence was most common in and adjacent to the silica breccias of the Southwest and Shattuck mine areas and partially mixed with oxidized copper orebodies. Sandy specular hematite was commonly associated with these cerussite deposits. as were various manganese oxides. Here, too, the cerussite was deposited as an in-situ replacement of galena. Deposits of this type were also of economic importance.

Cerussite occurred with a number of species, particularly supergene minerals. These are listed below:

anglesite
plattnerite
silver
sphalerite
azurite
leadhillite
galena
wulfenite
minium
smithsonite
hematite
leadhillite
goethite
cuprite
psilomelane
copper
malachite
calcite
chalcocite

Cast-like pseudomorphs of cerussite after calcite have been recognized in the district.

OCCURRENCES:

Briggs Mine, *1300 level;* Cerussite was found here as small crystals in vugs in chalcocite (Bateman and Murdoch, 1914).

Campbell Mine, Cerussite was an important ore mineral in this mine and was found in a number of areas as massive material that resulted from the in-situ replacement of galena, often with anglesite.
1800 level; Numerous specimens of opaque white to pale gray sixling twins, up to 5 cm, on psilomelane came from several stopes on this level. Also, from another area on this level came specimens of fine, unattached sixling twinned crystals to 7 cm, while another area produced intergrown, 1 cm sixling twins on and including malachite-coated copper. This same level produced numerous examples of 2 to 4 mm crystals on chalcocite with silver and leadhillite (Schwartz and Park, 1932).
1900 level, 105-C stope: As white to colorless single crystals and V- shaped twins to 1 cm, on or with malachite pseudomorphs after azurite, with later azurite overgrowths on the malachite. Sixling twins to 7 mm on malachite alone, while found, were far less common. Also, from elsewhere this level, cerussite occurred as 5 mm sixling twins on copper.

Cole Mine, *700 level;* A few specimens of cerussite are from here, occurring as a partial replacement of anglesite on galena with hematite and minor colorless wulfenite.
1200 level, 26-J stope; A small number of fine specimens with V- shaped twins of up to 5 cm on hematite came from this location.

Gardner Mine, An important ore mineral in this mine, cerussite was often found as rinds of several centimeters thickness on altering galena. Also, it rarely occurred as opaque, white to cream-colored sixling twins on siderite boxwork and light brown smithsonite.

Lowell Mine, *700 level;* Important as an ore mineral in this mine, cerussite was most often found as a fine-grained material with other lead oxide minerals in a siliceous rock (Tenney, 1913).

Nighthawk Mine, Cerussite was mined here in minor amounts as porous material with cuprite and malachite.

Shattuck Mine, This mine was the largest producer of cerussite in the district, however very few specimen-quality pieces were ever produced.

100 level; Large amounts were mined generally as a fine-grained material mixed with compact, acicular malachite.
200 level and 300 level; A large oxidation cave, aptly named the "lead cave," extended from well above the 200 to just below the 300 level. This was the source of large amounts of spongy to sandy, tan to reddish cerussite mixed with minor amounts of specular hematite. Also from this same area came loosely cemented, porous masses of tan to brown intergrown crystals 2 to 6 mm and boulders of fine-grained cerussite with cores of anglesite, grading into unaltered galena. This same area produced a few groups of sixling-twinned crystals from near the limestone contact that were invariably coated by an unidentified manganese oxide.

Southwest Mine, *3rd level;* An important ore mineral in the lead stopes near the Southwest Shaft, cerussite occurred as massive white to cream-colored material. Also from this level came a few unusual casts of cerussite after tabular calcite crystals to 1.2 cm.
6th level; Common here as impure "sand carbonate," cerussite was associated with a number of the lead oxides. This is the Hendricks Gulch occurrence noted by Ransome (1904). Also, from this level as abundant cream-colored masses, often of large size, that are an in-situ replacement of galena, frequently with unaltered cores and coated by plattnerite. It was common to find a veneer of minium that formed as an alteration product on this cerussite. From the edges of a copper orebody on this level, cerussite was found as 2 to 4 mm crystals in spongy masses of fibrous malachite.

Spray Mine, *800 level, 11-8 stope;* Spongy masses of small crystals with patches of silver along fractures were found here. These masses contained unaltered galena cores (Tenney, 1913).

Uncle Sam Mine, *"N" level;* Cerussite occurred here as 2 mm, colorless crystals scattered on thin plates of coarse malachite crystals.

White Tail Deer Mine, A surface cut near this mine contained important amounts of cerussite with anglesite as an alteration of galena (Tenney, 1913).

CESÁROLITE $PbH_2Mn_3^{4+}O_8$:

This is a rare species that is probably of supergene origin. Little is reported regarding cesárolite except that it occurs with other manganese oxides in the Paleozoic limestones (Hewett and Fleischer, 1960).

OCCURRENCES: The occurrence of this species in the district is recorded by a single specimen. It was found in a small, unnamed surface manganese deposit as a botryoidal material with a gray to steel-gray surface and a black interior.

CHALCANTHITE $Cu^{2+}SO_4 \cdot 5H_2O$:

This very abundant mineral has been recognized largely, if not exclusively, in post-mining occurrences. However, there is no doubt that it was common as a pre-mining supergene mineral, but because of its high solubility and the amount of water used in mining for dust suppression, it was not recognized. Mitchell (1921c) does include chalcanthite as an important supergene ore mineral but does not discuss the mode of its occurrence.

The most typical occurrence for chalcanthite was as a crust on the walls of mine workings in sulfide areas that have been open for several months to several years. It grew as an efflorescence that was the result of the decomposition of copper-bearing sulfides under moderately damp conditions. These crusts were almost always composed of chalcanthite overgrowing a number of other hydrated, copper-copper/iron-iron sulfates (Merwin and Posnjak, 1937).

Under more moist conditions, copper sulfate was transported and deposited as typically impure stalactitic forms, the most obvious form for the mineral. Bright blue when near pure and bluish green when combined with some iron, stalactites and, less often stalagmites, were abundant in many of the abandoned mine workings. The stalactites frequently had well-developed crystal faces forming the sides resulting in single crystal stalactites. It was not uncommon for these growths to be of large size. Stalactites several meters in length and meter-high stalagmites were frequently observed. In some instances, crosscuts were completely closed off by chalcanthite growths. These stalactites would grow at a rate of as much as 4 cm per month (Mitchell, 1921a). Cuprian melanterite was a common associated species with stalactitic chalcanthite. It was often difficult to visually distinguish it from chalcanthite.

Chalcanthite often formed in the low-grade sulfides used as backfill in old workings. In the stope backfill, it was commonly found as fibrous fillings in cracks and on the surfaces of the decomposing sulfides. Specimens of this type of chalcanthite are typically less prone to rapid desiccation than other types.

The least common occurrence for chalcanthite was as distinct crystals. On very rare occasion, crystals would form in small pools of concentrated copper sulfate solutions. Typically, these crystals were small and corroded in appearance. In a very few cases, sharp, well-developed crystals to 4 cm were found in these pools. However, as with most of the chalcanthite from the district, once these were removed from the mine environment, they quickly desiccated and decrepitate.

A large variety of sulfides and post-mining minerals has been found with chalcanthite. The more important are:

pyrite
chalcocite
chalcopyrite
bornite
melanterite
coquimbite
römerite
copiapite

OCCURRENCES:

Briggs Mine, *1400 level;* Noted on this level by Mitchell (1921b) as stalactites growing into mine openings below a pyrite-chalcopyrite ore that had sooty chalcocite on the fractures indication supergene activity.

Campbell Mine, Chalcanthite was very common throughout the sulfide-bearing portions of this extensive mine as stalactites and as crusts on mine walls, often with a number of other post-mining

minerals. It was particularly abundant in the several areas that had experienced sulfide mine fires because of the decomposition of the sulfides and the introduction of large volumes of water to control the fires.
1800 level; Several areas east of the Campbell fault on this level had post-mining, multi-mineral crust on the walls, with chalcanthite the most abundant constituent of the crust.
2400 level; An exceptionally large stalagmite of almost a meter in height and several meters across at the base formed in an abandoned stope.
2700 level; Bright blue stalactites to more than one meter in length formed on the timber below a stope that had once been on fire.
2833 level; Crystals to 2 cm formed in isolated pools of mine water. Also on this level were numerous stalactitic forms of chalcanthite, many of which were essentially single crystal stalactites to 12 cm.

Cole Mine, Many of the sulfide areas in this mine contained chalcanthite as a post-mining crust, often with other similar species.
800 level; Compact fibrous masses to 10 cm thick were found in backfill in an abandoned stope.

Gardner Mine, *400 level;* Chalcanthite was uncommonly abundant as crusts with other post-mining sulfates on crosscut walls, particularly in the porphyry and altered limestones.

Junction Mine, This was a widely distributed and locally abundant post-mining mineral in the sulfide areas of this huge mine.
1500 level, 42 crosscut; Stalactites of chalcanthite had developed to such an extent that they completely blocked this crosscut (two meters high).
1800 level; Tabular crystals of up to 4 cm formed in pools of concentrated copper sulfate solution on this level.

Lavender Pit Mine, Chalcanthite was common as crusts covering large areas in the porphyry areas following rainy periods. These would quickly desiccate once the available water dried up only to reappear with the next rains.

Sacramento Mine, Chalcanthite was widely distributed as post-mining crusts with an assemblage of other post-mining minerals and as stalactites throughout the sulfide portions of the mine, particularly in the porphyry block-caving areas from the 1200 level to the 1600 level. It is highly probable that the specimens studied by Merwin and Posnjak came from this mine.

Shattuck Mine, *800 level;* Crusts and stalactites of chalcanthite and other post-mining sulfates formed on this level in a high pyrite area that had been the site of a major sulfide mine fire in 1920.

CHALCOALUMITE $Cu^{2+}Al_4(SO_4)(OH)_{12} \cdot 3H_2O$:

Bisbee is the type locality for this uncommon mineral (Larsen and Vassar, 1925) and has produced the finest examples known.

Even though this species was not described until 1925, a number of samples of chalcoalumite were collected prior to this time and were usually misidentified as chrysocolla. The most typical mode of occurrence for chalcoalumite was as a crust on azurite and/or malachite and occasionally on goethite. These crusts appear to have largely been formed at the expense of copper carbonates as manifested by the typically corroded texture of the underlying azurite and/or malachite. Usually these crusts are thin, 2 to 4 mm, fibrous and blue-white to blue-green in color. In some instances, the carbonate has been completely removed and only a cast of the original mineral remains.

Chalcoalumite, while not exceedingly rare, has been recognized from only one very limited area within the district, and is the product of a late-stage supergene episode. This area was at or below the 200 level and above the 400 level of the Holbrook mine along the southwestern edge of the Sacramento Stock and its interface with the altered limestones. The necessary aluminum was probably derived from the intrusive units of the stock and/or the alteration minerals in the limestones by the sulfate solutions generated during late-stage supergene alteration. Copper was, of course, readily available to the moderately low pH solutions in the abundant azurite, malachite and cuprite formed by previous episodes of supergene activity.

It seems probable that the limited occurrence of chalcoalumite was also a result of the pervasive, often impermeable clays so typical in the area. The clays may well have limited the access of the aluminum sulfate-bearing solutions to azurite and malachite, which was very abundant in this part of the mine. . Cuprite has also shown to be a source of copper for the formation of chalcoalumite. However, copper, brochantite, atacamite and the other secondary minerals common in the area appear to have been unaffected by these aluminum-rich solutions.

Far less common were 1 to 2 mm clusters of translucent, blue -green crystals. These were found in small vugs in a hard, compact goethite or massive cuprite and not always directly associated with azurite or malachite. However, in most instances corroded copper carbonates could be found nearby.

A limited number of species have been associated with chalcoalumite. These are:

azurite
cuprite
goethite
copper
brochantite
malachite

As discussed above, chalcoalumite has been found as pseudomorphs after azurite and a replacement of malachite. Gibbsite is known to have replaced chalcoalumite.

OCCURRENCES:

Holbrook Mine, *200 level-400 level;* This area was the type locality for chalcoalumite. Found here as often large specimens with botryoidal crusts up to 1 cm thick on azurite and/or malachite. These crusts were often fibrous with a silky luster and were invariably formed at the expense of the underlying copper carbonates. Occasionally, the surface of these specimens was covered with drusy microcrystals of chalcoalumite.

Lavender Pit Mine, *Holbrook Extension;* The Lavender pit re-mined the original type locality area, producing a number of specimens similar to the initial discovery. However, several new forms of chalcoalumite were also found. Tiny, well-formed single and twinned crystals with a triangular form were found in small vugs in goethite or cuprite. Also, a small number of distinct pseudomorph casts after azurite crystals to 1 cm were recovered. These pseudomorphs are actually replacements of malachite that were originally pseudomorphs after azurite.

CHALCOCITE Cu_2S:

This was one of the most widely distributed and economically important copper minerals in the district. Chalcocite occurred in large amounts both as a supergene and as a hypogene mineral. It is visually indistinguishable from several other copper sulfides including djurleite and digenite. Thus, it is quite probable that some of the chalcocite references in the literature are in fact other minerals.

The most common form of chalcocite was as the pervasive supergene phase in the large, low-grade orebodies associated with the Sacramento Stock. The Sacramento pit, as well as the later, much larger Lavender pit, was economically successful because of secondary chalcocite. In this area, chalcocite formed as a result of the supergene alteration of disseminated, very low-grade, copper-bearing sulfides, principally pyrite with minor amounts of bornite and chalcopyrite. Here the chalcocite was deposited as thin replacement veneers on pyrite grains, crystals, or fracture planes. This made separation difficult in the flotation copper recovery processes for both mines and resulted in a low-grade concentrate, rarely over 16% Cu. However, it was not uncommon for much, if not all, of the pyrite to be replaced by chalcocite (Head, et al. 1932). More often though, the chalcocite was little more than a soot-like coating on the pyrite or other sulfide minerals present.

Chalcocite as a secondary alteration product was also abundant and economically significant in many of the underground orebodies. Here it was found as the supergene alteration product of both high-grade and low-grade copper/copper-iron sulfides. Chalcocite that was derived from high-grade protore was typically massive, often somewhat granular in appearance, and nearly pure, associated with minor amounts of hematite. Frequently, the secondary chalcocite of this nature was formed in situ as a direct replacement of the other sulfides such as bornite (Mitchell, 1921b). Partial or incomplete replacement was common, with the chalcocite having developed along exposed surfaces, fractures, and grain boundaries. Relic features of the original sulfides are rarely discernible in this chalcocite.

Chalcocite derived from low-grade sulfides usually formed as a coating or as a replacement of these sulfides and was typically far less pure and seldom compact. It was usually found as disseminated grains or earthy material in soft hematite or as sooty veneers on other sulfides, most commonly pyrite. Incomplete replacement of the coated sulfide was typical, with a sooty chalcocite/hematite mix along fractures as well as crystal or grain boundaries. Complete replacement of pyrite by chalcocite was not uncommon in the non-porphyry deposits (Mitchell, 1920a). Brimsmade (1907) noted fibrous chalcocite surrounding pyrite; this was probably formed as an in-situ replacement of one of the high-grade copper sulfide minerals.

Primary chalcocite was most often found as intergrowths and small, included masses in other copper/copper-iron sulfides. It was not uncommon however to find chalcocite as large, fine-grained, nearly pure masses that were in excess of 10 tons. Inclusions of small euhedral pyrite crystals were occasionally found in these masses. Usually these chalcocite masses were adjacent to equally large masses of bornite.

In spite of the abundance of chalcocite, crystals from the district are relatively uncommon. When found they were seldom on or associated with massive or relatively pure chalcocite. Rather, crystals of chalcocite tended to develop along open fracture planes and, to a much lesser degree, within pockets in bornite or a bornite/pyrite mixture.

For the most part, chalcocite crystals from the district are small (> 5 mm), steel-gray and prismatic; pseudohexagonal prisms developed through twinning were less common, but not rare. These too were typically less than 5 mm. Larger examples of both morphologies are known but are quite uncommon.

Post-mining chalcocite is possibly a common, but largely unrecognized mineral in the district. Bateman et al. (1912) noted it as rinds around massive pyrite in areas that had been burned by mine fires, an unfortunately far too common occurrence in Bisbee’s massive sulfide zones.

The majority of the hypogene minerals are associated with primary chalcocite. The more important are:

bornite
pyrite
hematite
quartz
chalcopyrite
sphalerite
stromeyerite

Supergene chalcocite is often associated with the primary minerals that alter to form this chalcocite. Many of the supergene minerals are associated with secondary chalcocite. The more common among these are:

malachite
digenite
cuprite
sengierite
covellite
hematite
leadhillite
tyuyamunite
brochantite
azurite
djurleite
sengierite
chlorargyrite
silver
cerussite

Even though chalcocite has been noted as a replacement of several sulfide species, it has only been found as a complete pseudomorph after very small pyrite crystals in the porphyry ores.

Alteration of chalcocite to other supergene minerals was extremely common. Covellite was a widespread alteration product of chalcocite. Malachite was also frequently found as a replacement of chalcocite. Indeed, many of the coarsely crystalline malachite specimens from Bisbee were formed in situ by the alteration of chalcocite. Azurite, while not an uncommon alteration product of chalcocite, was found far less often as a direct result of chalcocite alteration. Schwartz (1934) noted cuprite as an alteration product of chalcocite. Fibrous copper as a replacement of chalcocite has also been recognized, as have replacement crusts of copper on chalcocite (Emmons, 1917).

OCCURRENCES: Because of the wide distribution of chalcocite, only the more significant locations are noted.

Campbell Mine, *1600-1800 levels*; Chalcocite was found in several locations along the Campbell fault as massive, supergene chalcocite with malachite, silver, and chlorargyrite, and on the 1800 level with leadhillite as well. Schwartz and Park (1932) noted small cerussite crystals on fractures in chalcocite from this level.
2100 level; Handsome specimens were collected here that had chalcocite as 2 to 5 mm prismatic crystals on bornite/pyrite (Carl Trischka, personal communication, 1960).
2300 level; The Campbell ore body in this area contained significant chalcocite as large, nearly pure masses of primary material.
2566 level; Specimens of chalcocite as 8 to 10 mm pseudohexagonal twin crystals on bornite were found on this level.

Cole Mine, *800 level*; A large number of specimens of chalcocite in the form of massive supergene material with malachite and chlorargyrite were recovered from this level.
1100 level; Chalcocite of note was found in a number of widely separated locations on this level. In one instance, it occurred as supergene masses with large blotches of bright yellow tyuyamunite and minor malachite. At a different locality, in a stope 25 feet above the level, it occurred with sengierite, chlorargyrite, and malachite (Hutton, 1957). In an exceptional occurrence, chalcocite was found as 3.5 cm prismatic crystals. Unfortunately, the miners saved only 2 of these crystals, as they did not recognize the significance of their find. An interesting occurrence was noted by Bateman, et al. (1912) where it was found as large amounts of uncommonly pure supergene material at the interface of the Martin limestone and the parting quartzite
1400, *39-A stope*; Toward the end of mining in Bisbee, uncommonly large, almost pure masses of primary chalcocite were found and mined at this locality.

Holbrook Mine, *300 level 17 stope*; Chalcocite as a post-mining product in a fire zone, consisting of soft, 2 cm rinds on massive, granular pyrite was noted by Bateman, et al. (1912).
600 level; Incredibly pure masses of supergene chalcocite in excess of several tons were found on this level.

Junction Mine; An undesignated location in this mine produced chalcocite as rich material with stromeyerite (Schwartz and Park, 1932).
1500 level; Large masses of supergene chalcocite with silver and malachite along the fractures were mined on this level.

Lavender Pit Mine, Chalcocite was the principal ore mineral in this mine where it typically occurred as a largely sooty, secondary material coating or, rarely replacing pyrite.

Lowell Mine, Supergene chalcocite was abundant as an alteration product and enrichment of high-pyrite orebodies. This was the main ore mineral in the lower parts of the mine. It was also noted as a post-mining product in at least one of the many fire zones, occurring as a rind of pulverulent material on massive pyrite (Bateman, et al. 1914).

Sacramento Mine, It was secondary chalcocite, on or as a replacement of pyrite, which comprised the main ore for the block caving efforts in this mine. Also, hypogene chalcocite was abundant in the mixed sulfide, limestone replacement deposits mined here as well as in lesser amounts in the contact breccia deposit where it occurred as inclusions in chalcopyrite.

Shattuck Mine, *400 level*; As rich, supergene material largely altered to coarsely crystalline malachite was noted here by Bateman, et al. (1912).

CHALCOPHANITE $(Zn,Fe^{2+},Mn^{2+})Mn_3^{4+}O_7{\cdot}3H_2O$:

This is a secondary mineral of surprisingly limited distribution given the district wide abundance of zinc, iron, and manganese in the oxidized zones. However, when chalcophanite occurred it was almost always in substantial amounts.

Typically, chalcophanite occurred as drusy crusts of tabular crystals on other minerals such as goethite. It was occasionally found as massive material in botryoidal or stalactitic forms, some of which were also coated by a drusy crust of chalcophanite.

The species associated with chalcophanite are:

goethite
calcite
hemimorphite
copper

OCCURRENCES:

Cole Mine, *1300 level 26-K stope;* Here it was associated with hemimorphite as 0.1 to- 0.5 mm crystal inclusions; some specimens contained included copper or formed a rare coating on copper. Elsewhere on this level, a raise some 15 meters up hit pockets of sharp, blue-black, 2 to 3 mm octahedral crystals on leached Martin limestone.
1400 level, 7 crosscut; A small cave in the top of this crosscut contained a large number of fine specimens where massive, botryoidal, and stalactitic chalcophanite were often covered by bright drusy overgrowths. Boxwork goethite was also incrusted by drusy chalcophanite at this locality.

CHALCOPHYLLITE $Cu_{18}^{2+}Al_2(AsO_4)_3(SO_4)_3(OH)_{27}{\cdot}3H_2O$:

This supergene mineral was found in small amounts at several places within the district. While not particularly rare in several of the mines, very few specimens of note were ever found.

As is the case for many of the rarer supergene copper species from the district, chalcophyllite was generally found in association with cuprite. Typically, it occurred as thin, tabular, blue-green crystals in vugs or as thin coatings along fractures in the cuprite. Occasionally, compact blebs to 4 mm of chalcophyllite were found in massive cuprite.

The species found with chalcophyllite are:

cuprite
spangolite
goethite
copper
connellite
malachite

OCCURRENCES:

Cole Mine, *700 level, 110 stope; A* few specimens with sharp, 6 mm, blue-green, hexagonal crystals with minor connellite on cuprite were recovered from here.
1200 level, 202 stope; Fine specimens with scattered 3 mm crystals with malachite, spangolite, and connellite were found here during mining. Also, a few examples of greenish, 2 mm crystals in small vugs in goethite with minor malachite were produced as well.

Czar Mine, *100 level;* A small number of specimens with chalcophyllite as a thin crust of tiny crystals on cuprite was recovered from here. Connellite and goethite were associated with these examples.

Irish Mag Mine, The material from this mine that was studied by Palache and Merwin (1909) probably came from the locality discussed below.
1050 level; An orebody that consisted largely of cuprite, copper, and goethite produced a number of specimens with clusters of hexagonal crystals from 3 to 8 mm in vugs in cuprite and associated with connellite. Also, chalcophyllite occurred here as 0.5 mm hemispherical aggregates of bladed crystals on cuprite with connellite.

CHALCOPYRITE $CuFeS_2$:

This was the most widely distributed and abundant copper mineral in the district. There is little doubt that, for the underground mines, chalcopyrite was the most economically important of the copper minerals mined. Most of the hypogene chalcopyrite appears to have formed by replacement of earlier pyrite (Schwartz and Park, 1932). While the overwhelming majority of chalcopyrite from here is hypogene in origin, a few instances of supergene chalcopyrite have been recognized.

Typically, hypogene chalcopyrite was found as large, very impure, massive replacement bodies of many thousands of tons in size in altered limestone. These masses were usually intermixed with abundant pyrite as well as varying amounts of other sulfides, particularly those of copper. While in many of the deposits these often appeared to be nearly pure chalcopyrite, they invariably contain included substantial impurities such as pyrite and often quartz. Bornite was also a common inclusion in much of the apparently pure chalcopyrite. Pure chalcopyrite, even in hand specimens, was uncommon from Bisbee.

Chalcopyrite was also commonly found as a fracture filling in shattered pyrite and as interstitial chalcopyrite that was a finely disseminated material in the voids in granular pyrite, often reflecting the replacement of the earlier pyrite. Also, it occurred as apparent inclusions in pyrite, manifesting late-stage pyrite deposition. Both of these forms of chalcopyrite occurrences developed important orebodies. While disseminated chalcopyrite masses were recognized in a very few localities, they rarely were of sufficient grade to be considered ore (Ransome, 1904).

In spite of the abundance of chalcopyrite, crystals were rare. Small voids in massive material occasionally contained crystals and, less often, fracture planes in the chalcopyrite or other sulfides were sources of crystals. On rare occasion, a larger void in pyrite or one of the copper sulfides would contain crystals of chalcopyrite.

Supergene chalcopyrite was uncommon at best. While it has been recognized in several studies including Ransome (1904) and Trischka (1929) it is rarely obvious. For the most part secondary chalcopyrite was found replacing a pyrite/chalcopyrite mixture at the fringes of an orebody (Ransome, 1904). It was also widely distributed in very small amounts as inclusions in supergene siderite along boxwork planes with other supergene sulfides.

Under typical supergene action, chalcopyrite has been found to alter to chalcocite, bornite, covellite, and rarely malachite. Of these, chalcocite is by far the more common alteration product.

Pseudomorphs of goethite after small chalcopyrite crystals have been found. Even though chalcopyrite has replaced tremendous amounts of pyrite and relic textures were occasionally found, no discernible pseudomorphs of chalcopyrite after pyrite have been noted.

The most common species associated with chalcopyrite are:

- pyrite
- covellite
- digenite
- galena
- grossular
- bornite
- sphalerite
- djurleite
- hematite
- muscovite
- chalcocite
- quartz
- tennantite
- siderite
- langite
- malachite
- goethite
- tetrahedrite
- magnetite

OCCURRENCES: Because of the very common nature of chalcopyrite and the general lack of significant specimens, only the most important as well as a few typical occurrences will be noted.

Campbell Mine, Chalcopyrite was the most common ore mineral in the Campbell orebody (Schwartz and Park, 1932). Here, it occurred as relatively pure masses of great size grading into and surrounding low-grade pyrite cores. These cores contained substantial chalcopyrite as inclusions, interstitial fillings, and replacement rinds, but generally not enough to be economic.

2966 level, 55 stope; Sharp, iridescent sphenoidal crystals to 1.5 cm were found along a fault at the upper margins of this stope. These crystals were on small, colorless quartz crystals that were, in turn, on a compact, siliceous, specular hematite/pyrite/chalcopyrite matrix.

Gardner Mine, The contact breccia along the periphery of the Sacramento Stock complex contained very rich, relatively pure masses of chalcopyrite.

Junction Mine, A number of large orebodies with chalcopyrite as the most important ore mineral were mined here. Occasionally, clusters of modified crystals to 1 cm were found in these ores. Some fine examples of massive chalcopyrite ore were recovered from here.

Spray Mine, *700 level;* Ransome (1904) noted a large body of chalcopyrite of exceptional purity on this level.

CHALCOSIDERITE $Cu^{2+}Fe_6^{3+}(PO_4)_4(OH)_8 \cdot 4H_2O$:

This is a secondary mineral that is quite uncommon within the district. Chalcosiderite occurs here as thin crusts or scattered tiny crystals on quartz or hematite.

The most common species associated with chalcosiderite are:

quartz
hematite
chrysocolla

OCCURRENCES:

Cole Mine, *1200 level;* Chalcosiderite was found here in minor amounts as scattered, 0.5 mm bladed crystals on siliceous fragments with hematite.

Dallas Mine, ***1400 level, 10-D stope;*** A small number of specimens from this stope contained a bluish, microcrystalline crust of a member of the chalcosiderite-turquoise series which is either a copper-rich chalcosiderite or an iron-rich turquoise. Quartz, goethite and later cuprite are associated with these specimens. (see also turquoise).

Shattuck Mine, Chalcosiderite was reported from here in small amounts (Anthony, et al. 1995). Specimens of chalcosiderite as small, yellow-green, flake-like crystals on chrysocolla are known from this mine and are most probably the material referred to by Anthony, et al. (1995).

CHALCOSTIBITE $CuSbS_2$:

A hypogene mineral, chalcostibite was identified as a part of antimony-rich reaction rim on Sb rich enargite and tetrahedrite included in massive luzonite.

The most common species associated with chalcostibite are:

luzonite
enargite
tetrahedrite

OCCURRENCES:

Junction Mine, In a single specimen collected by one of the authors from an ore transfer raise on the 2566 level in the early 1970s contained very minor amounts of chalcostibite as grains included in reaction rims of Sb-rich enargite and tetrahedrite in massive luzonite also containing scattered euhedral quartz and pyrite crystals (Schumer, 2017).

CHAMOSITE $(Fe^{2+} AlMg,)_6 (Si,Al)_4O_{10}(OH,O)_8$:

This hydrothermal alteration species has been noted to occur in the district as the variety delessite by Anthony, et al. (1977). However, no information regarding the mode of occurrence or the area where it occurred is provided.

CHLORARGYRITE AgCl:

This was a widely distributed and locally abundant, but seldom noted, supergene mineral of significant economic importance to the district. In spite of its relative abundance, only one locality in the Cole mine produced any attractive specimens.

The most typical mode of occurrence for chlorargyrite was as a waxy crust on or with supergene copper ore minerals. Occasionally, it was found as a slickensided, thin layer along faults at the edges of orebodies. Here, too, supergene copper minerals, notably malachite, were typically present.

The species associated with chlorargyrite from the district are:

chalcocite
sengierite
calcite
covellite
malachite
tyuyamunite
silver
cerussite
leadhillite

Pseudomorphs of chlorargyrite after arborescent silver have been recognized from the district.

OCCURRENCES:

Briggs Mine, *1300 level;* Chlorargyrite was uncommonly abundant here as crust of microcrystals on heavily oxidized chalcocite with malachite and hematite.

Campbell Mine, *1900 level;* It was locally common along fractures in massive chalcocite with silver and malachite on this level (Schwartz and Park, 1932).

Cole Mine, A series of stopes from above the 800 level to the 1300 level contained chlorargyrite along with the copper ores (Hutton, 1957). The following occurrences are some of these.
800 level; Chlorargyrite occurred here as crusts and isolated patches to several centimeters on massive chalcocite with malachite.
1100 level; A stope some 25 feet above the level produced a number of specimens of chlorargyrite associated with chalcocite, covellite, malachite, and sengierite (Hutton, 1957). Chlorargyrite was also found on this level as slickensided crusts on minor fault planes in an altered limestone.
155 crosscut; This was part of the same general area noted above and was the source of fine specimens where the chlorargyrite occurred as sharp modified cubic crystals to 6 mm on fibrous malachite with minor sengierite.

Junction Mine, *1500 level;* A small number of specimens were found near the mule barn on this level with chlorargyrite as well-formed cubic crystals to 3 mm on fibrous malachite and/or massive chalcocite, often with silver.

Shattuck Mine, This species was noted from an unspecified locality in this mine as massive material cementing silica breccia fragments (Anthony, et al. 1995).
200 level; On this level, it was found as small masses that were replacements of arborescent silver.

Wolverine #2 Mine, An area near the center of the Warren claim and mined from this shaft produced a cerussite ore with notable chlorargyrite (Engineering & Mining Journal, 1908).

CHROMITE $Fe^{2+}Cr_2O_4$:

This hydrothermal species has been noted to occur in the district as a minor rock-forming mineral by Anthony, et al. (1995). However, no information regarding the mode of occurrence or the area where it occurred is provided.

CHRYSOCOLLA $(Cu,Al)_2H_2Si_2O_5(OH)_4 \cdot nH_2O$:

This most common of the copper silicates was not rare at Bisbee; nor was it nearly everywhere, as is typical at most similar Arizona deposits. In spite of the immense amounts of silica deposited during the several mineralizing phases, little silica was mobilized during supergene activity. Thus, while chrysocolla is a widespread and, locally abundant, it was not particularly common when compared to other Arizona copper deposits. In spite of its local relative abundance, good specimens of chrysocolla from Bisbee are exceedingly rare.

The majority of the chrysocolla from Bisbee is pale blue to blue-green, cryptocrystalline, and impure. Some is deep blue and opal-like when found, then quickly loses much of its color and becomes opaque with desiccation upon exposure to the dry surface atmosphere. Botryoidal masses, light blue in color, were not rare, but usually decrepitated due to water loss. Black to brownish-black chrysocolla is commonly found as inner alteration rinds on massive cuprite and is easily confused with the much less abundant tenorite.

In most parts of the district chrysocolla was a very late-stage mineral, often replacing other earlier copper minerals, notably malachite. It frequently occurred as green to blue-green grading into black outer rinds on altering cuprite that had replaced malachite. Also, chrysocolla frequently is found lining voids in goethite boxwork. Here too it is usually as a replacement of malachite, both acicular and massive. Occasionally the malachite replaced was itself a pseudomorph after other minerals such as copper, cuprite, or azurite. The result is an apparent pseudomorph of chrysocolla after the original species.

Large, irregular masses of impure chrysocolla occurred in the soft hematite/goethite rich clay-like mixtures around Sacramento Hill, particularly in the supergene-altered limestone at or near the intrusive contact zone. Some relatively pure, compact material was found in the highly siliceous contact breccias of this same area.

In the silica breccias of the Shattuck area, and, to a much lesser degree, those of the Southwest mine, chrysocolla occurred as a replacement of small siliceous fragments within the breccia. The silica/specularite matrix of these breccias was, on rare occasion, also partially replaced. In these instances, sufficient chrysocolla was often present to constitute an ore. The chrysocolla that formed in these breccias was often earthy and light blue. In a few areas small amounts of compact, light blue silica were formed, colored by the encapsulated earthy chrysocolla.

Post-mining chrysocolla occurred in several of the mines. It would form as a bright blue gel that originated from cracks or other openings below oxidizing sulfide stopes. Mine timbers were occasionally coated with this material. Goethite was often formed at the same time, but with very little intermixing in spite of the proximity of formation. As the gel would dry, a porous, lightweight crust would result with little of its color remaining.

The species that have been most commonly observed as associated with chrysocolla are:

goethite
malachite
azurite
aurichalcite
tenorite
shattuckite
hematite
quartz
cuprite
fornacite
calcite
copper
silver

Chrysocolla has been found as pseudomorphs after malachite and as apparent pseudomorphs after azurite, cuprite, and copper. However, there is no doubt that chrysocolla replaced malachite in all of these instances.

OCCURRENCES:

Cole Mine, Chrysocolla was locally abundant throughout the oxide ores with the most common form as rinds on altering cuprite.
1000 level; An uncommon occurrence of chrysocolla was noted here where it occurred as a compact material that is banded with blue-green to blue material. It formed at the contact of the ores with recrystallization limestone.
1300 level; Just off the shaft station on this level was a bright blue post-mining occurrence with flowstone-like material forming on the crosscut wall from water seeping out of a fault plane.

Copper Queen Mine, A small number of fine, sharp pseudomorphs after prismatic azurite crystals to 4.25 cm in length were found by the authors in this mine. These were encased in an unidentified, moderately hard, white material.

Czar Mine, Chrysocolla was common in this mine as alteration rinds on cuprite nodules. Also, it was found here as sharp pseudomorphs after azurite on hematite, often with later azurite.
200 level; Specimens of chrysocolla as veneers of pale blue material on botryoidal malachite and, less often, botryoidal azurite, came from this level. In this instance, it is easily confused with chalcoalumite or nordstrandite.

300 level; Compact, deep blue lumps that are complete replacements of cuprite nodules by chrysocolla with minor residual tenorite came from here as did distinct pseudomorphs after acicular malachite.

Higgins Mine, *Tunnel level;* The "Cuprite stope" on this level contained abundant chrysocolla as an impure material coating cuprite and to a lesser degree copper. Also on this level chrysocolla was found as post-mining stalactites and crusts to 1 cm on timber as well as on mine walls with post-mining goethite.

Holbrook Mine, Chrysocolla was common as botryoidal linings of boxwork openings in some of the more siliceous supergene ores. This material was often a replacement of earlier copper carbonates.
100 level; A mass of nearly pure chrysocolla several meters across was noted in the wall of a large cave some 40 feet above this level. It appeared that this chrysocolla was formed as a replacement of massive cuprite.

Lavender Pit Mine, *Holbrook Extension;* This mineral was widely distributed throughout this part of the Lavender pit as botryoidal crusts on goethite boxwork and as often attractive, large, irregular masses of mixed blue-green and a black material appears to be tenorite but that quickly cracked from desiccation on exposure. This latter material was associated with azurite and malachite.
Pseudomorphs of light blue to blue-white chrysocolla after azurite were not uncommon. The replaced crystals often exceeded a centimeter in size, however, the larger pseudomorphs were frequently rough in form.

Shattuck Mine, Chrysocolla was abundant throughout mine as crusts and linings on the open spaces in the silica breccias. Also, it occurred as replacements of small siliceous fragments in these breccias.
200 level; Pseudomorphs after acicular malachite and associated with shattuckite were found on this level.

Southwest Mine, Widely distributed throughout this mine, chrysocolla was common as alteration rinds on cuprite nodules, as crusts on goethite, or as fracture fillings in the silica breccias.
5th level; Pseudomorphs of chrysocolla after acicular aurichalcite with unaltered aurichalcite were found here, as were faithful pseudomorphs after malachite on goethite with unaltered malachite.
6th level; Chrysocolla was found along the walls of an abandoned stope as a post-mining material that formed from the alteration of chalcocite in a siliceous host rock. Also from this level came chrysocolla as light blue-green lumps that are complete replacements of cuprite nodules.

CHRYSOTILE $Mg_3Si_2O_5(OH)_4$:

This hydrothermal species is apparently uncommon within the district. Chrysotile has only been noted in a few localities; however, it is probably more common than the limited occurrences would suggest. Chrysotile was reinstated as the species name for the chrysotile polytypes, including clinochrysotile, in 2006.

Chrysotile occurs as a greenish-white fibrous material adjacent to ores in altered limestone.

The species associated with chrysotile are:

quartz	chalcopyrite	tremolite	diopside
pyrite	stevensite	chrysocolla	

OCCURRENCE:

Gardner Mine, *700 level, 48 drift*; A 10-meter-long zone of chrysotile with 4 cm fibers occurred here flanked by tremolite and diopside at the edge of a quartz/pyrite/chalcopyrite orebody (Tenney, 1913).

Lavender Pit Mine, *Holbrook Extension;* Minor chrysotile as clinochrysotile was noted as scaly, micaceous intergrowths with stevensite and chrysocolla (Anthony, et al. 1995).

CINNABAR HgS:

This primary mineral was found in small amounts at a single locality just west of the Quarry fault. It occurred as a light dusting to a thin film on fracture and foliation planes in Pinal schist with minor pyrite. The mine owner (a plumber with a most impressive collection), delighted in heating specimens with his blowtorch to show the ready conversion to mercury by heat.

The species associated with cinnabar are:

pyrite
quartz
muscovite

Elemental mercury was occasionally present in some of the specimens preserved by the owner of this small mine, but it appeared that it had been derived through heating and not a result of natural processes.

OCCURRENCES: A small, unnamed prospect adit on the south side of upper Tombstone Canyon had been developed on a mercury showing and produced a small number of specimens with cinnabar as either a dusting of red specks or, less often, a patchy film.

CLARINGBULLITE $Cu_4FCl(OH)_6$:

The finest known examples of this very rare mineral are from Bisbee. While this is not the type locality, a small sample from Bisbee of what eventually was described as claringbullite was investigated in the late 1960s independently by Sid Williams and John Anthony. Both determined that it was probably a new species, however insufficient material was available to complete the necessary descriptive work. Material from Africa was used to describe the species in 1977, but the accepted crystallography is based on Bisbee material.

The mode of occurrence for this species is as a very minor accessory mineral invariably associated with cuprite. Other copper-chlorine-containing minerals are typically present as well. Claringbullite is found as free-standing, soft blue, platy crystals to 5 mm within voids in massive cuprite nodules. The larger crystals are often composites of a number of crystals in subparallel/parallel growth.

The majority of minerals associated with claringbullite are also copper-chlorine combinations. The species found with it are:

cuprite
atacamite
paratacamite
clinoatacamite
spangolite
connellite
tolbachite
nantokite
tenorite
hematite
brochantite
malachite
goethite

OCCURRENCES:

Cole Mine, Claringbullite is known from this mine as a single specimen with minute crystals in a cuprite vug with brochantite, malachite, and connellite (Anthony, et al. 1995). It was this material that Sid Williams and John Anthony studied in the late 1960s.

Southwest Mine, 5th *level, 14 stope;* Claringbullite was found here as a small number of remarkable specimens with crystals up to 6 mm in vugs within massive cuprite. Atacamite, paratacamite, and less often, connellite, as well as spangolite, were associated with claringbullite at this locality, as were several other uncommon species typically found with cuprite nodules.

CLINOATACAMITE $Cu_2^{2+}(OH)_3Cl$:

This mineral is undoubtedly far more common that the single verified occurrence would suggest. Indeed, it is highly probable that much of the material identified as "paratacamite" is truly clinoatacamite.

As with its polymorphs atacamite and paratacamite, clinoatacamite is found in association with cuprite nodules at Bisbee. Here it has been recognized in small amounts in a number of specimens with other copper chlorine species as well as other copper and iron oxide minerals.

The species associated with clinoatacamite at Bisbee are:

cuprite
paratacamite
goethite
atacamite
spangolite
connellite
malachite
claringbullite
copper

OCCURRENCES:

Southwest Mine, *14 stope, 5th level;* A number of 2 mm, prismatic and orthorhombic appearing crystals were found in vugs in massive cuprite from this locality. They were associated with superb claringbullite and connellite as well as atacamite and what appear to be larger crystals of paratacamite.

CLINOCHLORE $(Mg,Al)_6(Si,Al)_4O_{10}(OH)_8$:

This hydrothermal mineral is common in the district as a result of the retrograde alteration of garnet-epidote tactites (Anthony, et al. 1995). Clinochlore is common and locally abundant as the variety penninite.

Typically, it was found either as coarse crystals or as small scaly crystals that ranged in color from a light green to olive-green. Large, coarse crystals were noted in the lower levels of both the Cole and Dallas mines (Anthony, et al. 1995). It was also abundant in the altered Bolsa quartzite north of the Dividend fault and as a matrix of a breccia dike in the upper reaches of Brewery Gulch (Anthony, et al. 1995).

The species associated with clinochlore are:

quartz
calcite
muscovite
epidote
grossular

OCCURRENCES:

Given the wide distribution of clinochlore within the district, only a couple of different localities in addition to the areas noted above will be discussed.

Lowell Mine, *1200 level;* Pale green crystals of clinochlore were a common alteration mineral in altered limestone/porphyry as noted by Tenney (1913).

Sacramento Mine, As green internal reflections indicate sheet silicate is a chlorite (Raman spectrum = clinochlore) in large grains of pyrite (30%) intergrown with chalcopyrite (50%), hematite (5%) magnetite (5%) in a gangue (10%) of quartz and minor sheet silicate. University of Arizona Mineral Museum specimen 5833 (Schumer, 2017).

Spray Mine, *300 level;* Nearly pure masses of the variety penninite occurred in altered porphyry on this level (Tenney, 1913).

CLINOCHRYSOTILE $Mg_3Si_2O_5(OH)_4$: *Clinochrysotile is no longer considered a valid species. The information provided herein is to be considered for reference only, allowing for the work of earlier researches to remain available.*

This hydrothermal alteration mineral is apparently uncommon within the district. Clinochrysotile has only been recognized from a single locality in small amounts as dark green, scaly crystals.

The species associated with clinochrysotile are (Anthony, et al., 1995):

stevensite
chrysocolla

OCCURRENCES:

Lavender Pit Mine, *Holbrook Extension;* Minor clinochrysotile was noted as scaly, micaceous intergrowths with stevensite and chrysocolla (Anthony, et al., 1995).

CLINOCLASE $Cu_3^{2+}(AsO_4)(OH)_3$:

This supergene species is apparently quite uncommon within the district. The only reference to clinoclase in the district is in Anthony, et al. (1995) where it is listed in the table of oxide-zone minerals at Bisbee.

CLINOZOISITE $Ca_2Al_3[Si_2O_{7]}][SiO_4](OH)$:

This hydrothermal species has been found as an alteration product in both the sediments and the several of the intrusive units. Clinozoisite was always found in small amounts as a minor constituent of a multi-mineral alteration assemblage. It is probable that it is more common than the limited recognized occurrences would suggest, in that much of the material identified as zoisite may indeed be clinozoisite.

Typically, clinozoisite occurred as euhedral grains or as small masses.

The species associated with clinozoisite are:

epidote
quartz
apatite
calcite
tremolite
muscovite
chlorite
zoisite

Pseudomorphs of clinozoisite after biotite group minerals have been noted from the district (Schwartz, 1958).

OCCURRENCES:

Gardner Mine, *900 level, 9 drift;* Clinozoisite occurred as euhedral grains in altered limestone with tremolite, apatite, zoisite, and epidote (Tenney, 1913).

Lavender Pit Mine, Pseudomorphs of clinozoisite after “biotite” were noted from here in one of the intrusive units in the Sacramento Stock complex (Schwartz, 1958).

COLUSITE $Cu_{12}VAs_3S_{16}$:

This hypogene mineral has been found in very small amounts in several places in the Campbell orebody. Here, colusite occurred as part of a complex mineral assemblage that were compound inclusions in sulfide ore minerals and as inclusions in or replacing pyrite. It was one of the more widely distributed of the minerals in these assemblages. Schumer (2017) also found minor amounts of colusite in similar mineralogy in specimens from the Cole, Dallas, Holbrook and Sacramento Mines.

The species associated with colusite are (Alan Criddle, personal communication, 1992):

wittichenite
djurleite
spionkopite
galena
digenite
hematite
petzite
sylvanite
kostovite
bismite
chalcopyrite
bismuthinite
bornite
acanthite
copper
rutile
altaite
mawsonite
sphalerite
covellite
gold
stromeyerite
quartz
bornite
pyrite
kiddcreekite
stannoidite
chalcocite
silver
emplectite
jalpaite
cuprite
tetrahedrite
kësterite
tennantite

OCCURRENCES:

Campbell Mine, Schumer (2017) recognized relatively abundant colusite in bornite-rich ores from an undetermined level in this mine.
1900 level, 1200 level, 2200 level, 2300 level, 124 stope and 125 stope and 2566 level; Colusite was noted by Criddle and Stanley (1986) in these areas of the Campbell orebody during their study of the ores. It was always found in small amounts as part of the complex assemblage included in or replacing sulfides and associated with a number of other species, particularity those containing tin, tungsten, and vanadium (Alan Criddle, personal communication, 1992).

Cole Mine, *1300 level, 39-A stope;* Massive steely chalcocite (80%) containing scattered pyrite grains (15%) and bornite. Pyrite contains colusite inclusions (Schumer, 2017).

Dallas Mine, Colusite was noted in minor amounts in bornite as a part of a large suite of accessory minerals including tennantite-tetrahedrite, sphalerite, mawsonite, stannoidite, galena, and native Au. Gold occurs intergrown with chalcocite in fractures and in one instance is intergrown with colusite (Schumer, 2017).

Holbrook Mine, Massive bornite contains rounded inclusions (<1%) of stannoidite, mawsonite, galena, and colusite. (60%) with chalcopyrite (30%) and supergene goethite (10%). Chalcopyrite shows selective replacement over bornite. Chalcopyrite is concave to bornite. Both chalcopyrite and bornite contain rounded inclusions of tennantite-tetrahedrite and sphalerite (Schumer, 2017).

Sacramento Mine, Massive sulfide ore composed of bornite (15%) and chalcopyrite (30%) with granular pyrite (50%). The bornite contains rare inclusions of tennantite-tetrahedrite and colusite. A later mineralization episode formed a dolomite vein and replaced bornite with enargite, which was in turn replaced by tennantite (Schumer, 2017).

CONICHALCITE $CaCu^{2+}(AsO_4)(OH)$:

This is a minor supergene mineral that is widely distributed, in small amounts, throughout the western and southern parts of the district.

The most common occurrence for conichalcite is in the many near-surface manganese deposits in these parts of the district. Few, if any, of these deposits are without at least a small amount of this mineral. In these, conichalcite occurred largely along the fringes of the manganese deposits, often at the limestone or silica breccia /host rock interface with the manganese ores. For the most part, it is in direct association with supergene manganese minerals.

All of the conichalcite from the manganese deposits appears to be vanadium-rich, once described as “higginsite” (Palache and Shannon, 1920). The material is emerald-green to a slightly yellowish-green. It is found as massive material to 1 cm thick in fracture-controlled veinlets. Crystals are uncommon, but when found they can be of extraordinary size. Soft manganese oxides have yielded free-floating crystals of a centimeter in length as well as small clusters of 5 mm crystals. Less often, crystals to 15 mm were found in open spaces in vein material cutting massive braunite.

Conichalcite that is not directly associated with the manganese deposits was far less common and restricted to the Czar, Southwest, and Shattuck mines. This material is much more of a yellow-green in color and occurs as little more than a thin crust on fractures with an occasional 2 mm crystal.

The minerals associated with conichalcite are:

calcite
mottramite
quartz
gold
pyrolusite
mimetite
descloizite
malachite
baryte
chrysocolla
hematite
braunite
aragonite

OCCURRENCES: Because of wide distribution of conichalcite in the near-surface manganese deposits and its almost always nondescript appearance, only the most prolific or unusual localities are listed below.

Czar Mine; At this mine, conichalcite has been found as a 1 mm thick botryoidal crust on malachite with minor unidentified manganese oxides.

Higgins Mine, *Twilight claim*; The open-cut manganese mine on this claim is some 300 feet above the tunnel level of the Higgins mine and connected by raises. Here conichalcite is abundant as massive vein material in hard braunite and much less often as crystals to 1.5 cm in soft manganese oxides. Massive, greenish/brown to yellow-brown mottramite, which might be confused with impure conichalcite, is an occasional associated species (Taber and Schaller, 1930).

Shattuck Mine, *200 level*; Several places on this level contained conichalcite as a thin crust on siliceous breccia fragments. It was also found as 2 mm prismatic crystals on chrysocolla.
300 level; Conichalcite was found as drusy linings in voids in a massive supergene hematite/gold ore on this level. In some instances, tiny flakes of gold occurred on the conichalcite. A second locality on this level had drusy conichalcite on goethite with later colorless calcite, University of Arizona specimen 15557 (05/30/2006 X-Rayed by the RRUFF Project).

Southwest Mine, *7th level*; A few specimens of conichalcite were found here as scattered tiny crystals and spotty crust on altered limestone on a small portion of a wall in a large cave. Minor mimetite is associated with conichalcite at this locality. Conichalcite has also imparted a light yellow green hue, to a very small amount of the calcite in this cave.

CONNELLITE $Cu_{19}^{2+}Cl_4(SO_4)(OH)_{32} \cdot 3H_2O$:

This mineral is widely distributed within the district, though never abundant. Some of the very best examples of this rare species are from Bisbee.

The vast majority of connellite found here is in direct association with cuprite. Most often, this is within cuprite as nearly pure, compact intergrowths or inclusions of radiating, bright azure-blue, acicular crystals to 1 cm. These connellite masses range in size from several millimeters to as much as 7 cm in greatest dimension. Compact veinlets of less 2 mm in width and several centimeters in length in massive cuprite were not uncommon.

Connellite, much less commonly, occurred as free-standing, acicular crystals to 7 mm in length in voids in cuprite, often with other rare or uncommon copper species. Felt-like masses covering areas of as much as 3 to 5 cm were also found on rare occasions. Typically, the crystals were bright blue, however; small, very thin crystals could be somewhat lighter in color.

A very few examples of connellite on goethite and not cuprite are known from the district. These are as isolated clusters to 1 cm and with a typical crystal length of 5 mm or less.

A small number of the specimens originally identified as connellite have, in fact, found to actually be buttgenbachite (Hibbs, et al. 2002, 2003). Other researchers have also noted buttgenbachite in specimens identified as connellite (Yang Hexiong, personal correspondence, 2018). The striking similarity between the appearance and association of the two species is so strong that a visual distinction is probably impossible. Undoubtedly, more of the Bisbee "connellite" specimens will be shown to be buttgenbachite.

The minerals recognized as being associated with connellite are:

cuprite
aurichalcite
chalcophyllite
claringbullite
malachite
paramelaconite
spangolite
tolbachite
tenorite
goethite
hematite
clinoatacamite
atacamite
paratacamite

Malachite as an alteration of and as pseudomorphs after connellite has been recognized from several localities.

OCCURRENCES:

Cole Mine, *700 level 99 stope and 110 stope;* Connellite was found in these two close locations as patchy masses of radiating crystals in massive cuprite with spangolite and minor chalcophyllite.
1000 level; Specimens from this level contained connellite in cuprite voids as free-standing 2 mm crystals.
1200 level, 202 stope; The largest known masses of connellite ever found were collected from this stope. It occurred here as 5 cm to 7 cm compact masses comprised of acicular, radiating crystals in massive cuprite. Occasionally, voids in the cuprite would contain 0.5-mm diameter crystals to 1 cm in length. Malachite, atacamite and, rarely, spangolite were associated with connellite from here.

Czar Mine, It was found at an unspecified locality in this mine as tufts of tiny crystals with aurichalcite (Roberts, et al. 1974). The fine connellite crystals associated with paramelaconite found as exceptionally large acicular crystals on the type specimens of paramelaconite (Koening, 1891b) is almost certainly from this mine. It also occurred as 5 mm free-standing crystals in radiating clusters on malachite coated cuprite.
200 level; 1 mm diameter crystals were found in vugs in cuprite, occasionally with spangolite, on this level.
400 level; Specimens were recovered from here as felted mats to 3 cm across, comprised of tiny acicular crystals, which occurred along fractures in massive cuprite. These were frequently associated with atacamite, malachite, and an unidentified, white clay-like mineral.

Holbrook Mine, Specimens very similar to the nearby Czar mine were found in this large, prolific mine as well as the single documented occurrence noted below.
200 level; Occasionally connellite was found here as radiating blebs in massive cuprite and as 0.5 to 1 mm diameter crystals in vugs in cuprite with paratacamite and, rarely, spangolite.

Irish Mag Mine, Palache and Merwin (1909) discussed connellite from this mine and it is probable that it came from the locality listed below.
1050 level; Connellite was relatively abundant in one stope on this level as bright blue, acicular crystals to 8 mm in radiating groups in vugs and along fractures in cuprite. Minor chalcophyllite was associated with this occurrence.

Lowell Mine, This otherwise specimen-poor mine contained some very fine connellite specimens as spotty patches of radiating, acicular crystals in massive cuprite and as 2 mm thick crystals to more than 1 cm in length in cuprite voids with crystalline cuprite. Connellite was mistakenly described from here by Holden (1922) as "ceruleofibrite," but later was shown to be connellite (Holden, 1924).

Shattuck Mine, Several small specimens from here are in the University of Arizona collection with a catalogue number of 1188. Analysis using single crystal X-ray diffraction by the RRUFF Project confirmed connellite (# R060503).

Southwest Mine, *5th level, 14 stope;* A number of very fine specimens of connellite were found at this location, occurring in several forms. Most commonly, it was found as bright blue, freestanding acicular crystals to 6 mm lining small voids in massive cuprite with paratacamite and claringbullite. Connellite was also found as a few exceptional specimens composed of closely spaced tufts of 2 to 3 mm crystals forming felt-like masses to 6 cm in voids along with 1 mm cuprite crystals.

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

This is a widely distributed, locally abundant mineral that has been recognized only in post-mining occurrences. It is highly probable however, that copiapite also occurred as a supergene mineral but was not recognized because of its solubility in water as well as its comparatively lack-luster appearance.

Copiapite typically occurred in moist, high pyrite, non-reactive rock areas as one of the later species of a multi-mineral, post-mining assemblage that formed as an efflorescence (Merwin and Posnjak, 1937). Here it was found as micaceous to granular, sulfur-yellow material usually on rhomboclase, coquimbite, melanterite, and voltaite with römerite. It also was found in very soft, moist and sticky, reniform masses of a meter or more across and up to 20 cm thick, extruding from oxidizing pyrite. Römerite was a very common associate with copiapite, as was melanterite in these cases. When dry, this material was often granular to pulverulent and much lighter in color.

The minerals associated with copiapite are:

pyrite
fibroferrite
melanterite
römerite
chalcanthite
paracoquimbite
rhomboclase
kornelite
voltaite
coquimbite

OCCURRENCES:

Given the very common nature of this species, only a few of the occurrences are noted below:

Campbell Mine, Copiapite was exceedingly common throughout the abandoned sulfide areas of this large mine. Typically, it was part of the often-thick post-mining crusts on many of the mine openings as well as large, soft, masses on the mine floors.
2100 level; An uncommon occurrence for this species was on this level where tabular 1 to 2 mm bright yellow crystals formed on the mine walls in a pyritic, siliceous, limestone area. Only minor melanterite was associated with these exceptionally large crystals of copiapite.

Cole Mine, In this mine, copiapite was common in many of the high pyrite workings as crusts and soft masses, often with melanterite.
800 level; Copiapite specimens as partial overgrowths of rhomboclase with voltaite on pyritic material were collected on this level.

Czar Mine, *400 level;* The porphyry area on this level and toward the Gardner mine contained abundant copiapite as a constituent of the post-mining crust on some of the mine openings.

Gardner Mine, *600-1000 levels;* Many of the abandoned, high-sulfide workings on these levels that were developed in the Sacramento Stock Complex rock units contained substantial amounts of copiapite as a constituent of the common post-mining mineral assemblage.

Higgins Mine, *Tunnel level;* Copiapite was found in small amounts on this level as a crust on crumbling pyrite with rhomboclase, as well as extrusions from stope floors.

Junction Mine, This was a common mineral in many of the sulfide areas as part of the crusts on mine walls along with other post-mining minerals. Also, it was found in a number of places as extrusions covering large areas of mine floors where it occurred as moist, soft, reniform masses, often with similarly occurring melanterite and römerite.
1500 level; An area near the Briggs Shaft contained an uncommonly thick, crystalline crust of copiapite on the mine walls with römerite.

Lavender Pit Mine, Crust of copiapite with melanterite, coquimbite and voltaite commonly form on the high pyrite portions of the older porphyry and the Pinal schist during the wet seasons.

Sacramento Mine, This mine was undoubtedly the source of material studied by Merlin and Posnjak (1937). In any event, copiapite was common in the pyritic porphyry areas as part of the post-mining assemblage incrusting many mine openings.

Shattuck Mine, *700 level;* Copiapite was found in small amounts with fibroferrite and melanterite on this level.

Southwest Mine, *7th level;* Sulfide stopes near the Wolverine interior shaft on this level contained copiapite as part of multi-mineral masses of a meter in diameter or more on decomposing pyrite.

COPPER Cu:

This was one of the most abundant and economically important supergene minerals found in the district. Every mine that produced secondary ores in any amount also produced elemental (native) copper in some amount.

The modes of occurrence are typical throughout the district in that copper was largely, but not exclusively, found in the abundant, non-reactive iron oxides, clays and/or rocks. Most common among these occurrences was numerous, small to tiny, isolated masses in the soft, clay-like minerals and/or iron oxides that formed as a result of supergene alteration. The iron oxides were typically impure goethite and hematite mixtures.

In the softer clays, as well as the ocherous phases of the iron oxides, sufficient amounts of often very small, isolated, copper particles were disseminated throughout the material to make it ore grade (5% copper or higher). Also, in these soft, typically plastic materials, copper less commonly occurred as larger, free-floating, unconnected, often-crystalline masses. These isolated masses would range in size from less than a centimeter to occasionally more than a meter across and several tons in weight. However, smaller clusters of crystalline masses of less than 10 cm were far more common. A great many fine specimens from this type of environment have been preserved. On very rare occasion, extremely large masses of nearly pure copper were found, but their unwieldy size and malleability made them difficult to mine, thus, they were more often than not considered a nuisance and as such usually left in place. More typically, the larger pieces were of no more than several hundred pounds in weight such as those noted by Douglas (1900) and were removed for their metal content.

In hard or compact materials, such as breccias, the intrusive units, and some phases of the iron oxides, copper was deposited along fractures, fragment boundaries, and in voids. Deposition along fractures resulted in flat sheets that were usually relatively thin, typically not crystalline, and of relatively small size. However, along some fractures there were the occasional, well-crystallized, dendritic specimens that reached up to 60 cm across.

Copper deposition in voids in the iron oxides was also a very common occurrence. This was in the harder iron oxides, where the voids were often bounded by boxwork planes. In these instances, the copper is usually well crystallized, with occasional individual crystals in excess of 2 cm. Most often, however, the copper was deposited as spongy crystalline growths. In some cases, the voids were calcite-lined prior to copper deposition (Tupper, 1915) and a second generation of calcite covering all or part of the copper was not uncommon. So common was copper on iron oxides that Schwartz (1934) suggested that the presence of iron oxides, particularly goethite, might well be the cause of precipitation of metallic copper.

Post-mining copper was common in many of the sulfide zones. Typically, it was found in sub-solution environments as microcrystalline growths on and replacing any number of iron and steel items such as rail, pipe, and spikes. Copper deposition would then, expanding from this core, forming irregular, but often linear masses. Some of these specimens were quite large. On rare occasion, the replacement of the iron by copper was faithful enough readily to recognize the replaced item. In many instances, close examination will show something of the form of the iron the copper grew around, thereby revealing its post-mining origin.

One occurrence of post-mining copper precipitating directly from moderately low pH, copper-rich solutions with minor cuprite and gypsum was observed by the author on the 2966 level of the Campbell mine in 1972. Bateman, et al. (1914) noted that post-mining copper and cuprite had formed in gob (backfill) as a result of low pH, high-copper mine waters passing through the fill.

Post-mining copper as a filling in and as a replacement of mine timber was found in the bottom of the Lavender pit. The timber was in a raise that had been used for many years to collect copperladen water generated in the pit and transfer it to an underground pump station for ultimate metal recovery. Copper had filled open spaces in the crushed timber as very thin layers on the wood itself. A second occurrence of post-mining copper in mine timber in the Holbrook mine is noted below (Bateman, et al. 1914).

A number of species are found associated with copper and often the growth of the other, later species has been at the expense of the elemental copper. Excepting the clay-like minerals, they are:

goethite
smithsonite
gypsum
tenorite
malachite
chalcocite
gold
cuprite
crednerite
calcite
silver
hematite
cuprite
bornite
wulfenite
siderite
delafossite
quartz
cerussite
antlerite

Copper has been noted as pseudomorphs after a few species, with striking pseudomorphs after cuprite the most notable (Rogers, 1910). Other species found as copper pseudomorphs are azurite, calcite, and delafossite. Also, sharp copper casts of gypsum, variety selenite, crystals were locally abundant. Pseudomorphs of cuprite, malachite, and goethite after copper have been found in the district as well. Copper as a replacement of fossil crinoid stem segments in the Holbrook mine.

Emmons (1917) suggests that the fibrous copper, which was, on rare occasion, found with chalcocite, was a replacement of the chalcocite. However, the in-situ replacement of massive chalcocite, bornite, and, much less often, cuprite by copper was not particularly uncommon in the supergene areas.

OCCURRENCES:

Baxter Tunnel; Bateman, et al. (1914) noted copper in this relatively small mine as handsome crystalline specimens associated with cuprite.

Campbell Mine, Schwartz (1934) noted copper from an undisclosed location in this huge mine as replacing cuprite and also as specimens associated with silver.
1300 level; Fine specimens came from here as free-floating, crystalline masses to 20 cm. The crystals are elongated octahedrons up to 2 cm in length speckled with wart-like 0.05 mm dodecahedral crystals.
1800 level; Specimens from here were found as delicate steel wool-like masses coated with malachite and with twinned cerussite crystals to 1 cm.
1900 level; Several adjacent stopes on this level contained abundant spongy material with cerussite filling fractures in soft goethite.
105C stope; Also on this level, copper was abundant as arborescent masses often with siliceous fossil crinoid buttons scattered throughout.
2100-2200 levels; During the late 1950s and early 1960s, an estimated 14,000 tons of native copper ore were mined from several adjacent stopes between these two levels. Much of the copper occurred as massive material that had been deposited along fracture planes in hematite and goethite. Numerous free-floating, crystalline masses were found in the soft hematitic clay-like

material that was interspersed within the harder hematite. These masses were typically less than 20 cm in length, however a few were recovered that were up to a meter in size. For the most part, the material was comprised of intergrown, 5 mm, modified octahedral crystals, and often partially covered with smaller such crystals. These specimens usually appeared grayish in color because of a thin veneer of cuprite that was, in turn, altering to malachite. The vast majority of the specimens recovered from here were chemically cleaned, removing all of the malachite and cuprite. A small number of single, skeletal, spinel twin crystals up to 12 cm and groups of such crystals were found as isolated pieces in the soft iron oxides. These too had partial overgrowths of small crystals.

Cole Mine, Copper was a common species in this large mine with many fine specimens having been recovered.
600 level; A single stope on this level produced copper as small, well-crystallized specimens that are uncommonly bright.
700 level; Spongy to well-crystallized masses up to 30 cm were found here that formed as discrete masses in clays. A small number of these had an odd iridescent look, largely greenish to reddish in color, caused by an extremely thin veneer of elemental gold. It appears that only the part of the copper not covered by clay was coated by gold.
1000 level; Copper was noted from several widely spaced localities on this level where it was common as dendritic growths, both free-floating and on goethite. It was found here as bright cuprite-coated specimens, some of which are associated with tiny siliceous fragments. Also, copper was noted as thin, corroded crystals up to 5 cm in length, which were coated with delafossite. Numerous lumps were found as replacements of cuprite nodules that were often covered with cubic pseudomorphs of copper after cuprite.
1200-1400 levels 26-J, 26-K and 26-L stopes; A series of stopes that were on the 26-orebody from just below the 1300 level to above the 1200 level produced a wide range of fine specimens. The upper portions (26-J stope) were the least prolific for copper, but doubly-terminated, spinel-twinned crystals up to 7 cm were found on calcite. The center part (26-K stope) yielded a large number of well-crystallized specimens that had spinel twins up to 18 cm in length. These were on hematite, associated with acicular malachite, and invariably coated with cuprite altering to tenorite. Copper from the lower area (26-L stope) was also found as large, spinel-twinned crystals on hematite, but here malachite was rare and the cuprite coating was unaltered.

Czar Mine, Copper was abundant in this mine; often as large pieces, as noted by Douglas (1899). Petereit (1907) noted a few specimens from here as unusually large crystals, some of which were coated by silver. Also, it was found as elongated dodecahedral crystals up to 4 cm, as well as numerous crystallized specimens on iron oxides and as isolated, unconnected pieces in clay-like materials. A few pseudomorphs of copper after 5 mm tabular azurite crystals were found in this mine.
300 level; Copper was recorded from the Southwest orebody on this level as large, well-crystallized masses (Douglas, 1900)

Dallas Mine, *1400 level, 10 stopes;* Copper occurred here as substantial amounts of crystallized material, often with cuprite and rarely with crednerite. Superb examples of pseudomorphs of copper after cuprite were found here, with the more common form as cubes, but replaced dodecahedrons of up to 1 cm were found as well. Many large pieces exceeding 100 kg of massive, often somewhat fibrous copper were found during mining of this area. Casts of selenite crystals in massive copper were also reasonably common in specimens recovered from this series of stopes.

Denn Mine, *1250 level;* Abundant copper was found in the fault gouge clays of the Dividend fault in several areas on this level.
1700 level; On this level, copper was commonly found as groups of 2 to 5 mm crystals.

Gardner Mine, Copper was found in several places on the intermediate levels near the porphyry/limestone contact as irregular masses cementing breccia fragments, often with massive cuprite. A small number of specimens with sharp 6 to 8 mm pseudomorphs of copper after octahedral cuprite on goethite with cerussite were recovered from this mine.

Higgins Mine, *Tunnel level;* Copper came from the "Cuprite Stope" on this level in large amounts, as flat sheets, with few small crystals, along fracture planes in altered limestone with cuprite, and as small, irregular masses in calcite with cuprite and delafossite.

Hoatson Mine, Copper was noted from this mine as crystalline material in calcite-lined vugs (Tovote, 1911).
1200 level; This may well be the same material described by Tovote (1911). It occurred as well-crystallized material in vugs of iron oxides often partially coated with calcite (Tupper, 1915).
1400 level; Copper was common near the bottom of the Hoatson orebody as somewhat spongy, malachite-coated specimens.

Holbrook Mine; It was recognized in this mine as post-mining material with cuprite that formed in gob (backfill) as a result of high-copper, low pH water passing through the fill (Bateman, et al. 1914).
300 level, 17 stope; Bateman, et al. (1914) also noted a post-mining occurrence of copper in mine timber at this location.
400 level; A single near-solid copper mass of undetermined size, but at least 3 meters by 4 meters by 4 meters, was encountered by a crosscut near the shaft station and left in place and drifted around because of its size and the difficulty of mining the highly malleable material. It was still in place in 1967 when one of the authors was last at the location. Guild (1910) noted the occurrence of copper at the margins of chalcocite-rich orebodies on this level.
600 level; Copper was relatively common on this level as 2 to 20 cm isolated masses that were often well-crystallized in hematitic clay-like material.

Irish Mag Mine, Copper was a common ore mineral on most of the lower levels of this mine and masses of several tons were not uncommon. It was also found here as exceptional pseudomorphs after cuprite, usually as cubes, some of which were modified with octahedral and dodecahedral faces, which occurred in cavities in goethite (Rogers, 1910).
850 level; Abundant in stopes on this level as often large, spongy, crystalline masses with cuprite and chalcotrichite.
950 level; Copper occurred here with crystalline cuprite in irregular masses and was the principal ore mineral (Ransome, 1904).
1050 level; It was noted here as tough, spongy masses of small crystals, occasionally incrusting chalcocite from which it had obviously formed (Ransome, 1904).

Junction Mine, Copper was common from the upper levels of this mine as malachite coated, spongy to steel wool-like growths on iron oxides. Several generations of copper deposition are typically evident, with the later generations showing little alteration to malachite.
1200 level; An important orebody consisting entirely of native copper was hit on this level in 1909 (Calumet & Arizona, 1910).
1500 level; An uncommon occurrence of 2 to 4-mm "ram's horn"-growth wires in voids in massive chalcocite. Also, copper came from here as asbestiform masses of parallel fibers in massive chalcocite. The individual fibers of copper are 1 to 2 mm in diameter, up to 5 cm in length and can be easily separated. An important orebody consisting of copper and "oxides" was found on this level in 1925 (Calumet & Arizona, 1926).

Lavender Pit Mine, It was found in the pit bottom as post-mining material deposited in and partially replacing mine timber.
Holbrook Extension; Copper was common here as often large, blackened masses, frequently with malachite and cuprite. Also as flattened, dendritic specimens on siliceous material with small tufts of antlerite. It was also found as numerous rounded masses of up 20 cm in white clay in the northwest most part of the extension. These are externally crystalline with internal radiating patterns and may well be replacements of other copper species. A good deal of this material remained in the pit wall at the time of closure.

Sacramento Mine; Copper was found here in many of the oxidized orebodies throughout this expansive mine, though good specimens were uncommon. One unusual occurrence was as small crystals on and included within botryoidal siderite. It was also found as a filling between fragments in a siliceous breccia or altered limestone.

Shattuck Mine, Guild (1910) noted that copper was especially abundant in this mine.
600 level; Copper was found on this level as handsome, well-crystallized specimen on goethite and hematite.
700 level; It was noted from here as large pieces of crystalline material with cuprite, variety chalcotrichite, in "dry bone" above a chalcocite orebody (Bateman, et al. 1914).

Spray Mine, *700 level - 800 level;* A considerably body of native copper was found first in this mine on the 700 level, then again on the 800 level, for a vertical extent of more than 100 feet (Stevens, 1904).

COQUIMBITE $Fe_2^{3+}(SO_4)_3 \cdot 9H_2O$:

This common, locally abundant species has only been recognized in post-mining occurrences. Like most such minerals, it is reasonable to believe that coquimbite also occurred as a supergene mineral but was not recognized.

Most often, coquimbite occurred as part of multi-mineral crusts along mine openings in moist, pyritic areas. In the work of Merwin and Posnjak (1937), it was found to be the most abundant mineral present in these crusts. In the crusts, it was usually found as lavender to pale purple, distinct crystals, but they were not always obvious. This was due, in part, to the complex intergrowths of these multi-mineral aggregates and their marked similarity to other associated minerals. The crystals were typically small, rarely in excess of 6 mm, and either lavender or, when very thin, a yellowish-green.

The species associated with coquimbite are:

pyrite
voltaite
paracoquimbite
römerite
halotrichite
chalcanthite
copiapite
kornelite
rhomboclase
melanterite

OCCURRENCES:

Campbell Mine, As a constituent of the abundant post-mining crusts from many areas of this large mine.
1800 level; Coquimbite was found in small amounts as tiny, needle-like crystals, yellow-green in color, with römerite.

Cole Mine, *700 level;* It was common here as a lavender crust, often with fine voltaite crystals
800 level; Coquimbite was abundant as the primary constituent of post-mining crusts that were often 2 to 5 cm thick on oxidizing, massive pyrite.

Czar Mine, *400 level;* Coquimbite occurred along the walls of one crosscut here as exquisite lavender crystals to 2 mm on copiapite.

Dallas Mine, *1800 level;* This mineral was abundant in several areas as part of thick, multi-mineral crusts on mine openings.

Higgins Mine, *100 level;* Patchy areas of coquimbite with paracoquimbite along with halotrichite occurred on oxidizing pyrite on the walls of a stope.

Junction Mine, Many areas in this huge mine had post-mining crusts coating portions of the openings in pyritic areas. Coquimbite was typically one of the minerals present in these growths.

Lavender Pit Mine, Crust of copiapite with melanterite, coquimbite and voltaite commonly form on the high pyrite portions of the older porphyry and the Pinal schist during the wet seasons.

Sacramento Mine, This mine is most probably the source of the material that contained coquimbite, which was studied by Merwin and Posnjak (1937). A number of areas in this mine had post-mining efflorescence containing coquimbite.

CORONADITE $Pb(Mn^{4+}_6,Mn_2^{3})_8O_{16}$:

The occurrence of this supergene mineral has been confirmed in just a few localities within the district. However, it was probably far more common than this limited number of occurrences would indicate. Of the many occurrences for manganese oxides in the district, only a very few have been studied and none of these were associated with the replacement lead deposits.

Usually, coronadite is found as a black to gray-black, massive, botryoidal crust with a fibrous structure. Less commonly, it occurred as very small grains in other manganese oxides.

The species recognized with coronadite are:

calcite
goethite
cerussite
neltnerite
braunite II
hübnerite
tilasite

OCCURRENCES:

Specimen number 99494 in the collection of the US Museum of Natural History is gray-black coronadite as a botryoidal crust. It is from an unidentified locality in the district.

Campbell Mine, *1800 level;* This mineral was locally abundant as a black, botryoidal material to 1 cm thick with scattered cerussite sixling twin crystals. Some of the coronadite from this area has a thin overgrowth of often iridescent goethite.

Cole Mine, *1300 level;* Here it was found in small amounts as a thick, gray-black, botryoidal overgrowth on goethite with scattered calcite crystals.

White Tailed Deer Mine, Found at a nearby surface outcrop in small amounts as tiny grains in braunite II (Sid Williams, personal communication, 1987). Anthony, et al. (1995) further noted that, in this occurrence, coronadite is also associated with neltnerite, hübnerite, and tilasite.

COSALITE $Pb_2Bi_2S_5$:

This hypogene mineral has been recognized in minor amounts at a single location within the district. Here it was found as exsolution blebs in galena.

The species associated with cosalite are (Fabien Cesbron, personal communication, 1981):

galena
aikinite
chalcopyrite
pyrite
sphalerite

OCCURRENCES:

Campbell Mine, Cosalite was found in this mine in very minor amounts as exsolution blebs in galena with chalcopyrite, pyrite, sphalerite, and aikinite (Fabien Cesbron, personal communication, 1981).

COVELLITE CuS:

This was a widespread, locally abundant mineral, as well as an important constituent of many of the orebodies within the district. Most covellite from here is of supergene origin, but some hypogene material has been recognized.

The typical occurrence for covellite was as deep blue-black to indigo-blue material with an occasional purplish iridescence. Supergene covellite formed as an alteration product of high-copper sulfides such as bornite, chalcocite, and chalcopyrite (Graton and Murdoch, 1913). As such, covellite is frequently found as a veneer or crust on these sulfides, as well as in fracture-controlled veins cutting the altering sulfides. Complete alteration of the original copper sulfide was often noted. Most of the covellite formed this way was compact and somewhat foliated. Large, nearly pure masses weighing many tons of this type of covellite were found in several of the mines.

Covellite was also derived from the supergene alteration of low-grade copper-bearing sulfides such as cupriferous pyrite and/or mixtures of any of the primary copper sulfides with pyrite. An earthy to sooty, deep blue to black material on fractures and along crystal boundaries was often the result of this alteration, although compact veinlets of covellite formed along some fractures in the altering sulfide mass as well. The complete alteration of low-grade ores to covellite often resulted in impure, earthy mixtures with hematite.

The limited amounts of hypogene covellite that have been recognized were found as a dense, often foliated material that is frequently included as blebs and masses in other copper sulfides. Crystals of covellite are most uncommon from the district and when found were small.

Most of the hypogene minerals have been found with covellite. The more important are:

bornite
hematite
chalcocite
pyrite
quartz
chalcopyrite

Supergene minerals found with covellite are:

hematite
malachite
chalcocite
silver
azurite
goethite

OCCURRENCES: Because of its wide distribution and generally nondescript nature, only the more important or unusual occurrences are noted.

Cole Mine, *500 level;* Small amounts of covellite were found in an exploration crosscut near the Congdon shaft on this level as a series of isolated pods of a ton or more, that were pure, foliated material in apparently unaltered limestone.

Holbrook Mine, *400 level;* A common ore mineral here, covellite was found in an exceedingly large mass of earthy material that contained nodules of nearly pure material that were up to 100 kilograms in weight. This was a supergene occurrence.

Junction Mine, *2000 level;* Covellite was common on this level in a large body of massive hypogene material mixed with bornite. One small pocket of crystals that were 4 to 5 mm in size and associated with tiny pyrite crystals was recovered from here.

Lavender Pit Mine, *Holbrook Extension;* Covellite was found in this part of the pit as large amounts of massive, blue-black material in the hanging wall of the Dividend fault. Many of the fractures in this covellite had thin films of elemental silver along them. Foil-like sheets of silver exceeding several meters were loosely attached to large, slickensided masses of covellite mixed with modest amounts of pyrite. A sample of this material taken by one the authors during mining assayed at 2,240 ounces of silver per ton or 1.12 ounces of silver per pound of covellite.

CREDNERITE $CuMnO_2$:

This supergene mineral appears to be relatively rare in the district. However, given the marked similarity in appearance as well as depositional environment of crednerite to the far more common delafossite, it is probable that it is more abundant, having been confused with delafossite.

Typically, crednerite was found as compact masses of silver-black, micaceous crystals intergrown with massive cuprite. Less frequently, it was found as black spheroids to 1 cm with copper.

As is obvious, crednerite formed in manganese-rich, iron-poor environments. In an examination of the few recognized specimens from Bisbee, no iron minerals were noted. This is unusual for a Bisbee supergene mineral in that vast majority are found in association with one or more of the supergene iron oxides.

The minerals associated with crednerite are:

cuprite

copper

quartz

calcite

OCCURRENCES:

Dallas Mine, *1400 level;* Crednerite occurred here in small amounts as bright black metallic spheroids to 1 cm with copper, quartz, and an unidentified clay-like mineral.

Higgins Mine, *Tunnel level;* Found in numerous small cuprite nodules that were randomly scattered throughout altered, manganese-rich limestone. Also, crednerite was noted with cuprite and copper in the *'Cuprite stope."*

Hoatson Mine, It was found in this mine as massive material composed of compact growths of micaceous crystals with massive cuprite. Also from here is University of Arizona specimen 6993 which was originally labeled as delafossite and cuprite. X-Rayed on 03/1977. X-Ray by Arthur Roe on 12/1982 #800 showing it to be crednerite.

CRYPTOMELANE $K(Mn^{4+}{}_7,Mn^{3+})O_{16}$:

This is a secondary mineral of apparent limited distribution within the district. It has been recognized only in two of the many small, near-surface manganese deposits scattered throughout the district.

Most of the recognized cryptomelane occurred as a metallic gray to gray-black fibrous variety. It was however, not rare to find cleavable cryptomelane in the same specimen as the fibrous material.

The minerals associated with cryptomelane are:

- braunite
- neltnerite
- jacobsite
- calcite
- pyrolusite

OCCURRENCES:

Cole Mine, Specimen 19216 in the University of Arizona collection is from this mine and is noted as having been "X-Rayed."

Number 4 claim, It was found at this locality as veins to 3 cm in the limestone adjacent to the main oxidized manganese orebody. Here it occurred as gray-black fibrous material along with cleavable cryptomelane. Very minor jacobsite and neltnerite were associated with it, as was calcite.

White Tailed Deer Mine; Cryptomelane was noted in samples from a nearby surface outcrop as sprays of gray, needle-like crystals in calcite with braunite (Sid Williams, personal communication, 1987).

CUPRITE Cu^{1+}_2O:

This is one of the most abundant and widespread of the copper supergene minerals in the district. Also, cuprite was an important ore mineral from the very beginning (Douglas, 1881a) and may well have been the most economically important non-sulfide ore mineral mined at Bisbee. Large masses of hematite-stained clays with disseminated cuprite and often copper were mined throughout the district and over most of its productive history. Some of the world's finest examples of this beautiful mineral have been found in the district.

A wide variety of minerals are found with cuprite from this district. The more common or important except for clays are listed below:

- goethite
- atacamite
- graemite
- malachite
- nantokite
- miersite
- delafossite
- claringbullite
- calcite
- chalcoalumite
- tolbachite
- chrysocolla
- chalcophyllite
- quartz
- azurite
- bromargyrite
- copper
- spangolite
- hematite
- paratacamite
- teineite
- tenorite
- connellite
- cassiterite

Several species have been noted replacing cuprite. These are copper, malachite, tenorite, azurite, goethite, and chrysocolla. Other replacements are highly probable, but so far unrecognized.

Pseudomorphs of cuprite after other minerals are uncommon from Bisbee. Only delafossite and copper have been noted as having been faithfully replaced by cuprite.

Post-mining cuprite was probably relatively common, but largely unrecognized. The author recognized post-mining cuprite in several places, as a thin veneer of tiny cubic crystals associated with post-mining copper in ponded mine waters. Post-mining cuprite was also noted to have developed in mine backfill (Bateman, et al. 1914; Trischka, 1931).

OCCURRENCES:

Baxter Tunnel; Cuprite was reported from here as fine specimens with copper (Bateman, et al. 1914).

Cole Mine, Common throughout the oxidized ores in this large mine, cuprite was economically very important.
1000 level; Several areas on this level produced the variety chalcotrichite, one of which yielded the finest examples known. Specimens of chalcotrichite on friable goethite as large as 60 cm with acicular crystals 3 cm in length were recovered. Also from this level were numerous samples of cuprite, variety chalcotrichite, on black, botryoidal goethite. Partial alteration to malachite was common, resulting in a gray cast to the specimens. In some instances, these were actually cuprite pseudomorphs after delafossite. An unusual occurrence of cuprite as elongated cubes to 2 mm in quartz-lined fossil shells with delafossite was also found on this level.
1100 level; The variety chalcotrichite was found here with the fibrous crystals on goethite oriented at right angles to each other on goethite. Drusy to coarsely crystalline crusts of cuprite on copper also occurred on this level.
1200 level, 202 stope; Large masses of cuprite as nodules were mined from this stope, occasionally with inclusions of radiating connellite to several centimeters across. Pockets in the cuprite, while typically small, contained gem-like modified cubes. Also from this stope were aggregates of bright, gemmy crystals with acicular malachite and, on at least one specimen, graemite and teineite.

Copper Queen Mine, Several locations in this small mine contained crystal-lined pockets in massive cuprite, usually with a white clay-like rind, though these were not common (Blake, 1909).
400 level; Found here as numerous specimens of 2 to 4 mm octahedral crystals, typically malachite-coated, on malachite that is usually covered with a thin veneer of goethite, or on goethite. Azurite is often associated with this occurrence. This locality was the same very orebody, largely mined through the Czar mine.

Czar Mine, Many fine specimens were recovered from this relatively shallow mine during its 60-year productive life. Most of these came from the large soft clay/iron oxide areas surrounding the oxide ores and in the Dividend fault zone. Also, small octahedrons of cuprite were occasionally found implanted on malachite and, less often, azurite. In these cases, there was almost always a veneer of iron or manganese oxides on the malachite or azurite before cuprite deposition. Cuprite, variety chalcotrichite, pseudomorphs after delafossite on goethite were also found here. Drusy

crusts of cuprite on needle-like crystals of copper were found in this mine as well. Some of these specimens are more than 50 cm across.
200 - 400 level; Discrete euhedral crystals and often large, irregular masses of cuprite were found in the iron oxides/clays in sufficient amounts to constitute ore. The masses had rinds of malachite, tenorite, and chrysocolla. Many of these contained vugs with cubic crystals of up to 1 cm in size. Also, from the 200 level were fine specimens of the variety chalcotrichite in vugs in goethite and associated with calcite.

Dallas Mine, *1400 level, 10-D stope;* Brilliant, blood-red cuprite crystals from 2 to 8 mm on copper with abundant white silica fragments were found here.

Denn Mine, Groups of sharp cubic crystals with copper in massive hematite were produced by this mine.

Holbrook Mine, Fine specimens of the variety chalcotrichite, lining or filling voids in goethite boxwork, were produced from this mine as were pockets of modified cubic crystals in massive cuprite. Octahedral crystals to 6 cm in goethite boxwork voids were also found here.

Higgins Mine, *Tunnel level;* An orebody known as the "Cuprite Stope" was most unusual. Along with huge amounts of massive material, it yielded a large amount of cuprite as translucent, blood-red, euhedral to subhedral, 1 to 2 cm crystal inclusions in massive brown calcite with crednerite, copper, and minor chlorargyrite.

Irish Mag Mine, Many exceptionally fine cuprite specimens were found during the short life of this very rich mine. Indeed, perhaps "The Mag" was the mine that produced the most specimens of this lovely mineral. Ransome (1904), notes that the orebodies here contained large crystalline masses with copper and "beautiful druses of isometric crystals." A great many specimens of 4 to 6 mm octahedral crystals on copper were produced as were a few specimens with crystals of up to 2 cm.
850 level; Tough, spongy masses of copper with 2 to 4 mm crystals contained the variety chalcotrichite as attractive partial coatings and, less often, dense linings of voids in the copper. Also, cuprite was abundant on this level as irregular masses surrounded with tenorite, chrysocolla and malachite (Ransome, 1904).
950 level; From a stope 650 feet northeast of the shaft it was noted as "glittering bunches --- penetrated by dendritic masses of bright metallic copper" (Ransome, 1904). Also from this level and some 400 feet southeast of the shaft as crystalline cuprite with copper (Ransome, 1904).

Junction Mine, Cuprite was found here as massive material altering to azurite (Mitchell, 1920b).

Juniper Flat, An unusual occurrence for cuprite was recognized here as a minor accessory mineral in calcite in some of the mineralized gold bearing quartz veins with brochantite, azurite, and malachite (Rob Bowell, personal communication 2004).

Lavender Pit Mine, *Holbrook Extension;* Uncommonly, huge masse of nearly pure cuprite with some copper were mined from this area of the pit. Some of these exceeded 20 tons in weight and contained scattered pockets of up to 20 cm that were lined with cubes to 6 mm or smaller dodecahedrons. Occasionally elongated cubes to 4 mm in length were associated with the typical cubic crystals. Also from this section of the pit came sharp octahedral crystals of up to 1 cm implanted on malachite or goethite. These occurred in vugs in siliceous goethite boulders along with other secondary copper minerals, particularly azurite and chalcoalumite.

Lowell Mine, Several of the oxide orebodies contained cuprite as massive material with rinds of tenorite, malachite, and chrysocolla. A small number of these masses had inclusions of connellite.

Sacramento Mine, Cuprite from here occurred as octahedral crystals to 6 mm on a spongy silica/goethite matrix and as the variety chalcotrichite filling voids of several centimeters in this same material. Specimens of the variety chalcotrichite on porphyry with scattered azurite crystals were recovered from this mine as well. Massive cuprite and copper occurred here as an in-situ replacement of primary copper sulfides, cementing angular, siliceous breccia fragments.

Shattuck Mine, *200 level;* Cuprite was found on this level as massive material altering to azurite (Bateman, et al. 1914).
500 level; A cave on this level contained numerous irregular lumps of cuprite coated with bright, acicular malachite as well as some calcite.
800 level; From here as the variety chalcotrichite with chalcocite (Bateman, et al. 1914). Also on this level just south of the shaft as the variety chalcotrichite on copper in “dry bone” above a chalcocite orebody (Bateman, et al. 1914).

Southwest Mine, Cuprite was common throughout this extensive mine, particularly in many of the clay-like areas of the oxide orebodies, where it occurred as irregular masses (nodules) that are probably in situ replacements of chalcocite.
3rd level; Noted in several stopes on this level where it occurred as residual cores in goethite with malachite along mineralized faults. Minor amounts of brochantite and/or connellite occurred as inclusions in the massive cuprite.
5th level, 14 stope; Cuprite occurred here as many irregular pods of massive material in clay-like iron oxides. The largest of these would weigh up to several hundred kilograms. A number of these masses had vugs that contained 2 to 6 mm cubic crystals associated with paratacamite, connellite, and spangolite. One large mass had open spaces that contained remarkable transparent modified cubic crystals up to 5 cm on an edge. These were on a base of acicular atacamite and are undoubtedly among the finest known examples of this species.
6th level; Cuprite came from several stopes on this level as pods in clay, some of which are almost completely altered to malachite and/or chrysocolla.

CUPROCOPIAPITE $Cu^{2+}Fe_4^{3+}(SO_4)_6(OH)$:

This mineral has only been recognized in post-mining occurrences. As such, cuprocopiapite was found as a very minor constituent of the multi-mineral crusts. Given the close resemblance of cuprocopiapite to other similarly occurring sulfates it was almost certainly overlooked at other occurrences.

Cuprocopiapite occurs as tiny, tabular crystals that are greenish-yellow in color and part of the multi-mineral crusts that form on oxidizing sulfides in mine openings.

The species associated with cuprocopiapite are:

quartz
rhomboclase
pyrite
copiapite
chalcopyrite
bornite

OCCURRENCES:

Junction Mine, *1800 level;* A crosscut leading toward the Sacramento mine in mineralized porphyry contained pyrite with minor amounts of chalcopyrite and bornite. On this a crust formed that contained minor amounts of cuprocopiapite on rhomboclase with abundant copiapite and other such post-mining sulfates.

CUPROPAVONITE $Cu_{0.9}Ag_{0.5}Pb_{0.6}Bi_{2.5}S_5$:

This hydrothermal mineral has been found in very small amounts in two areas of a single locality within the district. Here it was part of a complex, silver-rich mineral assemblage that was associated with base-metal sulfides as small to tiny inclusions.

The species associated with cupropavonite are (Alan Criddle, personal communication, 1992):

chalcopyrite
galena
silver
acanthite
copper
bornite
wittichenite
rutile
digenite
tennantite
sphalerite
hessite
stromeyerite
djurleite
gold
chalcocite
magnetite
pyrite
spionkopite
colusite

OCCURRENCES:

Campbell Mine, *1900 level;* It was found here in very small amounts as part of a complex ore assemblage in a siliceous hematite that hosted a brecciated chalcopyrite. A number of the above species were associated with cupropavonite at this locality. The galena and sphalerite are high in silver, containing from 0.3 to 0.5 percent silver respectively (Alan Criddle, personal communication, 1992).
2300 level, 126 stopes; Cupropavonite occurred with a number of other largely silver-bearing minerals as inclusions in chalcopyrite, bornite, sphalerite, chalcocite, and galena. The galena from here was also high in silver content, up to 1.8%, with the silver found as $AgBiS_2$ in solid solution (Alan Criddle, personal communication, 1992).

CUPROTUNGSTITE $Cu_3^{2+}(WO_4)_2(OH)_2$:

This rare supergene mineral has been found in only one locality on the eastern edge of the district.

The occurrence of cuprotungstite was as patches to 1 cm of a friable, almost earthy, yellow-green to green material surrounding residual kernels of chalcocite in a quartz/scheelite matrix. The minor mineralization associated with this occurrence is obviously post-Cretaceous, thus unrelated to the mineralization events which emplaced the economic ore deposits.

The species associated with cuprotungstite are:

quartz
goethite
scheelite
chalcocite
hematite

OCCURRENCES:

An unnamed prospect shaft approximately 2 km east of the Portage Lake mine contained modest amounts of this mineral as an apparent alteration product of supergene chalcocite and scheelite.

CYANOTRICHITE $Cu_4^{2+}Al_2(SO_4)(OH)_{12}\cdot 2H_2O$:

This is an uncommon mineral within the district and of secondary origin. Only a small number of specimens are known from here.

From the small number of available specimens, it appears that the cyanotrichite largely formed at the expense of other copper minerals, particularly malachite. Cyanotrichite was deposited relatively late as a felt-like coating of 5 mm acicular crystals on malachite and to a much lesser degree on azurite or, rarely, brochantite. The underlying copper species are almost always decidedly corroded whereas the parts of the specimen without cyanotrichite are largely free from corrosion.

It is probable that the depositional circumstances for cyanotrichite are somewhat similar to those of chalcoalumite and carbonatecyanotrichite, as all of the known examples of these three species are from the same area, the southwest contact zone of the stock and the limestone. Small amounts of moderately low pH sulfate solutions containing aluminum may have reacted with the earlier copper minerals forming the cyanotrichite. A more detailed discussion can be found in volume one, under the brief discussion of aluminum flooding noted in the western part of the Holbrook mine.

The abundant, often impermeable clay/iron and/or manganese oxide mixtures in the area may have controlled solution access to the copper carbonates, thus, restricting cyanotrichite formation. Most of the azurite and malachite found in this area either was encased in such materials or exhibited the characteristics of the corrosive action of iron, zinc, and/or aluminum sulfate solutions.

The minerals associated with cyanotrichite are:

malachite
azurite
goethite
brochantite

OCCURRENCES:

Lavender Pit Mine, *Holbrook Extension*; It was found here as bright blue acicular crystals covering a zincian malachite and drusy azurite. A later generation of 3 to5 mm dark blue azurite crystals was deposited on the cyanotrichite. Also from this area, cyanotrichite occurred as light blue patches of delicate fibrous crystals on brochantite.

D

DELAFOSSITE $Cu^{1+}Fe^{3+}O_2$:

This was a common supergene mineral widely distributed throughout the district, often in sufficient amounts to constitute an ore (Mitchell, 1921c). What are undoubtedly the finest examples of this species ever found are from Bisbee. Perhaps some of the specimens identified as delafossite are, in fact, the very similar appearing and occurring crednerite.

The most common occurrence for delafossite was as impure black earthy masses or usually small, silvery-black flakes disseminated in the common supergene clay/hematite/goethite mixtures. The flakes, which very much resemble graphite, can exceed 1 cm in size. On rare occasion, small voids in these materials would have well-formed tabular crystals in parallel growth. Crystals that formed under these conditions reached 1 cm in size.

Delafossite was frequently found as partial to complete coverings of the ubiquitous openings in the boxwork formations so typical of both goethite and hematite. This was usually as small (3 mm or less) hemispheres of thin, tabular crystals, usually closely packed. Similar coverings of small, randomly oriented, tabular, hexagonal crystals were less common, but not rare. Thin botryoidal crusts, both as very small crystals, and as massive material were also found.

Copper and, much less often, cuprite, were found coated with 2 to5 mm crystals of delafossite. In these cases, it appears that the delafossite formed at the expense of the underlying copper-containing mineral as they are invariably corroded.

Least common, yet the most striking among occurrences, was as multiple hexagonal crystals in parallel growths, oriented on small stalactites of hematite. These crystals were up to 1 cm across and covered stalactites equally long.

The several periods of supergene activity experienced in the western part of the district have left a confused paragenetic sequence particularly with delafossite. There may be several generations of cuprite and delafossite, sometimes one replacing part or all of the other. Typically, delafossite was later than copper, but earlier than cuprite.

Many of the early phase supergene minerals are associated with delafossite. These are:

hematite
copper
cuprite
calcite
malachite
goethite

Pseudomorphs of cuprite, copper, and malachite after delafossite are known from here. While it is common to find delafossite formed at the expense of copper and cuprite, no pseudomorphs of delafossite after these species have been recognized.

OCCURRENCES:

Briggs Mine, *1400 level, 254 stope;* Abundant delafossite was noted from this locality by Bateman, et al. (1914).

Cole Mine, This mineral was frequently found in many of the oxide ores on several levels of this extensive mine.
1100 level; The most notable occurrence for delafossite in this mine was on this level where it was found as superb groups of silver-black, tabular, hexagonal crystals to 1 cm; as clusters of poorly formed, platy crystals, often with small cuprite crystals; and as numerous micaceous flakes to 5 mm in a sericitic-type clay material.

Dallas Mine, *1400 level, 10 stope;* It was common in this stope as scattered clusters of platy crystals on copper that form 2 to 4 mm rosettes; occasionally it was partially altered to malachite. Also from here delafossite occurred as crusts of platy crystals completely covering copper.

Hoatson Mine, The occurrence of delafossite in the district was first noted at this mine by Tovote (1911).
1400 level; It was also noted on this level as micaceous flakes to 5 mm in a kaolinite matrix with copper, cuprite, and hematite (Rogers, 1913).

Sacramento Mine, University of Arizona specimen 6900 from this mine was originally labeled as tenorite. X-Rayed by Amber Mitchell and Cyprus Miami in 12/1995 indicated it to be delafossite.

Southwest Mine, Small crystals of delafossite were noted from this mine by Galbraith (1947).

Irish Mag Mine, This was a relatively common, widely distributed mineral from most of the productive levels in this mine. It commonly occurred as crusts of compact crystals coating goethite/hematite boxwork voids with later cuprite. It was also found here as 2 to 3 mm rosettes of small tabular crystals on hematite and/or copper as well as drusy, crystalline crusts on copper. Rarely, it was found as multiple hexagonal crystals in parallel growths oriented on and encasing thin hematite stalactites.

Uncle Sam Mine, A small number of specimens with tiny amounts of delafossite in vugs in hematite were found on the dump of this mine.

DESCLOIZITE $PbZnVO_4(OH)$:

A widely distributed, but uncommon supergene mineral that is found only in very minor amounts at all but one of the recognized localities. For the most part, descloizite occurred as a thin drusy crust or scattered tiny crystals.

The minerals that have been observed as associated with descloizite are:

calcite
malachite
anglesite
mottramite
hemimorphite
mimetite
pyrolusite
quartz
conichalcite
braunite
plattnerite

OCCURRENCES:

Dallas Mine, reported from here in small amounts (Bonillas, et al. 1916).

Higgins Mine, *Twilight claim;* From this manganese mine as a brown crust and microcrystals on a braunite/pyrolusite mixture
Tunnel level; A few specimens were recovered from here as groups of 4 to 6 mm brown, prismatic crystals and 2 mm tabular, translucent crystals on limestone breccia fragments with calcite.

Kentucky Tunnel, The dump of this small exploration working on the south side of Escabrosa Ridge contained small amounts of descloizite as tiny, translucent, brown crystals on quartz with mimetite, hemimorphite, and anglesite on oxidized galena.

Sacramento Mine, Bonillas, et al. (1916) reported the occurrence of descloizite in this mine.

Shattuck Mine, *600 level, 8 stope;* Most if not all of what was reported by Wells (1913) as cuprodescloizite (descloizite) from this locality is indeed mottramite (Taber and Schaller, 1930). However, minor amounts of descloizite have been recognized as scattered, tabular, minute crystals on siliceous fragments from the cave bottom on mottramite and with later calcite.

Southwest Mine, Descloizite was found in many of the small, unnamed, near-surface manganese deposits, particularly those on Queen Hill and along Escabrosa Ridge overlying the workings of the Southwest mine. In these instances, it appears to be a very late-stage mineral with few, if any, species except calcite deposited later.
7th level; Modest amounts of tiny descloizite crystals occurred in a raise leading to a large oxidation cave. It was found here as 0.5 mm translucent crystals with malachite on altered limestone and was partially overgrown by mimetite with later malachite and minor plattnerite.

DEVILLINE $CaCu_4^{2+}(SO_4)_2(OH)_6 \cdot 3H_2O$:

A rare secondary mineral in the district that typically formed in small amount as an in-situ alteration product of primary copper sulfides. The similarity of devilline to other alteration minerals such as chalcanthite and, to a lesser degree, brochantite may have caused many occurrences to go unrecognized.

The species associated with devilline at Bisbee are:

chalcocite
sphalerite
hydrozincite
bornite

calcite
gypsum
chalcopyrite
quartz
smithsonite
pyrite

OCCURRENCES:

Junction Mine, *1500 level;* It was rarely found here as tiny blue to blue-green crystals with minor gypsum on a mixture of chalcopyrite, bornite, chalcocite, and calcite in a long-abandoned stope. This may well represent a post-mining occurrence.

Lavender Pit Mine, *Holbrook Extension;* Platy blue crystals to 0.7 mm and scaly crusts of devilline occurred along fractures in oxidizing massive chalcocite in this part of the pit.

Southwest Mine, *3rd level;* It was found here as blue, 0.5 mm platy crystals on fractures and in small voids in oxidizing chalcopyrite associated with sphalerite in a calcite matrix. Also present were gypsum, smithsonite, and minor hydrozincite.
6th level; Devilline was recognized on this level as bright blue microcrystals along fractures in chalcocite with minor pyrite and gypsum. Also from this level as crusty patches of tiny crystals to several centimeters across on quartz with pyrite and chalcopyrite

DIABOLEITE $Pb_2Cu^{2+}Cl_2(OH)_4$:

This supergene species has been recognized from one locality and on a single specimen. It is not unreasonable to suggest that other specimens, if not other localities remain unrecognized.
The species associated with diabolite are:

silver
chalcocite
leadhillite

OCCURRENCES:

Campbell Mine, *1800 level, 105 stope;* Diabolite was noted on one specimen, where it occurred as tiny, bright blue, cubic crystals on chalcocite with, leadhillite and silver (Ron Gibbs, personal communication, 2014).

DIASPORE $AlO(OH)$:

This hydrothermal alteration mineral is widely distributed in small amounts in one of the intrusive units of the Sacramento Stock Complex. Here, diaspore was found as a microscopic constituent of a sericitized quartz monzonite (Anthony, et al. 1995).

The species associated with diaspore are:

quartz
muscovite
pyrite

OCCURRENCES:

Lavender Pit Mine, The altered portions of the younger porphyry unit of the Sacramento Stock Complex often contained microscopic diaspore as inclusions in muscovite (sericite).

DICKITE $Al_2Si_2O_5(OH)_4$:

This hydrothermal alteration species is common as an accessory mineral in the older porphyry unit of the Sacramento Stock Complex as well as in the underground porphyry dikes (Bryant and Metz, 1966). Dickite is visually indistinguishable from the more abundant kaolinite and, because of misidentification, may be more common than thought.

Typically, it occurs as a massive white to gray material in blebs to several centimeters replacing feldspars and to a lesser degree, "biotite," in the porphyry.

The species associated with dickite are:

quartz
rutile
pyrite
tremolite
alunite
apatite
zircon
calcite

OCCURRENCES:

Lavender Pit Mine, Anthony, et al. (1995) report dickite as dense, white material cementing pyrite.

Sacramento Mine, *1600 level;* Dickite with tremolite and calcite had largely replaced limestone in an area of this level (Tenney, 1913).

DIGENITE $Cu_{1.8}S_5$:

This species is undoubtedly widely distributed and forms under both hypogene as well as supergene conditions (Anthony, et al. 1995). However, only a few occurrences have been confirmed.

This is one of the several chalcocite-like minerals that cannot be visually distinguished from other similar species (Roseboom, 1964. Digenite was not recognized as a species separate from chalcocite until 1942 (Buerger, 1942). Because of this, none of the early studies noted this mineral.

Typically, digenite occurs as massive material intermixed with chalcocite and djurleite, as well as other secondary copper species under supergene conditions. Hypogene digenite is usually found as massive material mixed with chalcocite, bornite, and minor djurleite.

The species most frequently found with digenite are:

chalcocite
malachite
djurleite
cuprite
calcite
copper
bornite
sphalerite

pyrite
covellite
goethite

OCCURRENCES:

Campbell Mine, Digenite was noted from an unspecified level in this mine in small amounts as massive hypogene material with inclusions of sphalerite and pyrite (Navias, 1952).
1900 level, 2100 level, and 2200 level; Minor amounts of hypogene digenite were found by Criddle and Stanley in samples from these levels. Here it was found admixed with chalcocite, djurleite, bornite, and a wide assemblage of other lesser minerals as fracture fillings, fragment replacements, or rinds on brecciated limestone in the remaining, low-grade portions of the Campbell orebody (Alan Criddle, personal communication 1992).

Higgins Mine, *Tunnel level;* Minor supergene digenite was found with djurleite as scattered lumps to several centimeters in recrystallization limestone with malachite, calcite, and copper over a wide area near the property sideline with the Southwest mine.

Junction Mine, *2000 level;* Specimens 12946 in the University of Arizona collection from here are massive, brecciated, bluish-gray metallic digenite.

DIOPSIDE CaMgSi$_2$O$_6$:

This species is one of the contact-metamorphic minerals found as part of a multi-mineral alteration assemblage replacing limestone (Ransome, 1904; Bonillas, et al. 1916). As such, it was widely distributed, particularly near the Sacramento Stock Complex. Ransome (1904) noted that most of the limestone in the Spray mine below the 400 level and in the Irish Mag mine below the 850 level exhibited some degree of alteration to tremolite/diopside. This alteration ranged from minor to complete replacement.

Typically, diopside was found as colorless 0.1 mm grains (Ransome 1904) or tiny, stout prismatic crystals that were white to pale green in color. For the most part, diopside was found mixed with tremolite as tiny crystals or as grains in the matrix of unoxidized pyritic ores (Anthony, et al. 1995).

The species associated with diopside are:

actinolite
quartz
forsterite
chalcopyrite
tremolite
edenite
chlorite
grossular
bornite
wollastonite
sphalerite
pyrite
chalcocite
vesuvianite
calcite
epidote
andradite

OCCURRENCES: Diopside is so abundant and widely distributed that only a few of the typical occurrences are noted.

Gardner Mine, *1000 level;* Diopside was abundant here with tremolite, quartz, and epidote as gray-green masses that completely replaced limestone. Pyrite and chalcopyrite were associated with this assemblage.

Junction Mine, It was common in a number of places in this mine along with other contact-metamorphic minerals as a matrix for pyrite/chalcopyrite ores.

Sacramento Mine, *1400 level;* Diopside was found here as 2 mm greenish crystals in and replacing limestone with massive, fine-grained tremolite.

DIOPTASE $Cu_6Si_6O_{18.6}\cdot H20$:

This is a surprisingly rare mineral in the district given the local abundance of both copper and silica. Supergene in origin, only one locality is known for this species with very few specimens ever having been produced.

The silica breccias of the Shattuck Mine were a source for the majority of copper silicates species found within the district and dioptase is no exception. A late-stage mineral, dioptase was found as clusters of small crystals on aurichalcite or, less often, on malachite. In some cases, it appears that the dioptase formed at the expense of aurichalcite or malachite.

The minerals associated with dioptase are:

quartz
aurichalcite
hematite
malachite
calcite
hematite

Dioptase has been recognized as cast type pseudomorphs of poor quality after aurichalcite.

OCCURRENCES:

Shattuck Mine, Dioptase occurred as partial coatings or small clusters of 0.5 to 1 mm deep emerald-green crystals on aurichalcite or malachite that in turn, are on a matrix of siliceous breccia fragments, often with specular hematite and minor quartz. Minor calcite has been noted covering the dioptase on a small number of specimens.

DJURLEITE $Cu_{31}S_{16}$:

This species is undoubtedly widely distributed (Anthony, et al. 1995) and forms under hypogene as well as supergene conditions. However, only a few occurrences within the district have been confirmed.

Djurleite was not recognized as a species separate from chalcocite and digenite until 1966 (Roseboom, 1966). This is one of several chalcocite-like minerals that visually cannot be distinguished from similar species. Because of this, none of the earlier workers noted the presence of this mineral.

Typically, djurleite occurs as massive material intermixed with chalcocite and digenite and other secondary copper species under supergene conditions. Hypogene djurleite is usually found as massive material mixed with chalcocite, bornite, and digenite Schumer, 2017).

The species most frequently found with djurleite are:

chalcocite
malachite
pyrite
digenite
cuprite
covellite
calcite
copper
goethite
bornite
sphalerite

OCCURRENCES:

Campbell Mine, *1900 level, 2100 level, 2200 level;* Hypogene djurleite was recognized by Criddle and Stanley as a minor accessory mineral in samples from these levels. Here it was found admixed with chalcocite, digenite, bornite, covellite, and a wide assemblage of other lesser minerals as fracture fillings, fragment replacements, or rinds on brecciated limestone in the remaining low-grade portions of the Campbell orebody (Alan Criddle, personal communication 1992).

Cole Mine, *1300 level, 26K stope;* Spongy masses of tiny djurleite crystals, largely encased in calcite, were noted in a few specimens from here. The specimens appear to be black calcite crystals because of the encased djurleite. Malachite is present as a late-stage mineral and hematite is the typical matrix for these pieces.

Higgins Mine, *Tunnel level;* Supergene djurleite, as masses to several centimeters with few crystal faces, was found with digenite in a recrystallization limestone. Some alteration of djurleite to malachite had occurred and it was associated with calcite and copper.

DOLOMITE $CaMg(CO_3)_2$:

This species is widely distributed and abundant throughout the district. By far the most common mode of occurrence for dolomite is as a component of the dolomitic phases of the Martin limestone. Occasionally, areas of nearly pure dolomite were found in this sedimentary unit (Paul Levy, personal communication, 1977). It has not been determined if the high purity material is of hydrothermal origin or formed by sedimentary processes. Dolomite has also been recognized in relatively minor amounts in both hydrothermal and supergene occurrences.

Hydrothermal dolomite was most common as small, discontinuous, white to pink veins in the Martin limestone. Small pockets of pink crystalline dolomite that were hydrothermal in origin were occasionally found in Martin limestone as well.

Supergene dolomite was uncommon or at least not frequently recognized. Most supergene dolomite occurred as white to tan, late-stage overgrowths on calcite and/or aragonite. A great many calcites from Bisbee have markedly curved faces and saddle-shaped crystals indicating the possibility that they may be magnesian, if not dolomite.

The species associated with dolomite in the district include many of the species recognized from here.

OCCURRENCES:

Only those localities that have produced dolomite in an unusual form or as collector specimens will be noted.

Campbell Mine, *2833 level, 9 crosscut;* Specimens of massive, apparently altered, Martin limestone recovered from here in 1973 for use in the work of Levy, et al. (1977) were found to be exceptionally pure dolomite (Paul Levy, personal communication, 1977). Isolated pockets of tiny, pale pink to white crystals occurred in this material.

Higgins Mine, *Tunnel level;* Specimens of 6 to 8 mm pink, curved dolomite crystals with scattered clusters of 4 mm malachite sprays came from this area.

Holbrook Mine, *600 level; 95 drift;* Small pink dolomite crystals were found in marbleized Martin limestone (Tenney, 1913).

Junction Mine, *2566 level; Numerous* pink to pale pink veinlets of dolomite were found cutting Martin limestone at this location. On rare occasion, small pockets were found in these veins and contained 2 to 4 mm curved crystals.

Southwest Mine, *6th level;* Dolomite coating acicular aragonite and botryoidal calcite was found in voids in a silica breccia in a collapsed stope on this level.
7th level; Much of the acicular aragonite from a large cave above this level had partial overgrowths of white dolomite that becomes tan in color after several years of exposure to the surface environment.

Spray Mine, *900 level, 9 drift;* Massive dolomite was found here with abundant, massive pyrite, magnetite, and minor pyrrhotite (Tenney, 1913).

DUFTITE $PbCu(AsO_4)(OH)$:

This secondary mineral is quite rare in the district. Only a few specimens have been found at a single locality. The lead and lead/zinc deposits associated with the silica breccias in the Southwest mine area have been the source of this and a number of lead minerals.

The minerals associated with duftite are:

plumbojarosite
calcite
quartz

OCCURRENCES:

Southwest Mine, *6th level;* Several specimens from the dump of this level contained duftite as 0.5 cm masses of yellow-green duftite in a breccia largely composed of plumbojarosite, calcite, and quartz. Several small voids were lined with microcrystals on calcite. Occasionally, calcite-encased microcrystals of duftite were found in the breccia material as well.

DYSCRASITE Ag_3Sb:

This hypogene species is apparently quite rare within the district. The only reference to the occurrence of dyscrasite at Bisbee is in Anthony, et al. (1995) where it is listed in the table of primary minerals at Bisbee.

E

EDDAVIDITE $Pb_2Cu_{12}O_{15}Br_2$:

Note, while the status of eddavidite as a new, valid species and the name were accepted by the IMI, it is not official until published in a scientific journal. This effort is still pending.

Bisbee is the type locality for this recently discovered supergene mineral (Yang Hexiong, personal correspondence, 2018). The specimens used to describe eddavidite were on cavernous goethite as a thin crust or scattered crystals of 1 mm or less at the edge of highly oxidized copper - copper/lead orebodies with acicular malachite and had mistakenly been identified via X-RD as murdochite. It seems that both murdochite and eddavidite are present on the specimen as well and murdochite was what was used for the original test.

Just how rare of common this mineral may be at Bisbee is yet to be determined. Specimens of murdochite from several other localities have shown to be murdochite, as labeled. That being said, when the authors collected the site in the mid-1980s, several dozen specimens could have been removed, but the belief that it was a relatively common mineral coupled with the fact that very few of the specimens were attractive, much was left in place.

The species associated with eddavidite are:

goethite
malachite
calcite

OCCURRENCES:

Southwest Mine, *5th level, 54 crosscut;* Specimens collected here had murdochite as drusy crust or closely-spaced, isolated 1 mm crystals on goethite with varying amounts of acicular malachite and occasional calcite as tabular, 5 mm crystals. Occasionally, sharp, 2 mm crystals were found scattered on botryoidal or boxwork goethite.

EDENITE $NaCa_2Mg_5(Si_7Al)O_{22}(OH)$:

This hydrothermal species is apparently quite uncommon within the district. Edenite has been recognized in two localities as a minor constituent of metamorphosed or altered limestone. It occurred in altered and/or metamorphosed limestone as tiny fibers or flakes associated with other alteration minerals.

The species associated with edenite are:

tremolite
muscovite
kaolinite
quartz

OCCURRENCES:

Gardner Mine, *600 level;* Edenite was noted from here as white flakes in altered limestone with "sericite" and tremolite (Tenney, 1913).

Lowell Mine, *800 level***,** *820 drift;* White to gray, fibrous edenite was found here in altered limestone with tremolite and kaolinite (Tenney, 1913).

EMPLECTITE $CuBiS_2$:

This hydrothermal mineral has been recognized in small amounts at a single locality in one mine only. Here, emplectite was noted as a very minor accessory mineral in a complex, diverse, bismuth and silver-rich mineral assemblage. This assemblage occurred as micro-phase inclusions in siliceous hematite matrix associated with a highly altered dike of undetermined composition (Alan Criddle, personal communication, 1992).

The species associated with emplectite are (Alan Criddle, personal communication, 1992):

wittichenite
djurleite
spionkopite
galena
digenite
hematite
bismite
chalcopyrite
bismuthinite
bornite
acanthite
copper
sphalerite
covellite
gold
stromeyerite
quartz
chalcocite
silver
matildite
jalpaite
cuprite

It is worth noting that both the chalcocite and wittichenite contained 6% and 7% silver respectively.

OCCURRENCES:

Campbell Mine, *1600 level;* Emplectite was recognized from this part of the Campbell orebody in the work of Criddle and Stanley as part of a high bismuth/silver mineral assemblage (Alan Criddle, personal communication, 1992).

ENARGITE Cu_3AsS_4:

This hypogene species is quite common in small amounts in the primary ores of the district. In most instances, enargite was found as inclusions in copper sulfides, usually as small, rounded grains. Rarely, enargite occurred as irregular masses surrounded by sulfide minerals.

The species associated with enargite are:

chalcocite
tetrahedrite
bornite
chalcopyrite
famatinite
pyrite
tennantite

OCCURRENCES:

Campbell Mine, *1700 level;* Enargite was found in the ores here in small amounts as rounded grains in chalcocite with tetrahedrite, tennantite, and famatinite (Schwartz and Park, 1932).

Junction Mine, *2000 level;* Massive enargite with pyrite was found on this level as centimeter or larger inclusion in chalcopyrite.

ENDELLITE $Al_2Si_2O_5(OH)_4 \cdot 2H_2O$:

Endellite was discredited in 2006 and is now known as halloysite-10Å. The information provided herein is to be considered for reference only, allowing for the work of earlier researches to remain available.

Endellite appears to have formed under both hypogene and supergene conditions. Schwartz (1956) noted it as a part of the hydrothermal alteration suite in the Sacramento Stock replacing feldspars, while Anthony et al. (1995) record an occurrence in the Southwest Mine that is sure to be of supergene origin.

In either case, endellite was found as a white to cream colored, earthy material in small amounts. In the supergene occurrences, it was occasionally tinted yellow-brown by goethite.

The species associated with endellite are:

chrysocolla
chalcocite
malachite
kaolinite
goethite
muscovite
hematite
quartz

OCCURRENCE:

Endellite was widely distributed in small amounts in the younger porphyry unit in the Sacramento Stock Complex, which was mined by both the Sacramento Pit Mine and the Lavender Pit Mine.

Southwest Mine, *5 level;* Small amounts of white to yellow-brown endellite occurred in vugs in goethite with acicular malachite in a small stope just above the level.

ENSTATITE $Mg_2Si_2O_6$:

A member of the pyroxene group of rock-forming minerals. This hydrothermal species has been noted from the district as a minor rock-forming mineral by Anthony et al. (1995). No other information on the occurrence of enstatite from the district has been found.

EPIDOTE $Ca_2Al2\ Fe^{3+}[Si_2O_7](OH)$:

This hydrothermal alteration mineral is widely distributed throughout the district, usually in modest amounts. Epidote is one of the more common of the calc-silicate alteration minerals in the lower Paleozoic sediments adjacent to the various intrusive units. (Bonillas, et al. 1916). Bonillas, et al. (1916) also note epidote as a constituent of a small portion of the Abrigo limestone district wide with no clear relationship to hydrothermal influence. It has been found in the majority of the sediments of the district including the post-ore Cretaceous units.

Epidote was also quite common as an alteration mineral in the dikes in the underground mines (Schwartz, 1947). However, it was not particularly abundant in the porphyry units of the Sacramento Stock complex (Ransome, 1904; Schwartz, 1947).

Typically, epidote was found as a component of a multi-mineral alteration assemblage of contact-metamorphic origin in the sediments of the productive zone. Here it was commonly massive and close to the intrusive unit, quickly diminishing to thin veneers along fractures only a short distance away from the intrusive. Rarely, epidote occurred as clusters of tiny prismatic crystals lining voids or along fracture planes. In the porphyry dikes found underground, epidote was locally abundant, often as granular material that had, along with chlorite, replaced biotite (Schwartz, 1947, 1958).

The species most commonly associated with epidote are:

quartz
calcite
chalcopyrite
chlorite
pyrite
zoisite
muscovite
diopside
tremolite
wollastonite

OCCURRENCES:

As noted above, epidote is widely distributed throughout the district and associated with the alteration of the sediments as well as the intrusives.

EPSOMITE $MgSO_4{\cdot}7H_2O$:

This mineral has been recognized only in post-mining occurrences. Epsomite is widely distributed throughout the district, often in large amounts.

Typically, epsomite was found as delicate, hair-like, white, efflorescence on mine openings in pyritic limestone areas. Occasionally, “ram’s horn” formations composed of compact, fibers developed as well. White to colorless stalactites with colorless, prismatic, crystal terminations to 3 cm formed in a few areas, generally on mine timbers.

Least common of the occurrences were exceptionally large, fine, colorless, prismatic crystals to 5 cm on deep green cuprian melanterite. These had developed in ponded mine waters and, unless protected, quickly altered to hexahydrite on exposure to the atmosphere.

The species associated with epsomite are:

melanterite
pyrite
hexahydrite
siderotil
calcite

Well-formed pseudomorphs of hexahydrite after epsomite have been found in the district.

OCCURRENCES: Because of the wide distribution and general lackluster appearance, only the more significant localities are noted below.

Campbell Mine, Numerous areas in this mine contained epsomite as delicate, hair-like efflorescence on mine walls.
2700 level, 42 crosscut; Exceptional crystals of epsomite were found as colorless prisms to 5 cm on deep green cuprian melanterite growing in ponded mine waters.

Higgins Mine, *Tunnel level;* Epsomite was found here in small amounts as colorless to white stalactites on mine timbers and, to a much lesser degree, mine ceilings, with prismatic crystal terminations to 3 cm. Also found as patchy areas covered with white, fluffy material on pyritic limestone.

Junction Mine, *1800 level;* From this level in an area toward the Dallas mine as white, “ram’s horn”-like growths to 7 cm on limestone.

Sacramento Mine, *1800 level;* A crosscut near the raise that channeled the low pH water from the Lavender Pit area to the acid water pumps on this level was covered with a thick, wool-like crust of epsomite caused by the abundant sulfate-rich mist in the air.

Southwest Mine, A number of areas in this large mine contained epsomite as delicate hair-like growths on the mine walls.

EUGENITE $Ag_{11}Hg_2$:

This supergene species is a most uncommon mineral in the district. The occurrence of eugenite is limited to one locality in very small amounts.

Eugenite was found as inclusions in massive cuprite.

The species associated with eugenite are:

cuprite
tenorite
malachite

OCCURRENCES:

Southwest Mine, *5th level, 14 stope;* Small amounts of eugenite were found as clusters of 1 micron or less grains included in massive cuprite.

F

FAMATINITE Cu_2CuSbS_4:

This hypogene species is apparently quite uncommon in the district. It has been recognized only in small amounts. Typically, famatinite was found as inclusions in copper sulfides as small grains.

The species associated with famatinite are:

chalcocite
bornite
enargite
tennantite
tetrahedrite

OCCURRENCES:

Campbell Mine, *1700 level;* Schwartz and Park (1932) noted famatinite in small amounts from here as rounded grains in chalcocite with tetrahedrite, tennantite, and enargite.

Cole Mine, Nye (1968) noted famatinite as a minor ore mineral associated with the orebodies he studied in this mine.

FELSŐBÁNYAITE $Al_4SO_4(OH)_{10}\cdot 4H_2O$:

Formally known as "basaluminite," this rare supergene mineral has been recognized in just two localities in the district. In one of these occurrences, it is post-mining in origin.

Typically, felsőbányaite was found as a white crust of earthy material along fractures with other aluminum sulfates, principally hydrobasaluminite. Occasionally, it occurred as microcrystals (Anthony, et al. 1995). Much of the recognized felsőbányaite was probably formed as a dehydration product of hydrobasaluminite.

The species associated with felsőbányaite are:

hydrobasaluminite
calcite
quartz
pyrite
copper

OCCURRENCES:

Lavender Pit Mine, *Holbrook Extension;* Felsőbányaite was found in small amounts here as tiny spheroids of radiating crystals with copper and hydrobasaluminite. Also, it came from here as white crusts on fractures in a silicified limestone and as microcrystals (Anthony, et al. 1995).

Southwest Mine, *7th level;* A fault in massive pyrite on this level contained earthy felsőbányaite with hydrobasaluminite from which it was apparently derived. This occurrence is post-mining in nature.

FERRICOPIAPITE ($Fe_{2/3}^{3+}\square_{1/3}$) $Fe_4^{3+}(SO_4)_6(OH)_2 \cdot 20H_2O$:

This mineral has only been noted in post-mining occurrences. Because ferricopiapite occurs as a very minor part of the common, multi-mineral, post-mining crusts that form on mine openings, it could well have been overlooked.

Typically, ferricopiapite occurred as clusters of tiny, greenish-yellow to yellow tabular crystals. Often the crystals were somewhat rounded.

The minerals associated with ferricopiapite are:

pyrite
copiapite
rhomboclase

Ferricopiapite may well be pseudomorphs after copiapite as a result of oxidation of copiapite.

OCCURRENCES:

Campbell Mine, Ferricopiapite occurred in this mine in small amounts as clusters of 0.5 mm greenish-yellow to yellow crystals on oxidizing pyrite with rhomboclase and copiapite.

Lavender Pit Mine, University of Arizona specimen 18907 is labeled as having come from here.

FERRIMOLYBDITE $Fe_2^{3+}(Mo^{6+}O_4)_3 \cdot 7\text{-}8H_2O$:

This supergene mineral is rare within the district. A single locality for this mineral has been recognized.

Ferrimolybdite occurred here as a yellow, earthy, in situ residue formed by the oxidation of molybdenite.

The species associated with ferrimolybdite are:

quartz pyrite molybdenite

OCCURRENCES:

Lavender Pit Mine, Blebs of yellow, earthy ferrimolybdite were found in quartz veins along the footwall of the Dividend fault in the vicinity of the concentrator. Pyrite and unaltered molybdenite were also present, though encapsulated in the quartz.

FIBROFERRITE $Fe^{3+}(SO_4)(OH)\cdot 5H_2O$:

This species has only been found in post-mining occurrences. As with most such minerals, it is probable that supergene occurrences did exist in the district but were unrecognized because of solubility as well as a lackluster appearance.

Typically, fibroferrite occurred as patchy crusts on oxidizing pyrite.

The species associated with fibroferrite are:

pyrite melanterite copiapite

OCCURRENCES:

Shattuck Mine *700 level;* Fibroferrite was abundant locally on this level as a pale yellow fibrous crust on decomposing pyrite with melanterite and minor copiapite.

FLUORAPATITE $Ca_5(PO_4)_3F$:

The exact species of the apatite group mineral noted in the several early studies of the district has not been determined. It most probably was fluorapatite and is treated as such here. This hypogene species was common in small amounts in all of the intrusive units of the district as a minor accessory mineral. Less commonly, fluorapatite was recognized as a very minor part of a skarn assemblage adjacent to the Sacramento Stock Complex.

The Juniper Flat granite has small quantities of fluorapatite (Ransome, 1904). Both of the intrusive units in the Sacramento Stock complex also contained fluorapatite (Bonillas, et al. 1916; Bryant and Metz, 1966). Fluorapatite was also found in very minor amounts in the porphyritic dikes of the underground mines (Tenney, 1913).

Typically, fluorapatite was found as tiny, often well-formed crystals along with other similarly occurring accessory minerals. Gray to white crystals to 2 mm have been found in some of the porphyry dikes.

The species most commonly associated with fluorapatite are:

quartz
plagioclase
pyrope
muscovite
rutile
microcline
zircon
magnetite
orthoclase
“biotite”
albite
pyrite

A small number of pseudomorphs of turquoise after 1 mm fluorapatite crystals have been recognized from one locality within the district.

OCCURRENCES: Only a few typical localities in addition to those generally referred to above will be noted because of the wide distribution and nondescript nature of fluorapatite within the district.

Gardner Mine, *800 level;* Fluorapatite was a very minor constituent of a limited skarn developed at a porphyry/limestone contact. Magnetite and pyrope were associated with the fluorapatite.
900 level; Tiny, colorless crystals were noted by Tenney (1913) in an orthoclase/plagioclase mixture in one of the underground dikes.

Higgins Mine, *Tunnel level;* Noted from here by Schumer (2017) in a gangue of fluorapatite, chlorite, and quartz in association with chalcopyrite, tetradymite, sphalerite, pyrite, and scheelite.

Holbrook Mine, *500 level;* A sample of one of the intrusive porphyry units of the Sacramento Stock complex contained fluorapatite as an accessory mineral along with zircon in a matrix of orthoclase, “biotite”, quartz, and pyrite (Tenney, 1913).

FLUORITE CaF_2:

This is a widely distributed mineral in the district, but it is seldom abundant. The most typical mode of occurrence is as a minor accessory mineral in the intrusive units, particularly the Juniper Flat granite where it is found as veins, blebs, and bunches of massive, deep purple material that fluoresces a bright green.

Fluorite also occurred in quartz veins as light blue euhedral crystals to 2 cm in Gold Gulch on the southeastern edge of the district. For the most part, the fluorite crystals are encased in massive white quartz. In the occasional pocket, the fluorite is incrusted by an iron-stained layer of crystalline quartz. Also, in this general area, Anthony, et al. (1995) noted an occurrence of fluorite in brecciated, silicified limestone.
On the extreme eastern edge of the district a 30 cm wide vein of fluorite cuts the Cretaceous sediments, principally the Morita formation. Here it is associated with quartz and is highly color-zoned. The colors range from purple to blue to colorless over the distance of a few centimeters.

Fluorite also seems to locally occur in small amounts in the Bolsa quartzite at the contact with the Abrigo limestone in the mineralized part of the district.

The species that have been recognized as occurring with fluorite in the district include the typical assemblage for granite. Also noted by Anthony, et al. in a different environment are ilsemannite and scheelite. Additionally, the author has observed the following in the mines:

pyrite
calcite
chalcopyrite

OCCURRENCES: In addition to the above referenced localities outside of the productive area of the district, the below mines produced fluorite as well.

Campbell Mine, *2966 level;* Small (4 mm) green cubic crystals were found in several locations at the contact between the Abrigo limestone and the Bolsa quartzite.
3100 level, 42 crosscut; Attractive specimens of 1.5 cm lime-green cubic crystals on milky quartz crystals to 5 cm were collected in small numbers from this locality.

Concentrator Tunnel; This tunnel was driven to bring a water line to the first concentrator from the C & C mine. At one point, it intercepted a zone of hydrothermal leaching where the limestone had been dissolved, leaving a quartz boxwork that served as a matrix for 5 to 8 mm light blue cubes of fluorite. These fluorite specimens quickly fade on exposure to direct sunlight.

FORNACITE $Pb_2Cu(AsO_4)(CrO_4)(OH)$:

A rare supergene mineral in the district recognized from only a single locality. Here it was found in limited amounts. Typically, fornacite was found as a thin crust of radiating prismatic crystals or a spongy aggregate of tiny crystals. In a few instances hexagonal forms were developed by the crust. The material is usually an uncommon saffron-yellow in color or, less often, a greenish-yellow where the material is thicker.

The species associated with fornacite are:

chrysocolla
mimetite
calcite
murdochite
shattuckite
hematite

OCCURRENCES:

Shattuck Mine, *200 level, 174 prospect;* This area yielded a few specimens where fornacite occurred as a very thin, translucent crust on chrysocolla that had replaced malachite or on hematite.

FORSTERITE Mg_2SiO_4:

This hydrothermal species is apparently very limited in distribution within the district. Only a single occurrence has been noted.

Forsterite was found as part of a contact-metamorphic assemblage in the Martin limestone adjacent to the Sacramento Stock Complex. Here it occurred in small amounts as green, euhedral grains with other contact-metamorphic minerals.

The species associated with forsterite are:

epidote
pyrite
tremolite
quartz
zoisite

OCCURRENCES:

Spray Mine, *500 level, 27-3 stope;* Forsterite occurred here in small amounts as green grains surrounding pyrite blebs in metamorphosed limestone with tremolite, zoisite, quartz, and epidote (Tenney, 1913).

FREIBERGITE $Ag[Cu_4Fe_2]Sb_4S_{13-x}$:

This hypogene mineral has only been recognized in one mine. There is little doubt that some of the high-silver tetrahedrite noted in several of the other mines was actually freibergite. However, only the occurrence noted below has been authenticated. Typically, freibergite was found as patches and veinlets in copper sulfide ores.

The species associated with freibergite are:

bornite
pyrite
tetrahedrite
chalcocite

OCCURRENCES:

Campbell Mine, *2700 level;* Specimens collected by one of the authors from a very high-grade copper/silver orebody near the Junction shaft contained large amounts of freibergite as silver-gray irregular masses and veins in massive bornite/chalcocite with pyrite as well as minor argentiferous tetrahedrite.

FURUTOBEITE $(Cu,Ag)_6PbS_4$

Furutobeite is a hypogene mineral that was a very minor part of a complex, silver rich suite of accessory minerals in bornite-rich ores (Schumer, 2017).

The species associated with furutobeite are:

bornite
pyrite
tetrahedrite

OCCURRENCES:

Campbell Mine, *1600 level;* In very small amounts as silver-gray, irregular inclusions as veins in massive bornite/chalcocite with pyrite as well as minor argentiferous tetrahedrite.

G

GALENA PbS:

This typically hypogene species was immensely abundant in massive, mixed orebodies that were often in excess of 25,000 tons. Hogue and Wilson (1950) cover these deposits very well.

Galena was the most important lead ore mineral in the district, particularly in distal zones, (Schumer, 2017) and was mined continually from 1908 until 1953 (Mills, 1958). Production fluctuated over this period but was pushed during periods of high lead prices, most notably from 1945 through 1950 (Mills, 1958). It was also an important source of silver in most of the locations where it was mined. At the time of cessation of underground mining in mid-1975, a resource of approximately 2,000,000 tons of lead/zinc ores averaging 20% for the combined metals remained in the Campbell, Junction. and Denn mine areas. Galena was the lead mineral in this resource.

It occurred in mixed sulfide masses where one or more of the other dominant sulfides were pyrite, chalcopyrite, and sphalerite. Pure masses of galena of any size were uncommon. On both a macro and microscopic level, a number of inclusions of a variety of minerals, typically other sulfides, becomes obvious. Galena was found as compact masses that ranged from fine-grained to very coarse-grained, cleavable material. Occasionally, galena was found as granular masses, usually mixed with granular pyrite and minor specular hematite. These were difficult to mine as they flowed like sand when unconfined.

Galena was also common as minor inclusions in other sulfide minerals, notably chalcopyrite and pyrite. In these instances, it was not typically an ore mineral because of limited quantities.

Supergene galena has been recognized in very small amounts in a number of mines in the district. In these instances, it was invariably found as fresh-appearing inclusions along the cores of boxwork planes in supergene siderite (Bateman, et al. 1914). Several other typically hypogene sulfides, sphalerite, chalcopyrite, and pyrite, were often found as apparently supergene phases in minor amounts along with galena in siderite (Trischka, et al. 1929).

In spite of the abundance of this mineral in the district, distinct crystals were exceedingly rare and good collector-quality specimens are non-existent.

The more important species associated with galena are:

pyrite
anglesite
siderite
chalcopyrite
bornite
goethite
sphalerite
chalcocite
hematite
cerussite
quartz

Galena has been found altering to anglesite, cerussite, and other lead-lead/copper minerals, however no pseudomorphs after galena have been noted from the district.

OCCURRENCES: The below localities reflect the major productive areas and are representative, but not exhaustive.

Briggs Mine, *1400 level; A* large body of galena was mined from this level (Mills, 1958).

Campbell Mine, Galena was mined as an ore from just above the 1200 level to about the 2566 level (Mills, 1958; Hogue and Wilson 1950). Sphalerite was almost always associated with galena, particularly in the Campbell orebody, as was pyrite.
1600 level; A small number of specimens with 1.5 cm complex crystals with pyrite were found on this level by one of the authors.

Czar Mine, *400 level;* Substantial amounts of partially oxidized galena were mined from this level. Cerussite and anglesite were commonly the oxide minerals.

Denn Mine, Large amounts of galena and sphalerite were mined from here for many years, most notably in the late 1940s and early 1950s.

Gardner Mine, The first large-scale mining of sulfide (galena) ore for lead in the district was conducted in this mine (Mills, 1958). However, much of the galena was partially oxidized and caused recovery problems (Mills, 1958).

Junction Mine, This mine was the principal lead producer in the district. Large orebodies of galena mixed with sphalerite and other sulfides were mined largely during the 1930s and 1940s.

GERHARDITE $Cu^{2+}_2(NO_3)(OH)_3$:

This species is apparently quite rare within the district as it has been recognized only in small amounts on a couple of specimens. However, given its similar appearance to other, apparently more common species, which occur in the same environment, it is likely that other, unrecognized examples exist.

In one example, gerhardite occurred as 0.5 mm or smaller blue green to green, tabular crystals in a void in massive cuprite. The material could easily be confused with spangolite except for its pronounced dichroism.

The species occurring with gerhardite are:

cuprite
tenorite
goethite
likasite
azurite
malachite

OCCURRENCES:

Czar Mine; In a single specimen from this mine, gerhardite was noted as blue-green blebs to one mm in size in massive cuprite. Modest amounts of likasite were on this same specimen as was minor malachite.

200 level; A very early specimen of classic azurite on goethite with minor malachite coated cuprite octahedron from this mine had a clump of massive cuprite on the back side. This massive cuprite had a few very small vugs, which contained tiny gerhardite crystals.

GIBBSITE $Al(OH)_3$:

This species has been found as a secondary mineral in the eastern area of the Czar mine and that part of the Holbrook closest to Sacramento Stock/limestone contact. Gibbsite is commonly associated with earlier goethite, azurite, malachite and cuprite. It has also been recognized as a replacement of chalcoalumite (Palache, et al. 1944). However, there is some question in the minds of the authors if gibbsite did indeed replace chalcoalumite as suggested by Palache, et al. 1944) or if the striking similarity in appearance of blue/white gibbsite, a common form here, was confused as a replacement of chalcoalumite.

Irregular lumps of granular white to cream material have been found, as have similarly colored fine-grained masses. These occurred as pods in the supergene-altered limestone at the intrusive contact. Essentially pure gibbsite has been noted extruding from a 1 cm thick seam in an area of major rock settling (Blanchard, 1968). Post-mining gibbsite was observed by Bateman, et al. (1914) and Tenney (1913) in old gob (backfill) that had been altered by acidic mine waters.

The species associated with gibbsite are:

malachite
hematite
azurite
goethite
chalcoalumite
nordstrandite
copper

OCCURRENCES:

Czar Mine, *200 level, 227 drift;* This locality was at the top of the “Atlanta slice,” a stope worked out in 1893 and backfilled. Tenney (1913) noted that the backfill had altered to gibbsite by acidic mine waters and that post-mining malachite had been deposited.
200 – 400 levels; Gibbsite, as a white-blue/white partial coating of goethite, azurite and malachite was relatively common in the east part of these levels. This material is frequently mistaken for chalcoalumite, which it can closely resemble, but chalcoalumite always forms at the expense of earlier copper carbonates.

Holbrook Mine, There is little doubt that the material referenced by Palache, et al. (1944) as a replacement of chalcoalumite came from this mine. As noted previously, an unanswered question is was it ever truly chalcoalumite. Also, gibbsite was noted from here as a light blue crust on and cementing old gob (backfill). This is a post-mining occurrence that resulted from the action of acidic mine waters passing through and altering the backfill (Bateman, et al. 1914).
200-400 levels; Abundant gibbsite as a late-stage deposition was found with goethite, malachite and malachite, occasionally as tiny clusters of radiating crystals.

Lavender Pit Mine, Several parts of this large mine produced white to cream colored gibbsite as either fine-grained or granular masses that occurred as irregular lumps to 15 cm. Compact, almost

chalcedonic, veins of light blue gibbsite were found in this mine near the former site of the Gardner shaft.
Holbrook Extension; Handsome specimens with crusts of pale blue gibbsite on azurite and, occasionally, malachite was found in this section of the pit. The gibbsite could easily be confused with the chalcoalumite that it may have replaced. As this area of the pit exploited part of the Holbrook mine, this material is very similar to that produced much earlier by the Holbrook.

Spray Mine, *300 level, 114 drift;* Gibbsite was noted from here by Tenney (1913) as an alteration of feldspars, as thin, white, translucent platelets.

GLAUCONITE $(K,Na)(Fe^{3+},Al,Mg)_2(Si,Al)_4O_{10}(OH)_2$:

This rock-forming species is widely distributed and locally abundant in the Cretaceous sediments in the eastern portion of the district. Here, it is found as thin, pale green to blue-green discontinuous lenses and as rounded lumps that have weathered out of the largely calcareous sediments.

GOETHITE $Fe^{3+}O(OH)$:

This is one of the most abundant supergene gangue minerals found in the district. It is widely distributed and is associated in greater or lesser amounts with every secondary orebody found here. Many attractive and very different specimens of goethite have been recovered from Bisbee's mines.

While the depositional/formational mechanisms are all related to the supergene alteration of iron-bearing sulfides, different environments resulted in a variety of forms and characteristics. The most common was as a soft, fine-grained material frequently with admixed lepidocrocite. This was most commonly formed at the point where solutions contacted the limestone host rock (Blanchard, 1968).

At Bisbee, goethite was almost always associated with hematite of similar texture as distinct bands, irregular shapes, or in intimate mixtures. Under these conditions, the goethite/hematite mixtures, which usually included substantial amounts of supergene- derived clays, often contained sufficient copper minerals to be of economic importance.

Banded ocherous goethite and hematite were of common occurrences below many of the oxidized orebodies. Here the copper content was generally below the typical economic grade of 5% copper.

The second most common form of this mineral was as boxwork. This represented the replacement of the limestone adjacent to and particularly below the original sulfide ores. Boxwork is a relic of the fracture pattern of the limestone. It is probable that in many of these instances the goethite is a replacement of siderite (Trischka, 1928). The voids formed by goethite boxwork were frequent sites for the deposition of the later-formed supergene copper minerals. Copper, cuprite, azurite, and malachite were the most typical of these, with the latter two often completely lining the openings.

Delicate, plumose goethite often occurred as linings of the voids in boxwork and, less frequently, as a covering in the bottom of large pockets, suggesting a subaqueous deposition. In the latter case, colorless calcite would occasionally cover and preserve these otherwise very fragile forms.

Hard, compact, and massive goethite with a relatively small number of voids was also a frequent occurrence for this mineral. Occasionally, these masses would have a core of residual sulfide, usually massive pyrite. Thus, it would appear that goethite of this nature was formed in situ. This is further confirmed by the occasional presence of goethite pseudomorphs after pyrite as inclusions. Bands of radiating, splendent goethite with a black, botryoidal surface typically lined the few voids that formed and small goethite stalactites were not uncommon in these openings.

Goethite was a common mineral found in the many oxidation caves as well as the many often large voids that were associated with them. In the caves and voids stalactites of goethite were common. Often in excess of 50 cm., they were usually quite thin. Because goethite was one of the very early supergene minerals to form, many of these stalactites served as cores for other stalactitic growths, particularly calcite, and on rare occasion, malachite or azurite. This was particularly true when the opening was later filled with mineral-rich solutions. Many apparent azurite and crystalline calcite stalactites are truly sub-solution depositions on pre-existing goethite stalactites.

Post-mining goethite (originally deposited as one or more of the several iron hydroxides, then altered to goethite by desiccation) was common in many of the sulfide zones, forming as mining exposed iron sulfides to an oxidizing atmosphere. Goethite also formed as a rind on broken iron sulfides left in abandoned stopes. In those cases where small amounts of water passed through the stopes, the goethite would also be deposited as stalactites in the drifts or crosscuts below. Occasionally, these stalactites would be large enough and so closely spaced so that the opening was blocked. When originally deposited, post-mining goethite is a soft gelatinous material, but upon drying it becomes quite hard. However, the goethite that was deposited below the stalactites is usually friable and ocherous when dry.

Goethite has been found associated with most of the primary sulfides as an alteration product. Also, the vast majority of the secondary minerals are known to be associated with this common mineral.

Pseudomorphs of goethite after other species are common. Those recognized are:

- calcite
- aragonite
- smithsonite
- malachite
- pyrite
- siderite
- gypsum
- cuprite
- chalcopyrite
- brochantite
- copper
- azurite
- aurichalcite

The goethite pseudomorphs after pyrite were occasionally found as uncommonly faithful replacements (Blanchard, 1968).

OCCURRENCES:

Only a few of the more important or unusually occurrences of this ubiquitous species are noted below.

Campbell Mine, *2833 level, 45 crosscut;* A particularly interesting post-mining occurrence of goethite was at this location where it occurring as hard stalactites of up to 2 meters in length and 10 centimeters across, covering the timber for a distance of 6 meters. This occurrence was under a massive pyrite body, mined some 25 years earlier.

Cole Mine, *1000 level;* Goethite occurred here as a black, botryoidal crust partially coated with cuprite, variety chalcotrichite, or malachite that is a replacement of the cuprite.
1200 level; A stope on this level contained goethite as curious, black, thin stalactitic specimens that had web-like strands connecting the stalactites. A triangular pattern resulted in the voids between the stalactites.
1300 level; Compact, massive goethite on this level had boxwork voids with centimeter thick, black, lustrous, botryoidal crust linings. Also from this same locality came goethite as sharp pseudomorphs after cubic pyrite crystals of up to 1.5 cm.

Copper Prince Mine, A small number of sharp goethite pseudomorphs after 1 cm, calcite scalenohedrons with malachite were collected from here by one author in the late 1950s and in the mid-1970s by all three authors.

Copper Queen Mine, *300-400 levels;* Several nearby oxide orebodies on these levels contained goethite as dense, black stalactites, occasionally with pale malachite cores and partially coated by drusy azurite.
400 level; Goethite was abundant in the Southwest orebody on this level as brown stalactitic material often coated with a thin layer of white to pale yellow gibbsite with later malachite and scattered azurite crystals. Thin crusts of botryoidal pseudomorphs of goethite after azurite with later azurite and with malachite were also found here along with fine azurite specimens.

Czar Mine, Dump specimens collected from here contained goethite as thick botryoidal coverings of boxwork that are composed of compact fibrous crystals that range from black to brown in color.

Gardner Mine, Goethite was noted in this mine as bright, stalactitic, and botryoidal specimens from the base of an oxidizing pyritic mass (Blanchard and Boswell, 1928).

Higgins Mine, *Tunnel level;* Post-mining goethite was found on this level near the Wolverine and Arizona Mining Company property line as thick deposits on the crosscut bottoms and as stalactites and stalagmites associated with post -mining chrysocolla.

Holbrook Mine, *100 level;* An unusual occurrence of goethite was on this level where it was found as casts of 3 cm calcite crystals. Also, from here as thick, boxwork crusts that are replacements of siderite with malachite and azurite.

Irish Mag Mine, Goethite was noted here as stalactitic crusts with small cuprite druses (Blanchard and Boswell, 1928).

Junction Mine, *2700 level;* A large number of exceptional specimens of goethite were found here as bright, black, botryoidal material to 2 cm thick, with closely spaced stalactitic growths to 1 cm, which covered specimens of up to several meters across. The locality is in a small cave-like opening and a number of interconnected voids.

Lavender Pit Mine, *Holbrook Extension;* Goethite was abundant in this part of the pit as masses of varying purity of many thousands of tons resulting from the supergene alteration of sulfides. It was also found here as pseudomorphs after fibrous malachite, as well as after crystals of azurite and cuprite in cavities within a massive, siliceous goethite. It was common as handsome, iridescent coatings (locally called - *turgite*) along fractures in the gossan waste overburden removed during the stripping of Sacramento Hill as well. These specimens closely resemble some of the iridescent hematite, also from other parts of the pit.

Lowell Mine, *1000 level, 1003 drift;* Fine pseudomorphs of goethite after cubic pyrite crystals were found in altered limestone at this locality (Tenney, 1913).

Shattuck Mine, *200 level, 45 raise;* Boxwork goethite was abundant here with the voids commonly lined with plumose goethite and azurite as well as fibrous malachite and also as a light brown botryoidal material. Stalactites of up to 20 cm were also found here. Some of the smaller stalactites were overgrowths on malachite and/or azurite. It was common to have azurite and fibrous malachite as partial coatings on these stalactites.

Southwest Mine, Fine specimens of hollow goethite pseudomorphs after 10 cm calcite scalenohedrons, with later azurite and/or malachite, were found on an undetermined level in this extensive mine.
3rd level; A few specimens of goethite were collected here that were complete replacements of cuprite nodules with poorly formed pseudomorphs of goethite after cuprite crystals.
6th level; A series of large voids adjacent to a small collapse cave contained goethite as a myriad of closely spaced, thin, stalactites, some of which were coated with calcite, resulting in handsome specimens. Also from a different cave on this level came goethite as sharp casts of gypsum, variety selenite, crystals to 2 cm.

GOLD Au:

This mineral was widely distributed throughout the district and has been recognized in both its hypogene and supergene forms. In spite of its widespread nature, visible gold was uncommon and specimens from here were exceedingly rare and good specimens nonexistent.

Economically, gold did not become important to Bisbee’s mines until the advent of electrolytic refining in the late 1890s. This allowed for the separation of precious metals from smelted copper as well as for the purification of copper.

Hypogene elemental gold appears to have been at least a trace element in most of the primary ores. There is some reason to believe that much of this gold was emplaced during a late stage, multi-element mineralizing event or events that may have covered most of the district (Graeme, 1993).

Typically, the gold occurred as microscopic blebs included within the primary sulfides or sulfosalts. This was often along grain or mineral boundaries. As noted, visible gold was uncommon within the district, however, sporadic occurrences in many of the mines were recognized (Engineering & Mining Journal, 1926). When visible gold was found it typically occurred as small, irregular patches along fractures or within voids in massive sulfides, usually bornite. Gold also occurred in the supergene ores as flakes, small spongy masses, or, rarely wire-like growths.

Additional primary gold occurrences within the district that were not associated with the sulfide ores were at both its eastern and western boundaries in the Gold Gulch and Juniper Flat areas respectively. In each case, it was associated with small, hydrothermal quartz vein systems of undetermined ages, but the Gold Gulch is post-Cretaceous. Neither area produced economically important amounts of gold, though more than a few souls tried panning at Gold Gulch during the depression (C. Keeler, personal communication, 1950). Specimens from these areas are limited to a very few examples of massive white quartz, often rich with visible gold. Additionally, Tenney (1913) noted the occurrence of visible gold in a quartz vein striking N40°E in the Pinal schist some 490 meters N12°W of the NE corner of the Molvina mining claim, north of Castle Rock.

Supergene gold was even less often seen, though often indicated by routine assay. This lack of visual recognition could well have been a function of the typically small particle size or by being obscured by the abundant, often soft clays and iron oxides that were such a major part of supergene activity. In the few instances when it was found, the gold occurred as small spongy clusters of microcrystals or as specks and blotches on hematite.

The majority of primary minerals are recognized as being associated with gold. Goethite, hematite, quartz, and rarely conichalcite are the associated species with secondary gold.

OCCURRENCES:

Campbell Mine, *1600 level;* Exsolutions of native gold with stromeyerite and wittichenite, were noted by Schumer (2017) in his study of Bisbee sulfides.
1900 level; Gold occurred here in very small amounts with goethite, azurite and malachite along fractures in pyrite and chalcopyrite (Alan Criddle, personal communication, 1992).
2300 level, 125 stope; Minor amounts of gold were recognized with a broad assemblage of hypogene minerals (Alan Criddle, personal communication, 1992).

Cole Mine, *1300 level 39-A stope;* A number of specimens from this locality contained gold as small spots and blebs in voids and along fractures in massive bornite. Also, a few examples of gold oriented on small bornite crystals were produced from this stope.

Shattuck Mine, *300 level;* A limited number of small specimens of crystalline gold wire on iron-stained quartz crystals were recovered from here. Also from this level came a small number for specimens with gold in a spongy hematite with conichalcite.
400 level; A stope in a silica breccia produced a number of specimens where the gold occurred as spongy material filling voids or along fractures. This area also had gold as irregular, thin blotches

to 1 cm on fractures in a hematite-stained phase of the silica breccia. Both of these areas were subject to a substantial amount of gold loss through high-grading (Fathour, 1991).

Uncle Sam Mine, *"M" level;* In an unusual occurrence on this level, gold was found as small flakes with rounded features and tiny nugget-like forms in a loose, lightly iron stained quartz sand in the bottom of a small cave adjacent to a silica breccia. This material was, as noted, well rounded with the appearance of having been water worked.

GOLDFIELDITE $Cu_{10}Te_4S_{13}$:

This hypogene mineral has been found in small amounts as part of a complex, multi-mineral assemblage. Typically, goldfieldite was found as a fracture filling or as inclusions in massive pyrite along with other sulfides. A number of tellurides of lead, silver, bismuth, and gold were noted as compound inclusions in goldfieldite and sphalerite (Alan Criddle, personal communication, 1992).

The species associated with goldfieldite are (Alan Criddle, personal communication, 1992):

chalcopyrite
djurleite
sphalerite
stützite
calaverite
bornite
covellite
galena
stannite
tellurobismuthite
chalcocite
tetrahedrite
altaite
mawsonite
enargite
digenite
pyrite
hessite
rutile
quartz

OCCURRENCES:

Campbell Mine, *2100 level;* This area of the Campbell orebody contained goldfieldite in small amounts with a number of sulfide ore minerals as a fracture filling and inclusions in pyrite, all in a pyrite/calcite matrix (Alan Criddle, personal communication, 1992). A complex assemblage of many of the species noted above was associated with goldfieldite in this occurrence.
2300 level, 125 stope; Goldfieldite was found here as part of a complex mineral assemblage where it occurred as compound inclusions in pyrite as well as replacing granular pyrite (Alan Criddle, personal communication, 1992).

Junction Mine, Noted as inclusions in chalcocite-rich ores by Schumer (2017). Enargite, chalcopyrite and quartz were in the same specimen.

GORMANITE $Fe_2^{3+}Al_4(PO_4)_4(OH)_6\cdot 2H_2O$:

Gormanite is a rare species in the district, which has been recognized only in small amounts from a single locality. In 1975, Occidental Minerals was doing exploratory drilling in a long known, low-grade mineralized area north of the Dividend fault. A few samples of the drill core contained dark-green blebs and sprays of crystals to 8 mm. of an unknown mineral. It was not until the mineral gormanite was described some seven years later, using material from a Canadian deposit that this species from what is now known as the Cochise deposit at Bisbee was identified.

The species associated with gormanite are:

quartz
chlorite
pyrite
calcite

OCCURRENCES:

Cochise Deposit, A small number of samples containing gormanite were recovered from exploration, diamond drill, core samples from this deposit. Typically, the gormanite occurred as small, dark-green blebs encased in quartz or as isolated rosettes and radial sprays or prisms along fractures.

GOSLARITE $ZnSO_4\cdot 7H_2O$:

This species has been recognized only as a post-mining mineral in the district. There is little doubt that goslarite occurred as a part of the supergene process. However, given its high solubility and uninteresting appearance, it would have been overlooked. Tenney (1913) did note an occurrence of goslarite on fractured sphalerite with pyrite but did not indicate the nature of deposition.

Also, the marked similarity of the copper- and iron-bearing phases of goslarite to other, more common post-mining sulfates could easily have resulted in misidentification. The vast majority of sphalerite in the district is iron-rich and often associated with copper sulfides, thus, it is reasonable to assume that much of the goslarite formed would be cuprian or ferriferous.

The most typical mode of occurrence for goslarite was as silky, colorless to white, fibers as an efflorescence on mine openings. More compact, massive growths were almost “ram’s horn”-like in appearance and white in color. Several areas contained white to colorless stalactitic growths that occasionally reached large sizes. White crusts of goslarite quickly formed on sphalerite-bearing material allowed to remain underground and, to a lesser extent, on similar material on the surface during moist periods.

Occurrences of both the ferriferous and cuprian varieties of goslarite have been noted at several localities in small amounts. The ferriferous goslarite was brown to a greenish-brown while the cuprian goslarite was a green-blue to a bluish-white.

Because goslarite dehydrates to bianchite ($ZnSO_4\cdot 6H_2O$) so quickly on exposure to a dry atmosphere, it is doubtful that many, if any, specimens have survived.

The species associated with goslarite are:

sphalerite
chalcanthite
pyrite
melanterite
bianchite
epsomite
zincobotryogen

Delicate, poorly formed pseudomorphs of bianchite after goslarite crystals have been found in the district.

OCCURRENCE:

Campbell Mine, *1700 level;* Silky, colorless to translucent, green to blue-green (cuprian) goslarite fibers covering broken sphalerite, with chalcanthite and melanterite, were found here. Also, patchy, white crusts of goslarite formed on timbers in this same stope.
1800 level; Colorless to white goslarite stalactites, that were composite forms consisting of numerous crystals, occurred in several places on this level. Cuprian goslarite, also as stalactites and blue-green in color were locally abundant on this level near the shaft.
1900 level; On this level, composite crystal stalactites to 50 cm of goslarite formed in moist, abandoned zinc stopes and hung from chute timbers in the crosscuts below. These were usually colorless, becoming white where thicker.

Gardner Mine, *400 level;* Colorless goslarite fibers to 4 cm lined mine openings in one area on this level.

Higgins Mine, *Tunnel level;* Crusts of massive white goslarite were recognized on broken sphalerite in a stope on this level. Small amounts of silky, brown, ferriferous goslarite formed on the walls of this same stope. Minor epsomite was associated with goslarite at this locality.

Junction Mine, *1600 level;* Exceptional groups of centimeter-sized goslarite crystals formed antler-like stalactites to 20 cm in one spot on this level. The crystals were colorless to white.
1800; Golden-brown (ferriferous) and blue-green (cuprian) goslarite formed as patches composed of silky fibers up to several centimeters in length on this level.

Lowell Mine, *1400 level, 1422 drift;* Goslarite was found in small amounts at this locality as a film on sphalerite with pyrite by Tenney (1913).

Southwest Mine, *6th level;* A crosscut on this level near the Uncle Sam and Shattuck mines cut several small, bedding controlled, sphalerite replacement deposits. All of these are now nearly obscured with thick growths of silky, colorless to white, fibrous goslarite. At the fringes, the goslarite is the ferriferous variety, identical in form and golden-brown to brown in color. Some bianchite occurred on the outer, pyrite-rich portions of this zone. Minor melanterite was also associated with this occurrence.

GRAEMITE $Cu^{2+}Te^{4+}O_3 \cdot H_2O$:

This is an exceedingly rare secondary mineral for which Bisbee is the type locality (Williams and Matter, 1975). The finest examples of this species are from here. In two of the known occurrences in the district, graemite occurs as large blue-green composite crystals.

At the Cole and Shattuck locations, graemite has been found as an alteration product of teineite. It appears that the alteration to graemite may have occurred fairly late. Compact malachite completely encased some of the teineite at the type locality and this appears to have protected it from alteration whereas all of the exposed teineite was completely altered. A late-stage, oriented overgrowth of teineite partially coats graemite pseudomorphs after teineite in one instance. The genesis of the material, most probably from the Holbrook Mine is less clear as the minor amounts of graemite are present within teineite, thereby masking the relationship, if any.

The minerals known to occur with graemite are:

teineite	cuprite	malachite

As previously noted, graemite was most typically found as replacements after teineite.

OCCURRENCES:

Cole Mine, *1200 level*, *202 stope*; This is the type locality for graemite, where it was found as several, blue to blue-green intergrown 25 x 5 mm composite crystals that are pseudomorphs after teineite. Here it was associated with minor teineite, spongy malachite, and euhedral cuprite crystals.

Holbrook Mine, Minor amounts of graemite were noted in a single cuprite specimen, ex British Museum of Natural History (Evan Jones, personal communication, 2010), The graemite occurred as 3 mm, arborescent clusters of tiny crystals encased in later teineite. However, no documentation exists as to the source locality, However, based our experience with material form the Holbrook, it is our considered opinion that the specimen was probably recovered from this mine in the late 19th century.

Shattuck Mine, Graemite is recognized from here as a single, large (1 x 2 cm) composite crystal that is a pseudomorph after teineite. This specimen has an oriented, partial, second -generation overgrowth of teineite on the graemite pseudomorph and is associated with cuprite.

GRAPHITE C:

This species is typically of hydrothermal origin, however, the material found in the Warren district may have been of supergene origin. It appeared that the graphite found here was derived as a result of intense reduction of limestone by supergene fluids. The possibility certainly exists however, that this graphite was a relic of hydrothermal activity associated with the ore deposition and/or the intrusion of the adjacent dike.

Graphite occurred as thin, flexible flakes in sericite and as a metallic veneer on hematite.

The species associated with graphite are:

hematite	muscovite	copper

OCCURRENCES:

Dallas Mine, *1400 level;* Graphite was moderately abundant in a fault zone along an intrusive dike at the margin of an oxidized orebody. It occurred as both tiny flat flakes in massive, soft sericite and as a thin veneer on impure, compact hematite with copper.

GREENOCKITE CdS:

This hypogene mineral is widely distributed throughout the district in small amounts. Greenockite is probably far more common than the limited number of recognized occurrences would suggest. Also, because of the resemblance of greenockite to some of the ubiquitous iron oxides, as well as its typically nondescript appearance, it could easily have been overlooked. However, it is probable that much of the material visually identified as greenockite is actually hawleyite. This has not been confirmed.

Typically, greenockite occurred as a patchy, earthy coating along fractures in massive sphalerite. Rarely, it was found as microcrystals, again on massive sphalerite or, less often, galena.

The species associated with greenockite are:

sphalerite
pyrite
galena
smithsonite
anglesite

OCCURRENCES:

Campbell Mine, Greenockite was **c**ommon in small amounts in most of the sphalerite deposits of this mine.
2566 level; Unusually, large patches of microcrystalline yellow to yellow-orange greenockite were found along fractures in massive sphalerite and galena. Some minor smithsonite and anglesite had also formed as thin veneers in the fractures.

Gardner Mine, *900 level;* Thin, earthy greenockite was found on massive sphalerite with pyrite on this level.

Higgins Mine, *Tunnel level;* Specks to small patches of yellow-orange material was found on low-grade sphalerite ores here. Abundant pyrite was associated with this occurrence.

Holbrook Mine, Greenockite was common in small amounts in all the sphalerite ores produced from this mine.
400 level; Crusty patches of earthy, yellow greenockite were found on massive sphalerite in several places on this level. Some of this sphalerite was altering to yellow smithsonite.

Junction Mine, Greenockite was a minor accessory mineral with sphalerite in several areas of this mine. In one area, galena crystals were found that were partially coated by tan to greenish-tan greenockite.

GROSSULAR $Ca_3Al_2Si_3O_{12}$:

This hydrothermal mineral is widely distributed, usually in small amounts, throughout the district. Grossular was associated with the modest calc-silicate alteration of the limestones that surround the Sacramento Stock complex (Knopf, 1933). Most often grossular was observed as tiny, rounded crystals as part of an alteration assemblage (Ransome, 1904) and in the unoxidized pyritic ores (Anthony, et al. 1995).

Locally, small, compact masses of yellow-brown, granular grossular have been found. Pockets exposed after leaching revealed crystals to 5 mm. This occurrence was associated with pyrite/chalcopyrite ores.

The species associated with grossular are:

quartz
calcite
andradite
diopside
pyrite
wollastonite
tremolite
chalcopyrite
vesuvianite
sphalerite

OCCURRENCES: Only a few of the more typical or important occurrences are noted.

Campbell Mine, Rounded crystals of grossular were common with diopside and tremolite in some of the greenish matrix associated with pyritic ores from portions of this mine.

Irish Mag Mine, *1150 level;* The station on this level contained abundant grossular as tiny crystals with diopside and tremolite (Ransome, 1904).

Lavender Pit Mine, Grossular was found in altered limestone as masses of granular crystals with interstitial calcite, all as part of the localized skarn in and adjacent to the intrusion breccia. Pyrite and abundant chalcopyrite were associated with this occurrence.

Lowell Mine, *1000 level, 9 drift;* Masses of grossular and andradite with quartz, pyrite, and sphalerite were found here by Tenney (1913).

GROUTITE $Mn^{3+}O(OH)$:

This supergene mineral is apparently uncommon within the district. However, it is possible that with further examination it may be found in more of the many near-surface manganese deposits. In addition to the surface find noted below, groutite has also been recognized in one of the manganese oxide occurrences associated with the supergene copper deposits.

Typically, groutite occurred as tiny, dark brownish-black to black crystals associated with other manganese oxides.

The species associated with groutite are:

manganite
pyrolusite
braunite
quartz
calcite

OCCURRENCES:

Campbell Mine, The British Museum of Natural History has, in its collection, a specimen of groutite from an undesignated location in this mine (Alan Criddle, personal communication, 1992).
1800 level; Groutite came from this level as microcrystals on pyrolusite that occurred in a solution enlarged fault east of the Campbell fault.
2000 level; It was found here in small amounts as tiny dark brownish-black crystals coating soft manganese oxides with minor calcite.

Cole Mine, Specimens 13264 in the University of Arizona from this mine were confirmed by X-Rayed by Arthur Roe (#1262).

Higgins Mine, *Twilight claim;* Small, black, wedge-shaped groutite crystals were sparsely scattered on manganite along fractures in silica breccia fragments adjacent to a large, surface manganese deposit.

GYPSUM $CaSO_4 \cdot 2H_2O$:

This species was a common, widely distributed mineral, largely of supergene origin. Post-mining growths of the variety selenite were also frequently found in many of the mines.

While gypsum was a very common product of the supergene alteration of the sulfide ores throughout the district, very few specimens of note were ever found. Small selenite crystals or thin veneers of gypsum on fractures in oxidizing sulfides were common, particularly near the limestone/ore contact, but seldom were they of any size. The majority of occurrences for gypsum are from the western part. This is because of the large number of oxidation caves found in this section of the district, the principal mode of occurrence for this species.

Gypsum was found in a great many of the oxidation caves encountered during mining. In these openings, the most common form manifested by this mineral was as “ram’s horn”-like growths. While they typically extruded from the walls or ceilings of the caverns, a few small ones were found growing from the floor as well. Generally, less than 10 cm in overall length, a few “ram’s horns” were found that approached a meter. On rare occasion, included copper carbonates would impart a pale blue-green to green hue to these formations. Iron oxides would color the “ram’s horns" various shades of red-brown.

Also found in a few cave bottoms were light-weight blocks of very porous, almost sponge-like, intergrowths of small crystals. These blocks were white in color, up to 0.5 meter high and slightly less wide. They occurred both attached to the cave floor and free-floating. Often minor amounts of malachite were randomly included in the blocks. A vivid green fluorescence was a common feature of many of these blocks of gypsum.

The sections of cave floors would occasionally have areas covered with closely packed white to colorless crystals of the variety selenite. While these crystals were almost always less than 2 cm in length, a few in excess of 20 cm were recovered.

Post-mining gypsum developed as a result of low pH, high-sulfate water reacting with the limestone wall rock, thus it is largely restricted to the sulfide areas. Often gypsum rinds would form on rock fragments or mine walls where acid mine water was running or in ponds. Stalactites of gypsum would form on mine timbers as water dripped from abandoned stopes. Some of these stalactitic forms would be colorless composite crystals up to 15 cm in length. Other such formations were chalk-white and forced into serpentine forms, bending under their own weight as they reached the floor, yet continuing to grow. A length of greater than 3 meters was noted in several places.

Ponded mine water was often the site of crystal growth for the variety selenite. Many abandoned areas in the sulfide zones were sources of this variety as cave-ins or minor rock falls created dams. The color of the water controlled the crystal color. Shades of brown, imparted by the ubiquitous iron in the solutions, were the most abundant. White to colorless crystals were far less common.

Crystal size of post-mining gypsum was, to a certain extent, a function of solution depth. When the solutions were less than 5 cm in depth the crystals would reach the surface and start to connect with a horizontal growth. Typically, however, the solutions were well over 5 cm in depth and the crystals would achieve an average length of 5 to 7 cm.

A wide variety of minerals have been found with gypsum. The more important in order of relative occurrence are:

calcite
copper
chalcocite
sepiolite
chalcanthite
hematite
malachite
goethite
cuprite
aragonite
siderite
chalcopyrite

While gypsum has not been noted replacing any other species, a number of pseudomorphs after the variety selenite have been found. Faithful casts of often large selenite crystals by copper, malachite, and goethite from the district are not particularly rare. Other pseudomorphs, also all casts after selenite, include calcite, siderite, aurichalcite, and chrysocolla.

OCCURRENCES:

Only a few of the more typical or unusual occurrences are discussed below.

Campbell Mine, *1300 level;* Post-mining selenite crystals were found at the junction of two crosscuts on this level near the Galena shaft where 5 cm colorless crystals were on gypsum-cemented gravel and completely covering an area of 5 meters across.
2200 level, Denn Sideline area; The variety selenite was found here as fine specimens of 4 cm colorless crystals on spongy, post-mining copper.

Cole Mine, Selenite crystals were noted in several places along fractures on oxidizing chalcopyrite and chalcocite ores.

Dallas Mine, The variety selenite occurred here as handsome specimens consisting of colorless 3 cm crystals on malachite. Occasionally, minor calcite was associated with these specimens, which rarely was partially altered to yellow smithsonite.

Holbrook Mine, *500 level, 20 drift;* Long, thin, selenite crystals with copper and iron sulfates occurred along fractures in mineralized limestone in a transitional zone from supergene to primary ores (Tenney, 1913).

Junction Mine, *1400 level;* Post-mining selenite was found here in a long-abandoned working as white, composite crystal stalactites of up to 15 cm.
1500 level, 43 crosscut; Thin, 3-meter post-mining stalactites nearly closed off this crosscut. Several of the stalactites had reached the floor and were bowing under their own weight.

Sacramento Mine, *1200, 80 drift;* Colorless crystals of selenite to 1 cm occurred here in vugs in massive pyrite (Tenney, 1913).
1400 level, 13 crosscut and 5 crosscut; Crystals of the variety selenite were found in voids in boxwork siderite at these locations (Bateman, et al. 1914).

Shattuck Mine, *200 level;* Colorless selenite crystals occurred as a parallel overgrowth on small botryoidal malachite specimens in the side of a stope on this level. The malachite gave the specimens a deeper green, almost glassy appearance.
300 level; The large oxidation cave on this level contained areas near the bottom where colorless gypsum-coated calcite and highly fluorescent sepiolite occurred. "Ram's horn" growths of 6 cm were also part of this coating.

Southwest Mine, *4th level;* Exceptional selenite specimens came from this level as green, copper-stained, prismatic crystals to 20 cm. Also from this level, gypsum was found as 'ram's horn" growths to 30 cm on the walls of a large cave and as large porous blocks in the bottom of this cave.
6th level; A series of small oxidation caves on this level contained "ram's horn" growths up to 90 cm, often with some local iron staining. These same caves contained blocks of gypsum that ranged from alabaster-like to spongy masses, some of which have a vivid green fluorescence. Also, one of the cave floors was covered by centimeter-sized colorless crystals of the variety selenite.

H

HALLOYSITE-10Å $Al_2(Si_2O_5)(OH)_4 \cdot 2H_2O$:

(formerly endellite, see which, and halloysite)

This mineral is widely distributed throughout the district as an alteration product of both hydrothermal and supergene processes in the several intrusive units. Most of the recognized halloysite in the district is, however, a result of supergene activity.

Hypogene halloysite typically formed as an alteration of feldspars in the intrusive. In these occurrences it was found as small, white, soft masses. It was less commonly found as large masses of impure material, which occurred as part of an alteration replacement assemblage, usually at a porphyry/limestone contact.

The most common mode of occurrence for supergene halloysite is as compact, often soapy, irregular masses of material that are colorless to white to gray and occasionally reddish or a pale blue. Nearly pure pieces of halloysite to 20 cm came from the contact zone around the Sacramento Stock.

Post-mining halloysite has been noted where acidic mine waters were routed through gobbed (backfilled) stopes (Bateman, et al. 1914).

The species associated with halloysite are:

chrysocolla
chalcocite
silver

malachite
kaolinite
azurite

goethite
muscovite
malachite

hematite
quartz
cuprite

OCCURRENCES:

Holbrook Mine, *300 level;* Halloysite was abundant on this level as a post-mining material in the gob of old stopes that were being re-mined in 1912 for the copper deposited by acidic mine waters. The halloysite from here was pale blue in color (Bateman, et al. 1914). Also from the western part of this level, as a late-stage, partial coating on botryoidal azurite
300 level, 72 raise; Large masses of white halloysite with a mammillary surface were found here with minor chalcocite (Tenney, 1913).
400 level; It was found on this level as a translucent material containing flakes of bright silver with minor malachite. Also on this level, halloysite occurred as a common replacement of feldspars in an intrusive (Tenney, 1913).

Lavender Pit Mine, Anthony, et al. (1977) noted the occurrence here of greenish-gray crusts and pods of halloysite that resemble impure chrysocolla.
Holbrook Extension; Halloysite occurred here as often large pieces that were occasionally tinted by included malachite and/or hematite/goethite. White to gray-white halloysite was an occasional lining of small pockets in hard goethite with later malachite and pseudo-orthorhombic crystals of azurite and less commonly with octahedral cuprite.

Sacramento Mine, It was noted here as a common oxidation product with supergene sulfides (Bateman, et al. 1914).

Southwest Mine, *5th level;* In small amounts of white to yellow-brown material in vugs in goethite with acicular malachite in a small stope just above the level.

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

A common mineral in many parts of the district, halotrichite has only been recognized in post-mining occurrences. As with most post-mining sulfates, it is reasonable to assume that halotrichite occurred as a supergene mineral but was not recognized. Also, it is easily confused with other post-mining sulfates with similar form and color.

Typically, halotrichite occurred as a delicate fibrous efflorescence on mine openings in warm, moist, pyritic areas. These fibrous growths were usually only a few centimeters in length but in a few areas “ram’s horn”-like specimens reached more than 40 cm.

The species associated with halotrichite are:

melanterite
epsomite
fibroferrite
pyrite

OCCURRENCES:

Campbell Mine, It was common throughout many of the moist, pyritic areas of this mine.
1800 level; Extraordinary examples of halotrichite with silky white “ram’s horn” growths of 7 cm diameter and 46 cm in length were found in one area of this level.
1900 level; Multiple “ram’s horn” growths of halotrichite to 10 cm were found in attractive groups on this level.

Cole Mine, A number of pyritic areas contained halotrichite as a fibrous efflorescence on mine openings.
800 level; Thick coatings of white fibrous growths covered much of the mine walls in one area on this level.

Gardner Mine, *400 level;* Areas near the porphyry contact contained substantial amounts of halotrichite as delicate acicular crystals.

Higgins Mine, *Tunnel level;* The sulfide stopes and adjacent crosscuts on this level contained areas with abundant, fibrous halotrichite.

Junction Mine, Many of the pyritic areas contained halotrichite as fibrous growths on mine openings.
1600 level; Multiple growths of “ram’s horn”-like forms to 15 cm covered areas of up to a meter across on this level.

Sacramento Mine, Halotrichite was abundant in many of the workings in this large mine as a fibrous efflorescence.

Shattuck Mine, *700 level;* It was abundant here as fibrous growths on oxidizing pyrite with fibroferrite.

HAUSMANNITE $Mn^{2+}Mn_2^{3+}O_4$:

This hypogene mineral has been recognized at a single locality within the district. Here, hausmannite is found in minor amounts replacing limestone that also contained braunite (Anthony, et al. 1995).

The species associated with hausmannite are (Anthony, et al. 1995):

calcite
braunite

OCCURRENCES:

White Tail Deer Mine, A surface exposure near this mine contained hausmannite as coherent masses of small, gray, pseudo-octahedral crystals replacing limestone that contains braunite (Anthony, et al. 1995).

HEMATITE Fe_2O_3:

This species was an abundant, very widely distributed, mineral of both hypogene and supergene origin. It was one of the earliest minerals deposited during mineralization. In spite of its abundance, good specimens of hematite from the district are quite rare.

Hypogene hematite was a common alteration mineral, most often occurring as the variety specularite, which was found district-wide as massive, fine-grained to coarsely crystalline material. In the upper Paleozoic units, specularite was often associated with abundant silica and occurred with silica-replaced limestone. It was also found as masses of often large (1 cm) lamina with unidentified chlorite group minerals in parts of the Abrigo limestone. Gilbert (1926) indicated that much of the hematite in the contact zone around the Sacramento Stock formed as a hydrothermal replacement of magnetite.

Elsewhere, residual hypogene specularite is abundant as part of the matrix in the large silica breccias in the Southwest and Shattuck Mine areas. Here the hematite was usually encapsulated by the cryptocrystalline quartz matrix. On occasion, large volumes of loose specularite sand were found in or adjacent to the breccias. These specularite sands were usually associated with malachite-, cerussite-, or brochantite-rich ores. Hard, compact, and perhaps cemented, specular hematite was occasionally found along the periphery of the supergene-altered orebodies associated with the intrusive breccias in these areas.

Supergene hematite is probably the most prolific secondary mineral in the district. It is most obvious as the coloring agent in large gossans that covered the Sacramento Stock and on the hills to the north and northwest of the stock.

Alteration by supergene processes of the many, large iron-bearing sulfide replacement bodies generated immense amounts of hematite. This hematite ran the full range of hardness and purity. Soft, plastic masses of hematitic material were formed throughout the district and, because of included supergene copper minerals, usually copper and/or cuprite, were often of ore grade. These masses were rarely if ever pure hematite. A variety of supergene derived clay-like alteration minerals were formed with the hematite, as was goethite.

Large amounts of ocherous hematite was often found in the bottom of completely oxidized orebodies and/or pyrite masses in the western part of the district. These too often contained goethite and were beautifully banded red and yellow.

Compact, hard, massive hematite was a common constituent of many of the oxidized orebodies. It appears that these resulted when massive sulfides were altered in situ with the hematite remaining in place of the sulfides. Relic textures of the original sulfides were occasionally preserved in this type of hematite.

Replacement of the hosting limestones by hematite was a common feature of many of the of the supergene orebodies. Large areas of boxwork hematite reflected the fracture pattern of the original limestones. This replacement pattern was usually along the edges or below the orebodies and because it typically extended well beyond the limits of the ores, it served as a guide to ore. In many of these instances, it appeared that the hematite actually replaced earlier siderite (Trischka, et al. 1929).

"Turgite", the iridescent, hydrated variety of hematite, was common as thin, often highly iridescent, veneers on fracture planes in the gossan portion of the Sacramento Stock Complex. Elsewhere, very siliceous, heavily leached, collapsed areas above oxidized orebodies also contained significant amounts of highly iridescent turgite. Here, too, it occurred along fractures or as coverings on fragments. Rarely, iridescent botryoidal hematite was found in these environments as well as handsome specimens.

The vast majority of both primary and secondary minerals are associated directly or indirectly with the hematite of similar origin. Also, as noted above, some supergene minerals are associated with hypogene specularite in the silica breccia environments.

Hematite pseudomorphs after other species are surprisingly few given the abundance of the mineral. Pseudomorphs of hematite after chalcopyrite, pyrite, magnetite, calcite, siderite, and malachite have been recognized. Friehauf (1997) noted pyrite pseudomorphs thinly-bladed specular hematite.

OCCURRENCES: Only those localities that either best represent a typical type of occurrence or that have produced specimens of interest are noted.

Campbell Mine, The upper portions of the Campbell orebody were hosted by limestone that was largely replaced by specular hematite and fine-grained quartz.

Cole Mine, A number of areas in this mine contained specular hematite/quartz replacements of limestone similar to that at the Campbell mine.
1100 level; Well-formed hematite pseudomorphs after pyrite were common in one orebody on this level. These were typically somewhat elongated cubic forms to 2 cm that were partially hollow.

1400 level; Parts of the Abrigo limestone had been replaced by a combination of chlorite-group minerals with specular hematite. Occasionally, specularite replaced beds up to 10 cm thick over a long distance and contained foliated crystals up to a centimeter in diameter.

Copper Queen Mine, Large masses of bright red supergene hematite that were soft to pulverulent were associated with the single orebody in this mine.

Czar Mine, Compact supergene hematite from many of the orebodies was highly colored with variegated bands forming handsome specimens. Stalactitic forms to several centimeters in length with malachite were also found here during mining.

Higgins Mine, *Twilight claim;* An odd occurrence of hematite at this mine with unusual bronze-colored, soft, fine-grained hematite filling a wide fault zone.

Lavender Pit Mine, As compact masses of "needle ore" with bright crystals that would easily separate into individual, thin 10 cm-long pieces. This vein-like occurrence was up to 30 cm thick, with the compact crystals perpendicular to the walls. At a cross-structure, a calcite-cemented breccia of banded hematite was found with pieces that were individually up to 5 cm thick. A large number of very fine, highly iridescent specimens of the variety turgite were found in the upper parts of the gossan zone overlying the ores at this mine.

Portage Lake Mine, A prospect near this unproductive mine in the extreme eastern portion of the district produced interesting specimens of "needle ore." Here it occurred as reniform masses to 3 cm thick composed of columnar crystals that were easily separated from the mass.

Sacramento Pit Mine, The gossan over the deposit exploited by this early open pit mine contained substantial amounts of red hematite as exotic depositions along fractures that generally colored Sacramento Hill. Indigenous hematite formed as pulverulent, partial fillings of voids left by the removal of pyrite through supergene activity.

Shattuck Mine, Specular hematite was pervasive in the several silica breccias and the associated orebodies throughout the mine. Nearly pure specularite with a greasy feel was common, as were large areas of loose sandy to dust-like specularite.
100 level; It was found here as thick compact masses of nearly pure specularite crystals of 1 to 2 mm with malachite.
200 level, 45 raise; Hematite occurred here as compact supergene material that developed as reniform and stalactitic forms with minor malachite in Abrigo limestone.
400 level; Very attractive specimens of iridescent hematite with a botryoidal form were recovered from a small cave above this level. These were formed as botryoidal coatings to 5 mm thick, on angular pieces of massive specular hematite. Minor tan calcite was usually associated with these specimens.
600 level, 98 crosscut; A variety of forms of hematite were developed at this locality following the brecciation and remobilization of an otherwise typical large mass of fine- grained, compact specularite. The first generation of deposition was as a lustrous botryoidal to pisolitic lining up to 1 cm thick on the breccia fragments. Some of this material was then overgrown by sharp, tabular, hexagonal crystals to 3 cm in size, which are typically dull black. This was followed by a dusting

of bright microcrystals. A final period of deposition was characterized with many of the voids being filled by loose to spongy masses of intergrown, thin, often translucent tabular crystals to 4 mm or less.

Southwest Mine, Hematite was abundant in this mine as specularite, often unconsolidated, in the many orebodies associated with the silica breccias.
6th level; It came from here as bright crystals to 2 mm on siliceous fragments. Also from this level, hematite was found as compact specularite that has been polished to a mirror-like finish as a result of movement along a fault. Another locality on this level, near the Higgins sideline, produced attractive specimens of the iridescent variety turgite. This hematite was deposited on thin, flat, silica fragments at the margin of a silica breccia.

HEMIMORPHITE $Zn_4Si_2O_7(OH)_2 \cdot H_2O$:

This is a widely distributed mineral. Nevertheless, it is not particularly abundant in any of the many localities, a characteristic typical of the vast majority of supergene silicates found in the district.

Paragenetically, hemimorphite was always a very late-stage mineral. In almost all of the recognized occurrences it is found as the last mineral deposited. Hemimorphite has been noted on or encasing other late-stage minerals such as malachite, rosasite, copper, chalcophanite, and aurichalcite.

The depositional sites for this mineral are similar to several of the other zinc-bearing supergene minerals. Oxidation caves, in particular their lower portions, have often contained hemimorphite, though always in modest amounts. Here it occurred as concentrated sprinklings of 5 mm to 1 cm crystals. Occasionally, small patches of thin, white, massive material were found coating calcite on the cave walls. Rarely, white botryoidal specimens were found as well.

Within the boxwork voids of the supergene-derived goethite and hematite, hemimorphite occurred as a minor constituent of the ores. Under these conditions, it was often found as small clusters of divergent crystals that are sometimes oriented on other minerals.

Crystals larger than 1 cm from the district are quite rare. Only one locality has produced crystals of any size. These were from the Cole mine occurrence discussed below.

Other species that have been noted with hemimorphite are:

hematite
malachite
smithsonite
rosasite
goethite
gypsum
calcite
aurichalcite
copper
chalcophanite

OCCURRENCES:

Cole Mine, *1200 level, 26-J stope;* It was found here as white crystals to 3 cm in radiating clusters on calcite with aurichalcite and minor rosasite.
1300 level, 26-K stope; This locality is a lower part of the orebody noted above. Hemimorphite occurred as extraordinarily fine specimens of opaque crystals to 11 cm on hematite with modest inclusions of chalcophanite. Smaller crystals from this locality are typically colorless and formed in radiating clusters. All of the material from this locality fluoresces and phosphoresces a bright blue-white.

Junction Mine, *1500 level;* Radiating sprays of colorless to white hemimorphite crystals to 4 mm were found on reniform hetaerolite in one area of this level.

Kentucky Tunnel Mine, It was found in small amounts as 2 to 4 mm colorless crystals with mimetite, galena, and anglesite.

Southwest Mine, *3rd level;* Hemimorphite was locally abundant here as 5 mm clusters of radiating crystals on goethite, often encasing rosasite, and, less often, aurichalcite. Some of the rosasite occurred as replacements of malachite pseudomorphs after azurite.
5th level; Just below the 6th level hemimorphite occurred as colorless crystals on and often encasing 4 mm spheroids of rosasite.
6th level; It was abundant in the lead/zinc stopes on this level as colorless 2 mm crystals in radiating sprays with rosasite, aurichalcite, and chrysocolla. Also, a small cave on this level contained hemimorphite as white botryoidal material or as spongy masses of pale mauve-colored crystals to 3 mm on calcite.
10th level; Hemimorphite was found here as 6 to 8 mm colorless crystals on rosasite and calcite.

Uncle Sam Mine, *"A" level;* Clusters of bright, 3 mm crystals were scattered on fine specimens of rosasite replacements of malachite pseudomorphs after azurite in vugs along a meter-wide fault.

HENRYITE $Cu_4Ag_3Te_4$:

Bisbee is the type locality for this species (Criddle, et al. 1983) and one of only three reported occurrences for this rare primary mineral. Henryite was found in very small amounts in one locality in the district.

The typical occurrence for henryite is as anhedral grains from 0.1 to 0.5 mm enclosed in hessite and petzite. These minerals, in turn, are interstitial in subhedral, granular to massive pyrite (Criddle, et al. 1983).

The species associated with henryite are:

pyrite
calcite
hessite
altaite
petzite
sylvanite
rickardite

OCCURRENCES:

Campbell Mine, Drill core samples of massive pyrite contained inclusions of henryite as tiny blebs that are pale blue in reflected light and associated with hessite, petzite, rickardite, calcite, sylvanite, and altaite (Criddle, et al. 1983).

HESSITE Ag_2Te:

This hypogene species has been recognized in very small amounts in several locations in a single mine. Typically, hessite was part of a complex, micro-phase mineral assemblage that occurred as compound inclusions in sulfides, particularly pyrite, galena, and sphalerite (Alan Criddle, personal communication, 1992).

The species associated with hessite are (Alan Criddle, personal communication, 1992):

- pyrite
- rutile
- bornite
- gold
- stützite
- altaite
- sphalerite
- chalcopyrite
- digenite
- sylvanite
- melonite
- kostovite
- galena
- chalcocite
- covellite
- krennerite
- tellurium
- henryite
- colusite
- spionkopite
- quartz
- cassiterite
- rutile
- tellurobismuthite

OCCURRENCES:

Campbell Mine, *1900 level, 2100 level, 2300 level, 124 stope;* Hessite was found at these locations in the Campbell orebody in very small amounts as a minor component of compound inclusions of a complex, multi-mineral assemblage in sulfides (Alan Criddle, personal communication, 1992).
2300 level, 126 stope; Hessite occurred here in small amounts with other silver minerals as inclusions in chalcopyrite, bornite, sphalerite, chalcocite, and galena (Alan Criddle, personal communication, 1992).

HETAEROLITE $ZnMn^{3+}{}_2O_4$:

This supergene species has been found at several localities within the district and was quite abundant at several of the recognized occurrences. Some of the finest known examples of this mineral have come from the mines at Bisbee.

Hetaerolite is most probably far more common within the district than the few documented occurrences would indicate. For the most part, manganese minerals have been overlooked at Bisbee because of their lackluster appearance when compared with the copper-containing species.

Typically, hetaerolite occurred associated with the supergene ores as botryoidal or stalactitic masses, often of large size. The surfaces of the compact forms were usually a splendent silvery-gray in color grading into a brownish-black where the material was less dense. Drusy crusts of bright crystals on goethite were frequently noted as well.

Hetaerolite has been found associated with one of the many near-surface manganese deposits. Here, it occurred on the surface as coarse crystals in veins in limestone adjacent to a small deposit.

The species associated with hetaerolite are:

goethite
cerussite
chalcophanite
hemimorphite
hematite
malachite
calcite
azurite

OCCURRENCES:

Campbell Mine, *1900 level;* A solution cavity intercepted by a crosscut and adjacent to an oxidized copper/lead orebody contained large amounts of hetaerolite. It was recovered as numerous, often large, specimens that were botryoidal or stalactitic with a bright, silver-gray surface.
2566 level; Minor amounts of splendent, botryoidal hetaerolite with later pyrolusite and fine calcite crystals occurred on this level.

Cole Mine, *1300 level;* Drusy crust of hetaerolite formed on boxwork goethite on this level. This material can easily be confused with the more common chalcophanite with which it is occasionally associated.

Junction Mine, *1400 level;* Fine specimens of splendent reniform hetaerolite on goethite with later hemimorphite crystals came from this area of the mine.

Southwest Mine, *6th level;* Hetaerolite occurred in minor amounts adjacent to silica breccia hosted, oxidized, lead/zinc ores as small, bright botryoidal coatings on silica fragments with later calcite.

White Tail Deer Mine, Veins of manganese oxides cutting limestone on the surface near this mine contained hetaerolite as superb pyramidal crystals to 1.2 cm encased in calcite.

HEXAHYDRITE $MgSO_4 \cdot 6H_2O$:

This species has only been recognized in post-mining occurrences where it was clearly a dehydration product of epsomite.

Typically, it was found as white to cream-colored coatings on or as complete replacements of epsomite. Also, it often occurred as a white powdery residue when the thin, fibrous epsomite dehydrated.

The species associated with hexahydrite are:

epsomite
siderotil
rozenite
pyrite

Fine pseudomorphs of hexahydrite after epsomite crystals to 5 cm have been found.

OCCURRENCES:

Campbell Mine, *2700 level, 42 crosscut;* It was found here as sharp pseudomorphs after 5 cm epsomite crystals. Also from this area as a powdery material as part of a crust on mine walls with rozenite and siderotil.

HISINGERITE $Fe_2^{3+}Si_2O_5(OH)_4 \cdot 2H_2O$:

This supergene species is apparently of limited distribution within the district. However, it is probably far more common, but unrecognized because of its similarity to other, more common iron oxides.

Hisingerite was found as thin, resinous veneers on siliceous breccia fragments or linings in voids in these fragments. It was also found as tough, compact, impure masses mixed with goethite, often in large pieces.

The species associated with hisingerite are:

quartz
azurite
goethite
cuprite
hematite
copper
malachite

OCCURRENCES: Anthony, et al. (1977) first noted this mineral from an unspecified locality in the district.

Cole Mine, *800 level;* A thin veneer of hisingerite occurred on quartz fragments between the quartz and copper that had formed along fractures.

Lavender Pit Mine, *Holbrook Extension;* Large boulders of up to several meters across from here were composed of compact, very hard, brownish-black hisingerite and goethite. Small voids in these boulders contained malachite, azurite, and cuprite.

Shattuck Mine, *200 level;* Silica breccia fragments in one area on this level had small, thin patches of resinous hisingerite as well as similar material lining voids that had at one time contained sulfides.

Southwest Mine, *5th level;* A copper stope adjacent to a silica breccia on this level had small amounts of hisingerite as fracture fillings and as crusty coatings on breccia fragments.

HOCARTITE Ag_2FeSnS_4:

This hypogene mineral has been recognized in small amounts at a single locality within the district. In this occurrence, hocartite was a minor constituent of the complex, multi-mineral assemblage included in common sulfides in the Campbell orebody.

OCCURRENCES:

Campbell Mine, Hocartite was noted by Sid Williams while studying the ores from this mine (Sid Williams, personal communication, 1992).

HODRUŠHITE $Cu_8Bi_2S_{22}$:

This hypogene mineral has been recognized in small amounts at a single locality within the district. In this occurrence, hodrušhite was a minor constituent of the complex, multi-mineral assemblage associated with common sulfides in the Campbell orebody.

The species associated with hodrušhite are (Sid Williams, personal communication, 1992):

pyrite
chalcopyrite

OCCURRENCES:

Campbell Mine, Hodrušhite was noted by Sid Williams as steel-gray laths to 0.5 mm in pyrite while studying the ores from this mine (Sid Williams, personal communication, 1992).

HÜBNERITE $Mn^{2+}WO_4$:

This hypogene mineral is the manganese-rich end member of a solid solution series between hübnerite and ferberite. It. has been noted in small amount at several localities within the district. Hübnerite was always found at Bisbee as tiny grains included in other minerals, particularly in sulfides as a minor component of compound inclusions. These compound inclusions were a complex mineral assemblage with diverse elements represented. It is possible that some of the "wolframite" from this and other localities in the district is indeed hübnerite.

The species associated with hübnerite are (Sid Williams, personal communication, 1987):

coronadite
cryptomelane
bornite
braunite II
kiddcreekite
pyrite
braunite
"wolframite"
chalcocite
neltnerite
scheelite
chalcopyrite

OCCURRENCES:

Cole Mine, *1300 level;* Hübnerite occurred here as a minor component of complex inclusions in sulfide ores with kiddcreekite, "wolframite," scheelite, bornite, chalcocite, chalcopyrite, and pyrite (Sid Williams, personal communication, 1987).

White Tail Deer Mine, A surface outcrop near this mine contained very minor amounts of hübnerite as tiny grains included in braunite II with coronadite. Braunite, neltnerite, and cryptomelane were associated with the braunite II (Sid Williams, personal communication, 1987).

HYDROBASALUMINITE $Al_4(SO_4)(OH)_{10}\cdot 12\text{-}20H_2O$:

This rare supergene mineral has also been recognized as a post-mining mineral in the district. Because hydrobasaluminite readily alters to felsőbányaite through dehydration, it is doubtful that any specimens, which were removed from the mines, have survived. However, as recently as 2001, hydrobasaluminite was recognized underground in a post-mining occurrence.

In supergene occurrences, hydrobasaluminite was found in small amounts with other aluminum sulfates as white crusts along fractures in limestone near a porphyry contact. Rarely, it was found as exceptionally large, white to colorless crystals.

Under post-mining conditions, it occurred as white to colorless, acicular or bladed crystals.

The species associated with hydrobasaluminite are:

felsőbányaite
calcite
quartz
copper
pyrite
antlerite

OCCURRENCES:

Lavender Pit Mine, *Holbrook Extension;* It was found here as pearly-white flakes with felsőbányaite on fractures in silicified limestone (Anthony, et al. 1995). Also from this area hydrobasaluminite was found in minor amounts as a white crust on copper with minor antlerite and felsőbányaite.

Southwest Mine, *7th level;* Hydrobasaluminite has been found here in modest amounts as white to colorless, acicular crystals to 3 cm in voids in a fault zone cutting massive pyrite with impure, cream-colored, plastic hydrobasaluminite and felsőbányaite. Also, from nearby, it occurred as a post-mining growth, with 8 mm acicular to bladed crystals, on crushed mine timber.

HYDROBIOTITE $K(Mg,Fe^{2+})_6(Si,Al)_8O_{20}(OH)_4.nH_2O$(1:1 regular interstratification of "biotite" and vermiculite layers).

This hydrothermally-formed alteration species is apparently of limited distribution within the district. It has only been recognized in the older porphyry unit of the Sacramento Stock complex. Anthony, et al. (1995) indicate that hydrobiotite formed as a result of the intrusion of the quartz monzonite (younger porphyry unit).

Typically, hydrobiotite occurred as 2 mm or less, blackish flakes that look very much like "biotite."

The species associated with hydrobiotite are:

illite quartz allophane muscovite
pyrite

OCCURRENCES:

Lavender Pit Mine, Hydrobiotite occurred in small amounts in the older porphyry unit of the Sacramento Stock complex that was mined by this operation (Anthony, et al. 1995).

HYDROCERUSSITE $Pb_3(CO_3)_2(OH)_2$:

This supergene mineral is apparently quite rare in the district. It is entirely possible that in other occurrences hydrocerussite has gone unrecognized because of its nondescript appearance.

The typical mode of occurrence for hydrocerussite in the district is as a thin, white coating on galena.

The species associated with hydrocerussite here are:

quartz galena calcite

OCCURRENCES:

A surface exposure of a quartz-galena vein immediately west of the Lavender Pit contained minor hydrocerussite as a milky-white coating on galena.

Campbell Mine, Hydrocerussite was noted from an undetermined locality in this mine by Sid Williams (personal communication, 1987).

HYDROHETAEROLITE $HZnMn_{1.7}^{3+}O_4$:

This secondary mineral has been recognized in one locality only. There can be little doubt that it is far more common than this would indicate. However, the similarity of hydrohetaerolite to the ubiquitous manganese oxides in the supergene altered zinc deposits and the mixed manganese oxides in the many surface manganese deposits, could have caused it to be overlooked.

The typical occurrence for hydrohetaerolite is as a gray to black, botryoidal material with a fibrous structure. Lesser amounts of delicate, dark brown, fibrous crust have been found as well.

The species associated with hydrohetaerolite are:

calcite goethite hetaerolite hematite
malachite azurite cerussite

OCCURRENCES:

Campbell Mine, *1900 level, 105 stope;* A large number of fine hydrohetaerolite specimens with a gray botryoidal to stalactitic surface were recovered from here during the late 1930s to mid-1940s. Some of this material was plumose as well. Minor calcite was associated with this occurrence. Along the fringes of the oxidized copper/lead ores there were patches of friable, brownish-black hydrohetaerolite on altered limestone. Minor hetaerolite, goethite, and later calcite were directly associated with the hydrohetaerolite, while malachite, azurite, cerussite, and hematite were in the adjacent ores.

HYDROKENORALSTONITE $\square_2Al_2F_6(H_2O)$:

Formally ralstonite**,** this is an uncommon mineral that is exceedingly rare in the district. The local occurrence is unusual in that it is of supergene origin.

Vugs in massive cuprite are often the host for rare and uncommon minerals in the district. The only known occurrence of ralstonite at Bisbee is from this type of environment. It occurs as a white to colorless crust or white fibrous crystals of less than 0.1 mm on cuprite and, less frequently, on atacamite or paratacamite.

The species associated with ralstonite are:

cuprite
hematite
paratacamite
connellite
malachite
atacamite

OCCURRENCES:

Southwest Mine, *5th level*, *14 stope*; A small number of specimens with ralstonite as tiny clusters of microcrystals or crusts that are white to colorless on cuprite, atacamite, or paratacamite were found.

HYDROZINCITE $Zn_5(CO_3)(OH)_6$:

This supergene mineral has been recognized in only a few locations within the district. However, there is little doubt that it was far more common than the few confirmed localities would indicate. None of the noted occurrences have produced large amounts of hydrozincite nor have any specimens of particular interest been produced.

Typically, hydrozincite has been found as white to light gray crusts on other minerals, particularly sphalerite. All of the recognized hydrozincite from the district is highly fluorescent, giving the typical blue-white response to short-wave ultraviolet light.

The species found associated with hydrozincite are:

sphalerite
pyrite
malachite
smithsonite
calcite
goethite
hematite
quartz
azurite

OCCURRENCES:

Campbell Mine, *1600 level;* Hydrozincite was found on this level in minor amounts as a gray to white crust or thin film on zincian malachite.

Copper Queen Mine, *"B" level;* Post-mining hydrozincite occurred as spotty crust to 30 cm of white material on highly flourescent sphalerite with calcite

Higgins Mine, *Tunnel level;* Patchy, white crusts of hydrozincite formed along fractures in a massive sphalerite/pyrite/calcite mixture on this level. Also from another area it was found as a drusy crust on smithsonite that is in turn on sphalerite. Occasionally, lustrous crystals to 0.2 mm were found in voids in the smithsonite. The hydrozincite from here is fluorescent, giving a pale blue color.

Junction Mine, *770 level - 900 level;* Minor amounts of hydrozincite occurred here as clusters of tiny white crystals and as patches on light blue azurite. Also from these same areas, it was found as a porous gray-white material with "drybone" smithsonite.
1600 level; Hydrozincite was found here in small amounts a white crust lining voids and fractures in massive calcite.

Southwest Mine, *3rd level;* Minor amounts of hydrozincite were found here as gray-white crust on calcite along with minor sphalerite and pyrite.

I

"ILLITE" $(K,H_3O)(Al,Mg,Fe)_2(Si,Al)_4O_{10}[(OH)_2,H_2O]$:

Illite is a series name used to describe any of the series of clay-like micas which are essentially a potassium-deficient muscovite, one which frequently contains randomly sequenced montmorillonite/beidellite layers and is therefore no longer regarded as a separate species name. It is included here for the sake of completeness only, as the exact member of the series is typically not noted in the early papers referenced herein. The information provided is to be considered for reference only, allowing for the work of earlier researches to remain available.

This hydrothermal mineral is abundant and widely distributed in the intrusive units of the Sacramento Stock complex and in the dikes underground (Schwartz, 1947). In all instances, illite was formed as an alteration of the feldspars within the intrusive units.

Illite typically was found as a white to gray to pale green impure material that was very clay-like. It was a major component of a multi-mineral alteration assemblage in all of the intrusives.

The species associated with illite are:

quartz
allophane
chlorite
muscovite
alunite
pyrite
calcite
epidote
kaolinite

OCCURRENCES:

Illite is widely distributed in all of the intrusive units in the productive portions of the district (Schwartz, 1947, 1956).

ILMENITE $Fe^{2+}TiO_3$:

This hydrothermal species is widely distributed in small amounts as a minor accessory mineral in the Juniper Flat granite and in the Pinal schist. In both instances it was found as tiny grains along with other accessory minerals. The presence of ilmenite in the intrusive units of the Sacramento Stock Complex is implied by the occurrence of the alteration products of this mineral in the hydrothermal alteration assemblage. However, it has not been recognized in these units.

The species associated with ilmenite are:

quartz
muscovite
biotite
plagioclase
orthoclase
zircon
apatite
magnetite
tourmaline
chlorite

OCCURRENCES: The occurrences of ilmenite are the same as the Juniper Flat granite and the Pinal schist occurrences within the district.

ILSEMANNITE $(Mo_2^{6+}Mo^{4+})O_8 \cdot H_2O$: ?

The validity of this species is considered questionable by Back (2018). At Bisbee it is typically a supergene mineral that is fairly uncommon in the district. In at least two of the three recognized occurrences ilsemannite was found as a post-mining growth.

The species associated with ilsemannite are:

quartz
pyrite
muscovite
fluorite
scheelite

OCCURRENCES:

A small, unnamed prospect near Warren contained ilsemannite as blue stains on intensely silicified limestone with fluorite and scheelite (Anthony, et al. 1995).

Lavender Pit Mine, It occurred here as a pale blue, powdery crust on porphyry in a dike near the concentrator.
Holbrook Extension; Following rains, ilsemannite can be found along the highway road cut north of this part of the pit as indigo-blue blooms to several meters in size on mineralized Pinal schist. During dry times, it becomes very pale in color, even white, suggesting alteration to another species.

IODARGYRITE AgI:

This supergene mineral is apparently quite rare within the district. Only a single locality has been recognized with very small amounts of iodargyrite present.

In this occurrence, iodargyrite occurred as a minor constituent of a complex, bismuth-rich mineral assemblage on the fringes of mined-out stopes in the upper portions of the Campbell orebody.

The species associated with iodargyrite are:

aikinite
mottramite
acanthite
silver
kettnerite

OCCURRENCES:

Campbell Mine, Iodargyrite came from an undetermined level in the upper parts of this mine as very small amounts with aikinite, mottramite, acanthite, silver, and kettnerite (Sid Williams, personal communication, 1987).

J

JACOBSITE $(Mn^{2+},Fe^{2+}, Mg)(Fe^{3+},Mn^{3+})_2O_4$:

This is a hypogene mineral that appears to be most uncommon in the district. The typical occurrence is where jacobsite was found as small, apparent exsolution blebs, to 5 mm in massive cryptomelane veins that were up to 3 cm in width, along with minor braunite. These veinlets are of hydrothermal origin in limestone and are adjacent to massive replacement manganese deposits.

Other species associated with jacobsite are:

calcite
pyrolusite
neltnerite
braunite
cryptomelane

OCCURRENCES:

Number 4 Claim; This small, near-surface manganese deposit was largely braunite; but the veins in the hosting limestone were largely massive cryptomelane with minor neltnerite at the limestone contact and with blebs of black to gray-black jacobsite included in the cryptomelane.

JALPAITE Ag_3CuS_2:

This hydrothermal mineral has been recognized in small amounts in a single mine. Here, jalpaite was noted as a very minor accessory mineral in a complex, silver and bismuth-rich, diverse mineral assemblage. This assemblage occurred as micro-phase inclusions in siliceous hematite matrix associated with a highly altered dike of undetermined composition (Alan Criddle, personal communication, 1992).

The species associated with jalpaite are (Alan Criddle, personal communication, 1992):

- wittichenite
- djurleite
- spionkopite
- galena
- digenite
- hematite
- bismite
- chalcopyrite
- bismuthinite
- bornite
- acanthite
- copper
- sphalerite
- covellite
- gold
- stromeyerite
- quartz
- chalcocite
- silver
- matildite
- emplectite
- cuprite

It is worth noting that the associated chalcocite and wittichenite contained 6% and 7% silver respectively.

OCCURRENCES:

Campbell Mine, *1600 level;* Jalpaite was recognized from this part of the Campbell orebody in the work of Criddle and Stanley as part of a high silver/bismuth mineral assemblage (Alan Criddle, personal communication, 1992).

JAROSITE $KFe_3^{3+}(SO_4)_2(OH)_6$:

This was a common secondary mineral of wide distribution throughout the district. Jarosite was common in the gossan cap of Sacramento Hill as an alteration product of pyrite with goethite (Schwartz, 1947). Most of the high-pyrite oxidized limestone-replacement orebodies contained jarosite.

The most typical occurrence for this species is as small crystals on a non-reactive matrix, particularly porphyry, quartz, hematite, or goethite. Often, jarosite is found on one of the iron oxides that is an in-situ product of pyrite oxidation.

Large masses of an earthy mixture of goethite and jarosite were found with some of the orebodies associated with the silica breccias of the Southwest and Shattuck mine areas.

The minerals associated with jarosite in the district include many of the other supergene species. The more common are:

hematite
siderite
goethite
malachite
quartz
calcite
lepidocrocite
plumbojarosite

OCCURRENCES:

Campbell Mine, Several areas of this mine contained jarosite associated with the oxidizing pyritic ores, most notably in the upper portions of the Campbell orebody.

Czar Mine, Dump specimens from here contained 1 to 2 mm amber-colored tabular jarosite crystals on hematite that were formed by replacing pyrite, occasionally with hematite pseudomorphs after pyrite. Goethite with 2 mm yellow-brown to red-brown jarosite crystals was common at this mine. Also, jarosite came from here as bright golden-yellow, 0.1 mm crystals on siderite with hematite.

Hoatson Mine, *1200 level;* Jarosite was recognized on specimens from here in small amounts as tiny golden-brown crystals on goethite that were in turn on malachite. In some instances, the goethite was poorly connected to the malachite except in those areas where the jarosite had been deposited. This gave the misleading appearance of jarosite having been directly deposited on malachite.

Junction Mine, *1200 level;* It was abundant here as tiny yellow-brown crystals on friable goethite that was an in-situ replacement of massive pyrite.

Lavender Pit Mine, Jarosite was common in the gossan portions of the several intrusive units as well as in the mineralized portions of the Pinal schist as tiny, amber-colored crystals along fractures and in the voids left by pyrite oxidation. It was also found as thick compact masses composed of yellow-brown, micaceous crystals.

Sacramento Mine, Jarosite was common in the portions of this mine that were blocked caved as crystalline crusts along fractures close to the ore-waste contact.

Sacramento Pit Mine, The Sacramento Stock Complex, which hoisted the ores in this very early open pit operation had a classic gossan that contained substantial amounts of jarosite as tiny crystals in voids and along fractures.

Shattuck Mine, It was noted from an unspecified level in this mine as brilliant 1 mm hexagonal scales on massive hematite (Schaller, 1916). Also, it was found here as 3 to 5 mm yellow-brown crystals on a siliceous hematite (USNMNH specimen 93626). Earthy mixtures of jarosite with goethite and modest to abundant plumbojarosite were found in several areas in the specular hematite-rich silica breccia environments, most notably from the orebodies in what was called the “lead cave” from just below the 300 level to the 200 level.

Southwest Mine, *3rd level;* Jarosite came from a fault zone cut by this level as massive micaceous to granular material of up to 3 cm thick with a drusy surface.
5th level to 7th level; It was common in masses of several thousand tons as impure earthy material mixed with goethite, specular hematite, and, to a much lesser extent, plumbojarosite. These were apparent replacements of massive pyrite bodies associated with the silica breccias. Also from these levels jarosite was recognized as amber-colored crusts or pseudohexagonal crystals to 2 mm on hematite, goethite, or siliceous breccia fragments. Later, malachite in small amounts is associated with some of the crystalline specimens.

Uncle Sam Mine, A small number of specimens from this mine contained jarosite as 0.5 mm amber-colored crystals as a partial coating on large brochantite crystals.

JOHANNITE $Cu(UO_2)_2(SO_4)_2(OH)_2 \cdot 8H_2O$:

This is an uncommon mineral in the district that has been found only in small amounts as an efflorescence on decomposing pyrite, which contained a very minor amount of uraninite.

The species found associated with johannite are:

pyrite
zippeite
uranopilite
uraninite
gypsum

OCCURRENCES:

Cole Mine, This species has been recognized on only a small number of specimens collected in the late 1940s from an unspecified level in this mine. On these, it was found as an efflorescence on decomposing sulfides as a green to blue-green crust with gypsum and minor zippeite as well as uranopilite.

JÔKOKUITE $Mn^{2+}SO_4 \cdot 5H_2O$:

This uncommon species has been recognized in modest amounts in a single post-mining occurrence.

The species associated with jôkokuite are:

alabandite
pyrite

OCCURRENCES:

Junction Mine, *2300 level;* Minor amounts of post-mining jôkokuite were found in broken alabandite left in the stope during mining. It occurred as a soft, granular, pink to white material to 5 mm thick filling fractures.

K

KAOLINITE $Al_2Si_2O_5(OH)_4$:

This common species has formed under both supergene and hydrothermal conditions with the latter the more prevalent. Supergene kaolinite was very abundant with most being residual material from the alteration of porphyry and/or of limestones which had been enriched with aluminum during some phase of the mineralization or alteration.

Typically, supergene kaolinite was found as soft, white, and impure masses, often colored reddish or green by iron or copper respectively. It was an important component of the abundant, soft, supergene “ferruginous clays” (Tovote, 1911) or “ledge matter” (Douglas, 1900) that were so commonly associated with the completely oxidized ores. The soft, kaolinitic/hematitic/goethitic clays frequently contained sufficient copper to be of ore grade.

Many fine specimens of copper, cuprite, azurite (roses), and malachite were formed in these plastic, non-reactive, largely kaolinitic clays. The clays were, however, very troublesome for the miners because they were quite sticky and would not easily move through the ore transfer system, and they stuck in the mine cars when dumped, causing further aggravation. They were also a problem because any ground pressure would force them into the open workings, often completely filling them in just a few hours.

Hydrothermal kaolinite occurred as an alteration product of feldspars (Schwartz, 1947) and, to a lesser degree, “biotite” (Schwartz, 1958). The porphyry units of the Sacramento Stock Complex, as well as the underground porphyry dikes, have all been heavily altered with almost all of the feldspars and “biotite” replaced by clay minerals. Kaolinite is one of the major components of the alteration suite that has replaced these minerals.

The species most commonly associated with kaolinite are:

hematite
copper
muscovite
epidote
goethite
cuprite
allophane
rutile
malachite
delafossite
ilmenite
azurite
quartz
pyrite

OCCURRENCES:

Because of the very common nature and wide distribution of kaolinite, coupled with its nondescript appearance, only a few typical occurrences will be noted.

Czar Mine, *200 level-400 level;* Huge amounts of soft kaolinite, almost always mixed with one or more of the iron oxides and other clay/clay-like minerals, were associated with the orebodies along the Dividend fault, where the famous azurite “roses” were found and in other areas. It is these masses that Douglas (1900) referred to as “ledge matter.” Douglas (1900) notes that some of the kaolinite was sufficiently pure to use as a furnace lining in the smelter.

Hoatson Mine, Kaolinite was abundant in portions of this mine as both white and iron-stained material as a major constituent of the oxide ores. It was found as large, irregular masses and interlayered with altered limestone. In both instances, sufficient copper, cuprite, and delafossite were present in sufficient amounts to make this material an ore (Tovote, 1911).

Holbrook Mine, *200 level;* A locality 80 meters south of the shaft contained snow-white kaolinite streaked with veinlets of malachite (Ransome, 1904). As was the case in the nearby Czar mine, abundant, impure kaolinite was associated with the famous azurite “roses” particularly in the Dividend fault zone. as well as many of the orebodies on this and other levels,

Lavender Pit Mine, *Holbrook Extension;* Mining in this portion of the pit frequently hit masses of supergene kaolinite that were soft with a waxy appearance and ranged in color from red to yellow to greenish to white over a very short distance.

Sacramento Mine, *500 level;* Porphyry samples collected here had all of the feldspars altered to mostly clay minerals, of which kaolinite was a component (Schwartz, 1947).

KËSTERITE $Cu_2(Zn,Fe)SnS_4$:

This hypogene mineral has been recognized in small amounts at a single locality within the district. In this occurrence, kësterite was a minor constituent of the complex, multi-mineral assemblage that was associated with common sulfides in the Campbell orebody.

The species associated with kësterite are (Sid Williams, personal communication, 1992; Alan Criddle, personal communication, 1992):

chalcopyrite
djurleite
sphalerite
stützite
calaverite
cassiterite
melonite
kiddcreekite
bornite
covellite
galena
stannite
tetradymite
gold
volynskite
chalcocite
tennantite
altaite
mawsonite
sylvanite
goldfieldite
colusite
digenite
pyrite
hessite
rutile
tellurium
kostovite
wittichenite

OCCURRENCES:

Campbell Mine, Kësterite was noted by Sid Williams while studying the ores from this mine as a thin, crystalline crust on pyrite-chalcopyrite ore (Sid Williams, personal communication, 1992). *2100 level, 2200 level,* On these levels, kësterite was a minor component of a complex, tin-rich mineral assemblage that formed as fracture filling in massive pyrite and as inclusions in pyrite (Alan Criddle, personal communication, 1992).

2300 level, 125 stope; This stope contained a very complex assemblage of tin-tungsten-tellurium-vanadium minerals, including tiny amounts of kësterite, that were included within and replacing granular pyrite (Alan Criddle, personal communication, 1992).
2566 level; This mineral was part of a very complex assemblage of tin-tungsten-tellurium-vanadium minerals replacing pyrite on this level (Alan Criddle, personal communication, 1992).

KETTNERITE CaBi(CO$_3$)OF:

This mineral has been recognized in small amounts at a single locality within the district. In this occurrence, kettnerite may have been supergene in origin, but the genesis is not certain. Here, it was a minor constituent of the complex, multi-mineral assemblage typically associated with common sulfides in the Campbell orebody.

The species associated with kettnerite are (Sid Williams, personal communication, 1987):

aikinite
iodargyrite
mottramite
acanthite
silver

OCCURRENCES:

Campbell Mine, Kettnerite was noted by Sid Williams in specimens from an undetermined level in the upper parts of this mine. It occurred in very small amounts as inclusions in aikinite, with mottramite, acanthite, minor iodargyrite and silver (Sid Williams, personal communication, 1987).

KIDDCREEKITE Cu$_6$SnWS$_8$:

Bisbee is the co-type locality for this rare primary mineral. The Kidd Creek mine in Timmins, Ontario, Canada is the other co-type locality.

Kiddcreekite occurs at Bisbee as anhedral grains to 50 µm that are cores to zoned, subhedral colusite grains or as compound intergrowths with colusite, tungsten-bearing colusite, stützite, and altaite included in other sulfides and can be seen only in polished sections (Harris, et al. 1984).

The species associated with kiddcreekite are (Harris, et al. 1984; Sid Williams, personal communication, 1987; Alan Criddle, personal communication, 1992):

pyrite
stannoidite
mawsonite
cassiterite
nolanite
petzite
galena
stützite
stannite
colusite
“wolframite”
rutile
melonite
aikinite
colusite
kësterite
kiddcreekite
magnetite
tellurium
hessite
chalcopyrite
altaite
nekrasovite
scheelite
quartz
sphalerite
hematite
djurleite

covellite
tellurobismuthite
krennerite
digenite
calaverite
hübnerite
bornite
sylvanite
scheelite
kostovite
gold

OCCURRENCES:

Campbell Mine, Kiddcreekite was found in very small amounts as anhedral grains that appear pale gray, occasionally with a purplish tint in reflected light. Here it was associated with tungsten-bearing colusite, stützite, and altaite all included in massive, granular pyrite (Harris, et al. 1984). Undoubtedly, one or both of the occurrences detailed below provided material for the original description of this species.
2200 level; Kiddcreekite occurred in tiny amounts in pyrite as an anhedral inclusion and associated with several copper sulfides and other tin-tungsten minerals (Alan Criddle, personal communication, 1992).
2300, 124 stope; It was noted from here as part of a compound inclusion with other tin minerals and was sometimes associated with krennerite, calaverite, altaite, sylvanite, kostovite, petzite, and gold (Alan Criddle, personal communication, 1992).

Cole Mine, *1300 level, 39-A stope;* Material from this locality consisted of crystalline chalcocite on massive pyrite/bornite/chalcopyrite that contained tiny grains of kiddcreekite with "wolframite," hübnerite, and scheelite (Sid Williams, personal communication, 1987).

KORNELITE $Fe_2^{3+}(SO_4)_3\cdot 7H_2O$:

This locally abundant mineral was recognized in post-mining occurrences only. Typically, kornelite was found as part of a crust on mine openings in moist, pyritic areas. It was usually formed in the upper part of a post- mining mineral assemblage that developed as porous excrescences (Merwin and Posnjak, 1937).

The species recognized as associated with kornelite according to Merwin and Posnjak (1937) are:

pyrite
rhomboclase
römerite
copiapite
coquimbite
voltaite
chalcanthite

OCCURRENCES:

Campbell Mine, Kornelite was recognized here as pale pink fibrous growths on copiapite and voltaite (Fabien Cesbron, personal communication, 1981).

Czar Mine, *400 level;* Large clusters of violet to pale pink, acicular kornelite crystals occurred here on coquimbite and cuprian melanterite.

Sacramento Mine, It is highly probable that the specimens studied by Merwin and Posnjak (1937) came from this mine. In any event, there is no doubt that the Copper Queen mine was not the source as indicated in the literature. Kornelite was locally abundant in this mine as pale pink, acicular crystals and silky tufts on coquimbite and rhomboclase with voltaite.

Southwest Mine, *7th level;* Kornelite was locally abundant as radiating sprays of light pink to violet acicular crystals to 8 mm in a sulfide stope, as the last mineral deposited in a multi-mineral, post-mining crust. Emerald-green cuprian melanterite and yellow copiapite were the associated species.

KOSTOVITE CuAuTe$_4$:

A hydrothermal mineral that has been recognized in very small amounts at a single locality. Here, it was part of a complex mineral assemblage that was found as compound inclusions in pyrite as well as replacing granular pyrite (Alan Criddle, personal communication, 1992) or as small grains in quartz (Sid Williams, personal communication, 1987).

The species associated with kostovite are (Alan Criddle, personal communication, 1992; Sid Williams, personal communication, 1987):

chalcopyrite
bornite
chalcocite
digenite
djurleite
covellite
tennantite
pyrite
sphalerite
galena
altaite
hessite
stützite
stannite
mawsonite
rutile
calaverite
tetradymite
sylvanite
tellurium
cassiterite
gold
goldfieldite
rucklidgeite
melonite
kësterite
volynskite
colusite
wittichenite
kiddcreekite

OCCURRENCES:

Campbell Mine, Small, grayish grains of kostovite were found in quartz by Sid Williams in specimens from an undetermined level of this mine. The associated minerals were pyrite, chalcopyrite, altaite, goldfieldite, and very minor amounts of melonite (Sid Williams, personal communication, 1987).
2300 level, 125 stope; Tiny amounts of kostovite were found here as compound inclusions in pyrite and as part of a multi-mineral assemblage replacing granular pyrite (Alan Criddle, personal communication, 1992).

KRENNERITE Au$_3$AgTe$_8$:

This hypogene species has only been recognized in very small amounts in two areas at a single locality. Here it was part of a tellurium-tin-rich, complex mineral assemblage in sphalerite, galena, and chalcopyrite. Krennerite occurred as micro-phase, compound inclusions in these ore minerals (Alan Criddle, personal communication, 1992).

The species associated with krennerite are (Alan Criddle, personal communication, 1992):

sphalerite
galena
chalcopyrite
tennantite
tetrahedrite
bornite
covellite
stannoidite
colusite
mawsonite
kësterite
kiddcreekite
altaite
sylvanite
calaverite
petzite
kostovite
tellurobismuthite
gold
hematite
rutile
"wolframite"

OCCURRENCES:

Campbell Mine, *2100 level;* Krennerite was noted in tiny amounts from here as one of the several tellurium minerals forming compound inclusions in sulfides (Alan Criddle, personal communication, 1992).
2300 level, 124 stope; Krennerite was observed in specimens from here by Alan Criddle as rare inclusions in the sulfide ore minerals (Alan Criddle, personal communication, 1992).

KRUPKAITE $CuPbBi_3S_6$:

Krupkaite occurs as a hypogene species, which has only been recognized in small amounts at a single locality. Here it was part of a tellurium-tin-rich, complex mineral assemblage in sphalerite, galena, and chalcopyrite.

The species associated with krennerite are (Schumer, 2017):

pyrite
chalcopyrite
cupropavonite
galena
sphalerite

OCCURRENCES:

Campbell Mine, Noted in polished sections from an undetermined level in a mixture of cupropavonite and krupkaite with small irregular grains of chalcopyrite and euhedral pyrite. Pyrite from this association is always euhedral and contains inclusions of chalcopyrite and cupropavonite-krupkaite, indicating equilibrium deposition (Schumer, 2017).

KTENASITE $(Cu^{2+},Zn)_5(SO_4)_2(OH)_6 \cdot 6H_2O$:

This species has been recognized in small amounts as a post-mining mineral at a single locality. Here it was found sparingly as a crust on chalcopyrite/pyrite ores (Sid Williams, personal communication, 1992).

OCCURRENCES:

Campbell Mine, Specimens from an unspecified level in this mine contained small amounts of ktenasite as a crust on chalcopyrite/pyrite (Sid Williams, personal communication, 1992).

KURAMITE $Cu_2CuSn^{4+}S_4$:

This is a hydrothermal mineral that has been found in very small amounts at a single locality within the district. Here it occurred as tiny inclusions in sphalerite (Sid Williams, personal communication, 1987).

The species associated with kuramite are (Sid Williams, personal communication, 1987):

sphalerite
altaite
melonite
pyrite

OCCURRENCES:

Campbell Mine, Kuramite occurred here as tiny grains included in sphalerite that in turn were large patchy inclusions in massive altaite with melonite, all of which were in massive pyrite (Sid Williams, personal communication, 1987).

L

LANGITE $Cu_4^{2+}(SO_4)(OH)_6 \cdot 2H_2O$:

This is an uncommon, but widely distributed secondary mineral in the district (Roberts, et al. 1990). Usually, langite at Bisbee is on or near chalcopyrite (Anthony, et al. 1995). The few noted localities based on preserved specimens in collections, which probably do not adequately represent the true extent of distribution for this mineral in the district.

One locality in the Lavender pit produced a few specimens of langite that appear to be post-mining in origin. In this instance malachite was acted on by sulfate mine waters after mining had opened the area.

The species associated with langite in the district are:

chalcopyrite
malachite
pyrite
goethite
quartz
chalcocite

OCCURRENCES:

Campbell Mine, *2566 level;* Langite was found here in small amounts as 0.1 mm blue-green, pseudohexagonal crystals along fractures in oxidizing chalcopyrite.

Higgins Mine, *Tunnel level;* Several of the sulfide stopes on this level contained minor langite as patchy crust of 1 mm crystals on an oxidizing chalcopyrite/pyrite mixture.

Junction Mine, It occurred in several areas in this extensive mine as tiny crystals or crusts of crystals on chalcopyrite and/or chalcocite.

Lavender Pit Mine, Several places in the contact breccia areas contained langite as sky-blue, tabular crystals to 1 mm and as crusts on chalcopyrite and chalcocite.
Holbrook Extension; A few specimens of malachite with bright blue langite crystals to 2 mm were found in an old Holbrook mine working uncovered by the open pit mine. It appears that the langite was deposited on the malachite by mine waters after initial mining in the Holbrook had opened the area. There is minor surficial alteration of these langite crystals to brochantite.

LAUMONTITE $Ca(Si_4Al_2)O_{12}\cdot 4H_2O$:

This hydrothermal alteration species has been noted to occur in the district by Anthony, et al. (1995). However, no additional information regarding the mode of occurrence or the area where it occurred is provided.

LEADHILLITE $Pb_4(SO_4)(CO_3)_2(OH)_2$:

This species occurred as a secondary mineral and is of limited distribution and abundance within the district.

The most common occurrence for leadhillite is as small, thin tabular crystals and crusts that are white to colorless, on fractures in massive chalcocite with cerussite and malachite. Typically, the small crystals are oriented parallel to the fracture surface. Thin white veins in soft goethite are also one of the more common forms. The veins are actually composed of closely packed tabular crystals in parallel growth.

A small number of fine crystal specimens are known from where the veins had open spaces. The resultant pockets, while seldom more than 10 cm across, were completely lined by white, tabular crystals that were from 1 to 2 cm in length and 1 cm high.

A third mode of occurrence was as 5 mm or less white to gray crystals on small siliceous breccia fragments. These fragments were usually attached together by massive leadhillite.

The minerals associated with leadhillite are:

chalcocite
quartz
malachite
cerussite
silver
hematite

OCCURRENCES:

Campbell Mine, *1800 level;* Leadhillite was reasonably abundant in one copper stope on this level where it occurred as small crystals on chalcocite with malachite, cerussite and silver (Anthony, et al. 1995). Also on this level, but in a lead stope, leadhillite was found in small amounts as clusters of 1 to2 cm crystals in vugs in earthy goethite and rarely as prismatic, gray crystals to 3 cm. Also, from a nearby crosscut on this level, minor amounts of leadhillite were recovered as small gray to white crystals on quartz fragments.

Cole Mine, Small amounts of leadhillite were found here as tabular crystals on massive chalcocite with malachite (Anthony, et al. 1995).

LEPIDOCROCITE $Fe^{3+}O(OH)$:

A common, but seldom recognized, supergene mineral, lepidocrocite is widely distributed through-out the district. The similarity of lepidocrocite to goethite, in both appearance and depositional environments, has undoubtedly resulted in it being confused with the more common goethite with which it is typically associated.

Much of the lepidocrocite occurs as fine-grained material admixed with pulverulent goethite and is difficult to distinguish from the goethite. When recognized, lepidocrocite is usually found as tiny micaceous crystals. It is most commonly recognized as thin, elongated crystals, usually standing on edge in voids or as rosette-like clusters of small crystals often forming crust on goethite or specular hematite.

The majority of the common supergene minerals found at Bisbee have been found with varying amounts of lepidocrocite as a part of the “limonite” gangue minerals so commonly seen.

OCCURRENCES:
Only the more notable localities for this mineral are listed below.

Cole Mine, *1100 level;* Abundant lepidocrocite was found here as crusts of 0.5 mm rosettes on goethite with malachite. Also, it occurred as thin, parallel 1 cm crystals in vugs of goethite or altered limestone with malachite.

Copper Queen Mine, *“A” level; It* was found here in small amounts as thin, golden-brown, tabular crystals to 1 cm on calcite with azurite on a goethite/lepidocrocite matrix. Lepidocrocite also occurred on this level as micaceous masses of 1 to 2 cm thin crystals in sericitic clays with goethite.

Shattuck Mine, Dump specimens from here contained red-brown rosette-like crystal clusters to 5 mm on goethite or compact specular hematite. Malachite is commonly associated with lepidocrocite at this mine.

Southwest Mine, 5th *level;* A small stope on this level produced fine specimens of this mineral as thin, golden-yellow crystals to 1.5 cm in vugs with acicular malachite.

6th level; Lepidocrocite was found here as brown crusts of rosette-like crystal clusters to 2 mm on goethite.

“LEPIDOLITE” K(Li,Al)3(Si,Al)4O10(F,OH)2:

Lepidolite *is a series name used to describe any of the series of micas trictahedral on or close to the trilithionite-polyliyhionite join: light micas containing substantial lithium (Back & Manddarino, 2008) and is therefore no longer to be regarded as a species name. It is included here for the sake of completeness only, as the exact member of the series is typically not noted in the early papers referenced herein. The information provided is to be considered for reference only, allowing for the work of earlier researches to remain available.*

This hydrothermal mineral is quite rare within the district. It has been recognized in small amounts at a single locality.

The species associated with lepidolite are those typical of granite.

OCCURRENCES:

Gardner Mine, *800 level, 46 drift;* Lepidolite was recognized from here in a granite through thin section work by Tenney (1913).

LIKASITE $Cu_3^{2+}(NO^3)(OH)^{5}\cdot 2H_2O$:

While likasite has been recognized in but two localities within the district, its similarity in color and occurrence to the more common connellite/ buttgenbachite may have caused some confusion. It is very possible that this uncommon supergene species will be found on other specimens as they are examined more closely.

The species associated with likasite are:

cuprite
gerhardite
malachite
claringbullite
atacamite
connellite
paratacamite
spangolite

OCCURRENCES:

Czar Mine, A single specimen containing likasite on cuprite has been recognized ex British Museum of Natural History (Bob Downs, personal communication, 2010). It occurred as radiating clusters of 3-4 mm, bright-blue tabular crystals in voids in a cuprite nodule. Minor malachite and sparing amounts of gerhardite were associated with the cuprite as well.

While no documentation exists as to the original source location, based on our familiarity with material from this mine, it is our considered opinion that it was the source.

Southwest Mine, *5^{th} level, 14 stope,* Likasite was noted from this locality as part of a complex supergene assemblage, in very minor amounts. It occurred as bright blue, 2-3 mm striated, tabular crystals in voids in cuprite nodules with paratacamite, atacamite spangolite, connellite and claringbullite or as a partial covering of 6-8 mm paratacamite coated cuprite crystals.

LIME CaO:

This rare mineral has been recognized only in a single post-mining occurrence as impure material (<30% available CaO on analysis) that was a result of a prolonged mine fire. Some of the sulfide mine fires in the upper Campbell mine burned for decades, effectively calcining the surfaces of the limestone host rocks as well as small pieces of limestone within the burned sulfides. Also, in those areas where the fire gases were vented, calcining took place and developed lime as a thin, surface veneer along the walls of the mine openings very close to the fire, particularly the main vent. The intense heat of the venting gases caused the mine openings to fracture and spall producing large volumes of thin pieces of limestone that also experienced surface calcining. Powdered lime to 0.5-meter-deep layer on the bottom of some of the mine openings, having fallen from the sides and top of the workings.

Very few other mineral species were recognized as being associated with lime, largely because of the extremely uncomfortable environment created by a combination of heat ($+60^0$), but most of all the clouds of choking dust generated by even the slightest activity. Every step in the powdery material brought with it more fine dust that burned the eyes and made every breath painful. However, nearby, hematite was noted as a replacement of the burned sulfides, and in one area, elemental sulfur had been deposited on what appeared to be lime by the fire gasses.

OCCURRENCES:

Campbell Mine, *1300 level;* Lime was locally abundant here as an impure powdery coating that was the result of the calcining of limestone walls in the main fire zone and in portions of the principal crosscut which served as a vent for the fire gasses.

LINARITE $PbCu^{2+}(SO_4)(OH)_2$:

This supergene mineral is apparently quite uncommon in the district. Its striking similarity to azurite may however, have caused other occurrences to go unrecognized.

The minerals recognized as occurring with linarite are:

hematite
quartz
malachite
paratacamite
brochantite
atacamite

OCCURRENCES:

Cole Mine, *700 level, 110 stope;* Linarite was noted in a few specimens from here as rare as patches of up to 5 mm in hematite with malachite.

Juniper Flat, Linarite was recognized here as a minor accessory mineral in some of the mineralized gold bearing quartz veins with brochantite, atacamite, paratacamite, and malachite (Rob Bowell, personal communication 2004).

LIROCONITE $Cu_2^{2+}Al(AsO_4)(OH)_4 \cdot 4H_2O$:

Liroconite is a supergene mineral apparently of very limited distribution. It should be noted that its striking similarity to azurite could easily have led to its misidentification.

The few specimens of liroconite that have been recovered are all associated with chrysocolla.

OCCURRENCES:

Lavender Pit Mine, *Holbrook Extension;* One area near the edge of the older Sacramento pit produced a small number of specimens where liroconite occurred as clusters of tabular, translucent bright blue crystals to 2 mm on and in voids in a friable, pale blue/white chrysocolla. The friable nature of the chrysocolla makes these specimens quite fragile. It was common for the liroconite to flake off with the desiccation of the chrysocolla.

LITHARGE PbO:

This typically nondescript species has been recognized at a single locality but is almost certainly more common given the abundance of thoroughly oxidized cerussite ores in the district.

The species recognized directly associated with litharge are:

massicot
cerussite
calcite

OCCURRENCES:

Southwest Mine, *6 level;* Litharge is one of the many supergene lead minerals mined in the near-surface deposits that were exploited by this mine. Here, it occurred in small amounts of brick-red, earthy material with minor litharge and abundant calcite and as a thin coating on cerussite.

LUZONITE $Cu_2CuAsS4$:

This is a hypogene mineral that is difficult to distinguish from several other copper sulfosalts that were common in the district. As a consequence, it is possible that this mineral was more common than the single specimen would indicate. Schumer (2017) found luzonite as a constituent of one of several chalcocite-rich ore type containing: enargite/luzonite + pyrite + kaolinite-dickite, confirming the probable wider distribution.

The species recognized directly associated with luzonite are:

chalcostibite enargite tennantite tetrahedrite

OCCURRENCES:

Junction Mine, Luzonite was found here as fine-grained massive material. The single specimen was collected by one of the authors in 1972 from the residual material around an ore transfer chute on the 2566 level of this mine. This transfer system handled all ores mined below the 2200 level and above the 2566 level prior to 1957, so it cannot be determined with any certainty where in the mine the specimen originated.

The specimen is composed of luzonite with very minor amounts of bornite. Chalcostibite occurs as irregular grains exhibiting caries texture concave to luzonite. Enargite and tennantite-tetrahedrite occur as partial rims on chalcostibite between it and luzonite Schumer (2017).

M

MAGNESITE $MgCO_3$:

This species has been recognized in small amounts as a hydrothermal alteration product of portions of the Martin limestone adjacent to the Sacramento Stock Complex. Magnesite occurred here as white, cryptocrystalline blebs to several centimeters and as small masses in recrystallization limestone.

The species associated with magnesite are:

calcite hematite quartz

OCCURRENCES:

Lavender Pit Mine, Compact nodules of white magnesite occurred in Martin limestone. These were easily freed from the encasing, recrystallization limestone.

MAGNETITE $Fe^{2+}Fe_2^{3+}O_4$:

This is an abundant and widely distributed hydrothermal mineral throughout the district. The most typical modes of occurrence are as a minor accessory mineral in all of the intrusive units in the Sacramento Stock and most of the dikes in the underground mines or as a contact alteration mineral in the limestones (Tenney, 1933). It was often one of the first minerals to replace limestone during mineralization (Schumer, 2017)

Magnetite also occurred as isolated replacement masses in the limestones, often a considerable distance away from the intrusives, as a result of hydrothermal metamorphism (Tenney, 1933; Hogue and Wilson 1950). It was also found in important amounts in the intrusion breccias surrounding the Sacramento Stock (Bonillas, et al. 1916). The Juniper Flat granite contained magnetite as a minor accessory mineral with muscovite, apatite, tourmaline, and zircon (Ransome, 1904).

When magnetite occurred in the intrusion breccias or in the limestones as an alteration mineral, it was often in large masses intergrown with hematite and pyrite. In these instances, the hematite was largely formed as a replacement of the earlier magnetite (Gilbert, 1926).

The primary copper minerals were often associated with magnetite in the limestone replacement deposits and contact breccia environments along with the previously noted pyrite. Several species of garnet and a number of calc-silicate minerals were noted as being commonly associated with magnetite and the primary ore minerals in the limestone close to the porphyry (Bateman, et al. 1914; Notman, 1913) as well as in the intrusion breccias (Bonillas, et al. 1916).

Generally, magnetite was found as scattered, tiny octahedral crystals in the intrusive units while in the limestones and intrusion breccias it occurred as compact masses of anhedral grains. Small euhedral crystals were occasionally found in the gradational contact of the magnetite with the limestone. In spite of the large volumes of magnetite present in the district, no specimens of any quality are known to have been recovered.

The majority of the primary minerals and many of the secondary minerals were associated with magnetite throughout the district. However, pyrite and chalcopyrite were the most common (Trischka, 1938).

OCCURRENCES:

Campbell Mine, Magnetite was common in small amounts in association with the hypogene ores throughout this extensive mine. Criddle and Stanley noted magnetite as a minor constituent of the ores from the Campbell orebody (Alan Criddle, personal communication, 1992).
2566 level; It was found here as scattered sharp 1 to 2 mm octahedral crystals, which were an accessory mineral in a dike.
2800 level; Magnetite occurred here in large amounts as fine-grained, compact material cut by quartz and pyrite veinlets.

Gardner Mine, Large, compact masses of magnetite were common throughout the mine.
800 level, 862 drift; Massive magnetite was noted altering to goethite in this area by Tenney (1913).
1000 level, 1012 drift; Magnetite had been partially replaced by pyrite at this locality (Tenney, 1913).

Lowell Mine, *1000 level, shaft station;* Most of the station on this level was cut in massive magnetite. Pyrolusite and goethite were associated with this occurrence (Tenney, 1913).
1300 level; On this level, massive magnetite that was coarsely crystalline was altering to goethite as a result of supergene activity (Tenney, 1913).

Oakland Mine, Dump specimens from this small mine contain granular masses of magnetite that were composed of euhedral 2 mm dodecahedral crystals loosely cemented by late-stage calcite. Pyrite and hematite were associated with this occurrence.

Sacramento Mine, Large masses of limestone had been replaced by magnetite adjacent to the Sacramento Stock in this mine. Pyrite and quartz were commonly associated with the magnetite here.

Spray Mine, *500 level, 77 drift;* It was noted from here as a replacement of limestone by massive granular magnetite with pyrite and quartz. The limestone graded from white to pink as the amount of disseminated magnetite increased (Tenney, 1913).

MALACHITE $Cu_2^{2+}(CO_3)(OH)_2$:

This is one of the most abundant and widely distributed secondary minerals in the district. Malachite was frequently found in sufficient quantities to constitute an ore. In fact, the very first copper orebody mined in the Copper Queen Open cut was largely malachite.

Huge amounts of malachite were produced very early on and Bisbee quickly became noted for high quality material. Kuntz (1885a, 1887) believed that the Bisbee malachite was of sufficiently good quality that it could be used for ornamental purposes as the Russian material had been. However, this type of malachite was not as abundant as originally thought and nothing became of this effort (Douglas, 1899). Yet, the extraordinary beauty of malachite from here was undeniable and Bisbee quickly became justifiably famous for the many fine malachite specimens it produced.

The depositional environments for malachite are quite varied. They range from circumstances where malachite is the first supergene mineral formed to those where it is the last, as well as subaqueous to open, subaerial environments. Much of the malachite found at Bisbee was formed as an in-situ replacement of other copper minerals. It also commonly occurred as an in-situ replacement of limestone along fractures and bedding planes, but in sufficient quantity to be economically important. Replacement of fossils in these limestones by malachite was not uncommon, but very few of these were of sufficient quality to be of interest to collectors.

Malachite's most common mode of occurrence was as earthy masses and veinlets of fibrous material irregularly distributed in soft iron oxides, usually goethite. This represents the very late stage of oxidation and enrichment for what were probably relatively low copper/high-iron sulfide replacement bodies. These were often underneath the oxidation caves that formed as a result of the supergene alteration of the original sulfides. Under these conditions malachite formed wherever there was available residual carbonate following the heavy leaching of carbonate host rock by the acid developed during supergene activity. Except for that near the limestone host rock, much of the malachite found under these circumstances was actually a replacement of azurite, cuprite, and to a much lesser degree, copper. The needed carbonate for the alteration of the latter two minerals to malachite was provided by dissolved carbonate or carbon dioxide in the ground water.

Malachite was often deposited in the many open spaces created by the formation of hard goethite/hematite boxwork. This deposition was usually as acicular crystals to 1.5 cm in length occasionally completely lining the void. Most often this was along the outer edges of the orebodies, which again was a function of available carbonate. It appears that acicular crystals such as these were deposited in a subaqueous environment.

Other malachite deposition in boxwork environments resulting from the oxidation of high-copper/low-iron sulfides was either the direct formation of malachite boxwork or the deposition of relatively thick malachite on thin iron oxide boxwork planes. In a few cases the malachite almost filled the open spaces, resulting in nearly solid masses. Individual blocks weighing more than 5 tons of this type of malachite were found in several of the districts' mines. Typically, though, the malachite boxwork had an abundance of open spaces with botryoidal surfaces and was covered, not infrequently, with later azurite as scattered crystal clusters or as a botryoidal overgrowth. In a few areas some of the malachite was very light in color, reflecting a possible modest zinc content.

Important amounts of malachite were found as a direct, in situ alteration product of high copper sulfides, particularly chalcocite. Typically, this alteration was often incomplete with impure rinds covering the sulfide masses. Veins of pure, often highly crystalline malachite were developed along fractures in massive chalcocite. When the alteration was complete, the resultant malachite was usually a combination of coarsely crystalline material in “jackstraw” growths around the exterior and closely grown, compact, fibrous crystals inside. Voids lined with small acicular crystals were occasionally found in the compact, fibrous portions of these masses.

In the case of other copper sulfides or copper bearing sulfides that altered directly to malachite, the exteriors were impure to very impure mixtures of iron oxides, clay-like minerals, and malachite. The interiors were spongy mixtures of iron oxides and malachite. Veins cutting the altering sulfides were usually mixed with large amounts of iron oxides as well. The limestones adjacent to the altering copper sulfides were replaced to varying depths by malachite that ranged from somewhat impure, compact fibrous material to friable or earthy deposits that were often of important size.

Malachite as a replacement of cuprite was commonly found, often as nearly pure, large masses. In most instances, the malachite was a compact fibrous material with few if any relic characteristics of the cuprite remaining. On occasion, the malachite that had replaced the cuprite was in the form of coarsely crystalline, “jackstraw” masses. This was more typical of the replacement of smaller cuprite pieces. Only on very rare occasion were the cuprite crystal forms preserved.

The malachite for which Bisbee is so famous was never truly abundant. The large, thick, banded, botryoidal masses and the often velvet-like, chatoyant pockets were only occasionally found as were the bright acicular sprays that formed hard, compact, irregular pieces suspended in soft to plastic clays/clay-like iron and manganese oxides.

Each of these forms had a distinctive depositional environment. Banded malachite up to 60 cm thick was found in parts of the Czar/Holbrook mine areas. Elsewhere in the district, it seldom occurred more than 8 cm in thickness. The thick (>2 cm) botryoidal-mammillary material appears to have had an open air, gelatinous origin. This is based on relic gel characteristics in the malachite and the nature of post-mining malachite found in several of the mines. This same origin is probable for the many specimens where the 1 to 2 cm thick malachite is generally spheroidal in form and standing in strong relief on the goethite matrix.

Along the edges of some of the high-grade, malachite-dominated orebodies, isolated pockets of velvet-like and chatoyant malachite were occasionally found. Frequently, only part of the void was malachite, with the remainder an iron or manganese oxide. This malachite was seldom more than 2 cm in thickness and was composed of compact fibrous crystals with a pronounced chatoyancy. These pockets ranged in size from 10 cm to more than a meter in their greatest dimension. Typically, they were at or very close to the limestone/ore contact. Often just a few centimeters of soft iron or manganese oxide were between them and the limestone. Botryoidal and stalactitic forms were the typical features of these pockets as were solution lines, indicating different solution levels during deposition.

The soft, supergene iron and manganese oxides occasionally had irregular, free-floating masses of malachite suspended within. These malachite masses were seldom more than 30 cm across and were composed of radiating sprays of hard, compact, fibrous crystals. The soft oxides were easily removed leaving these lustrous masses completely free of matrix. It was not uncommon to have azurite crystals on the part that was not covered with oxides during formation.

Substantial amounts of malachite formed as a replacement of azurite. All forms of azurite appear to have been replaced by malachite; thus, it is not always obvious when malachite formed through the replacement of azurite. Pseudomorphs of malachite after azurite were common throughout the district in the oxidized portions of the deposit. Many fine specimens reflecting this feature were recovered from a number of the mines.

In some areas all of the azurite was completely replaced with little other than a few remaining pseudomorphs to indicate that it had ever been present. The replacement of azurite by malachite was so complete that no obvious evidence remained to indicate this replacement took place. A good example is the replacement of earthy azurite by earthy malachite.

On occasion, specimens were found where completely altered material was adjacent to fresh, unaltered azurite. In these instances, the unaltered azurite was protected from the atmosphere and therefore alteration by a covering of clay, or fine-grained iron, or manganese oxides. In other cases, the remaining azurite was the banded, subaerial-deposited material while that which had altered to malachite was crystalline, subaqueous-deposited material. No small part of the interlayered azurite and malachite from Bisbee is of this origin.

Post-mining malachite was of relatively common occurrence in the district. It commonly formed as a result of high-copper, moderately low pH solutions contacting limestone. Mine water in many of the sulfide zones was of this nature. For the most part, post-mining malachite was a friable rind on limestone that was up to 10 cm in thickness. Historically, the miners were confused as to why waste rock used as backfill in some old workings was ore just a few years later. It was because high-copper, acidic mine water had been allowed to flow through the broken, largely limestone waste in the backfill, forming malachite. Several early geologists, Bateman, et al (1912) and Trischka (1931) recognized the process, but the typical miner could not believe that malachite would form in just 20 years or less. In some instances, the malachite that formed was very similar to that associated with the ores. Botryoidal crusts formed around some of the limestone fragments, and, near the bottom of the backfilled workings, banded malachite of up to 7 cm in thickness developed. This led to the incorrect belief that in the early days malachite was a waste and was used as backfill. On rare occasion, this malachite would form around mine scrap, such as rail spikes or nails. When found during formation, post-mining malachite was gelatinous in nature.

Many of the minerals species, particularly gangue and other supergene minerals, have been found with malachite at Bisbee, but the most frequently occurring are:

goethite
hematite
pyrolusite
azurite
smithsonite
cuprite
chalcocite
chalcopyrite
bornite
copper
tenorite
cerussite

Malachite has been found as excellent pseudomorphs after azurite, cuprite, copper, brochantite, calcite, and delafossite. The minerals recognized as pseudomorphs after malachite are goethite, chrysocolla, shattuckite, and chalcoalumite.

OCCURRENCES:

Atlanta Mine, *300 level - 400 level; Malachite* was the principal ore mineral in the Atlanta Mine. While little mining actually took place here, it real importance is that its development led to the discovery of the orebodies that saved Bisbee from abandonment, after the nearby Copper Queen Mine was exhausted in 1884. The few specimens recovered from here were reportedly malachite partially covering drusy azurite. However, no specimens confirmed from here are known. The information is on the occurrence is verbal given one of the authors in the early 1950s.

Campbell Mine, The Campbell orebody produced many fine malachite specimens, all of which are pre-Cretaceous in age.
1300 level; The last round in a short raise that connected to a preexisting Briggs crosscut produced the finest malachite pseudomorphs after azurite from the district, indeed, these may be the finest specimens ever found at Bisbee. These came from a pocket that was 2 meters by 1 meter and 25 cm high, with the bottom lined with sharp crystals to 15 cm. Groups of as many as 60 crystals on goethite with minor acicular malachite were recovered, as were a number of lesser specimens and hundreds of single crystals.
1600 level; Large plates of reniform to stalactitic malachite were found on this level. This material, excluding the stalactites seldom exceeded 2 cm in thickness. The surface of these malachites is very fine grained, appearing almost intensely rubbed. This characteristic is not restricted to this occurrence, however. Interestingly, the stalactites, when found, were oriented a ± 25^0 northwesterly, reflecting pre-Cretaceous deposition and suggesting no post-Cretaceous malachite deposition. Once removed, this orientation is lost, as the stalactites appear perpendicular to the

malachite forming the base. Also from here were fine malachite pseudomorphs after 7 cm tabular azurite crystals.
1800 level; Fine specimens of malachite pseudomorphs after azurite crystals to 8 cm. These were in groups of crystals on massive malachite with radiating patterns of coarse crystalline malachite that were also a replacement of azurite. Most had angular siliceous fragments included in the malachite.
1900 level, 105-C stope; Exceptional lustrous pseudomorphs of malachite after composite, azurite crystals on a matrix of unaltered azurite were found in this stope. A great many other pseudomorphs of malachite after azurite of several different morphologies also came from different parts this very productive stope. These were typically 2 cm or less and often had a thin veneer of a light green zincian malachite. A few large (10 to 20 cm.) malachite pseudomorphs after azurite were recovered at the limestone/ore contact. These specimens had lustrous, velvet-like surfaces, or a pockmarked surface caused by spotty clays, which were removed by washing. Both instances reflect a later overgrowth of malachite in a subaqueous environment, which was pre-Cretaceous as well. A number of fine specimens were collected from the relatively small area of this stope and several crystal forms were present.

Boulders to 1 meter of mixed azurite and malachite were found at the limestone margin of this stope. The material was typically massive, yet lustrous, which reflected the fact that all of the malachite was a replacement of azurite. Many very attractive, colorful specimens of, what were essentially broken faces, were recovered over the years Fine-grained to clay-like hematite was usually associated with these specimens as a coating or void filling, some of which defied all cleaning attempts.

Cole Mine, *600 level;* While raising he back of a crosscut on this level several meter-sized, very lightweight masses of loose, fibrous material that were pale green in color fell from an open space. When washed, irregular forms composed of sprays of bright crystals of up to 2 cm in length were revealed.
1200 level, 26-J stope; A number of spongy masses to 60 cm that were pseudomorphs after copper were recovered from here. Some of these were associated with calcite. Also from this location were irregular compact masses to 10 cm with the surface altered to a soft, zincian malachite. Light green, fibrous zincian malachite on goethite was common from this locality as well.
1300 level, 26-K stope; Many attractive specimens of delicate, acicular malachite on copper and cuprite with hematite were recovered from here.
1400 level, 26-L stope; A small number of superb specimens of brilliant, blocky crystals to 1 cm in clusters on calcite were found at this location.

Copper Prince Mine, Malachite was the principal ore mineral in this small, short-lived mine. It occurred as pulverulent replacements of limestone and as material to 5 cm thick with a plumose pattern. Acicular malachite was abundant as handsome specimens with thick linings in boxwork voids and as coatings on stalactitic goethite.

Copper Queen Mine, The original orebody at this mine was largely malachite with a substantial amount of calcite (Wendt, 1887a; Douglas, 1899).
Open cut – Surface to the- "B" level; Large amounts of botryoidal malachite to 10 cm thick with a plumose growth pattern and associated with calcite were mined from this orebody. Stalactites

with alternating layers of malachite and calcite were found in the upper portions of the open cut. The outermost layer was invariably calcite (Wendt, 1887b).
300 level, Queen; Intergrown cluster of radiating crystals with a striking satiny luster were found in plate-like masses measuring nearly a meter. These clusters were often poorly connected resulting in few specimens of larger than 10 cm surviving. The malachite from here was associated with thin plates of goethite and often a very thin coating of later goethite. Also from the 200 level were large masses of compact, chatoyant, botryoidal material with velvet-like surfaces.
400 level, Queen = (200 level Czar); The Southwest orebody on this level produced beautiful specimens with lustrous clusters of divergent sprays of crystals. These often had the exposed surfaces lightly stained by goethite and frequently were associated with tiny octahedra of cuprite coated by or altered to malachite.

Czar Mine, This mine produced Bisbee's finest, classic botryoidal, malachite specimens. Douglas (1900) noted, what we believe to be a most apt description the occurrence of malachite in the Czar, and closely reflects what we have noted in our extensive field work in this mine;

"The Copper Queen mine has become famous for its beautiful specimens of carbonates, both malachite and azurite. The malachite is never found in such and compact masses as to make it commercial valuable for decorative for decorative purposes: because, occurring in generally thin botryoidal masses, it is usually streaked with manganese, which detects from its purity. Its most striking mode of occurrence is in geodes, which are lined with velvety crystals of the same material. These hallow spheres, the walls of which are composed of concentric layers, are rare, but when found, are usually imbedded in soft, wet, ferruginous of manganese clays, such as constitute the gangue, or "ledge-matter" of nearly all of the ore: and occur at no great distance from a limestone wall, or partition."

An important aspect of the "geodes" that Douglas refers to, is that they were typically isolated individuals in soft clay/clay-like materials and were usually removed as single, complete unit, excepting what may have been broken off at the time of discovery. Most of these soft ores were mined by pick and shovel only, with the pick often breaking off some part of the mass during mining. In other words, the specimen recovered was most often the whole of the piece, less what was broken during discovery and removal. This is not true for specimens recovered from the more abundant, harder ores.

200 level; Large pockets to 1.5 meters of chatoyant malachite several centimeters thick with velvet-like or satiny surfaces were found as isolated individuals in the soft, iron-rich clays at the edge of many of the orebodies, see above from Douglas, (1900). However, the majority were less than 25 cm. Stalactites of malachite were a common feature of these pockets. Even though these pockets were physically separated, solution lines, reflecting changing solution levels during deposition, were not uncommon and when seen in place strongly suggest some manner of fluid connection. Both subaqueous and subaerial depositional characteristics are frequently noted in the same specimen.

Plate-like pieces of reniform, often chatoyant, as large as a meter and 10 cm thick, were removed from open spaces in the harder ores. Also malachite came from here as large botryoidal forms with later azurite. A small number of malachite pseudomorphs after azurite rosettes were found in the marginal areas of the Dividend fault on this level. Typically, these were of tabular crystal groups or spheroids with small crystal points covering the surface. Malachite stalactites were uncommonly abundant in the orebodies of the Belle Isle claim, just south of the shaft on this level where many specimens were collected in 1891 for the Colombian Exposition (Bateman, et al. 1914), including the large (3.54 ton) malachite/azurite/goethite specimen now in the American Museum of Natural History came from here (Chicago Daily Tribune, 1893).

300 level; Large masses of malachite and/or azurite were mined from this level. Many of the openings contained stalactites to 7 cm and had well-defined solution levels indicated by horizontal lines marking functionating solution levels and depositional changes. The soft manganiferous or hematitic clays contained isolated pieces of malachite to 20 cm that were composed of lustrous diverging sprays of crystals, often on centimeter + thick malachite.

400 level; Malachite in boxwork form was abundant here and was partially covered with pisolitic azurite. Also boxwork malachite was frequently found without azurite. Close examination of this material will occasionally reveal that it is, in fact, a replacement of azurite. Large plates up to 50 cm of botryoidal malachite with delicate, velvet-like surfaces and boxwork forms were recovered from this level as well. Compact masses of coarsely crystalline malachite as direct, in-situ replacements of chalcocite, were frequently found on this level. Malachite pseudomorphs after bladed azurite crystals to 4 cm on dark siliceous goethite came from this level.

Holbrook Mine, Many of the very best specimens of this handsome mineral came from this mine. The Chicago Daily Tribune (1893) notes attractive specimens of malachite from here with silver specks.

100 level; A large oxidation cave had thick crusts of malachite with acicular overgrowths coating parts of the walls, and stalactitic forms to 45 cm in a few of the pre-cave pockets, later exposed in the cave walls.

200 level; Large plates of reniform malachite to 10 cm thick came from this level in abundance.

300 level; Light green, possibly zincian, malachite was abundant in this area of the Holbrook mine. These were botryoidal in form and frequently partially overgrown by light blue azurite. Late-stage acicular malachite, reflecting subaqueous deposition, typically much darker green, coated some of these specimens.

400 level; Huge masses of banded, chatoyant malachite to 60 cm thick, with reniform surfaces were found in a collapsed siliceous breccia. Boxwork malachite was common throughout this mine but most abundant on this level. Often, pisolitic azurite as 5-6 mm lustrous spheroids or crystal cluster was deposited on this malachite.

500 level; Malachite as in-situ replacement of massive chalcocite and/or bornite was found as coarsely crystalline masses up to 50 kilos in several places on this level.

600 level; A small cave encountered in the early 1920s produced a number of large plates of lustrous, intergrown, tabular 1 cm malachite pseudomorphs after azurite overgrown on pale malachite. Stalactites of up to 1 meter with clusters of tabular, almost rosette-like, pseudomorphs of malachite after azurite were also recovered from this cave. These were also on pale malachite and often associated with a late-stage gray/green clay-like mineral (allophane?) coating some specimens. Pale blue/green massive allophane was associated with many of the specimens recovered from here.

Irish Mag Mine, 5*50 level;* An extraordinary occurrence was found on this level with coarsely crystalline malachite lining a cave. Almost 10 meters of this fibrous material was cut as development approached the cave (Engineering and Mining Journal, 1910). This material was somewhat friable, so as a result few large specimens were recovered.

Junction Mine, Malachite was noted from here as massive material that was a replacement of cuprite or azurite (Mitchell, 1920).
770 level; It was common in some areas on this level as irregular masses in a soft manganese material. These specimens are quite different from any other Bisbee malachites and are easily identified. They were a light green with little banding and usually with bright blue, partial overgrowths of azurite as specks or. Unusual erratic forms resulted when the soft matrix material was removed. Also, from here as thin veneers of malachite on wad boxwork with scattered specks of bright, light blue azurite.
900 level; It was found here as uncommonly bright green material to 10 cm thick on a soft black matrix with later azurite.
1600 level; Radiating sprays of bright, coarse malachite crystals were found on this level as linings along fractures in massive chalcocite. Also from here malachite was found as masses of compact, radiating crystals that formed as a complete replacement of chalcocite.

Lavender Pit Mine, *Holbrook Extension;* Many of the malachite specimens found in this part of the Lavender pit were identical to those produced by the upper levels of the Holbrook mine because the same areas were remined. In late November of 1969, a mass of banded to plumose malachite was uncovered that produced an estimated 5.5 tons of specimens. The mass was left between two stopes mined in the late 1890s that had caved in making continued mining too dangerous to undertake. It measured 12 meters long by 1 meter wide and ranged from 20 to 60 cm thick. However, ground movement had broken the material into hundreds of pieces of up to 90 kilos though most were much less. Nearby, large pieces of boxwork malachite with azurite were recovered in 1970. One of these weighed nearly 700 kilos.

Sacramento Mine, *1100 level;* Superb malachite pseudomorphs after bladed azurite crystals on a goethite/hematite matrix came from this level. Most of these reflected a period of malachite replacing azurite followed by deposition of a thin layer of a manganese oxide, which in turn was partially covered by an oriented overgrowth of azurite that also altered to malachite.
1200 level; Fine specimens of bright, acicular malachite on azurite boxwork came from this level. In some instances, a later generation of azurite occurred as scattered 4 mm crystals on the malachite. Also from here, malachite was found as indistinct stalactites that exhibit alternating layers of malachite, azurite, and goethite
1400 level; Thick, bladed malachite pseudomorphs after azurite on massive cuprite were found in small numbers on this level.

Shattuck Mine, Coarsely crystalline masses as replacements of chalcocite were noted from an unspecified level in this mine by Bateman, et al. (1914). These specimens were less compact than those from elsewhere in the district and the open areas revealed fine specimens.
200 level, 69 prospect; Malachite occurred here on massive, compact shattuckite as uncommonly large, sharp, bright crystals to 1 cm long and 2 mm wide.
200 level, 45 raise; Malachite as acicular crystals with small, bright azurite crystals was abundant here. Also, malachite as highly chatoyant coatings to 2 cm on goethite were found as were the occasional stalactite to 7 cm in voids in the goethite.

300 level; It was found here as very faithful pseudomorphs of malachite after large brochantite crystals that occurred in the typical “jackstraw” fashion.
500 level; A few handsome specimens of bright acicular crystals on irregular lumps of cuprite with minor calcite were found here in a collapse breccia in the bottom of a small cave. Also, malachite came from here as isolated pockets to 18 cm with velvet-like interiors and occasionally with 3 cm stalactites.
700 level; Reniform material to 7 cm thick with banded patterns was found here.

Southwest Mine, *3rd level;* Malachite was abundant in many of the orebodies on this level as the principal copper ore mineral. Acicular malachite was found here as attractive specimens lining voids in boxwork goethite and as bright coatings on cuprite nodules.
4th level; A small cave on this level produced malachite stalactites up to 10 cm in length and as botryoidal groups. Both of these forms were covered by a later generation of soft, acicular malachite. Sharp pseudomorphs of malachite after 7 mm calcite scalenohedrons were found in a single small pocket on this level.
5th level; Large masses of coarsely crystalline, dark green material that appear to be a replacement of chalcocite were common in the ores here. It also occurred as fine specimens of velvet-like linings of pockets in goethite and banded hematite, a few of which have colorless calcite crystals overgrowing part of the malachite. Also, from this level malachite was noted as sharp pseudomorphs after atacamite to 6 mm on/in massive cuprite.
6th level; Many fine examples of acicular malachite crystals to 1 cm lining voids in goethite and/or hematite came from this level. Calcite occasionally followed the malachite overgrowing and included the acicular malachite forming these handsome classic Bisbee specimens.

Spray Mine, Malachite pseudomorphs after azurite with bladed crystals to 7 cm on unaltered azurite came from this mine.
600 level; Isolated masses of malachite as lustrous acicular crystals in connected clusters of divergent, radiating sprays occurred in soft, manganiferous clays on this level. Specimens of this material to 20 cm were recovered. Coliform malachite, largely overgrown by bright azurite in 20 cm+ specimens were recovered from stopes on this level.

Uncle Sam Mine, Malachite came from here as an alteration product of brochantite crystals including a few very faithful pseudomorphs after “jackstraw” clusters of 2 cm brochantite crystals.
A level; Also, malachite was seen as nodules of coarsely crystalline replacements of cuprite nodules to 8 cm in soft, goethitic material on this level.
N level; Thin plates of bright 4 mm malachite crystals on goethite with small colorless cerussite crystals came from here.

MANGANITE $Mn^{3+}O(OH)$:

This species has been recognized as a supergene mineral at a few localities within the district. It is very probable that manganite is more common than the limited occurrences would suggest, particularly in the near-surface manganese deposits.

In two of the recognized occurrences, manganite was found with other supergene manganese minerals as needle-like crystals. At the third occurrence, it was found as fibrous material.

The species associated with manganite are:

pyrolusite
braunite
quartz
calcite
romanèchite

OCCURRENCES:

Higgins Mine, *Twilight claim;* Manganite was found here as needle-like crystals in a pyrolusite/quartz mixture on the edge of this large manganese deposit. Minor calcite was present as were small, black, wedge-shaped groutite crystals.

Lowell Mine, 1000 *level;* While sinking this shaft a vein-like deposit of pyrolusite with distinct needle-like crystals of manganite was cut (Tenney, 1913).

Number 4 Claim; Very small amounts of fibrous manganite were found here with pyrolusite, romanèchite, and braunite.

MARCASITE FeS_2:

This common, typically low-temperature mineral is most probably widely distributed throughout the district as a very minor constituent of some of the massive sulfide replacement deposits, as well as concretions in the sediments, but unrecognized. Undoubtedly, many of the small bunches of iron sulfide so commonly hit by mine development in otherwise unaltered, barren limestones were marcasite. Thus, the single confirmed occurrence listed below is most probably not fully representative of the actual distribution of marcasite at Bisbee.

OCCURRENCES:

Cole Mine, *1400 level;* Marcasite was found in small amounts in small rounded masses in unmineralized Abrigo limestone as small, fine-grained masses with a radial internal structure.

MASSICOT PbO:

This is a secondary mineral of apparently very limited distribution in the district. The apparent limited distribution may well be a function of massicot not being recognized because of its typical earthy nature and general similarity to other oxide zone minerals such as goethite.

Massicot occurred as a lemon-yellow to yellow-orange earthy material that is an alteration on litharge.

The species associated with massicot are:

litharge
cerussite
calcite

OCCURRENCES:

Southwest Mine, *6th level;* Massicot has been found here in small amounts as earthy, lemon-yellow blebs in and/or yellow to yellow-orange crust on litharge with cerussite and abundant later calcite.

MATILDITE $AgBiS_2$:

This hydrothermal mineral has been recognized in small amounts in a single mine. Here, matildite was noted as a very minor accessory mineral in a complex, bismuth- and silver-rich, mineral assemblage. In this assemblage, matildite occurred as micro-phase inclusions in siliceous hematite matrix associated with a highly altered dike of undetermined composition (Alan Criddle, personal communication, 1992).

The species associated with matildite are (Alan Criddle, personal communication, 1992):

wittichenite
djurleite
spionkopite
galena
digenite
hematite
bismite
chalcopyrite
bismuthinite
bornite
acanthite
copper
sphalerite
covellite
gold
stromeyerite
quartz
chalcocite
silver
emplectite
jalpaite
cuprite

It is worth noting that both the chalcocite and wittichenite from here contained 6% and 7% silver respectively.

OCCURRENCES:

Campbell Mine, *1600 level;* Matildite was recognized from here by Criddle and Stanley as part of bismuth/silver mineral assemblage (Alan Criddle, personal communication, 1992).

MAWSONITE $Cu_6Fe_2SnS_8$:

This hydrothermal mineral has been recognized in small amounts in several places. In all instances, it was typically a component tin-tungsten-vanadium-rich complex mineral assemblage that was found as compound inclusions in various sulfides as well as replacing granular pyrite (Alan Criddle, personal communication, 1992), (Schumer, 2017).

The species associated with mawsonite are (Alan Criddle, personal communication, 1992), (Schumer, 2017):

chalcopyrite
djurleite
sphalerite
stützite
calaverite
cassiterite
melonite
wittichenite
bornite
covellite
galena
stannite
rucklidgeite
gold
kësterite
kiddcreekite
chalcocite
tennantite
altaite
tetradymite
sylvanite
goldfieldite
volynskite
digenite
pyrite
hessite
rutile
tellurium
kostovite
colusite

OCCURRENCES: Criddle and Stanley noted all of the below occurrences in their work on the ores of the Campbell orebody (Alan Criddle, personal communication, 1992). Schumer (2017)

Campbell Mine, *2100 level;* Compound inclusions of mawsonite were noted in pyrite with other tin minerals in samples from here.
2200 level; Mawsonite was noted from this level as part of a tin-rich assemblage that occurred as inclusions in mixed copper sulfide ores.
2300 level, 125 stope; Mawsonite occurred as a minor component of multi-mineral, compound inclusions in a sphalerite-galena-chalcopyrite mixture at this locality.

Cole Mine, *1300 level, 39-A stope;* Accessory tennantite-tetrahedrite and mawsonite occur within bornite course, granular pyrite (50%) cemented by bornite (Schumer, 2017).

Dallas Mine, Mawsonite was noted in minor amounts in bornite as a part of a large suite of accessory minerals including tennantite-tetrahedrite, sphalerite, stannoidite, galena, and native Au. Gold occurs intergrown with chalcocite in fractures and in one instance is intergrown with colusite (Schumer, 2017).

Holbrook Mine, Massive bornite contains rounded inclusions (<1%) of stannoidite, mawsonite, galena, and colusite. (60%) with chalcopyrite (30%) and supergene goethite (10%). Both chalcopyrite and bornite contain rounded inclusions of tennantite-tetrahedrite and sphalerite (Schumer, 2017).

LAVENDER Pit Mine, *Holbrook Extension;* Massive sulfide composed of bornite (80%), chalcopyrite (15%), and pyrite (5%).Pyrite contains rare inclusions of bornite. Tiny inclusions of mawsonite, stannoidite, and galena occur throughout bornite, regardless of proximity to chalcopyrite. Mawsonite occurs as rims on most stannoidite grains. Chalcopyrite is concave to bornite and contains scattered inclusions of tennantite-tetrahedrite (Schumer, 2017).

MEIONITE $Ca_4Al_6Si_6O_{24}CO_{3+}$:

This hydrothermal alteration mineral is apparently rare within the district. “Scapolite” was identified in thin section from specimens of altered limestone by Tenney (1913). It is almost certain that the species noted is indeed meionite.

The species associated with meionite are:

calcite	tremolite	wollastonite

OCCURRENCES:

Holbrook Mine, *500 level;* Samples of altered Abrigo limestone from near the Spray shaft on this level contained abundant scapolite (meionite) with tremolite and wollastonite (Tenney, 1913).

MELANTERITE $Fe^{2+}SO_4 \cdot 7H_2O$:

This mineral was widely distributed, often in large amounts, throughout much of the district. In all of the recognized occurrences melanterite was formed under post-mining conditions, commonly in pyrite-rich areas. It is almost certain that it also formed under supergene conditions, but its high solubility and typical nondescript appearance could well have caused it to be overlooked. On exposure to a dry environment, melanterite alters to other iron sulfates with lower hydration levels, such as siderotil and rozenite. Under these conditions, it becomes opaque, pale yellow in color and often pulverulent.

Most melanterite was a light brown in color, but white material was not uncommon. Pisanite, the cuprian variety of melanterite, shows various shades of green to bluish-green as a function of the amount of copper that has substituted for iron (Palache, et al. 1951). This too was also quite common and locally abundant.

Typically, melanterite formed as a silky delicate efflorescence on mine openings. Thick, lustrous crusts of fibrous melanterite frequently covered large areas along mine openings and timbers below massive pyrite bodies. Some of these crusts were 10 cm in thickness. It was not unusual to have acicular crystals to 1 cm in length, as clusters or overgrowths on wall rock and timber.

Stalactitic melanterite was also very common. These forms could exceed a meter in length. Cuprian melanterite stalactites were abundant as well and were often confused with the much bluer chalcanthite. Less frequently, melanterite formed large, transparent, pseudo-octahedral crystals in stagnated mine waters.

The species most commonly associated with melanterite are:

chalcanthite	pyrite	goethite	epsomite
hexahydrite	siderotil		

OCCURRENCES: Only a few of the many localities are noted below.

Campbell Mine, *2700 level, 42 crosscut;* A blocked drainage ditch contained exceptional crystals of cuprian melanterite as blue-green, transparent, 18 mm pseudo-octahedrons with 5 cm epsomite crystals. The water had a crust of tan fibrous melanterite.

2833 level; Greenish to bluish-green cuprian melanterite stalactites to 20 cm were abundant under an abandoned stope on this level.

Cole Mine, *900 level;* Acicular crystals of melanterite to 1 cm that were almost colorless, formed in clusters on timbers below an old stope here.

Czar Mine, *400 level;* A 10 cm thick crust of greenish cuprian melanterite formed on a highly pyritic limestone over an extensive area on this level.

Junction Mine, A great many areas in this large mine contained melanterite in several forms. Stalactites were the most common and, often cuprian, they frequently reached a meter in length.

Southwest Mine, *6th level;* Snow-white, acicular, melanterite formed a crust to 7 cm thick covering the walls and back of a drift under massive pyrite. Occasional greenish patches were observed in this material. Nearby, yellow-brown, acicular melanterite coated chute and manway timbers to several centimeters thick. Some of this material was overgrown on post-mining goethite stalactites measuring a meter or more.

MELONITE $NiTe_2$:

This hydrothermal mineral has been noted in very small amounts at several places in a single mine. In these instances, melonite occurred as inclusions in sulfides or as part of a complex mineral assemblage replacing granular pyrite.

This may well be the mineral that appeared to be niccolite (nickeline) in the work done by Schwartz and Park (1932) on the Campbell ores as well as the niccolite noted by Nye (1968).

The species associated with melonite are (Sid Williams, personal communication, 1987; Alan Criddle, personal communication, 1992):

chalcopyrite
djurleite
sphalerite
stützite
calaverite
cassiterite
calaverite
wittichenite
bornite
covellite
galena
stannite
rucklidgeite
gold
kësterite
kiddcreekite
chalcocite
tennantite
altaite
tetradymite
sylvanite
goldfieldite
volynskite
rhodostannite
digenite
pyrite
hessite
rutile
tellurium
kostovite
colusite

OCCURRENCES:

Campbell Mine, *2200 level;* It was found in small amounts here as reddish-gray to brown (in reflected light) grains in pyrite and sphalerite with calaverite, rhodostannite, altaite, quartz, and volynskite (Sid Williams, personal communication, 1987).

2300 level, 125 stope; Melonite occurred here in tiny amounts as part of a complex mineral assemblage that was included in pyrite and replacing granular pyrite (Alan Criddle, personal communication, 1992).
2566 level; Melonite was found as intergrowths in a complex mineral assemblage replacing pyrite at this locality Criddle, personal communication, 1992).

METAVOLTINE $(K,Na)_8Fe^{2+}Fe^{3+}_6(SO_4)_{12}O_2 \cdot 18H_2O$:

This mineral has been recognized in a single post-mining occurrence only. At the recognized locality it is reasonably abundant. Here, metavoltine was part of a multi-mineral assemblage that formed an extruded crust on pyritic limestone. Here, it was found as stacks of tiny, hexagonal plates.

The species associated with metavoltine are:

pyrite
calcite
copiapite
coquimbite
voltaite
römerite

OCCURRENCES:

Campbell Mine, *2100 level;* Greenish-yellow metavoltine was part of a multi-mineral crust covering a large area on pyritic limestone mine walls on this level.

MICROCLINE $KAlSi_3O_8$:

This rock-forming mineral has long been known from the district. Tenney (1913) recognized microcline as the dominant feldspar in a dike on Mt. Martin. More recently it has been found in small amounts from several additional areas. Microcline is almost always a small portion of the material historically identified as orthoclase in both the Juniper Flat granite and the intrusions in the Sacramento Stock complex.

It typically occurs as gray to tan to reddish phenocryst in the intrusives of the district. Occasional crystals to 1 cm have been found in the Juniper Flat granite.

The species most commonly associated with microcline are:

quartz
muscovite
"biotite"
orthoclase
rutile
magnetite

OCCURRENCES:

The distribution of the Juniper Flat and the Sacramento Stock Complex are the occurrences for microcline within the district.

MIERSITE $\mathrm{(Ag,Cu)I}$:

This is an extremely rare secondary mineral within the district. Only a few specimens from one locality are known.

Like so many of the rare species found in Bisbee, miersite is associated with cuprite. Here it is either directly emplaced on cuprite or on a mineral that is on cuprite.

The species that have been observed in association with miersite are:

cuprite
chlorargyrite
malachite
bromargyrite
atacamite

OCCURRENCES:

Southwest Mine, *5th level*, *14 stope*; A few specimens of miersite were found at this locality where it occurred as 0.5 mm sharp, bright yellow tetrahedrons on atacamite, as 1 mm complex crystals in vugs in cuprite, and as yellow, irregular waxy blotches of miersite to 1.5 mm on fractures in cuprite.

MIMETITE $\mathrm{Pb_5(AsO_4)_3Cl}$:

This is a widely distributed supergene mineral that is never found in large amounts within the district. Mimetite is most abundant in the many near-surface manganese deposits.

Most of the small workings on the manganese outcrops scattered across the top of Queen Hill contain modest amounts of this mineral as do a number of the other similar deposits elsewhere in the district.

The species recognized as associated with mimetite are:

malachite
quartz
manganite
copper
beudantite
bayldonite
descloizite
calcite
galena
hemimorphite
plattnerite
pyromorphite
pyrolusite
anglesite
wulfenite

OCCURRENCES:

Campbell Mine, *1800 level;* Mimetite was found on this level in small amounts as yellow, 1 mm prismatic crystals on hematite with wulfenite and malachite-coated copper.

Cole Mine, *600 level;* Mimetite was noted as coming from a fault zone on this level with malachite (Anthony, et al. 1995).

Czar Mine, Specimens collected from a cut in the dump of this mine had radiating clusters of yellow, 3 mm mimetite crystals on quartzite with malachite.

Higgins Mine, *Twilight claim;* It was common in small amounts as yellow-brown 1 to 2 mm crystals on manganese oxides and silica breccia fragments with calcite, malachite and, rarely, pyromorphite. This is similar to the material so commonly found in the many other nearby manganese deposits.

Kentucky Tunnel; The dump at this prospect on the south side of Escabrosa Ridge contained a number of pieces of oxidizing galena in a vuggy quartz. In this material, mimetite occurred as tiny yellow crystals associated with one or more of the following: descloizite, hemimorphite, anglesite, and bayldonite, as well as quartz and galena.

Shattuck Mine, Reported from here with cerussite (Anthony, et al. 1995). A dump specimen collected by the authors contained yellow 0.5 mm crystals of mimetite with malachite and bayldonite.
200 level, 174 prospect; In small amounts as bright yellow micro-crystals within voids in shattuckite with quartz, malachite and hematite.

Southwest Mine, *7th level;* Found here as transparent yellow prismatic crystals to 3 mm on a hematite/goethite matrix with plattnerite and calcite in a large cave. Also from this same cave came tiny yellow/green crystals and films on altered limestone with later calcite and aragonite. This material closely resembles conichalcite. One-millimeter yellow crystals on hematite or spongy to granular quartz occurred some 10 meters lower in the raise leading to this cave.

MINIUM $Pb_2^{2+}Pb^{4+}O_4$:

This supergene mineral, while locally abundant, does not appear to be widely distributed within the district. Minium is entirely restricted to either silica breccias or porphyry dikes. It is probable that this is a function of the preferential deposition of minium by carbonate-free waters (Takahashi, 1960).

Typically, minium occurred as pulverulent masses or loose coatings on and as an alteration product of other lead minerals. In these instances, it very much resembled hematite. Much less often, it was found as thin, greasy appearing, alteration rinds on cerussite or anglesite.

The minerals associated with minium are:

galena
goethite
cerussite
hematite
anglesite
massicot
plumbojarosite
calcite

OCCURRENCES:

Campbell Mine, *1800 level; It* was found here in small amounts as an alteration product of cerussite and/or anglesite that in turn is on unaltered galena. Some of the minium from here is mixed with hematite and as a result is hard to notice.

Gardner Mine, The oxide lead ores common in this mine contained substantial amounts of minium as an alteration product of other secondary lead minerals.

Lavender pit Mine, *Holbrook Extension;* A cuprite in the University of Arizona collection, number 9672, contained minor amounts of minium as well as paratacamite (per U of A). The specimen was collected in 1972 by the authors.

Shattuck Mine, *300 level;* It was found here in small amounts as a powdery material that was a replacement of cerussite.

Southwest Mine, *5th level, 14 stope;* Very minor amounts of minium was noted on a very few specimens of massive cuprite with paratacamite and atacamite. It's very similar appearance to dust from breaking massive cuprite, that very close examination under magnification, is required to identify the material.
6th level; Minium was abundant as a constituent of the mixed lead ores mined from a near-surface stope on this level as pulverulent masses with granular cerussite and particularly as alteration rinds on irregular lumps of cerussite.

Uncle Sam Mine, Minium was a minor constituent of the supergene lead ores in this mine.

MOLYBDENITE MoS_2:

This hypogene mineral is surprisingly uncommon in the district. Typically, molybdenite is abundant in southwestern U.S. porphyry copper deposits, Bisbee is a notable exception, however. In spite of its apparent rarity, molybdenite is probably more common than the few localities given would indicate. But, because no specimens of note were found and only a very few examples were saved as molybdenite is perceived to be uncommon in the deposits at Bisbee.

The typical mode of occurrence for molybdenite is as small amounts of massive material associated with other massive sulfides or as films on fractures in the sulfides (Anthony, et al. 1995) or as blebs in quartz.

The species associated with molybdenite are:

pyrite

quartz

bornite

ferrimolybdite

OCCURRENCES:

Campbell Mine, *3100 level, 15 crosscut;* This long, hot and wet prospecting crosscut explored, at depth, the area under the Lavender pit and minor amounts of molybdenite were found here by one of the authors, as thin, silvery, films on quartz and, to a lesser degree, on mineralized Pinal schist.

Cochise Deposit, Cochise Porphyry contain stockwork hosted to pervasive sericitic and K-silicate alteration with associated chalcopyrite-molybdenite mineralization (Stegen et al., 2005). Copper mineralization in the shallow advanced argillic zone was leached and redeposited as supergene chalcocite to form the Cochise Zone ore body (Lang et al., 2001).

Gardner Mine, *1000 level, 1021 drift;* Molybdenite was noted from here in small amounts as linings of fractures in a porphyry with pyrite and chalcopyrite by Tenney (1913).

Lavender Pit Mine, The uncommon occurrences of molybdenite from here were as massive, bladed material with bornite and minor pyrite in the contact area on the south east side of the pit and near the site of the Gardner shaft in altered Escabrosa limestone. The Dividend fault zone near the concentrator contained minor amounts of molybdenite as blebs encased in quartz with pyrite. Much of the exposed molybdenite at this site had been altered to ferrimolybdite since 1951.

MOTTRAMITE $PbCu^{2+}(VO_4)(OH)$:

Mottramite is a relatively uncommon, supergene mineral within the district. Only at the Shattuck locality did it occur in any quantity.

The Shattuck occurrence was in what was locally referred to as the “vanadium cave.” This was a 20-meter diameter by 5-meter-high opening that formed as an oxidation style cave over a mixed lead/copper orebody. Wells (1913) identified the material from here as “cuprodescloizite” based on some contained exotic zinc. However, Taber and Schaller (1930) correctly identified it as what is now known as mottramite.

The minerals found associated with mottramite are:

braunite
pyrolusite
silver
calcite
conichalcite
acanthite
malachite
goethite
kettnerite
volborthite
iodargyrite

OCCURRENCES:

Campbell Mine, Very small amounts of mottramite were noted in a study of the complex ores in the Campbell orebody. Here, it was associated with iodargyrite, silver, acanthite, and kettnerite (Sid Williams, personal communication, 1987).

Dallas Mine, Minor amounts of mottramite (cuprodescloizite) were noted from here by Bonillas, et al. (1916).

Higgins Mine, *Twilight claim;* Mottramite occurs in modest amounts in the open cut manganese mines above the tunnel level as dark, olive-green, anhedral, cleavable masses up to 2 cm across in massive, granular braunite with a vanadium-rich conichalcite (Taber and Schaller, 1930). Over the years, the authors have made dozens of trips to this mine, finding but two pieces of mottramite.

Sacramento Mine, Minor amounts of mottramite (cuprodescloizite) were noted from here by Bonillas, et al. (1916).

Shattuck Mine, *600 level, 8 stope;* It was found in several forms in the "vanadium cave" above this level. Stalactites of up to several centimeters in length and 8 mm in diameter with a radiating structure were noted by Wells (1913). Botryoidal forms occurred in the upper portions of the opening, while the walls were largely covered with dark brown to black, velvety, reniform masses up to 5 mm thick. These masses were typically poorly attached to a soft, supergene-altered limestone. A consequence of this poor attachment was that the vast majority of such specimens recovered were small. The floor of the cave was littered with angular rock fragments that were also covered with a 2 mm drusy crust of mottramite.

Mottramite was also reported on the 600 level as scattered, small, compact masses associated with oxidized lead and copper ores (Mining and Scientific Press, 1914). This occurrence was most probably in the ores underlying the "vanadium cave" referred to above.

MURDOCHITE $Cu_6Pb(O_{6.4}\square_{1.5})Cl$:

This mineral species was originally described with material from Tiger, Arizona, but had been previously found at Bisbee in amounts too small to be described using the equipment available at the time (Bideaux & Wallace, 1997). At Bisbee, it is a late-stage secondary mineral of wide distribution, with local abundance.

Murdochite occurs most frequently as a thin crust or scattered crystals of 1 mm or less on goethite boxwork or altered limestone at the edge of highly oxidized copper - copper/lead orebodies. Occasionally, sharp, 2 mm crystals were found scattered on botryoidal or boxwork goethite. The newly described mineral, eddavidite is easily mistaken for murdochite (Yang Hexiong personal communication, 2018).

Minerals that have been observed with murdochite are:

goethite
hematite
quartz
malachite
plattnerite
calcite
bromargyrite
eddavidite

OCCURRENCES:

Cole Mine, *1200 level, 26-J Stope;* Murdochite occurred here in small amounts as bright, one mm crystals with plattnerite on rosasite and goethite.

Copper Queen, *Myers Tunnel level;* This area of the Copper Queen was mined in the 1930s by lessees, but minor amounts of cuprite were left behind, on which murdochite and calcite were present as a late-stage deposit on the massive cuprite which also contained small scattered nest of, acicular buttgenbachite crystals.

Czar Mine, *100 level;* Murdochite was found in the upper part of the new Southwest orebody as scattered to dense clusters of 1 mm splendent, black crystals on boxwork goethite with acicular malachite.

Higgins Mine, *Tunnel level;* Here, it occurred as drusy crust of tiny crystals on siliceous breccia fragments with specular hematite and minor plattnerite.

Holbrook Mine, *100 level;* Murdochite was reasonably abundant on the walls of a large cave above this level as 2 mm crystals on spongy malachite and was partially covered by later calcite.

Shattuck Mine, Dump specimens from an undetermined level in this mine had murdochite as 1 to 2 mm crystals on goethite with acicular malachite.
200 level, 174 prospect; Minor murdochite as found here as 1 mm clusters of 0.1 mm octahedral crystals. Also from this level in small amounts as scattered 2 mm crystals with plattnerite and minor bromargyrite on siliceous breccia fragments. The breccia fragments are partly dusted with tiny specular hematite crystals.

Southwest Mine, *4th level;* A stope near the Uncle Sam Shaft contained murdochite as a drusy film on slightly supergene altered Martin limestone with minor malachite.
5th level, 54 crosscut; Specimens collected here had murdochite as drusy crust on goethite boxwork. A second locality on this extensive level was from a small sag cave where murdochite occurred as centimeter-sized patches composed of 0.5 mm crystals on goethite with malachite, chrysocolla as pseudomorphs after malachite, goethite epimorph cast of gypsum and typical cave type calcite. Eddavidite was first noted on specimens from here.

MUSCOVITE $KAl_2\square Al\,Si_3O_{10}(OH)_2$:

This rock-forming and hydrothermal alteration species is widely distributed and very abundant within the district. It is commonly associated with the ore minerals as a part of the gangue assemblage. The variety “sericite” is extremely common as both a rock-forming and alteration mineral.

Muscovite as a rock-forming mineral is a common accessory in the Juniper Flat granite (Ransome, 1904). This is its most common form of occurrence in the district where it was usually found as anhedral blebs to several millimeters in size. Rarely, euhedral “books” to 2 cm were found in the pegmatitic phases.

The variety sericite as a metamorphic, rock-forming mineral is abundant in the Pinal schist where it, along with quartz, are the principal constituents of this Pre-Cambrian unit (Ransome, 1904).

It is also common as an alteration mineral in the younger porphyry of the Sacramento Stock complex and the underground porphyry dikes (Bryant and Metz, 1966). Schwartz (1947) did find the sericitization of the underground dikes to be less intense than that in the stock.

Typically in the intrusive units, sericite occurred, along with other similar minerals, as alteration replacements of feldspars and “biotite” (Schwartz, 1947). Sericite was usually found as isolated blades or streaks in earlier kaolinite. However, the complete replacement of feldspars as well as “biotite” by sericite were also noted (Schwartz, 1947).

Masses of nearly pure sericite to several ten of centimeters were occasionally found. These white to tan, plastic masses were composed of tiny bladed crystals that gave a drusy appearance. Pyrite was often found as euhedral crystals in this type of material.

The species most commonly associated with muscovite are:

- quartz
- kaolinite
- orthoclase
- chlorite
- allophane
- alunite

OCCURRENCES:

The distribution of the rock units noted above is largely the occurrences of muscovite in the district.

N

NAMBITE $Cu(BiO)_2(VO_4)(OH)$:

This supergene mineral is quite rare in the district. The species has been confirmed by Raman studies on a single specimen. (Jim McGlasson, personal communication, 2021)

Nambite has been found associated with:

- tangeite
- chrysocolla
- quartz
- hematite

OCCURRENCE:

Shattuck Mine,
Nambite has been observed as dark-green, tabular crystals $\leq$ .25 mm with tangeite on quartz with chrysocholla and hematite.

NANTOKITE $CuCl$:

While this mineral has been confirmed from only one locality, there is good reason to believe that was more widely distributed in the district. This is based on the distinctive effect it has on cuprite as it alters on exposure and a number of cuprite specimens from several other mines show the distinctive iridescence caused by this alteration.

In the one confirmed occurrence, nantokite was found as colorless, translucent masses completely filling voids to 3 cm in massive cuprite. It was also rarely observed as complex, creamy white crystals up to 5 mm.

On exposure to the moist mine atmosphere, nantokite readily alters to a pasty paratacamite extruding from the cuprite while giving off a strong, often overwhelming chlorine odor. This paratacamite becomes pulverulent after drying. The cuprite was distinctively colored in addition to the formation of paratacamite. An iridescent sheen is added to the cuprite well beyond the limits of the newly deposited paratacamite. This sheen appears to occur only when a cuprite/nantokite combination is suddenly exposed to the atmosphere such as during mining.

While nantokite is typically found in direct association with only cuprite and copper, a number of copper/chlorine minerals have been found just several centimeters away. It appears that nantokite may well be the source of both copper and chlorine for a number of the often-rare minerals containing these, and other elements, which typically occur only in cuprite at Bisbee.

The minerals that nantokite has been observed with are:

cuprite
spangolite
connellite
tolbachite
atacamite
copper
paratacamite

OCCURRENCES:

Czar Mine, The occurrence of nantokite from this mine is implied by the fact that several of the cuprite specimens from this mine show the distinctive signs of nantokite alteration.

Lowell Mine; A small number of cuprite/connellite specimens from this locality have the typical indications of nantokite alteration that occurs on exposure to the atmosphere. Thus, here too the occurrence of nantokite is implied.

Southwest Mine, *5th level, 14 stope;* Large amounts of nantokite were found during the collection of cuprite specimens at this locality. It occurred as a colorless filling of voids in massive cuprite and as small, complex crystals in voids in cuprite. In the latter case, nantokite was associated with atacamite, tolbachite, and paratacamite.

NATROLITE $Na_2[Al_2Si_3O_{10}]\cdot 2H_2O$:

This hydrothermal species has been recognized in small amounts in several locations within the district. It occurs as an alteration product of other hydrothermal minerals.

Typically, natrolite was found as fibrous material that ranged from white to brown to pinkish in color.

The species associated with natrolite are:

calcite
quartz
clinochrysotile
hematite

OCCURRENCES:

Lowell Mine, *1300 level;* It was found in an unspecified area of this level in small amounts as white, fibrous to needle-like crystals partially replaced by quartz (Tenney, 1913).
17 drift; Minor natrolite was also recognized here as fibrous material in calcite (Tenney, 1913).

Spray Mine, Massive natrolite occurred in this mine as a brown to pink fibrous material with quartz and clinochrysotile in a part of the Sacramento Stock Complex (Tenney, 1913).

NEKRASOVITE $Cu_{18}Cu_8V_2Sn_6S_{32}$:

This hypogene mineral was found as a micro-phase of a complex mineral assemblage replacing pyrite in the Campbell orebody.

The species associated with nekrasovite are (Sid Williams, personal communication, 1987; Alan Criddle, personal communication, 1992):

kësterite
stannoidite
mawsonite
colusite
kiddcreekite
quartz
calcite
pyrite
hematite

OCCURRENCES:

Campbell Mine, *2566 level;* Zincian nekrasovite was found as part of a very complex tin, tungsten, and vanadium mineral assemblage on this level (Alan Criddle, personal communication, 1992). It occurred as blebs to 0.7 mm, which, in reflected light, were a brownish to bronze color (Sid Williams, personal communication, 1987).

NELTNERITE $CaMn_6^{3+}SiO_{12}$:

This mineral has been noted from a single locality within the district. It is highly probable that additional work on the many limestone-hosted, braunite-containing manganese deposits will find neltnerite to be more widely distributed.

At the single recognized occurrence, neltnerite was found as inclusions in braunite II.

The species associated with neltnerite are (Sid Williams, personal communication, 1987):

braunite
braunite II
hübnerite
coronadite
tilasite

OCCURRENCES:

White Tail Deer Mine, A nearby surface outcrop contained neltnerite as tiny (1 mm) included, oval crystals at the interface between braunite and braunite II and within braunite II that occurred as cores in large braunite crystals (Sid Williams, personal communication, 1987). Anthony, et al. (1995) suggest that these three species are independent and stable phases. Coronadite, hübnerite, and tilasite were also associated with neltnerite at this locality.

NOLANITE $(V^{3+},Fe^{2+},Fe^{3+},Ti)_{10}O_{14}(OH)_2$:

Nolanite is a hydrothermal mineral that has been found in modest amounts at a single locality. Here, nolanite occurred as part of a very complex assemblage of tin-tungsten-vanadium minerals replacing pyrite (Alan Criddle, personal communication, 1992).

The species associated with nolanite are (Alan Criddle, personal communication, 1992):

stannoidite
mawsonite
scheelite
roscoelite
magnetite
hematite
stannite
colusite
cassiterite
rutile
stützite
galena
kësterite
kiddcreekite
“wolframite”
tellurium
melonite
chalcopyrite
nekrasovite
pyrite
altaite
sphalerite
hessite
quartz

OCCURRENCES:

Campbell Mine, *2566 level;* Modest amounts of nolanite were found associated with the above-noted species as part of a complex assemblage replacing pyrite (Alan Criddle, personal communication, 1992).

NORDSTRANDITE $Al(OH)_3$:

This supergene species appears to be uncommon, if not rare at Bisbee. However, its striking similarity in both appearance and occurrence to chrysocolla, chalcoalumite, alunite and its polymorph, gibbsite would make certain identification difficult. It has been noted as sky-blue and white to gray to blue-gray material.

The species associated with nordstrandite are:

malachite
goethite
gibbsite

OCCURRENCES:

Holbrook Mine, A single specimen of nordstrandite in the Carnegie Museum of Natural History, number CM 9892 is a confirmed example of this species from Bisbee. It was acquired by the museum in January 1890 (Debra Wilson, personal communication, 2014). Given the acquisition date and the nature of the specimen and the aluminum minerals present, it could only have come from the Holbrook Mine.

Another confirmed specimen, also from the Holbrook Mine, contains nordstrandite as a thin, crust-like, partial coating of white to blue white on azurite with malachite. The azurite and malachite are typical of very early azurite and malachite from the 200-300 levels of this mine.

O

"OLIGOCLASE" now considered a variety of albite (see also). The information below is preserved to allow the work by others to be referenced.

This rock-forming mineral has been found in several of the intrusive units at Bisbee as well as in the Pinal schist. While locally abundant, oligoclase was never found in large amounts.

The species associated with oligoclase are:

apatite
pyrite
rutile
quartz
magnetite
chlorite
ilmenite
muscovite

OCCURRENCES: Only a couple of typical occurrences will be noted because of the wide distribution and nondescript nature of oligoclase in the district. In his study of the Pinal schist, Ransome (1904) noted oligoclase with chlorite and oligoclase. The Juniper Flat granite contained oligoclase with muscovite, apatite, tourmaline, and magnetite (Ransome, 1904).

Holbrook Mine, *500 level;* Oligoclase was noted as part of a mineral assemblage along in one of the porphyry units with "biotite" and quartz with pyrite (Tenney, 1913).

OPAL $SiO2.nH_2O$:

This species has been recognized in small amounts at several localities in two adjacent mines. There is, however, little doubt that opal is far more common than this would suggest.

The hyalite variety was found as a very late-stage, thin, partial coating on calcite. The partial coatings were colorless, very thin crusts, often composed of intergrown microscopic spheres. Massive common opal was found as brownish to tan material that was up to a centimeter thick. All of the opal recognized in the district is highly fluorescent with a green response to SW UV light.

The species associated with opal are:

calcite
hematite
quartz
goethite
aragonite

OCCURRENCES:

Higgins Mine, *100 level;* Along the fringes of a large collapsed stope above this level were pockets of calcite, several of which had spotty, partial coatings of highly fluorescent hyalite opal on the calcite. These pockets were in limestone that graded into massive supergene hematite/goethite.

Southwest Mine, *6^{th} level;* Several specimens of massive, tan to brownish or gray common opal with quartz were recovered from the dump of this level. This opal was typically green in fluorescence with some cream-colored response to short wave light as well.

ORTHOCLASE $KAlSi_3O_8$:

This important rock-forming mineral is the dominant feldspar in the Juniper Flat granite and the intrusive units within the Sacramento Stock Complex (Ransome, 1904). For the most part, the orthoclase in the intrusives that are part of the stock have been completely altered, as have those in the underground dikes.

Typically, orthoclase was found as a major constituent of the majority of the intrusives within the district where it formed as small, euhedral crystals seldom more than a centimeter in length. Often, it was microperthitic, particularly in the Juniper Flat granite (Ransome, 1904). Unaltered, sharp crystals to 1.5 cm have been found in at least one of the underground dikes (Tenney, 1913).

The species most commonly associated with orthoclase are:

quartz
"biotite"
ilmenite
microcline
albite
plagioclase
magnetite
muscovite
tourmaline

OCCURRENCES:

The occurrences of orthoclase in the district are the same as the occurrences for the majority of the intrusive units. Inasmuch as no specimens of note are known to have been produced, no specific localities are listed.

OSARIZAWAITE $Pb(Al,Cu)_3(SO_4)_2(OH)_6$:

This supergene mineral is apparently limited in occurrence to the Southwest/Shattuck Mine areas. However, given the similarity of osarizawaite to some of the more common copper minerals, particularly malachite, it is possible that other occurrences have been overlooked. Indeed, in both the recognized localities, the material had been exposed for decades before it was noticed.

The typical occurrence for osarizawaite is as small clusters of indistinct crystals or as more massive material in voids in boxwork goethite.

The species associated with osarizawaite are:

calcite
goethite
malachite
hematite

OCCURRENCES:

Copper Prince Mine, A small number of dump specimens mined in 1882 and collected in 1974 contained clusters of tiny, yellow-green, tabular, hexagonal osarizawaite crystals on a goethite/hematite boxwork with malachite and calcite.

Shattuck Mine, Osarizawaite was particularly common in the old workings of this mine as a pistachio-green material on goethite (Anthony, et al. 1995).

P

PARACOQUIMBITE $Fe_2^{3+}(SO_4)_3 \cdot 9H_2O$:

This is an apparently rare post-mining mineral in the district. Its similarity to the dimorph, coquimbite, may have caused it to be overlooked, however. As with other post-mining minerals, it is probable that paracoquimbite occurred as a product of supergene activity but was not recognized.

At one locality, paracoquimbite occurred as violet crystals to 0.5 mm forming scepter-like growths on needle-like coquimbite crystals. At a second, it was found as small, pale violet, complex crystals with coquimbite and other post-mining minerals.

The species associated with paracoquimbite are:

coquimbite
copiapite
pyrite
rhomboclase
halotrichite
voltaite

OCCURRENCES:

Campbell Mine, Paracoquimbite has been recognized in specimens from this mine in very small amounts as tiny, bright, pale violet, complex crystals oriented on coquimbite with voltaite, rhomboclase, and copiapite.

Higgins Mine, *100 level;* Oxidizing pyrite from this area had small patches of tiny, yellowish coquimbite crystals with transparent, violet, scepter growths of paracoquimbite crystals to 0.5 mm in size. Halotrichite was associated with this occurrence.

Lavender Pit Mine, Paracoquimbite has been recognized in minor amounts on a number of specimens collected from several locations on the highly pyritic older porphyry on the north side of the pit.

PARAMELACONITE $Cu^{1+}_2Cu^{2+}_2O_3$:

Bisbee is the type locality for this exceedingly rare mineral (Koening, 1891b). No additional examples of this mineral have been found in the district since the type material was discovered in the late 1880s. The finest known examples of this species are from here.

This secondary mineral is associated with cuprite as are so many of the other rare to uncommon species from the district. It occurs as stout, prismatic crystals to 3 cm on goethite that in turn is on cuprite. Connellite in felt-like aggregates of acicular crystals is intimately associated with the paramelaconite (Koening, 1892).

The species that have been found with paramelaconite are:

goethite
tenorite
connellite
malachite
copper
cuprite

OCCURRENCES: Only two specimens were recovered from the original discovery. Subsequently, several very small pieces were trimmed from these. While the purported source is the Copper Queen mine, we doubt this designation as the Copper Queen Mine had been closed for several years. Further, local lore has it that these specimens were on a shelf in the Copper Queen assay office at the Czar mine when Foote was shown them (M. J. Cunningham, personal communication, 1954). In any event, upon his return to the East, he sold both specimens to Clarence Bement for the-then princely sum of fifty dollars apiece (Frondel, 1941).

Paramelaconite occurred here as large prismatic crystals on goethite with connellite (Koenig, 1891a). A very minor surficial alteration to malachite can be noted on some crystals.

PARATACAMITE $Cu_2^{2+}Cl(OH)_3$:

Bisbee has produced what may well be the finest examples of this supergene mineral. While this species does not appear to be widely distributed in the district, its often-nondescript appearance may have resulted in misidentification. All known examples of paratacamite from here are associated with cuprite.

The most typical occurrence is as a pale green veneer or powdery incrustation on cuprite. In many cases, this crust appears to be an alteration product of nantokite, which readily alters to paratacamite on exposure to the atmosphere. A substantial increase in volume occurs with this alteration causing the newly formed paratacamite to extrude from the site, often filling any adjacent voids.

Distinct crystals of paratacamite are uncommon from the district and, when found, are typically less than 5 mm in size. However, large, complex composite crystals of up to 1 cm have been recovered.

The species recognized as associating with paratacamite are:

cuprite
malachite
claringbullite
atacamite
spangolite
connellite
tenorite
hematite
nantokite

OCCURRENCES:

Cole Mine, Paratacamite was found in specimens of cuprite from this mine as 2 to 3 mm prismatic crystals with malachite and hematite.

Czar Mine, Specimens from the dump of this mine collected by the authors in 1967 contained paratacamite as gray-green coatings on fractures in massive cuprite.

Holbrook Mine, A specimen of massive cuprite found on the dump of this mine by one of the authors in 1952 contained 5 mm equant crystals of dark green paratacamite in a vug with cuprite crystals.
200 level; Small crystals of paratacamite were found in voids in massive cuprite with connellite on this level.

Juniper Flat: Paratacamite was recognized here as a minor accessory mineral in some of the mineralized gold bearing quartz veins with brochantite, atacamite, linarite, and malachite (Rob Bowell, personal communication 2004).

Lowell Mine, Paratacamite has been recognized on many cuprite specimens from this mine as a thin, gray-green film along fractures.

Southwest Mine, *5th level, 14 stope;* Exceptional specimens of paratacamite were found at this locality. Crystals up to 1.5 cm occurred in vugs in cuprite with spangolite, claringbullite, and atacamite. Also paratacamite from here occurred as a pale green, pulverulent material in cuprite vugs, which formed as an alteration of nantokite and was easily removed with water. However, some cuprite crystals in these vugs had a very thin veneer of gray-green paratacamite that remained after washing.

PARATELLURITE TeO_2:

This is a rare secondary mineral, which has been found in small amounts as part of a complex mineral assemblage at a single locality.

OCCURRENCES:

Campbell Mine, Paratellurite was noted in the ores from an undetermined level in this mine by Sid Williams (personal communication, 1987).

PEARCEITE $[(Ag_9CuS_4)][(Ag,Cu)_6(As,Sb)_2S_7$:

This hypogene mineral appears to be quite rare within the district. Like a number of such minerals, pearceite occurs as small inclusions in sulfides and could have easily been overlooked.

In the one documented occurrence, pearceite was found as inclusions in a mixture of massive chalcocite and bornite.

The species associated with pearceite are:

pyrite
bornite
chalcocite

OCCURRENCES:

Campbell Mine, *1700 level, 113 stope;* Pearceite was found here in small amounts as clusters of anhedral, black grains in a mixture of massive chalcocite and bornite with minor pyrite (USNMNH specimen number 100455).

PECTOLITE $NaCa_2Si_3O_8(OH)$:

This hydrothermal mineral is apparently quite rare within the district. It has only been recognized in small amounts from a single locality.

In this occurrence, pectolite was found as a very minor constituent of a hydrothermal replacement assemblage in limestone.

The species associated with pectolite are:

wollastonite
epidote
chlorite
quartz
pyrite

OCCURRENCES:

Lowell Mine, *1200 level, 3 drift;* Pectolite was found here as radiating needle-like crystals to 4 mm with wollastonite, epidote, chlorite, quartz, and pyrite (Tenney, 1913).

PETZITE Ag_3AuTe_2:

This is a hydrothermal mineral and only minor amounts of petzite have been found in the district. Typically, it occurred as minor inclusions in massive sulfides with a number of other minor accessory minerals as part of a late stage assemblage.

The species associated with petzite are (Alan Criddle, personal communication, 1992):

altaite
sylvanite
colusite
kostovite
stützite
krennerite
rutile
gold
hessite
calaverite
goldfieldite
tellurobismuthite
pyrite
sphalerite

OCCURRENCES:

Campbell Mine, *1900 level, 2200 level, and 2300 level, 124 stope;* Minor amounts of petzite were recognized in these areas of the Campbell orebody with a varying assemblage of the above noted minerals (Alan Criddle, personal communication, 1992).

PHARMACOSIDERITE $KFe_4^{3+}[(OH)_4(AsO_4)_3]\cdot 6\text{-}7H_2O$:

This species was found as a supergene mineral in very limited quantities.

The typical occurrence for pharmacosiderite was as minute crystals in leached gossan/ porphyry. Here, the crystals were amber in color and had formed along fracture surfaces in the porphyry.

Associated with pharmacosiderite were:

psilomelane
hematite
quartz

OCCURRENCES:

Lavender Pit Mine, A few specimens with scattered, 0.1 mm amber, octahedral crystals of pharmacosiderite on psilomelane were recovered from the number 7 dump of this mine in 1970 by one of the authors.

PHOSGENITE $Pb_2(CO_3)Cl_2$:

This is a very rare supergene mineral for the district. While only one locality has been recognized, closer examination of existing material may well bring additional localities to light.

The following species have been found with phosgenite at Bisbee:

calcite
copper
hematite

OCCURRENCES:

Cole Mine, *1100 level;* Phosgenite was recognized on specimens from here as 5 mm colorless prismatic crystals on calcite with copper. The phosgenite from here could easily be confused with calcite, however, the calcite from this locality is highly fluorescent, while the phosgenite is not.

PICKERINGITE $MgAl_2(SO_4)\cdot 22H_2O$:

This mineral has only been found in post-mining occurrences. The apparent limited distribution may be a function of the strong resemblance of pickeringite to other, more common post-mining minerals.

The single occurrence for pickeringite was as an efflorescence on mineralized dolomitic limestone.

The species associated with pickeringite are:

calcite
pyrite
dolomite

OCCURRENCES:

Shattuck Mine, *500 level;* Colorless, prismatic pickeringite crystals to 1 mm with corroded, rounded faces were found here on mine walls.

Lavender Pit Mine, *Holbrook Extension;* Minor pickeringite was found here with amounts of pale blue scorzalite in massive variscite in specimens from this area of the pit (Rob Bowell, personal communication 2004).

“PLAGIOCLASE”

Part of the Albite-Anorthite Series. The members of this series are abundant as constituents of all of the intrusive rocks within the district. The exact mineral that early workers identified as “plagioclase” is largely uncertain. The information provided here is to be considered for reference only, allowing for the work of earlier researches to remain available.

Plagioclase is a minor rock-forming mineral in the Juniper Flat granite (Bonillas, et al. 1916) which it is the most abundant occurrence of this group within the district. Ransome (1904) noted modest amounts of plagioclase in samples from a dike on Escabrosa Ridge. He equated this dike to one of the units in the Sacramento Stock Complex.

In both instances, plagioclase was found as a zonation phase in other feldspars.

The species most commonly associated with plagioclase are:

quartz
muscovite
“biotite”
microcline
orthoclase
albite

OCCURRENCES:

The areas that host the Juniper Flat granite in the northwestern portion of the district, as well as Escabrosa Ridge, comprise the occurrences of this mineral group within the district.

PLANCHEITE $Cu_8(Si_4O_{11})_2(OH)_4 \cdot H_2O$:

This is a secondary mineral of very limited distribution within the district.

The silica breccias of the Shattuck mine area have been the source of the majority of the copper silicates produced from the district and plancheite is no exception. The large amount of available copper in the breccias that was remobilized over several episodes of supergene activity, coupled with the available silica mobilized during the supergene process, appear to be the reasons. Similar conditions existed in the adjacent Southwest/Higgins Mine area, however only modest amounts of a few of these mineral types were found.

Plancheite usually occurred as a thin botryoidal crust or as isolated clusters of 2 mm acicular crystals on breccia fragments. A second, less common mode of occurrence is as irregular, impure blebs in altered limestone adjacent to a silica breccia.

The species associated with plancheite are:

quartz
shattuckite
calcite
hematite
willemite

OCCURRENCES:

Higgins Mine, *Twilight claim*; The open-cut manganese workings some 300 feet above the tunnel level contained modest amounts of plancheite associated with a silica breccia. Here, it occurred as 1 cm spots in an altered limestone and mixed with shattuckite. Highly fluorescent, 1 mm. willemite crystals are associated with this occurrence

Shattuck Mine, *200 level, 174 prospect;* Very minor amounts of plancheite were found here as scattered clusters of tiny, acicular crystals with shattuckite and malachite.
400 level; Plancheite was noted here as botryoidal crust on breccia fragments with specular hematite (Sid Williams, personal communication, 1981).

PLATTNERITE PbO_2:

This supergene species is widely distributed in small amounts within the western part of the district. It’s generally nondescript appearance may well have caused it to be overlooked elsewhere.

Plattnerite that did not form directly on other secondary lead minerals and at their expense appears to have been the most common. This exotic phase of the mineral was most abundant in the areas adjacent to the silica breccias that are found in the Southwest and Shattuck mine areas. Under these circumstances, plattnerite occurred as scattered 1 mm crystals on goethite or siliceous breccia fragments, often with minor amounts of later calcite. On occasion, concentrations of crystals on goethite or altered limestone with crystals from 3-5 mm in size and in radiating patterns of several centimeters were found as well.

Plattnerite that formed replacing other lead minerals in place appears to have been less common. However, it must be noted that the vast majority of the oxidized lead orebodies had been completely mined before plattnerite was recognized as a distinct species. What has been found is as earthy, irregular masses of impure material scattered throughout ocherous mixtures of iron, iron/lead, and lead oxidation products. Additionally, plattnerite has been found as drusy to earthy crusts on and replacing massive cerussite.

The species most typically associated with plattnerite are:

goethite
hematite
hemimorphite
calcite
massicot
cerussite
mimetite
malachite
murdochite
stolzite
quartz

OCCURRENCES:

Cole Mine, *1300 level. 26-J stope;* Modest amounts of plattnerite were found here as splendent, black, 0.5 mm crystals on malachite with rosasite.

Holbrook Mine, *100 level;* A small section of a large cave above this level contained significant plattnerite as bright 0.5 mm crystals on and included in calcite. Also, it was found here as drusy crystals on altered limestone with rosasite as well as exceptionally large (2 to 3 mm) crystals lining small voids in hematite.

Shattuck Mine, *300 level;* The silver-rich areas in what was called the “lead cave” on this level contained some plattnerite as scattered microcrystals on silica breccia fragments with murdochite, bromargyrite, and specular hematite.

Southwest Mine, *5th level;* It was found on this level as sharp 0.5 mm crystals with calcite.
6th level; Plattnerite was common in the remnants of several of the oxidized lead zinc orebodies here as microcrystalline veneers on and along fractures in massive cerussite. Also from this level were 1 mm prismatic crystals of plattnerite on and included in calcite. A small cave on this level contained plattnerite as thin, often twinned crystals to 2 mm on spongy masses of cerussite with hemimorphite and minor stolzite.
7th level; Attractive specimens, for the species, were found here as 4 cm patches of radiating 2 to 3 mm crystals on altered limestone with calcite and, occasionally, mimetite. This occurrence is along a fault that forms one wall of a large oxidation cave.

PLUMBOJAROSITE $Pb_{0.5}Fe_3^{3+}(SO_4)_2(OH)_6$:

This secondary mineral is almost certainly more common in the district than the few confirmed localities would suggest. Its typically nondescript appearance, coupled with the marked similarity to pulverulent goethite and jarosite, may well have masked other occurrences. There is little doubt that much of the "yellow lead ores" noted by Bateman (1914), and others in the Southwest mine as well as those mined in the Shattuck and Gardner Mines contained substantial amounts of plumbojarosite.

Typically, plumbojarosite occurred in non-reactive host rock environments as often large, ocherous masses mixed with pulverulent goethite and jarosite. Crusts of tiny crystals on silica fragments, goethite and hematite were also common. In both instances plumbojarosite was generally yellowish to yellow-brown in color. Galena deposits with a high pyrite content in or adjacent to the silica breccias appear to have been the source of the plumbojarosite in the Southwest and Shattuck Mines.

Post-mining plumbojarosite has been observed at several localities. Here, too, plumbojarosite has been derived from a high-pyrite galena combination.

The species most commonly associated with plumbojarosite are:

goethite
calcite
malachite
hematite
cerussite
beaverite-Cu
jarosite
anglesite
quartz
azurite

OCCURRENCES:

Atlanta Mine, A few specimens of earthy plumbojarosite with calcite were found on the dump of this mine by one of the authors in 1967.

Campbell Mine, 1500 *level to 1800 level;* Modest amounts of plumbojarosite were found in several places in the oxidizing lead, lead/copper ores along the Campbell fault on these levels. It occurred as an earthy, yellow-brown material with goethite and hematite as well as minor amounts of anglesite, cerussite, azurite, and malachite.
1600 level; Plumbojarosite was found here in small amounts as tiny hexagonal crystals along fractures formed by post-mining oxidation in a pyrite/galena mixture. The material hosting the plumbojarosite had been blasted and then left in the stope because it did not meet the high lead grade (10%) required.

Gardner Mine, Based on residual material seen here by the authors, plumbojarosite was an important constituent of the oxide lead ores that Mills (1958) reported as being mined here from 1910 until 1915.

Higgins Mine, *Tunnel level;* A post-mining occurrence was recognized here where plumbojarosite was found as 0.1 mm hexagonal crystals in broken pyrite/galena ore. Quartz and minor sphalerite were associated with the ores.

Shattuck Mine, *200 level to 300 level;* Plumbojarosite was common as a yellow-brown, earthy material in the silica breccia parts of the "lead cave" along with jarosite and goethite. Cerussite and calcite were associated with this material close to the limestone contact.

Southwest Mine, *3rd level to 7th level;* Important as an ore mineral from several stopes on these levels, plumbojarosite was found in large, earthy, typically impure masses mixed with goethite and jarosite. Anglesite and cerussite were associated with plumbojarosite near the limestone contacts.
6th level; Large amounts of similarly appearing beaverite-Cu were found admixed with the far more abundant plumbojarosite in specimens collected from this level. Abundant calcite was, later deposited, cementing lumps and lining voids created by the slumping of these ores. Elsewhere on this level, plumbojarosite was found in a stope near the Sunrise Shaft as earthy, yellow material overgrown with malachite and cerussite.

POLYBASITE $[(Ag9CuS4)][(Ag,Cu)_6(Sb,As)S_7]$:

This hypogene mineral is found only in small amounts at a few locations in the district. However, because of the typically small size of the particles of polybasite it is probable that other occurrences have been overlooked.

Typically, polybasite occurred as small, anhedral grains in copper or lead/zinc sulfide ores. Bonillas, et al. (1916) first noted it in ores from the district as a few small grains included within massive galena from an unspecified mine. Bornite, galena, chalcopyrite, and sphalerite are the more common hosts of polybasite inclusions.

The species associated with polybasite are:

bornite
calcite
galena
quartz
sphalerite
pyrargyrite
chalcocite
chalcopyrite

OCCURRENCES:

Campbell Mine, Polybasite was found in specimens from this mine as tiny grains with pyrargyrite and sphalerite in massive bornite with calcite.

Gardner Mine, A common, minor, accessory mineral from several areas of this mine, it was found in association with galena and pyrite as well as minor sphalerite (Tenney, 1913).

Junction Mine, *2700 level;* A mixture of massive bornite and chalcocite from here contained blebs to 2 mm of polybasite.

POWELLITE $CaMoO_4$:

A secondary mineral with an apparent limited distribution in the district. Powellite has been reported from several locations, but only one occurrence can be confirmed.

Typically, powellite was found in small amounts as straw-colored to whitish material in massive quartz.

OCCURRENCES:

Bisbee Queen Mine, Anthony, et al. (1995) reported powellite from this exploration shaft on the eastern side of the district.

PREHNITE $Ca_2Al_2Si_3O_{10}(OH)_2$:

This hydrothermal mineral was found in small amounts in contact-metamorphic environments. Prehnite was found as small, well-formed crystals in a contact-metamorphosed limestone.

The species associated with prehnite are:

quartz
calcite
epidote
grossular

OCCURRENCES:

Cole Mine, *800 level and 1000 level;* Prehnite occurred on these levels in contact- metamorphosed limestone adjacent to dikes as small crystals with quartz, calcite, epidote, and grossular (Fabien Cesbron, personal communication, 1981).

PSEUDOMALACHITE $Cu_5^{2+}(PO_4)_2(OH)_4$:

This apparently rare secondary mineral has only been recognized in small amounts at three occurrences in one mine and at a single locality in a second.

The typical occurrence for pseudomalachite is as an overgrowth on malachite or other supergene copper minerals. In at least one case, it formed at the expense of the underlying malachite.

Species that have been found with pseudomalachite are:

malachite
cuprite
azurite
variscite
quartz
copper

OCCURRENCES:

Lavender Pit Mine, *Holbrook Extension;* Three areas in this part of the pit produced pseudomalachite and all were near the intrusive stock. In the uppermost locality it was found as a greenish-black veneer on and replacing botryoidal malachite. The lower occurrence was as a deep green, drusy crust, also on massive malachite. Azurite and quartz were associated with pseudomalachite at both of these occurrences. In the third area, pseudomalachite formed on copper and cuprite as a thin, drusy crust in pockets in variscite.

Southwest Mine, *6th level, 17 stope;* Several small pieces of a siliceous breccia from this locality had a thin, spotty crust of tiny, but brilliant pseudomalachite crystals.

PUMPELLYITE $Ca_2(Fe,Mg,Mn)Al_2(SiO_4)(Si_2O_7)(OH_2)\cdot H_2O$:

One of the species of this hydrothermal alteration group has been noted to occur in the district by Anthony, et al. (1995). However, no information regarding the exact species, mode of occurrence or the area where it occurred is provided.

PYRARGYRITE Ag_3SbS_3:

This hypogene mineral has been found in very small amounts at a single locality within the district. There is a real probability that pyrargyrite is more abundant that it would appear given the nature of the ore mineralization at Bisbee.

The single occurrence noted was as 2 mm massive inclusions in sulfide ores.

The species associated with pyrargyrite are:

bornite

polybasite

sphalerite

calcite

OCCURRENCES:

Campbell Mine, Pyrargyrite occurred in minor amounts as 2 mm anhedral inclusions in massive bornite. Polybasite and sphalerite were also present as inclusions in the bornite. Calcite was associated with the bornite in these specimens, as was pyrite.

PYRITE FeS_2:

This hypogene mineral is the most common sulfide mineral within the district. After quartz, pyrite is the most prolific hydrothermal mineral deposited during the several mineralizing episodes at Bisbee. Immense deposits of pyrite have been found throughout the productive portions of the district. Masses of siliceous pyrite weighing into the tens of thousands of tons are common, and some exceeded a million tons in weight. Underlying all of the main ore zones except the Campbell orebody are incredibly large masses of siliceous pyrite (Bryant and Metz, 1966). Most of these contain low-grade copper and may well represent an important resource at some future time. Bryant (1968) has estimated that in excess of several hundred million tons of pyrite were deposited in the district.

Typically, pyrite occurred in large, compact, and impure masses. Quartz was the most common impurity. Texturally, the massive pyrite ranged from almost aphanitic to granular to discrete, intergrown, coarse crystals. Vugs in massive material often contained small crystals. Euhedral crystals commonly occurred as isolated individuals or small clusters in soft clays as well as sericite or chlorite. Often large masses of unconsolidated, granular pyrite were encountered during mining in a number of areas. This material was very sand-like and would flow into any open space. Even the knotholes in timber had to be plugged to stop the flow. This fine-grained material represented a very real fire hazard, as the small particles tended to oxidize rapidly. The exothermic reaction of pyrite decomposition would generate enough heat to ignite timber or other combustible materials. These in turn would set the sulfides on fire. Pyrite in general, was the most common cause of the many mine fires that plagued the district.

Pyrite was a principal constituent of almost all of the primary sulfide orebodies mined at Bisbee. It often formed a low-grade core within the orebodies (Trischka, 1938; Hogue and Wilson 1950; Bryant and Metz, 1966). Pyrite was also almost always found intermixed with the ore minerals, even in their purest state.

Often, the silicified limestones adjacent to the sulfide replacement deposits and the intrusive dikes contained disseminated pyrite, particularly along structurally weak zones such as bedding planes. This pyrite, often as euhedral crystals, would continue for many tens to hundreds of meters along these features into the otherwise unmineralized limestone.

The Sacramento Stock Complex contained substantial amounts of pyrite. Bryant and Metz (1966) estimated that the older porphyry unit, as a whole, contained between 15% and 18% sulfide as pyrite. Much of the Pinal schist near the stock contained large amounts of pyrite as well.

Apparently syngenetic pyrite is locally abundant in portions of the Morita formation on the eastern edge of the district. It occurs as well-formed, centimeter-sized, slightly elongated, cubic crystals.

In spite of the immense volumes of pyrite in the district, sharp, distinct crystals were not particularly common and good collector specimens were actually quite rare.

Pyrite has been found associated with the vast majority of the hypogene minerals in the district as well as a few of the supergene species.

Faithful pseudomorphs of hematite and goethite after pyrite have been found in several places. Chalcocite pseudomorphs after small pyrite crystals were not uncommon in the porphyry ores.

OCCURRENCES:

Campbell Mine, Pyrite was literally everywhere in this large mine. It was the core of most of the orebodies (Hogue and Wilson 1950) and large masses of nearly pure pyrite were frequently found. The limestone country rock contained variable amounts of pyrite, often for many hundreds of meters from the closest known ore. Few specimens of this mineral worth recovering were ever found in this mine.
2100 level; Large plates of bright, heavily modified pyritohedral crystals to 1.5 cm were found in a massive pyrite body that was brecciated and partially healed by later pyrite.

Cole Mine, *1200 level;* This level produced many hundreds of individual pyritohedral crystals in soft sericite. Some of these reached 8 cm in size. While these crystals were well formed, the faces were typically somewhat rough because many tiny similar crystals had been deposited on the faces. *1400 level;* A few groups of pyritohedral crystals to 12 cm were found embedded in sericite at the edge of a large, massive pyrite body on this level. Unfortunately, these pyrites had a tendency to decompose after a few years. Also on this level were many distorted, heavily striated cubic crystals as singles and groups in chloritized limestone with specular hematite and quartz.

Czar Mine, Pyrite was common in the lower levels of this mine but only one unusual occurrence was of note.
400 level; Small fossil brachiopods were found on this level that had been faithfully replaced by pyrite in unmineralized limestone.

Higgins Mine, *Tunnel level;* Large masses of granular pyrite were associated with the limited chalcopyrite/bornite ores near the interior shaft on this level. A number of centimeter-sized, modified cubes occurred in the fault zones associated with these deposits.

Junction Mine, Many large bodies of massive pyrite were found during mining at this huge operation and pyrite was invariably associated with sulfide ores here. It was common for the few voids in the massive material to contain small, bright crystals of pyrite, often with quartz crystals.

Lavender Pit Mine, Pyrite was ubiquitous in the ores of this mine as well as the hosting Sacramento Stock Complex. Most of the pyrite from here had a thin coating of supergene chalcocite, which was the principal ore assemblage for this operation. Numerous modified crystals to 2 cm were found here during mining, often in massive quartz. Few of these were attractive specimens.

Shattuck Mine, *800 level, 9-7 stope;* Large crystals of pyrite occurred in vugs in massive material on this level (Bateman, et al. 1914).

Spray Mine, *500 level, 99 stope;* Cubic crystals to 1 cm were found here in unconsolidated, sandy pyrite (Tenney, 1913).

PYROLUSITE $Mn^{4+}O_2$:

This supergene species has been recognized as an important component of the ores in a number of the near-surface manganese deposits and as a common gangue mineral in many of the oxidized copper orebodies. Pure, easily discernible pyrolusite is relatively uncommon, however.

Pyrolusite occurs as a massive, hard, compact material to soft pulverulent masses, as well as granular material in the manganese deposits. For the most part, it is associated with other supergene manganese oxides that are frequently quite similar in appearance.

Pyrolusite was the most common of the manganese oxides associated with the supergene copper deposits. In these instances, it is typically impure soft, pulverulent material that was often mud-like when first found underground. Large, impure masses of this type of pyrolusite were associated with some of the more thoroughly oxidized ores, particularly those containing azurite and malachite in the Czar Mine and, to a lesser degree, the Holbrook Mine.

It is probable that this later pyrolusite was derived by supergene action on altered limestone adjacent to orebodies containing substantial amounts of manganese. This altered limestone was typically bleached, recrystallized, and found to contain substantial amounts of introduced manganese. The amounts of introduced manganese are in the 12% (Schwartz, 1959) to 13 % (Hogue and Wilson 1950) manganese range.

Pyrolusite dendrites were common in several areas in the district.

The species associated with pyrolusite are:

braunite
cryptomelane
malachite
manganite
hematite
calcite
groutite
goethite
quartz
romanèchite
azurite

OCCURRENCES: Only a few localities will be noted because of the lack of significant specimens.

Cole Mine, *1000 level;* Fine examples of pyrolusite dendrites occurred here along fractures in supergene altered limestone with minor malachite.

Czar Mine, Large amounts of pyrolusite, along with other manganese oxides, occurred in the oxide orebodies of this mine. Azurite and malachite were commonly associated with pyrolusite in these occurrences.

Higgins Mine, *Twilight claim;* Pyrolusite was noted in this large manganese deposit by Ransome (1920) as well as Palache and Shannon (1920). Also, pyrolusite has been found here as radiating, needle-like crystals along fractures in siliceous wall rock.

Southwest Mine, *7th level;* Portions of a large cave contained substantial amounts of soft, often mud-like manganese oxides along its bottom. Pyrolusite was a major component of this material, which was apparently derived from altered limestone.

PYROMORPHITE $Pb_5(PO_4)_3Cl$:

An uncommon secondary mineral in the district, it was found in small amounts at only a few localities. Pyromorphite is one of the very late-stage minerals in all of the recognized localities.

The minerals associated with pyromorphite at Bisbee are:

malachite
pyrolusite
mimetite
goethite
calcite
hematite

OCCURRENCES:

Campbell Mine, Tiny amounts of pyromorphite have been noted by the author on specimens of malachite from the upper levels of this mine.

Higgins Mine, *Twilight claim;* Specimens collected from the dump of the manganese workings on this claim contained pyromorphite as apple-green microcrystals with calcite and later mimetite on pyrolusite.

Shattuck Mine, Pyromorphite from an undetermined level in this mine occurred as apple-green patchy crusts on malachite as scattered 2 mm crystals exhibiting cavernous growth and with later 1 cm malachite pseudomorphs after azurite.

Southwest Mine, A small prospect shaft above the 10th level portal in Uncle Sam Gulch contained pyromorphite as apple-green to greenish yellow microcrystals in calcite vugs with fibrous malachite and goethite.

PYROPE $Mg_3Al_2Si_3O_{12}$:

This hydrothermal mineral was found in small amounts at a single locality. In this occurrence, pyrope was recognized as rounded grains associated with magnetite and apatite.

OCCURRENCES:

Gardner Mine, *800 level, 62 drift;* Pyrope was recognized in thin section work by Tenney (1913) on material from here.

PYROPHYLLITE $Al_2Si_4O_{10}(OH)_2$:

This is a relatively common hydrothermal species in the district. Pyrophyllite occurs as soft, whitish to gray talc-like material that closely resembles other hydrothermal alteration minerals.

The species associated with pyrophyllite are:

quartz
dickite
muscovite
magnetite
pyrite
alunite
baryte
rutile

OCCURRENCES:

Anthony, et al. (1995) noted an occurrence of pyrophyllite near Warren. Baryte was associated it with this occurrence.

Lavender Pit Mine, Pyrophyllite was common in the altered, older porphyry unit of the Sacramento Stock Complex as an intergranular filling and as replacements of plagioclase and "biotite" phenocryst (Bryant and Metz, 1966).

PYRRHOTITE $Fe_{1-x}S(x=0.1-0.2)$:

This typically common hypogene mineral was surprisingly scarce in the district. It was noted in small amounts in several localities, all of which are in the contact zone adjacent to the Sacramento Stock or one of the underground porphyry dikes. Often it was associated with magnetite and to a lesser degree, specular hematite (Bonillas, et al. 1916). Pyrrhotite was always found as a massive material with no examples of any crystals known.

The species associated with pyrrhotite are:

pyrite
magnetite
hematite
tremolite
chalcopyrite
calcite
dolomite
sphalerite
quartz

OCCURRENCES:

Gardner Mine, *900 level;* Massive pyrrhotite was found with magnetite, hematite, pyrite, sphalerite, and chalcopyrite (Tenney, 1913).

Lowell Mine, *1100 level 15 drift:* It was recognized in thin section work on samples from here by Tenney (1913) as inclusions in pyrite with magnetite and chalcopyrite.

Sacramento Mine, *1400* level; Pyrrhotite occurred in minor amounts with magnetite and hematite in tremolite (Tenney, 1913).

Spray Mine, *900 level, 9 drift;* It was found here in small amounts with abundant, massive pyrite and magnetite in dolomite (Tenney, 1913).

Q

QUARTZ SiO_2:

This is the most common and widely distributed species introduced during mineralization. Quartz has been recognized in almost all of its more common forms within the district.

The most common form for quartz is as the ubiquitous silicification that took place in the earliest mineralization phase. This material typically was very fine-grained and intimately mixed with a number of other gangue minerals and later ore minerals. Large volumes of limestone were replaced by quartz, usually along with one or more of the iron minerals -- pyrite, hematite and/or magnetite.

As a rock-forming mineral, quartz was an important component of all of the Pinal schist as well as all of the intrusive units throughout the district. Large masses were common in the Juniper Flat granite, often accompanied by minor mineralization. Quartz was also common as the primary constituent of several of the sedimentary units and abundant as chert in some of the Paleozoic limestones.

It was this mineral that was dominant in the large silica breccias in the Southwest and Shattuck mines and the many barren quartz breccias in the eastern portion of the district as well.

Bold outcrops of white, hydrothermal "bull quartz" are common in the Cretaceous sediments of the area. This is particularly true for the extreme eastern part of the district near the Bisbee Queen Mine and Gold Gulch area, where it often contained abundant visible gold.

Quartz as petrified wood was not altogether uncommon in some of the Cretaceous sediments. Without exception, this material was brown to black and generally unattractive.

Chalcedonic quartz was common in small amounts throughout the district (Nye, 1968). The silica breccias of the Southwest and Shattuck areas contained much of this type of material. While it was not uncommon to find supergene copper minerals overgrown by chalcedony, no specimens of note were found.

In spite of the abundance of quartz, crystals of quartz were relatively uncommon and crystals of any size or quality were quite rare. It was however, common to find drusy to small quartz crystals lining small voids in the silicified materials throughout the district. Crystals to 5 mm were not altogether uncommon under these conditions. Voids in the common silicified pyrite masses frequently contained small crystals with a few examples of centimeter crystals known from this environment.

Crystals, both colorless and milky, to 10 cm have been found in the massive quartz in the Cretaceous units. Occasionally, pockets of centimeter-sized or rarely larger crystals occurred in the Bolsa quartzite, particularly at the contact with the Abrigo limestone.

Amethystine quartz was widely distributed in small amounts in the primary ores. Usually the amethyst was in small crystals and pale in color. There was one occurrence in the Junction mine where the color of the amethyst was fairly intense.

Quartz cast pseudomorphs after calcite have been recognized from several localities within the district. Other pseudomorphs by quartz from the district are unknown.

OCCURRENCES: Only a few of the more interesting localities will be noted because of the widespread, typically unimpressive nature of this common species.

Bisbee Queen Mine, *100 level;* Small (>1 cm), but transparent and brilliant citrine-yellow crystals lined fist-sized vugs in the silica breccia that this mine was exploring.

Campbell Mine, *2966 level;* Amethyst crystals to a centimeter in length occurred in vugs in pyrite/chalcopyrite ores in a stope mined from this level.
3100 level, 42 crosscut; Crystals to 5 cm with green fluorite were found by one of the authors, while conducting geologic mapping here. These crystals were white in color.

Cole Mine, *1100 level;* Plates of amethyst quartz to 25 cm were found on this level. These were composed of 5 mm pale crystals on siliceous, pyritic limestone.

Easter Sunday Mine, This small gold mine on the eastern fringe of the district produced a small number of well-formed, quartz casts of two-centimeter calcite scalenohedrons.

Higgins Mine, *Tunnel level;* Loose, doubly terminated, milky crystals to 15 cm were found in soft material derived from oxidized pyrite in the footwall of a fault near a sulfide stope on this level.

Junction Mine, *2566 level;* Amethystine quartz casts of calcite scalenohedrons to 10 cm with later goethite-coated calcite were found on this level.
2700 level; A very large pocket produced a great many amethyst specimens. The crystals ranged in size from 2 to 9 mm in width and up to 8 mm in length. Color intensity varied from almost colorless to nearly black as a function of location within the opening. Those crystals closer to the bottom were typically larger and darker. Calcite was common as a partial overgrowth on these specimens.

Southwest Mine, Small pockets of thin, red, centimeter-long crystals with included specular hematite were found in a silica breccia in this mine.

R

RAMSDELLITE MnO_2:

This supergene species has been identified as a constituent of several of the near-surface manganese deposits in the district. While ramsdellite is not rare in these deposits, it is not particularly abundant.

For the most part, ramsdellite occurred as an earthy material and rarely as small steel-gray, metallic crystals with a divergent structure. Less often, it was found as tiny prismatic crystals along fractures in mixed, massive manganese oxide ores.

The species associated with ramsdellite at Bisbee are:

braunite
cryptomelane
conichalcite
manganite
hematite
groutite
goethite
romanèchite
calcite

OCCURRENCES:

Higgins Mine, *Twilight claim;* Ramsdellite was a modest constituent of the ores mined here as an earthy material. It was also found as compact, cleavable masses of divergent crystals to 1 cm thick with calcite and very minor conichalcite. Fractures in the mixed, massive manganese ores here were occasionally lined with drusy ramsdellite crystals.

White Tailed Deer Mine, Several of the small, near-surface manganese deposits close to this mine contained modest amounts of ramsdellite as both earthy material and as tiny, tabular crystals.

RANSOMITE $Cu^{2+}Fe_2^{3+}(SO_4)_4 \cdot 6H_2O$:

This rare mineral was recognized in post-mining occurrences in several widely spaced locations in the district. The similarity of ransomite to cuprian melanterite and less so to chalcanthite may have caused it to be overlooked in other occurrences.

Typically, ransomite occurred as small, bright blue to dull blue, acicular crystals as part of a multi-mineral crust on mine openings in warm, moist pyrite/copper sulfide areas. Ransomite was typically the top-most mineral in these crusts.

The species associated with ransomite are:

römerite
chalcopyrite
voltaite
rhomboclase
pyrite
bornite

OCCURRENCES:

Campbell Mine, *1800 level;* Large areas of a pyrite/minor chalcopyrite zone were partially covered by crusts of bright blue ransomite as small acicular crystals with melanterite, and minor römerite and voltaite.

Cole Mine, *700 level;* Found in small amounts as patchy crust of blue acicular crystals on pyrite with minor bornite.

Higgins Mine, *Tunnel level;* Small clusters of pale blue, radiating crystals of ransomite were found with other post-mining minerals in a massive sulfide stope near the Wolverine interior shaft on this level by the authors in 1998.

RHODOCHROSITE $Mn^{2+}CO_3$:

This was an uncommon mineral from the district in spite of the abundance of manganese in the ores. All of the recognized occurrences are of hypogene origin and are generally associated with alabandite.

The species associated with rhodochrosite are:

alabandite
calcite
pyrite
dolomite

OCCURRENCES:

Briggs Mine, *1500 level, 104 stope;* It was noted from here as inclusions of massive material in calcite at the limestone contact with ore (Bateman, et al. 1914).

Higgins Mine, *Tunnel level, 3 crosscut;* Rhodochrosite was found here in a dolomitic limestone as small amounts of massive material with alabandite (Hewett and Rove, 1930).
100 level; As massive material with paragenetically earlier alabandite in a manganiferous dolomite (Hewett and Rove, 1930).

Junction Mine, *1500 level, 78 stope;* It was observed here with sphalerite and galena by Bateman, et al. (1914).
2200, 2300 and 2433 levels; as part of a multi-mineral fault gangue in the Mountain Maid orebody mined on these levels.
2300 level; This was the most prolific locality for rhodochrosite in the district. Here it was usually found as massive material as thin veins or as very tin linings in cracks in alabandite and associated with sphalerite. It also rarely occurred as small, pale pink tabular crystals in massive alabandite and as 2 mm highly modified scalenohedrons in small voids in alabandite. These voids were usually at the limestone contact with the sulfides.

RHODONITE $Mn^{2+} SiO_3$:

This hypogene mineral has been noted in modest amounts at several locations in the district. by Nye (1968).

The species associated with rhodonite are:

alabandite
rhodochrosite
quartz
calcite
magnetite
hematite
pyrite
siderite
anhydrite
dolomite
braunite

OCCURRENCES:

Campbell Mine, From and undetermined level in this mine as a part of a primary manganese mineral assemblage with alabandite and rhodochrosite associated with sulfide deposits (Nye, 1968).

Cole and Dallas Mines, In these mines as a minor gangue mineral with sulfide ores (Nye, 1968).

RHODOSTANNITE $Cu_2FeSn_3S_8$:

This hypogene mineral was noted at a single locality in one mine. In this instance it was part of a complex assemblage in pyrite and sphalerite.

The species associated with rhodostannite are (Sid Williams, personal communication, 1987):

- pyrite
- altaite
- sphalerite
- melonite
- calaverite
- volynskite
- galena

OCCURRENCES:

Campbell Mine, *2200 level;* Rhodostannite was recognized as micro-phase inclusions in a pyrite-sphalerite ore with the above noted minerals (Sid Williams, personal communication, 1987).

RHOMBOCLASE $(H_5O_2)Fe^{3+}(SO_4)_2\cdot 2H_2O$:

This locally abundant mineral has been recognized in post-mining occurrences only. It is highly probable that rhomboclase occurred as a supergene mineral as well but its solubility and nondescript appearance may have caused it not to be recognized.

Typically, rhomboclase occurred as white to pale yellow fibrous growths forming part of efflorescent crusts that partially lined mine openings in warm, moist areas of oxidizing pyrite. It is almost always associated with other post-mining iron sulfates. Usually, rhomboclase is formed in contact with the decomposing pyrite with other similar species overgrowing it, often forming a crust that can reach 10 cm in total thickness. Small, colorless to white stalactites of rhomboclase have been found as well.

The species associated with rhomboclase are:

- voltaite
- chalcanthite
- römerite
- ransomite
- coquimbite
- copiapite
- kornelite
- halotrichite

OCCURRENCES:

Campbell Mine, Many areas of this large, sulfide-rich mine contained post-mining crusts composed of a number of minerals, including rhomboclase.
1800 level; Large areas of several crosscuts near the shaft on this level contained crusts composed of several post-mining minerals including white to blue-white rhomboclase.

Cole Mine, *800 level;* Small white to gray tabular crystals of rhomboclase formed directly on pyrite wall rock and were partially overgrown by voltaite and copiapite.

Czar Mine, *400 level;* Small, white bladed crystals formed a patchy crust on a pyritic porphyry for almost 35 meters along the walls of a crosscut near the old Holbrook shaft on this level.

Higgins Mine, *Tunnel level;* Colorless to white stalactites to 4 cm with a radiating internal pattern were found directly on oxidizing, massive pyrite here. Minor copiapite, halotrichite and römerite were present as well. Also, it was found here as white to yellow-white fibrous growths on oxidizing pyrite with copiapite.

Junction Mine, Rhomboclase was a common part of the abundant post-mining assemblage throughout this vast mine. Typically, it occurred in the areas where pyrite was oxidizing in non-reactive rocks such as a porphyry or highly siliceous pyritic areas.

Sacramento Mine, The material studied by Merwin and Posnjak (1937) almost certainly came from this mine and not the Copper Queen as reported by the literature. Here it was part of a multi-mineral, post-mining assemblage that included voltaite, römerite, coquimbite, copiapite, and chalcanthite. Many areas in this large mine contained these post-mining crusts, most of which contained rhomboclase.

RICKARDITE $Cu_{3-x}Te_2$:

This primary mineral is apparently quite rare in the district. However, given the distribution of tellurium in the district, the typical small particle size of the tellurium-bearing minerals at Bisbee and its general similarity to bornite, other rickardite occurrences may have gone unrecognized.

Typically, rickardite occurred as tiny blebs and grains included in other minerals.

The species associated with rickardite are:

henryite
sylvanite
hessite
petzite
pyrite

OCCURRENCES:

Campbell Mine, Rickardite occurred here in very small amounts as minute patches of compound grains with sylvanite in henryite (Criddle, et al. 1983)

Junction Mine, It was noted from here by Crawford (1930) as small purple grains in a sulfide pulp sample. A positive analysis for tellurium coupled with the distinctive purple color was considered a positive identification. Thus, there is some doubt surrounding this occurrence.

ROMANÈCHITE $(Ba,H_2O)_2(Mn^{4+},Mn^{3+})_5O_{10}$:

This supergene mineral was widely distributed, generally in small amounts, in many of the near-surface manganese deposits. In several of these deposits it was found in sufficient amounts to constituent an important part of the ores mined.

Typically, romanèchite formed as a result of the alteration of alabandite (Junction mine) or braunite (Higgins mine). Most of it occurred as a brownish-black to black earthy material with small amounts as a black, compact material.

The minerals associated with romanèchite are:

braunite
baryte
pyrolusite
hematite
calcite
goethite
manganite

OCCURRENCES:

Higgins Mine, *Twilight Claim;* Romanèchite was an important ore here and occurred in large amounts as a black to brown-black soft, spongy material that was an alteration product of braunite, along with unaltered braunite, pyrolusite, baryte, hematite, and calcite.

Junction Mine, *1300 level;* The large manganese deposit on this level first noted by Ransome (1920) was largely romanèchite. Here it was formed as an alteration of alabandite and was generally soft and earthy. Goethite as well as several other unidentified manganese oxides were associated with romanèchite at this occurrence.

Number 4 Claim; Large parts of the ores mined here were soft to compact romanèchite associated with braunite, pyrolusite, and minor manganite.

RÖMERITE $Fe^{2+}Fe_2^{3+}(SO_4)_4 \cdot 14H_2O$:

This is a widely distributed and locally abundant mineral that has only been recognized in post-mining occurrences. There can be little doubt, however, that römerite also occurred under pre-mining, supergene conditions, but was not recognized.

The most common form for römerite was as a brown to yellow-brown, very fine-grained to granular growth as a part of the common, multi-mineral, post-mining crusts on pyrite. These crusts formed on pyritic rocks in warm, moist areas. Also, römerite often occurred in large, moist, soft masses overgrowing and including other post-mining minerals. These masses were frequently quite impure, containing other similar minerals and including pyrite fragments, as well as timber pieces and small rock chips, as they grew extrusion-like.

The species most commonly associated with römerite are:

pyrite
coquimbite
melanterite
rhomboclase
kornelite
voltaite
paracoquimbite
copiapite
halotrichite

OCCURRENCES:

Campbell Mine, This was one of the more common post-mining minerals in this large mine. It was found in numerous places as part of the common crusts in old mine workings.
1800 level; Thick crusts of römerite were extruding from the floor of mine workings in several areas on this level.

Cole Mine, Many areas in this mine contained the typical post-mining crust of minerals with römerite as one of the principal constituents.

Dallas Mine, The lower portions of this mine, particularly toward the Lowell and Junction mines, had developed thick post-mining growths containing römerite.

Higgins Mine, High-sulfide material on the dump developed a römerite/copiapite mixture that would appear following rain.
Tunnel level; Massive yellowish römerite was found in a sulfide stope on this level. It was associated with melanterite.

Junction Mine, Römerite was one of the principal minerals in the post-mining crust that were so common throughout the high-sulfide portions of this extensive mine.
1500 level, 44 crosscut; Spongy crust of römerite were extruded from the pyritic floor of this area to a thickness of 40 cm.

Lavender Pit Mine, This is one of the more common post-mining minerals that form on the pit walls in moist, high-pyrite areas, typically with voltaite. As might be expected it is constantly removed and regenerated by the normal wet and dry cycles.

Sacramento Mine, This mine was almost certainly the source of the material studied by Merwin and Posnjak (1937) and not the Copper Queen as stated in the literature. Here römerite occurred in a number of places as a main constituent of the common post-mining crusts that formed along the mine openings, particularly in the porphyry.

ROQUESITE $CuInS_2$

This hypogene mineral was recognized by Schumer (1917) as a very minor component of a complex sulfide mix.

The species associated with roquesite are:

chalcopyrite	bornite	chalcocite	digenite
sphalerite	tellurium	kostovite	pyrite

OCCURRENCES:

Campbell Mine, *2000 level;* Tiny amounts of roquesite were found here as compound inclusions in pyrite and other sulfide minerals as part of a multi-mineral assemblage in granular pyrite in bornite-rich ores (Schumer, 2017).

ROSASITE $(Cu^{2+}, Zn)_2(CO_3)(OH)_2$:

This is a widespread supergene mineral, particularly in the western part of the district, though seldom found in large amounts. Bisbee has produced the some of the finest examples known of this attractive mineral.

Rosasite was typically a late-forming mineral in the supergene process. Its most common mode of occurrence was as small, scattered blue to blue-green spheroids and irregular masses of less than 1 cm on goethite or hematite boxwork. On rare occasion, the small spheroids were on a smithsonite boxwork. Thin, discontinuous veinlets of rosasite along relic boxwork planes in soft goethite or manganese oxides were common in some areas.

The finest specimens of this species were found as blue-green, mammillary or botryoidal linings of voids, usually in boxwork goethite or hematite. Stalactitic forms would also develop in these openings. Manganese oxides in boxwork form were also host to these types of rosasite deposition.

Much of the rosasite at Bisbee appears to have formed as the result of the action of low to moderate pH, zinc-rich solutions on malachite. In many instances the replacement is complete with little or no alteration of the physical form of the original malachite. However, replacement veneers of rosasite on malachite are one of the more commonly recognized occurrences for this mineral.

The minerals known to occur with rosasite are:

goethite
hemimorphite
malachite
calcite
smithsonite
murdochite
aurichalcite
pyrolusite
hematite
plattnerite

Rosasite has been recognized as partial to complete replacements of several forms of malachite. Among these are the replacements of what probably were originally pseudomorphs of malachite after azurite or cuprite resulting in an apparent pseudomorph of rosasite after azurite or cuprite. This replacement resulted from the malachite being subjected to zinc sulfate solutions of varying strength, pH or time.

OCCURRENCES

Cole Mine, *1200 level, 26-J stope;* What may well be the finest examples of this species were found at this locality as deep blue to green reniform and stalactitic specimens of up to 30 cm, often with colorless calcite on hematite.

Copper Queen Mine, *"A" level;* It was reasonably common in several places on this level as 1 to 2 mm spheres on hematite.

Czar Mine, Rosasite came from here as replacement veneers on malachite that occasionally have distinct, relic solution lines where the malachite is unaltered above the apparent line or where the malachite is covered by calcite. Also, from this mine rosasite was found as 2 to 4 mm veins and botryoidal linings in voids in soft manganese oxides. Small spheres (2 mm) of rosasite occurred here on boxwork goethite with aurichalcite and were often covered with tiny, colorless hemimorphite crystals.

Holbrook Mine, *100 level*; Rosasite was noted by the authors on this level as 5 mm spheroids on punky altered limestone or on impure goethite with plattnerite and calcite. This occurrence is along the wall of an oxidation cave in an area not covered with travertine. Other minerals that are nearby but not directly associated are murdochite and malachite.
200 level; It came from here as replacement veneers of 2 mm thickness on zincian malachite.

Southwest Mine, *3rd level;* A number of specimens from the lead/zinc stopes on this level contained rosasite as pseudomorphs after small tufts of acicular malachite with hemimorphite.
5th level; This level had rosasite that occurred as 2 to 4 mm spherical inclusions in calcite.
6th level; A stope 90 feet above the level contained rosasite as velvety crusts to 4 mm thick on black, altered Martin limestone with some hydrozincite, which had formed as an alteration of rosasite. Also, from this same stope, it was found as 1 to 2 mm spheroids perched on colorless hemimorphite blades and as overgrowths on acicular aurichalcite. It was also found in another stope some 75 feet above the level as a velvety 2 mm crust on limestone with later delicate, colorless to white calcite crystals. Elsewhere on this level, rosasite was found as 2 mm spheroids on calcite and aragonite in a small cave above an orebody.
10th level; Small specimens of reniform material with calcite and hemimorphite were found here.

Uncle Sam Mine, *"A" level;* Fine, apparent pseudomorphs of rosasite after azurite crystals to 1.5 cm associated with minor, later, 2 mm hemimorphite crystals, as well as aurichalcite and some residual malachite were found here. These pseudomorphs are often incomplete replacements by rosasite of malachite pseudomorphs after azurite. While crystals of less than 1 cm were usually totally replaced, the larger crystals have only a surficial alteration that did not exceed 5 mm with the cores remaining malachite.
"B" level; It was found here as velvet, botryoidal linings to 1 cm thick of pockets in the walls and in boulders in a small oxidation cave. Aurichalcite also occurred in these pockets as a partial overgrowth on the rosasite.

ROSCOELITE $KV_2\square AlSi_3O_{10}(OH)_2$:

This rare hypogene mineral is a member of the mica group (Anthony, et al. 1995). It has been found in minor amounts at a single locality in one mine. At this occurrence it was part of a very complex assemblage of tin-tungsten-vanadium minerals that formed as a replacement of pyrite (Alan Criddle, personal communication, 1992).

The species associated with roscoelite are (Alan Criddle, personal communication, 1992):

stannoidite
mawsonite
scheelite
nolanite
magnetite
hematite
stannite
colusite
cassiterite
rutile
stützite
galena
kësterite
kiddcreekite
"wolframite"
tellurium
melonite
chalcopyrite
nekrasovite
pyrite
altaite
sphalerite
hessite
quartz

OCCURRENCES:

Campbell Mine, *2566 level;* Modest amounts of roscoelite were found on this level associated with the above species and as part of a complex assemblage replacing pyrite (Alan Criddle, personal communication, 1992).

ROZENITE $Fe^{2+}SO_4 \cdot 4H_2O$:

This mineral has been recognized in post-mining occurrences only. The apparent limited distribution of this mineral is undoubtedly a result of its nondescript appearance.

Rozenite typically occurs as part of the multi-mineral, post-mining assemblage in many of the pyritic zones of several mines. Here, it was found as a white powdery efflorescence on other post-mining minerals. In the Campbell occurrence, rozenite, along with siderotil, appeared to be a dehydration product of melanterite caused by a change in ventilation patterns that brought in dryer air.

The species associated with rozenite as noted by Anthony, et al. (1995) and Graeme (1981) are:

pyrite
coquimbite
copiapite
hexahydrite
siderotil

OCCURRENCES:

The occurrence listed in Anthony et al. (1995) as the Copper Queen mine is almost certainly a different locality. In this case, rozenite was noted as a powdery white crust on coquimbite, copiapite, and other post-mining minerals.

Campbell Mine, *2700 level, 42 crosscut;* Rozenite was found in small amounts at this locality as a white crust on pyritic limestone with hexahydrite.

RUCKLIDGEITE $PbBi_2Te_4$:

This hydrothermal mineral has been recognized only in very small amounts at a single locality. Here, it was part of a complex mineral assemblage that was found as compound inclusions in pyrite as well as replacing granular pyrite (Alan Criddle, personal communication, 1992).

The species associated with rucklidgeite are (Alan Criddle, personal communication, 1992):

chalcopyrite
djurleite
sphalerite
stützite
bornite
covellite
galena
stannite
chalcocite
tennantite
altaite
mawsonite
digenite
pyrite
hessite
rutile

calaverite
cassiterite
melonite
wittichenite
tetradymite
gold
kësterite
kiddcreekite
sylvanite
goldfieldite
volynskite
tellurium
kostovite
colusite

OCCURRENCES:

Campbell Mine, *2300 level, 125 stope;* Tiny amounts of rucklidgeite were found here as compound inclusions in pyrite and as part of a multi-mineral assemblage replacing granular pyrite (Alan Criddle, personal communication, 1992).

RUTILE TiO_2:

This hydrothermal species is widely distributed in very small amounts in the several intrusive units. The Juniper Flat granite in the northwestern portion of the district contained rutile as a minor accessory mineral (Anthony, et al. 1995). Bryant and Metz (1966) reported rutile in both of the intrusive units comprising the Sacramento Stock Complex in the area of the Lavender pit. Schwartz (1947) also noted it as clusters of crystals in sericite pseudomorphs after "biotite" in one of the porphyry units near the top of Copper Hill, well north of the Dividend fault.

Rutile typically occurred as cluster of microscopic, needle-like crystals in and with other species in granitic rocks. The more common species associated with rutile are:

quartz
plagioclase
magnetite
zoisite
apatite
hematite
muscovite
"biotite"
chlorite
orthoclase
kaolinite
allophane

OCCURRENCES: Because rutile is so widespread and found only in microscopic crystals, just a few typical occurrences to supplement those generally referenced above will be noted.

Holbrook Mine, *500 level;* Several areas on this level contained altered pyritic porphyry with minor rutile that formed as an alteration of sphene (titanite) and/or ilmenite (Tenney, 1913).

Gardner Mine, *1000 level, 21 drift;* Needle-like crystals of rutile were found in quartz in one of the porphyry units here (Tenney, 1913).

Sacramento Mine, *1000 level;* Rutile was a common accessory mineral in the mineralized stock on this level (Tenney, 1913).

S

SANIDINE $(K,Na)AlSi_3O_8$:

This hydrothermal species has been noted to occur in the district by Anthony, et al. (1995) in their table of rock-forming, gangue, and alteration minerals at Bisbee. However, no information regarding the mode of occurrence or the area where it occurred is provided.

SCHEELITE $CaWO_4$:

This hypogene mineral is relatively uncommon within the district. Scheelite occurs here in small amounts in several areas. Typically, it was found in very small, if not tiny amounts in quartz veins in the Cretaceous sediments. Thus, it is obviously post-Cretaceous.

Scheelite was also noted as part of tin-tungsten and vanadium-rich, compound inclusions in a complex mineral assemblage within sulfide ore minerals in a pyrite, quartz, and calcite matrix (Alan Criddle, personal communication, 1992; Sid Williams, personal communication, 1987) and as a minor gangue mineral by Schumer (2017) who also noted the sulfidation of Sn and W to make the accessory sulfides of these phases (stannoidite, tungstenite, etc.) in place of earlier cassiterite and scheelite.

The species associated with scheelite are (Alan Criddle, personal communication, 1992; Anthony, et al. 1995):

- pyrite
- nekrasovite
- cassiterite
- tellurium
- stützite
- fluorite
- stannoidite
- mawsonite
- nolanite
- sphalerite
- hessite
- ilsemannite
- stannite
- kiddcreekite
- quartz
- altaite
- chalcopyrite
- chalcocite
- kësterite
- calcite
- “wolframite”
- magnetite
- cuprotungstite

OCCURRENCES:

An unnamed prospect shaft in the extreme southeastern part of the district, approximately 2 km. east of the Portage Lake mine, contained modest amounts of scheelite as tan patches to 10 cm in massive white quartz with chalcocite and minor cuprotungstite.

Anthony, et al. (1995) noted scheelite from an unspecified locality near Warren. It occurred in a silicified limestone with fluorite and ilsemannite.

Campbell Mine, *2566 level;* Very small amounts of scheelite were found as part of a tin-tungsten-vanadium-rich, complex assemblage that occurred as inclusions in sulfides (Alan Criddle, personal communication, 1992).

Cole Mine, *1300 level;* Scheelite came from this level in minor amounts with kiddcreekite, hübnerite, pyrite, bornite and chalcopyrite, and all in specimens that have a crust of chalcocite crystals and some elemental gold (Sid Williams, personal communication, 1987).

Higgins Mine, *Tunnel level;* Schumer (2017), noted scheelite from here by in a gangue of fluorapatite, chlorite, and quartz in association with chalcopyrite, tetradymite, sphalerite and pyrite.

SCHORL $NaFe_3^{2+}Al_6(Si_6O_{18})(BO_3)_3OH$:

The tourmaline group mineral noted by Ransome (1904) in his work on the district and that found by Bonillas, et al. (1916) is schorl. It was recognized as a minor accessory mineral in one of the several intrusive units as well as in the Pinal schist. Typically, schorl was found as nests of tiny crystals included in other minerals or as isolated prisms to 0.25 mm in size.

The species associated with schorl at Bisbee are:

quartz
zircon
ilmenite
orthoclase
sericite
muscovite
magnetite
fluorapatite
chlorite

OCCURRENCES:

Ransome (1904) found schorl as nests of tiny, prismatic crystals in muscovite in the Juniper Flat granite. It was also included in quartz and orthoclase. Bonillas, et al. (1916) also recognized schorl as a microscopic accessory mineral in this intrusive unit.

In the Pinal schist, schorl occurred as tiny isolated prisms in a sericite/quartz matrix with chlorite, zircon, and magnetite (Ransome, 1904).

SCORODITE $Fe^{3+}AsO_4 \cdot 2H_2O$:

A secondary mineral of limited distribution, it appears to be restricted to the oxidized capping of the younger porphyry unit of the Sacramento Stock Complex

The species associated with scorodite are:

pyrite
goethite
quartz

OCCURRENCES:

Lavender Pit mine, Rare, vitreous, patchy crust of gray- blue scorodite were noted by one of the authors in vuggy, quartz-rich oxidized porphyry with minor, corroded pyrite during the stripping operations in the mid-1960s.

SCORZALITE $(Fe^{2+},Mg)Al_2(PO_4)_2(OH)_2$:

This unusual species has been found in tiny amounts only, in what appears to be a supergene environment.

The species associated with scorzalite are:

variscite	pickeringite

OCCURRENCES:

Lavender Pit mine *Holbrook Extension;* Tiny amounts of pale blue scorzalite were noted in massive variscite in specimens from this area of the pit (Rob Bowell, personal communication 2004). Minor pickeringite was associated with this material as well.

SENGIERITE $Cu_2(UO_2)_2(VO_4)_2 \cdot 6H_2O$:

This is a rare secondary mineral that has been found in only one mine in the district. When it was first identified at Bisbee, this occurrence was the first recognized in the United States (Hutton, 1957).

The most typical mode of occurrence for sengierite here was as bright, yellow-green patches on chalcocite that were pulverulent to drusy in appearance. Rarely, it was found as tiny crystals in cavities in chalcocite.

The minerals recognized as being associated with sengierite are:

chalcocite	malachite	covellite	chlorargyrite

OCCURRENCES:

Cole Mine, *1100 level;* Sengierite was moderately abundant at this one locality as bright patches to 5 cm on fracture faces in massive chalcocite with minor malachite. In a few instances, tabular, bluish-green crystals to 0.02 mm were found in small voids in the massive chalcocite.

SEPIOLITE $Mg_4Si_6O_{15}(OH)_2 \cdot 6H_2O$:

This typically hydrothermal alteration mineral is probably more common than the few confirmed localities would suggest.

Two distinct types of occurrences have been recognized within the district. One of these is the typical hydrothermal alteration type of occurrence while the other is of a somewhat nebulous origin.

The material developed through hydrothermal alteration is derived from the alteration of the dolomitic Martin limestone and was found as a tan, impure fibrous material (Fabien Cesbron, personal communication, 1981). In the other type of occurrence, sepiolite has been found as white, light-weight, almost popcorn-like forms in the bottom of two oxidation caves.

Many tons of this type of sepiolite occurred in these caves, both of which are in the Martin limestone. It is possible that it was a residual product from the dissolving of the limestone. However, it seems more reasonable that the sepiolite was deposited in the openings, probably when these parts of the caves were filled with water.

The species associated with sepiolite are:

talc
antigorite
dolomite
calcite
aragonite

OCCURRENCES:

Cole Mine, *1000 level;* Hydrothermally developed sepiolite occurred here in epizonally altered Martin limestone with talc and antigorite (Fabien Cesbron, personal communication, 1981).

Southwest Mine, 6th *level;* Numerous small, rounded, spongy pieces and compact nodules of sepiolite occurred in the bottom of a small oxidation cave just above this level. Many of these were overgrown or connected into clusters with a thin crust of dolomite. A mild green fluorescence is characteristic of these specimens.
7th level; One part of a very large oxidation cave 80 feet above the level contained large volumes of loose, light, almost popcorn-like pieces of sepiolite filling the bottom of this area of the cave. Acicular aragonite had overgrown a small amount of this material.

SHATTUCKITE $Cu_5(Si_2O_6)_2(OH)_2$:

Bisbee is the type locality for this mineral (Schaller, 1915), however, it was never particularly common, even at the type locality. In all, three separate occurrences for this species have been recognized in the district.

Shattuckite from the type locality appears to have largely been formed at the expense of malachite by direct replacement, with the occasional formation of distinct pseudomorphs. Also, many of the specimens recovered from here show relic textures of the original malachite. In some cases, however, the copper may have been at least partially remobilized as the form of the shattuckite is decidedly different and there is less evidence of malachite as a direct source. The distribution of the two forms are intermixed in the type locality - a small, near-vertical fault controlled, lenticular and thoroughly oxidized ore pod at the edge of a silica breccia.

The material that is an obvious malachite replacement is quite compact, often grading into malachite, and occasionally with included, residual malachite showing alteration rinds. In color, this shattuckite is often slightly darker in hue.

Typically, the material that is not obviously a replacement of malachite is much less compact and contains a number of voids with oolitic forms. The small spheroids are usually covered with tiny, acicular crystals that range in hue from light to dark blue.

A second occurrence for shattuckite has a markedly different appearance. In this instance, it is found as patches up to a centimeter across in limestone that is partially replaced by an undetermined manganese oxide. Here, the shattuckite is intimately intergrown with planchéite.

Other species that are associated with shattuckite are:

malachite
chrysocolla
quartz
hematite
plancheite
“bisbeeite”
willemite
calcite

As noted above, shattuckite has been found as pseudomorphs after malachite. “Bisbeeite” is associated with some shattuckite as pseudomorphs after shattuckite included in shattuckite pseudomorphs after malachite. Chrysocolla has been observed as a partial replacement of fibrous shattuckite as well.

OCCURRENCES:

Higgins Mine, *Twilight claim;* The large manganese mine on this claim contained irregular patches of shattuckite mixed with plancheite in altered limestone and associated with willemite and calcite surrounded by a massive silica breccia.

Lowell Mine, A shallow prospect shaft very near this mine contained minor amounts of shattuckite as small, irregular blebs in chrysocolla. As is typical for the species, it had formed as a replacement of malachite. Unaltered malachite and quartz were also associated with shattuckite at this occurrence.

Shattuck Mine, *200 level*, *169 prospect;* This is the type locality for shattuckite which still contained some material when the mine was briefly reopened in 1974. It occurred here as compact masses that are usually an obvious replacement of malachite and often associated with coarsely crystalline malachite that is partly altered to shattuckite. Also, shattuckite occurred here as small spheroids of radiating acicular crystals in voids associated with malachite, minor chrysocolla and, rarely, “bisbeeite.” Also, a few masses to 50 cm were found as compact replacements of silica breccia fragments, encased in the silica breccia along the controlling fault.

SIDERITE $Fe^{2+}CO_3$:

Siderite is an abundant, widely distributed mineral throughout the district. The vast majority of the siderite found here is of supergene origin. However, locally, significant amounts of hypogene siderite have been recognized as a component of the gangue mineralogy in the lead/zinc orebodies and to a lesser degree, some chalcocite rich orebodies (Schumer, 1917).

Siderite was one of the earliest forming of the supergene minerals which developed by the reaction of iron sulfate-rich waters with limestone (Tenney, 1933). It was usually found in boxwork forms reflecting deposition along fractures and the ultimate removal of portions of the limestone below or in the footwall of oxidizing sulfide bodies. Supergene alteration of the iron sulfide components of copper as well as of lead and zinc orebodies and pyritic masses all produced siderite. Typically, the material was found as fine-grained or drusy botryoidal growths on the boxwork planes up to 2 cm thick and frequently iridescent. Continued oxidation of the sulfides altered siderite to goethite while retaining the boxwork form (Ransome, 1904; Trischka, et al. 1929; Tenney, 1933).

Trischka, et al. (1929), in discussing its use as a guide in prospecting as well as its relationship to ores, notes that siderite was found in large masses under chalcocite ores and, in places, was associated with boxwork smithsonite. Mine rock and air temperatures were substantially elevated in siderite zones, an indication of ongoing supergene activity (Trischka, et al. 1929). Large volumes of trapped carbon dioxide were occasionally liberated during the mining of the siderite zones. In some instances, so much carbon dioxide was liberated that it was necessary to evacuate the miners from the area for safety reasons because of this gas (Bateman, et al. 1914).

Elemental copper, cuprite, and malachite have all been found as inclusions in siderite and are obviously secondary, but are relatively rare. In one instance in the Czar mine, sufficient copper and cuprite were in included in siderite to constitute ore (greater than 5% copper) (Bonillas, et al. 1916). Far more common as inclusions in the siderite boxwork cores were euhedral crystals of sulfide minerals that appear to be supergene in origin. Pyrite, chalcopyrite and sphalerite (Trischka et al. 1929) were common. Bateman. et al. (1914) as well as Bonillas, et al. (1916) also observed galena as an inclusion along with the aforementioned sulfides and suggested that they all had a supergene genesis.

Hypogene siderite has been noted as gangue in a number of places in the district, however, it is almost certainly more common than the few recognized occurrences would indicate. The most typical occurrence is as a massive material associated with primary sulfides.

The most common minerals associated with siderite were:

calcite
quartz
gypsum
goethite
chalcocite
pyrite
galena
smithsonite

Pseudomorphs of siderite after calcite have been found in several places within the district and pseudomorphs after small pyrite crystals were noted in one mine. Goethite pseudomorphs after siderite were common in several localities.

OCCURRENCES:

Campbell Mine; Schwartz and Park (1932) noted massive "mangano" siderite with sulfide ores at an unspecified locality in this mine.

Cole Mine, *1300 level;* Siderite was noted by one of the authors at this locality as clusters of 6 mm tan crystals on bornite that are of hypogene origin.

Czar Mine; Siderite was common here as fine grained, iridescent, botryoidal material encasing supergene sulfides, particularly on the lower levels. The siderite from the Czar was often found altering to goethite (Trischka, et al. 1929) and less frequently replaced by smithsonite. Bonillas, et al. (1916) noted that some siderite in this mine had served as a depositional base for considerable amounts of cuprite and copper. Occasionally, it was also found as a thick, massive material with a surface covering of 2 to 4 mm rhombohedral crystals.
300 level 92-7 stope; Boxwork siderite with inclusions of copper and cuprite was found in a fault zone at this locality (Tenney, 1913).

Dallas Mine, *1400 level;* Clusters of tan to brown 2 mm crystals were found here as a patchy overgrowth on cuprite and copper.

Gardner Mine, *800 level*; Botryoidal crust of siderite to 1 cm formed on sphalerite with occasionally with 2 to 4 mm sphalerite crystals on the siderite. Also it was found here as pseudomorphs after 6 to 8 mm pyrite crystals in limestone. Additionally, from this level, in the 813 drift and near the Irish Mag sideline, hypogene siderite was found as tiny crystals lining vugs in a mixture of sphalerite and chalcopyrite (Tenney, 1913).
900 level, 1 drift; Fine, brown to reddish brown crystals to 5 cm on needle-like quartz crystals came from here (Tenney, 1913). This was probably hypogene material.
1550 level; On this level and close to the Lowell mine, siderite occurred as a large mass of thick, botryoidal material in boxwork form below a partially oxidized body of semi-massive pyrite and chalcopyrite (Blanchard, 1968).

Hoatson Mine; Siderite came from here as 4 mm transparent rhombohedrons scattered on massive boxwork siderite.

Holbrook Mine; Siderite was very common in the deeper parts of this mine and was occasionally associated with smithsonite boxwork (Trischka, et al. 1929; Bateman, et al. 1914).

Junction Mine, *2200-2566* levels; An area from just above the 2200 level down almost to the 2566 level was comprised of large masses of boxwork siderite that included numerous interconnected voids and small caves. A great many fine, often very large specimens of iridescent, botryoidal and stalactitic siderite were recovered from this remarkable locality. Typically, this material was iridescent with drusy, dark brown crystals overgrown on compact tan siderite. Some non-iridescent, drusy, tan examples were found below the 2300 level, while specimens from well above the 2300 level often have a thin, late stage crust of dull siderite crystals that precipitated on the side that faced almost upwards but inclined enough to suggest possible pre-Cretaceous deposition in a subaqueous environment. However, inasmuch as the partial coating appears to have been a precipitate, one can only assume a vertical fall. Inclusions of apparently supergene pyrite, sphalerite, and minor galena along the boxwork planes were common from all parts of this occurrence.

Lavender Pit Mine, *Holbrook Extension;* Siderite was common here as boxwork forms made of thin botryoidal crusts occasionally associated with smithsonite. Also, it was rarely found as very faithful pseudomorphs after 2 cm scalenohedral calcite crystals.

Lowell Mine, *1100 level, 1107 drift;* Drusy, boxwork material with inclusions of apparently supergene pyrite, sphalerite, and chalcopyrite was found here by Tenney (1913).
1200 level; Siderite was common on this level and in large amounts below an oxidizing orebody and, in part, altering to goethite (Tenney, 1913).
1400 level; It was noted from here as botryoidal material encasing sphalerite by Bateman, et al. (1914).

Sacramento Mine; Siderite was very abundant in this mine as often large, handsome, botryoidal specimens that are fine-grained and iridescent. These specimens are often associated with siliceous breccia fragments and, on rare occasion, copper and malachite, both as inclusions in the siderite and as scattered crystals in vugs in the siderite. Also from here as primary siderite that occurred cementing fragments in a copper sulfide breccia (Trischka, et al.1929).
900 level, 929 drift; Substantial amounts of boxwork siderite with inclusions of pyrite, sphalerite and chalcopyrite were found at a porphyry-limestone contact on at this locality (Tenney, 1913).
1*300 level to 1500 level*; An extensive zone of boxwork material with gypsum occurred here (Bateman, et al. 1914).
1400 level, *23 crosscut*; Crystals of hypogene siderite occurred in small vugs in massive pyrite at this locality (Bateman, et al. 1914).
1500 level, 1523 drift; Fine specimens of siderite as botryoidal material with a silky luster cementing silica breccia fragments, occasionally with minor sphalerite, came from here (Tenney, 1913).

Spray Mine, *500 level, 5-88-3 stope;* From the 8th floor of this stope (70 feet above the level) came siderite as iridescent, silky linings of siderite boxwork voids encasing what appears to be supergene chalcopyrite (Tenney, 1913).

SIDEROTIL $Fe^{2+}SO_4 \cdot 5H_2O$:

This species has been recognized only as a post-mining mineral. A nondescript mineral, siderotil may well have been overlooked at other types of occurrences.

Siderotil typically occurs as a dehydration product of melanterite and this was certainly the case at Bisbee. It was found as a white to cream-colored material coating and replacing melanterite.

The species associated with siderotil are:

pyrite
hexahydrite
rozenite

Fragile, unstable pseudomorphs of siderotil after 1 cm pseudo-octahedral melanterite crystals have been recognized in the district.

OCCURRENCES:

Campbell Mine, *2700 level, 42 crosscut;* This area contained large amounts of post-mining minerals as spotty crust along the walls and as growths in and covering ponded mine waters with several centimeters of dirty-white crust.

Siderotil formed as pseudomorphs after cuprian melanterite, a result of dehydration caused by the ponded waters evaporating due to a change in ventilation. It also formed on the nearby pyritic mine walls, again as an alteration product of melanterite. Hexahydrite and rozenite were associated with siderotil at this locality.

SILVER Ag:

This is a widely distributed, but seldom abundant mineral within the district. Brimsmade in 1907 noted that silver values in the ores averaged 0.25 ounces per ton for each one percent copper, a trend that largely continued throughout the mining history of the district. Silver was economically important, with more than 100,000,000 ounces produced from 1895, when refining changes allowed for silver recovery (Douglas, 1913a) until 1975 when the mines closed (Stanley Keith, personal communication, 1980). It has been recognized as occurring under both hypogene and supergene conditions.

Hypogene silver was apparently pervasive in the majority of the primary ores as well as the low-grade, multi-element, largely pyritic cores to the high-grade replacement deposits. In their independent studies, Sid Williams as well as Alan Criddle with Chris Stanley found silver to be associated with many of the primary ore minerals in the Campbell orebody. Typically, it occurred as very small, isolated blebs, or as microscopically thin films on grain boundaries, and as inclusions in the other mineral grains (Sid Williams, personal communication, 1987; and Alan Criddle, personal communication, 1992).

Supergene silver was recognized far more often than its primary source largely because it was now often visible to the unaided eye. In spite of its relative abundance, few silver specimens of note were recovered from Bisbee's mines. Most of the supergene silver was found associated with the very early stage, secondary sulfides. Typically, it occurred as thin sheets that formed along fracture planes in chalcocite and, to a much lesser degree, covellite. Less often, silver was found with supergene clay minerals or as modest amounts interlayered with gouge in faults.

Silver was also often found associated with copper. In these instances, it occurred as small, spongy masses scattered over the surface of the copper. Included blebs of silver within copper were not uncommon, but seldom recognized because of the typical black tarnish. Silver as a coating or overgrowth on copper has been noted from the district (Petereit, 1907), but is quite rare.

Hypogene silver has been observed on a microscopic level with all of the common and many of the uncommon primary ore minerals as well as many of the hypogene gangue minerals. Supergene silver is, however, associated with a surprisingly small number of secondary minerals. These are:

- chalcocite
- cerussite
- copper
- malachite
- chlorargyrite
- leadhillite
- hematite
- bromargyrite

halloysite

Bromargyrite has been found as pseudomorphs after silver.

OCCURRENCES:

Campbell Mine, Silver was a minor, but widely distributed constituent of the ores throughout the Campbell orebody (Alan Criddle, personal communication, 1992).
1600-1800 levels; On these levels, silver occurred as thin sheets along fracture planes in massive chalcocite. It was usually associated with malachite and chlorargyrite on the upper levels and with malachite and leadhillite or cerussite on the 1800 level.
1900 level; Schwartz and Park (1932) noted silver from here in small amounts in a siliceous, hematite-stained material with chlorargyrite.
1600-2566 levels; The Campbell orebody on these levels contained minor amounts of hypogene silver in generally microscopic particles associated with other primary ore minerals (Sid Williams, personal communication, 1987; Alan Criddle, personal communication, 1992).

Cole Mine, *800 level;* This level produced specimens with silver on fracture planes in massive chalcocite with malachite and minor chlorargyrite.
1100 level; Exceptional (for Bisbee) specimens of silver were found here as relatively thick, crystalline sheets along clay-lined fractures in impure chalcocite with very minor malachite or rosasite.

Czar Mine, An unusual specimen of silver from here was sent to the 1884 New Orleans Exposition. It was described as "a cup like mass with a 3-inch mushroom growing from the center" (Engineering & Mining Journal, 1884). The silver coatings on large copper crystals that were noted by Petereit (1907) are most likely from this mine as well.
300 level; Abundant silver came from here as large, thin pieces interlaid with fault gouge in the Dividend zone.
400 level; Silver was found here as small spongy masses on crystalline copper with malachite. Also, it occurred on this level as small inclusions in copper.

Gardner Mine, *400 level, 44 drift;* It was found here as flakes and patches on chalcocite with malachite (Tenney, 1913).

Holbrook Mine, Silver was found in this mine as 5 mm flakes included in translucent halloysite with malachite and goethite. It was also reported as specks on malachite “in a very tasty appearing show” (Chicago Daily Tribune, 1893).

Junction Mine, *1500 level;* One of the authors collected specimens of silver from here that occurred as thin sheets and blotchy films of supergene silver on fracture planes in massive compact fine- to coarse-grained chalcocite. Malachite and large amounts of chlorargyrite were associated with this silver.

Lavender Pit Mine, *Holbrook Extension;* A large number of thin sheets of silver occurred along closely spaced fractures in massive covellite. Samples of this material taken by the author during mining assayed 2,240 ounces of silver per ton, or 1.12 ounces of silver per pound. Also from this part of the pit, silver was found as bright flecks in translucent halloysite with malachite. This was very similar to the material from the Holbrook mine referenced above.

Lowell Mine, *1400 level, 1406 drift;* Silver was noted by Tenney (1913) from here as linings on fractures in massive supergene chalcocite.

Sacramento Mine, *1500 level, 1526 drift;* It occurred here in small amounts as flakes on chalcocite with tetrahedrite, galena, and bornite (Tenney, 1913).

Shattuck Mine, *300 level;* Silver was found in the "lead cave" on this level as thin wire-like crystals partially to completely replaced by bromargyrite.

Spray Mine, *800 level, 11-8 stope;* Silver was noted here as centimeter-sized patches on spongy cerussite that had a galena core (Tenney, 1913).

SMITHSONITE $ZnCO_3$:

Widely distributed and locally abundant, this was the most common supergene zinc-bearing mineral in the district. Typically, it was yellow to yellow-brown to brown in color. Minor amounts of smithsonite have also been found that were white to gray. In spite of the tremendous amount of copper available, no copper-tinted smithsonite is known to have occurred.

The most common occurrence of smithsonite was as boxwork forms or as porous to earthy masses ("dry bone"). Crystalline material was most uncommon in the district. Paragenetically, smithsonite was deposited early, in many places replacing limestone, including fossils, and rarely siderite (Trischka, 1929). Later, modest amounts of the copper carbonates were often deposited on the boxwork smithsonite, with azurite being far more common than malachite.

Except as linings of boxwork voids, reniform smithsonite was not particularly common, and was most often found as thin veneers on limestone, iron oxides, and rarely, calcite. The brown material could easily be confused with the more common ankerite or siderite. Smithsonite was often associated with supergene siderite.

The replacement of smithsonite by other species is more often suggested than certain. This is largely due to the scarcity of crystals. It would appear that in some cases, zincian copper carbonates may have formed at the expense of smithsonite. Goethite has occurred as a replacement of smithsonite.

Siderite is known to have been replaced by smithsonite (Trischka, et al. 1929).

Minor amounts of post-mining smithsonite have been recognized on sphalerite ores left underground.

Other species most commonly associated with smithsonite in the district are:

goethite
malachite
goslarite
calcite
sphalerite
azurite
cerussite
siderite
hemimorphite
hematite
copper
hydrozincite

OCCURRENCES:

Campbell Mine, *1900 level, 105-C stope;* One of the authors collected a number of yellowish, drybone specimens, largely covered with copper as spongy to arborescent growths. The copper crystals were quite thin and, thus fragile. Crinoid stem segments replaced by smithsonite were found here as well.

Copper Queen Mine, White boxwork forms of smithsonite with thin goethite cores and as rare 2 mm white crystals came from this mine. The boxwork material is often partially coated by manganese oxides along with scattered tiny azurite crystals and minor aurichalcite.
"A" level; Smithsonite was found here in small amounts as blue-white reniform boxwork linings with cerussite (pseudomorphs after tabular calcite) and minor rosasite.

Cole Mine, *1200 level, 141F stope;* Sharp yellow 2 to 4 mm crystals of smithsonite occurred on crystalline azurite and goethite in specimens from this locality.

Holbrook Mine, *200-300 levels;* Substantial amounts of yellow smithsonite was mind here for the copper associated with it as small, but glassy clusters of azurite crystals making for handsome specimens. It was largely in thin walled, boxwork forms with azurite, and, occasionally malachite, on many of the void walls.

Higgins Mine, *Tunnel level;* Small patches of post-mining smithsonite occurred on sphalerite left underground along with post-mining hydrozincite and goslarite.

Junction Mine, *770 level;* Several very rich orebodies on this level produced substantial amounts of gray to yellow-gray drybone type of smithsonite. While the smithsonite was less than attractive, it often served as the matrix for superb, bright blue azurite. This occurrence is believed by the authors to represent the pre-Cretaceous supergene alteration event.

Lavender Pit Mine, *Holbrook Extension;* Large amounts of boxwork smithsonite with botryoidal surfaces were found when this area of the pit was mined. Colors ranged from a grayish-yellow to yellow with some of the yellow being bright and lustrous. Azurite and, to a much lesser degree, malachite occurred scattered across these specimens.

Southwest Mine, *3rd level;* Small amounts of white to gray boxwork and porous drybone smithsonite with minor hydrozincite and calcite were found near the Southwest Shaft on this level.

SPANGOLITE $Cu_6^{2+}Al(SO_4)(OH)_{12}Cl \cdot 3H_2O$:

This rare supergene mineral is widely distributed, in very small amounts, throughout the western and southern portions of the district. It is highly probable that Bisbee is the type locality for this species (Palache and Merwin, 1909), (Bideaux & Wallace, 1997). In any event, the finest known examples of spangolite are from here, as are all of the truly great spangolite specimens.

Spangolite from the district is always found close to cuprite, usually in direct association. Most typically, it is found as irregular 3 to 5 mm blebs included in massive cuprite that appear as flat, bluish-green cleavage faces.

Distinct crystals of spangolite from Bisbee are exceedingly rare. When found, the most typical mode of crystal occurrence is as isolated hexagonal forms or as a cluster of several randomly intergrown crystals on cuprite. While usually less than 2 mm in length, these crystals may in other cases be quite large for the species. Individual crystals of 2 cm across are known, as are crystals to 1 cm in length.

In those rare instances when spangolite occurs as crystals on goethite or hematite, it is usually where the iron oxide is residual from the alteration of cuprite. Malachite is a very common associated mineral in these instances.

The minerals that have been found in association with spangolite are:

cuprite
paratacamite
chrysocolla
hematite
chalcophyllite
atacamite
tenorite
goethite
claringbullite
connellite
malachite

OCCURRENCES:

Cole Mine, *600 level, 80 stope;* University of Arizona specimen 14868, as 3 mm crystals in a vug and cleavages in massive cuprite with chrysocolla.
1200 level, 202 stope; A few specimens with 2 mm crystals in crystal-lined vugs in massive cuprite were recovered here, as were a small number of specimens that contained chalcophyllite as well. It was also found here as tiny, irregular inclusions in massive cuprite that contained connellite.

Copper Queen Mine, This mine may be the source of the type material described by Penfield in 1890 (Palache and Merwin, 1909). However, it is equally possible that the adjacent Czar Mine was the source, as the cuprite on they type specimen is far more similar that which we have seen in the Czar than that from the Copper Queen.

Cuprite Mine, Several specimen of vuggy cuprite with a spangolite crystals of 5 mm x 12 mm was collected by one of the authors from the dump of this mine in 1967.

Czar Mine, Exceptional specimens with spangolite crystals of 1 cm in height and a width of 2 cm in vugs in massive cuprite and associated with minor connellite were collected from this mine. Frondel (1949) also noted spangolite crystals from this mine.
200 level; A few specimens of 1 mm spangolite with connellite in massive cuprite were collected on this level.

Holbrook Mine, A number of examples with cleavage faces of up to a centimeter across in massive cuprite with connellite are known from here.
300 level; Fine specimens of 5 mm x 1 cm crystals in crystal-lined vugs in cuprite were collected from here.

Irish Mag Mine, *1050 level;* Spangolite was found here as 3 mm crystals on brilliant cuprite crystals. Also, here, it occurred as 6 mm crystals on a cuprite/hematite matrix with malachite.

Southwest Mine, *5th level, 14 stope;* The authors collected specimens here that contained spangolite as crystals to 4 mm in length with claringbullite, atacamite, and paratacamite in vugs in massive cuprite.

SPERTINIITE $Cu^{2+}(OH)_2$:

This rare supergene mineral has been recognized only at one locality. This single locality produced just a small number of specimens.

The occurrences contained spertiniite as a sparse, pale blue-green drusy crust on atacamite. A scaly internal structure was noted where the crust was broken.

The species associated with spertiniite are:

atacamite
cuprite
paratacamite
goethite

OCCURRENCES:

Southwest Mine, *5th level, 14 stope;* Spertiniite occurred here in very small amounts as a spotty, sparse crust on crystalline atacamite in vugs in cuprite with paratacamite and goethite.

SPESSERTINE $Mn_3^{2+}Al_2Si_3O_{12}$:

This contact-metamorphic mineral was noted only in a few localities in modest amounts. In all cases it was part of a skarn developed adjacent to intrusive dikes.

Typically, spessertine was found as reddish-brown to brown, compact, granular masses. Small pockets lined with crystals to 1 cm were common in this material. Ore minerals, particularly chalcopyrite, were quite often associated with spessertine as interstitial fillings.

The species associated with spessertine are:

quartz
chrysocolla
bornite
calcite
azurite
goethite
chalcopyrite
cuprite
pyrite
malachite

OCCURRENCES: A specimen with spessertine crystals of nearly a centimeter in size with interstitial chalcopyrite is in the USNMNH collection (specimen 119229). The exact locality within the district for this specimen, was not recorded.

Cole Mine, *700 level;* Massive spessertine from a skarn adjacent to a dike on this level contained pockets lined with crystals to 5 mm with azurite and minor malachite.

Junction Mine, Spessertine was a common mineral on the fringes of the orebodies near the several intrusives as well as the Sacramento Stock Complex in this mine.

Lavender Pit Mine, *Holbrook Extension;* Large masses of granular, subhedral spessertine were found in this section of the pit, some of which contained voids with chrysocolla and malachite on goethite. These voids were originally filled with sulfides.

SPHALERITE ZnS:

This common ore mineral was widely distributed throughout the district, frequently in large amounts. Orebodies of many thousands of tons were exploited in several of the mines in the eastern part of the district. Sphalerite was the only economically important zinc ore mineral, from which some 355,000,000 pounds of the metal were produced (Mills, 1958).

Many who have studied the mineralization at Bisbee have suggested that sphalerite was deposited early (Bain,1952; Tenney, 1913) while others (Schwartz, & Park, 1932) saw it to be the last. Schumer (2017) see it as early and remobilized and redeposited. He suggested that "*Relict sphalerite and galena in chalcopyrite and bornite indicate progressive dissolution and redeposition of sphalerite and galena throughout the mineralization process*" (Schumer, 2017).

Typically, sphalerite ores were found in large, impure masses often associated with galena and/or chalcopyrite and were usually adjacent to other sulfide masses. Sharp contacts often existed between the zinc/lead ores and the copper ores (Hogue and Wilson 1950). Zinc/lead ores contained large amounts of galena along with sphalerite while copper/zinc deposits had chalcopyrite as the other principal economic mineral. In those deposits where zinc alone was the only economically important mineral, and there were many such orebodies, pyrite was the most common associated sulfide mineral. Minor amounts of sphalerite occurred in almost all of the primary ores as included grains (Bonillas, et al. 1916).

Almost all of the sphalerite from the district was iron-rich and therefore black in color. It occurred as compact, fine-grained material to coarse-grained, cleavable masses. Crumbly, almost gravel-like sphalerite was found in those areas where the first stages of supergene alteration were underway. Large pieces of pure sphalerite were uncommon. It was usually intimately associated with other sulfides such as galena, chalcopyrite, and/or pyrite. Many other mineral species were also found as usually tiny inclusions in sphalerite (Schumer, 2017).

Rarely, small crystals of sphalerite were found in voids in massive sphalerite. No collector-quality specimens are known to have occurred in the district.

Sphalerite was noted in large bodies in the western part of the district (Bonillas, et al. 1916), however, there does not appear to have been any mining just for zinc in this area. Some minor byproduct zinc was produced as a result of lead mining in this area, however. All of the important zinc production from the district came from the Campbell, Junction, and Denn mines (Mills, 1958; Hogue and Wilson 1950) in the eastern part of the district.

What is apparently supergene sphalerite has been found in several areas in the district always as small, very fresh-looking inclusions in/or on supergene siderite. In these instances, it generally formed along the boxwork planes and was associated with apparently supergene galena, chalcopyrite, and pyrite.

The species most commonly associated with sphalerite are:

galena
chalcopyrite
greenockite
pyrite
bornite
quartz
smithsonite
hematite
chalcocite

OCCURRENCES:

Briggs Mine, Sphalerite in large masses was reported from here by Bonillas, et al. (1916).

Copper Queen Mine, *B level;* A small mass of several hundreds of tons of highly fluorescent sphalerite were left in place by early miners, as zinc was not an economic metal in the 1880s when first found. Specimens from here are often triboluminescent.

Campbell Mine, This huge mine was the main producer of sphalerite in the district. Many very large orebodies were mined from above the 1200 level to the 2833 level (Hogue and Wilson 1950; Mills, 1958). Some fine-grained sphalerite from the lower levels exhibited triboluminescence.

Czar Mine, Bonillas, et al. (1916) noted that large bodies of sphalerite occurred in this mine.

Denn Mine, This mine was the third most important producer of sphalerite ores in the district. Most of the sphalerite here was associated with galena and near the Campbell/Junction sideline areas, from the 2300 level to the 2833 level.

Gardner Mine, Sphalerite was abundant in several areas of this mine. In some cases, it was associated with the important lead deposits and mined.
700 level, 44 drift; Crystals to 7 mm on siderite were noted from here by Tenney (1913). This may well be a supergene occurrence.

Higgins Mine, Small amounts of sphalerite were found by the authors in several areas of this mine, particularly on the 100 and 200 levels on the Backbone claim.

Junction Mine, A great amount of zinc and lead /zinc ores were mined here. This mine was a close second to the Campbell in zinc production. Sphalerite was mined from orebodies from above the 1000 level to the 2700 level. Bright orange florescence was occasionally found in some of the fine-grained material from the Junction.

Sacramento Mine, *1400 level, 40 drift;* Large amounts of sphalerite were found here associated with pyrite and minor chalcopyrite (Tenney, 1913).

Southwest Mine, The lower portions of this mine, particularly that part close to the Southwest Shaft, contained significant amounts of partially oxidized sphalerite. However, it was too low grade to be mined.

SPIONKOPITE $Cu_{39}S_{28}$:

This supergene species is apparently quite rare within the district. It is, however, reasonable to assume that further investigations of sulfides undergoing supergene alteration may well reveal other localities for this mineral. In the single locality, spionkopite was found in small amounts as a supergene alteration product of other, largely supergene, copper sulfides.

The species associated with spionkopite are (Alan Criddle, personal communication, 1992):

wittichenite
digenite
djurleite
galena
hematite
hessite
jalpaite
malachite
bismite
acanthite
chalcopyrite
bornite
copper
rutile
bismuthinite
tennantite
sphalerite
quartz
covellite
stromeyerite
bismuth
goethite
gold
chalcocite
cuprite
silver
emplectite
colusite
azurite
matildite

It is worth noting that both the chalcocite and wittichenite associated with spionkopite contained 6% and 7% silver respectively.

OCCURRENCES:

Campbell Mine, *1600 level;* It was recognized from this part of the Campbell orebody in the work of Criddle and Stanley as part of a complex mineral assemblage that was rich in silver and bismuth (Alan Criddle, personal communication, 1992).
1900 level; Spionkopite was noted from here in very minor amounts as part of a broad assemblage of supergene copper minerals replacing chalcopyrite (Alan Criddle, personal communication, 1992).

STANNITE Cu_2FeSnS_4:

This is a hypogene mineral of apparent very limited distribution within the district. Stannite was found at several locations, all within the Campbell orebody, and always in very small amounts. Here it was typically found in micro-phases as a minor component of tin-vanadium-tellurium- or tin-vanadium-tungsten-rich, compound inclusions in or replacing common sulfides, particularly pyrite.

The species associated with stannite are (Alan Criddle, personal communication, 1992):

chalcopyrite
djurleite
sphalerite
stützite
calaverite
cassiterite
melonite
wittichenite
magnetite
bornite
covellite
galena
aikinite
tetradymite
gold
kësterite
kiddcreekite
roscoelite
chalcocite
tennantite
altaite
mawsonite
sylvanite
goldfieldite
volynskite
“wolframite”
nolanite
digenite
pyrite
hessite
rutile
tellurium
kostovite
colusite
hematite
cupropavonite

OCCURRENCES:

Campbell Mine, *2100 level;* On this level, stannite was a minor component of a complex, tin-rich mineral assemblage found as compound inclusions in pyrite (Alan Criddle, personal communication, 1992).
2200 level; Stannite came from this level in small amounts as a part of a complex, tin-rich mineral assemblage found replacing pyrite and as inclusions in pyrite (Alan Criddle, personal communication, 1992).
2300 level, 125 stope; This stope contained a very complex assemblage of tin-tungsten-tellurium-vanadium minerals, including tiny amounts of stannite, that were included within and replacing granular pyrite (Alan Criddle, personal communication, 1992).
2566 level; This mineral was part of a very complex assemblage of tin-tungsten-tellurium-vanadium minerals replacing pyrite (Alan Criddle, personal communication, 1992).

STANNOIDITE $Cu_8(Fe,Zn)_3Sn_2S_{12}$:

This hypogene mineral was found at several localities all within the Campbell orebody as well as occurrences in the Cole, Dallas and Lavender Pit mines. In the Campbell, stannoidite occurred as a coating on, or as an infilling between pyrite grains (Anthony, et al. 1995). It also occurred as part of a complex, tin-rich assemblage that formed compound inclusions in pyrite (Alan Criddle, personal communication, 1992). While at the Cole, Dallas and Holbrook mines, as a part of small rounded inclusions of a large suite of accessory minerals (Schumer, 2017).

The species associated with stannoidite are (Anthony, et al. 1995; Alan Criddle, personal communication, 1992):

canfieldite
tennantite
bornite
krennerite
kostovite
gold
sphalerite
tetrahedrite
covellite
calaverite
hematite
galena
mawsonite
colusite
altaite
petzite
chalcopyrite
kësterite
kiddcreekite
sylvanite
goethite

OCCURRENCES:

Campbell Mine, Selected samples of stannoidite-rich ore from this mine contained as much as 4% tin and 4% silver (Anthony, et al. 1995).
2200 level; Stannoidite occurred here as interstitial growths in massive pyrite (Sid Williams, personal communication, 1981).
2300 level, 124 stope; Tin-rich, compound inclusion in sulfide ore minerals from here contained minor amounts of stannoidite (Alan Criddle, personal communication, 1992).

Dallas Mine, Stannoidite was noted in minor amounts in bornite as a part of a large suite of accessory minerals including tennantite-tetrahedrite, sphalerite, mawsonite, galena, and native Au. Gold occurs intergrown with chalcocite in fractures and in one instance is intergrown with colusite (Schumer, 2017).

Holbrook Mine, Massive bornite contains rounded inclusions (<1%) of stannoidite, mawsonite, galena, and colusite. (60%) with chalcopyrite (30%) and supergene goethite (10%). Chalcopyrite is concave to bornite. Both chalcopyrite and bornite contain rounded inclusions of tennantite-tetrahedrite and sphalerite. Stannoidite occurs as much larger grains against sphalerite (Schumer, 2017).

Lavender Pit Mine, *Holbrook Extension;* In massive sulfide composed of bornite (80%), chalcopyrite (15%), and pyrite (5%), where chalcopyrite is concave to bornite and contains scattered inclusions of tennantite-tetrahedrite. Away from chalcopyrite, bornite contains zones of graphic chalcocite-bornite exsolutions. Pyrite contains rare inclusions of bornite. Tiny inclusions of mawsonite, stannoidite, and galena occur throughout bornite, regardless of proximity to chalcopyrite. Mawsonite occurs as rims on most stannoidite grains (Schumer, 2017).

STEVENSITE $(Ca/2)_{0.3}Mg_3Si_4O_{10}(OH)_{2\,?}$:

Back, (2018) notes that this species is questionable. Irrespective, the below information is provided to allow researchers to access to the historic information. This hydrothermal alteration species has been recognized at only one locality within the district. Stevensite occurred in small amounts as intimate intergrowths with clinochrysotile (Anthony, et al. 1995).

OCCURRENCES:

Lavender Pit Mine, *Holbrook Extension;* Stevensite occurred here in the oxidized ores as intimate intergrowths with clinochrysotile (Anthony, et al. 1995).

STIBICONITE $Sb^{3+}Sb_2^{5+}O_6(OH)$; ?

Atencio et al. (2010) has indicated stibiconite is a questionable species. This is in line with the revised nomenclature of the minerals of the pyrochlore supergroup. Irrespective, the below information is provided to allow researchers to access to the historic information. This supergene mineral is apparently quite rare within the district with but a single locality and only a few known specimens. It is however, quite possible that other specimens or localities may exist given the typically unimpressive nature of stibiconite.

Stibiconite occurred as a pale-yellow crust in voids and on the surface of massive chalcocite, or as tan to cream pseudomorphs after small stibnite crystals in voids and along fractures in a siliceous material.

OCCURRENCES:

Cole Mine, *1000 level;* This is the only recognized locality for stibiconite. Specimen number 28,997 in the American Museum of Natural History collection represents the occurrence as do a small number of other specimens in other collections.

STIBNITE Sb_2S_3;

This hypogene mineral is quite uncommon in the district with a only small number of specimens having come from a single locality. In this one locality, stibnite was found in voids in a siliceous material as small clusters of radiating crystals to 4 mm, which are altering to stibiconite.

The species associated with stibnite here are:

quartz
pyrite
chalcocite
stibiconite

Pseudomorphs of stibiconite after stibnite have been recognized in the district.

OCCURRENCES:

Cole Mine, *1000 level;* A small number of specimens from an unspecified location on this extensive level contain stibnite as clusters of small radiating crystals that are often partially altered to stibiconite.

STOLZITE $PbWO_4$:

This rare supergene mineral is apparently quite uncommon in the district. However, given the typically very small size of the stolzite crystals and the small amounts in an occurrence, it could easily have been overlooked both where noted as well as other areas.

Typically, stolzite was found in small amounts as tiny crystals with other secondary minerals.

The species associated with stolzite are:

cerussite
chalcocite
plattnerite
silver
malachite
chlorargyrite
hemimorphite

OCCURRENCES:

Campbell Mine, *1800 level;* Tiny, yellow-gray to tan tabular crystals of stolzite occurred on a few chalcocite specimens from this level associated with silver and malachite.

Southwest Mine, *6th level;* Specimens of cerussite from a small cave on this level contained a few 0.1 mm, red-orange, dipyramidal crystals with hemimorphite and plattnerite.

STROMEYERITE $AgCuS$:

This supergene mineral has been noted in several mines in the district. Given the typically high silver content of Bisbee's supergene ores, it is possible that stromeyerite was far more common than the few confirmed occurrences would suggest.

Stromeyerite was usually found as gray, bladed intergrowths to 1 cm in copper sulfides. It has also been noted as grains included in copper sulfide mixtures.

The species associated with stromeyerite are (Schwartz and Park, 1932; Alan Criddle, personal communication, 1992):

jalpaite
djurleite
spionkopite
galena
digenite
hematite
tetrahedrite
bismite
chalcopyrite
bismuthinite
bornite
acanthite
copper
famatinite
sphalerite
covellite
gold
stromeyerite
quartz
enargite
malachite
chalcocite
silver
matildite
emplectite
cuprite
tennantite
hematite

OCCURRENCES:

Campbell Mine, *1600 level;* Stromeyerite was recognized from this part of the Campbell orebody in the work of Criddle and Stanley as part of a high silver/bismuth mineral assemblage (Alan Criddle, personal communication, 1992). It is worth noting that the chalcocite associated with this assemblage contained 6% silver.
1700 level; Blades of stromeyerite were noted as coarse intergrowths in chalcocite that occurred as inclusions in bornite with tetrahedrite, tennantite, and small amounts of famatinite (Schwartz and Park 1932).

Cole Mine, Stromeyerite was reported in specimens from here by Bideaux, et al. (1960).
800 level; It occurred here in small amounts as irregular intergrowths in massive chalcocite with minor hematite.

Junction Mine, Stromeyerite was observed in chalcocite from this mine by Schwartz and Park (1932).
1500 level; Stromeyerite was found by one of the authors here as coarse, subgraphic intergrowths in supergene chalcocite that has a surficial alteration to malachite. Elemental silver occurs as thin patches along fractures in this material.

STÜTZITE $Ag_{5-X}Te_3$:

This hydrothermal species has been recognized in small amounts from several localities in a single mine. Here, stützite was found as part of a diverse mineral assemblage either as lead-gray coatings on small pyrite crystals (Sid Williams, personal communication, 1987) or as micro-phase intergrowths in sulfides (Harris, et al. 1984; Alan Criddle, personal communication, 1992).

The species associated with stützite are (Alan Criddle, personal communication, 1992):

altaite
chalcocite
calaverite
stannite
magnetite
sphalerite
tellurobismuthite
gold
“wolframite”
nekrasovite
goldfieldite
hessite
melonite
scheelite
bornite
krennerite
kiddcreekite
rutile

OCCURRENCES:

Campbell Mine, *2100 level, 2200 level, 2300 level-125 stope and 2566 level;* Stützite was noted from the Campbell orebody in these areas, included in sulfide ore minerals as micro-phases as part of a complex assemblage (Sid Williams, personal communication, 1987; Harris, et al. 1984; Alan Criddle, personal communication, 1992).

SULFUR S:

This species has been recognized in both supergene and post-mining occurrences. The apparent limited distribution of sulfur may well be a result of its physical similarity to several of the iron sulfates, causing it not to be recognized.

Sulfur that formed as a result of supergene activity is usually found as tiny yellow crystals in cavities left by the oxidized sulfide or as crystals on the altering sulfides. Post-mining sulfur formed in much the same way, as exposed sulfides oxidized, and also as small crystals deposited under fumarole-like conditions caused by sulfide mine fires.

The species associated with sulfur in the district are:

quartz
hematite
pyrite
sphalerite

OCCURRENCES:

Campbell Mine, *1300 level;* Brilliant sulfur crystals to 5 mm formed on the mine opening walls in the main vent for the fire gases in the area close to the fire.

Junction Mine, *1500 level;* Small crystals of sulfur were found here with sphalerite (Galbraith, 1947).

Lavender Pit Mine, Sulfur was noted from here as crystals in voids that resulted from the leaching of pyrite (Anthony, et al. 1995).

Wolverine and Arizona Number 2 Mine, Small sulfur crystals were found in a sandy material above an oxidizing orebody in this mine (Tenney, 1913).

SYLVANITE $(Au,Ag)_2Te_4$:

This hypogene mineral has been recognized in very small amounts in several areas in a single mine within the district. In these occurrences, sylvanite was a minor constituent of the complex, multi-mineral assemblage that was associated with common sulfides in the Campbell orebody.

The species associated with sylvanite are (Criddle, et al. 1983; Alan Criddle, personal communication, 1992):

chalcopyrite
djurleite
sphalerite
stannite
tetradymite
cassiterite
melonite
kiddcreekite
cupropavonite
bornite
covellite
altaite
mawsonite
volynskite
gold
kësterite
rickardite
tellurobismuthite
chalcocite
tennantite
hessite
rutile
henryite
goldfieldite
colusite
petzite
galena
digenite
pyrite
stützite
calaverite
tellurium
kostovite
wittichenite
hematite

OCCURRENCES:

Campbell Mine, Sylvanite was found in tiny amounts as micro-phase inclusions in henryite from an undocumented level in this mine (Criddle, et al. 1983).
2100 level; On this level, sylvanite was a minor component of a complex, tin-tellurium- rich mineral assemblage that formed as fracture filling in massive pyrite and as inclusions in pyrite (Alan Criddle, personal communication, 1992).
2300 level, 124 stope; It was found here as a rare constituent of the mineralogically-complex, compound inclusions in sulfide ore minerals (Alan Criddle, personal communication, 1992).

125 stope; This stope contained a very complex assemblage of tin-tungsten-tellurium-vanadium minerals, including tiny amounts of sylvanite, that were included within and replacing granular pyrite (Alan Criddle, personal communication, 1992).

SZOMOLNOKITE $Fe^{2+}SO_4 \cdot H2O$:

This species has been recognized as a post-mining mineral only. It occurred as a crust encasing pyrite grains from which it was derived (Anthony, et al. 1995).

OCCURRENCES:

Lavender Pit Mine, Szomolnokite was noted here as a brown, warty crust encasing pyrite, particularly in heavily pyritized areas. It is locally abundant on the pit walls.

T

TALC $Mg_3Si_4O_{10}(OH)_2$:

This hydrothermal alteration mineral is undoubtedly far more common than the limited recognized occurrences would suggest. Talc formed as a contact-metamorphic mineral in the dolomitic limestones. It was usually associated with and easily confused with the serpentine group minerals.

OCCURRENCES:

Boras Mine, *900 level;* Talc occurred here as massive material in the epizonally altered, dolomitic Martin limestone (Fabien Cesbron, personal communication, 1981).

Spray Mine, Talc was noted from here by Tenney (1913) as a result of contact metamorphism.

TANGEITE $CaCuVO_4(OH)$:

This supergene species is known from a single specimen. The species has been confirmed by Raman studies. (Jim McGlasson, personal communication, 2021)

The species observed with tangeite are:

nambite
quartz
chrysocolla
hematite

OCCURRENCE:

Shattuck Mine;

Tiny, yellow-green, prismatic, crystal ≤ .1 mm coating massive quartz with nambite, chrysocolla and hematite.

TEINEITE $Cu^{2+}Te^{4+}O_3 \cdot 2H_2O$:

This is an exceedingly rare secondary mineral within the district. Only three examples are known from here, yet the Bisbee specimens contain crystals that are among the finest known for the species.

Teineite occurs as bright blue prismatic crystals and as oriented overgrowths on graemite pseudomorphs after teineite. It appears that teineite might be a mineral that formed fairly early during supergene alteration. Paragenetically, teineite followed cuprite, a typically early secondary species, and preceded malachite, a mineral that often forms during the later stages of supergene activity.

Teineite appears to alter to graemite readily. The only surviving material occurred either as a second-generation overgrowth or as crystals that were imbedded in malachite and therefore protected from alteration or inside of cuprite nodules.

The species associated with teineite are:

malachite

cuprite

graemite

Graemite is found as pseudomorphs after teineite.

OCCURRENCES:

Cole Mine, 1200 *level*, *202 stope*; An exceptional example of teineite came from here with sharp, bright blue, prismatic crystals to 5 mm in length in fibrous malachite with cuprite and graemite pseudomorphs after teineite.

Holbrook Mine, Tiny amounts of teineite were noted in a single cuprite specimen. The teineite occurred as complete overgrowths of 3-millimeter, arborescent clusters of tiny graemite crystals, ex British Museum of Natural History (Evan Jones, personal communication, 2010). It also occurred as isolated, tiny hexagonal prisms, which could easily be confused for spangolite, as the encased bluish-green graemite modifies the color from the typical electric blue.

However, no documentation exists as to the source locality. Based our experience with material form the Holbrook, it is our considered opinion that the specimen was probably recovered from this mine in the late 19th century.

Shattuck Mine; Oriented 1 cm teineite overgrowths on graemite pseudomorphs after teineite with later cuprite are on the single known specimen from this mine.

TELLURITE TeO_2:

This supergene mineral has been recognized in only one mine within the district. Here it was found in very small amounts in its typical occurrence as an oxidation product of elemental tellurium, where it occurred as thin alteration films.

OCCURRENCES:

Campbell Mine, Tellurite was found here in samples from an unspecified level studied by Criddle and Stanley in their review of the Campbell orebody (Alan Criddle, personal communication, 1992).

TELLURIUM Te:

This hypogene mineral has been recognized at several places in a single mine. Here it was, relatively, one of the more abundant tellurium-containing species. Elemental tellurium occurred as irregular, tin-white grains and rarely blebs up to 3 mm in sulfides with other tellurium minerals.

The species associated with native tellurium are (Sid Williams, personal communication, 1987; Alan Criddle, personal communication, 1992):

- stannoidite
- mawsonite
- cassiterite
- nolanite
- petzite
- hematite
- djurleite
- kostovite
- gold
- stannite
- colusite
- "wolframite"
- rutile
- tennantite
- galena
- covellite
- tellurobismuthite
- krennerite
- kësterite
- kiddcreekite
- magnetite
- kiddcreekite
- melonite
- aikinite
- digenite
- calaverite
- tellurite
- nekrasovite
- scheelite
- quartz
- sphalerite
- hessite
- chalcopyrite
- bornite
- sylvanite

OCCURRENCES:

Campbell Mine, *2200 level;* Tellurium was found on this level in tiny amounts as part of a complex mineral assemblage included in sulfides (Alan Criddle, personal communication, 1992).
2300 level, 125 stope; Elemental tellurium was a component of a high-tellurium assemblage, which, along with tin-tungsten-vanadium minerals, was found as inclusions in pyrite and replacing granular pyrite (Alan Criddle, personal communication, 1992).
2566 level; Minor amounts of native tellurium occurred here with several other tellurium minerals in a high tungsten-vanadium mineral complex replacing pyrite (Alan Criddle, personal communication, 1992).

TELLUROBISMUTHITE Bi_2Te_2Te:

This hypogene mineral has been found in two localities at a single mine within the district. In this occurrence, tellurobismuthite, while found in small amounts, was one of the more abundant tellurium minerals in a complex, multi-mineral assemblage in the Campbell orebody. This complex assemblage was typically found as compound inclusions in sulfides (Alan Criddle, personal communication, 1992).

The species associated with tellurobismuthite are (Alan Criddle, personal communication, 1992):

- chalcopyrite
- bornite
- chalcocite
- digenite
- djurleite
- covellite
- tetrahedrite
- calaverite
- sphalerite
- pyrite
- goldfieldite
- galena
- cassiterite
- rutile
- magnetite
- mawsonite
- colusite
- stannite
- altaite
- kësterite
- hessite
- sylvanite
- krennerite
- petzite
- aikinite
- stützite
- tellurium
- tennantite
- kiddcreekite

OCCURRENCES:

Campbell Mine, *2100 level;* Tellurobismuthite was relatively abundant on a number of lead-silver-gold-bismuth tellurides that, along with other minerals, were intergrown in sulfides (Alan Criddle, personal communication, 1992).
2200 level; Here, it was part of a complex, high tin-tellurium, multi-mineral assemblage that formed as inclusions in common sulfides (Alan Criddle, personal communication, 1992).

TENNANTITE $Cu_6[Cu_4(Fe,Zn)_2As_4S_{13}$:

This hypogene mineral was widely distributed, usually in minor amounts, in many of the primary orebodies in the district. While tennantite was locally abundant, it was only of modest importance as an ore mineral.

Typically, tennantite was found as small, anhedral inclusions in other ore minerals (Bonillas, et al. 1916; Schwartz and Park, 1932). It was almost always associated with other similar sulfosalt inclusions. On rare occasion, tennantite was found as large, nearly pure masses included in massive sulfides. Massive tennantite was also found with minor inclusions of other copper sulfosalts and, less often, pyrite and/or copper sulfides.

Crystals of tennantite were uncommon in the district, with a single locality known to have produced the few examples. These were formed at the fringes of an orebody and were exposed only by removing the encasing calcite.

The species most commonly associated with tennantite are:

- chalcopyrite
- bornite
- chalcocite
- pyrite
- covellite
- tetrahedrite
- calcite
- hematite

galena sphalerite

OCCURRENCES: Because this species is so widely distributed and typically nondescript, only the more important and a few typical occurrences are noted below.

Campbell Mine, Tennantite was one of the more common accessory minerals in ores from the 1900 level, 2200 level, and 2300 levels, along with a very complex assemblage of tin-tungsten-bismuth-tellurium minerals that occurred as inclusions in the more common sulfides (Alan Criddle, personal communication, 1992).
1700 level; Schwartz and Park (1932) noted minor amounts of tennantite in the ores from here. It occurred as rounded grains in chalcocite with tetrahedrite, enargite, and minor famatinite, all in massive bornite.
2566 level; Nearly pure masses of steel-gray tennantite to 20 cm were found in the Campbell orebody on this level. This material had included grains of pyrite and was associated with calcite. Sharp, modified crystals to 2 cm were encased in the calcite.

Denn Mine, *3100 level;* Massive tennantite in quartz was found in abundance in a stope on this level associated with massive pyrite. This material was decidedly argentiferous.

Holbrook Mine, *300 level, 67 stope;* Centimeter-sized inclusions of tennantite were found in massive bornite-chalcopyrite-chalcocite ores here. Pyrite and galena were also inclusions and covellite was a surficial alteration on some of the copper sulfides (Tenney, 1913).

Junction Mine, Minor amounts of tennantite were found as inclusions in the copper sulfides from several parts of this very large mine.

TENORITE $Cu^{2+}O$:

This was probably a relatively uncommon secondary mineral that was associated with the oxidized orebodies in the district. However, pure material has always been rare as noted by Guild (1929). Much of what is believed to be tenorite is actually black chrysocolla.

The most common occurrence for tenorite was as an impure, earthy material intermixed with clays and/or iron oxides along with other supergene copper minerals. Tenorite was also found in small amounts as an earthy phase associated with the supergene manganese oxide bodies. In both cases the combination of tenorite and other copper minerals were often sufficient to make the material ore grade (5% or greater copper).

In hard, massive goethite and, to a lesser degree, similar hematite, tenorite was found as nearly pure material filling small voids and lining larger ones. The larger openings frequently had later malachite and occasionally azurite deposited on the tenorite. In most instances, the copper carbonates may have been an alteration product of the tenorite.

Tenorite was most commonly recognized as an alteration of cuprite. Often this alteration of the cuprite would be incomplete and rinds of impure tenorite would surround the remaining cuprite cores. This tenorite was typically resinous in luster and frequently had a further alteration rind of malachite and/or chrysocolla. This is the same material that Koening (1902) described as the species “melaconite.” Work by Hunt and Kraus (1916) and Guild (1929) both demonstrated that “melaconite” was not a distinct species, but rather a mix of tenorite, chrysocolla, and malachite.

Massive, but lightweight, mixtures of impure tenorite with malachite, chrysocolla, and azurite were found in several parts of the district. Often these specimens contained black chrysocolla that is easily confused with tenorite. On exposure, this material usually became friable because of a loss of water by chrysocolla.

Crystalline cuprite occasionally had a very thin surface veneer of tenorite that gave a black appearance to the crystals. Here too, it was an alteration of the underlying cuprite. Malachite as well as chrysocolla is frequently noted as replacing massive tenorite.

The minerals commonly known to occur with tenorite are:

goethite
copper
malachite
cuprite
calcite
quartz
chrysocolla
azurite
hematite
pyrolusite

Tenorite is often recognized as replacing massive cuprite and very rarely as pseudomorphs after cuprite crystals.

OCCURRENCES:

Cole Mine, *1200 level, 202 stope;* Tenorite was abundant here as alteration rinds on cuprite nodules.
1300 level, 26-K stope; It occurred here as thin coatings on crystalline cuprite with copper and later malachite.

Czar Mine, Tenorite was very common in a number of places in this mine as an alteration product of cuprite as rinds on massive material. Also, it was common as an impure, earthy material in many of the oxidized orebodies and as massive resinous material mixed with chrysocolla and associated with azurite, malachite, and later chrysocolla.

Southwest Mine, 5th *level, 14 stope;* It was frequently found as alteration rinds on massive cuprite boulders and nodules and in turn is altering to malachite and chrysocolla.
6th level; Tenorite was found on the fringe of a huge stope above this level as complete replacements of isolated, euhedral 5 mm cuprite crystals in a kaolinitic clay. This is one of the few confirmed occurrences of pure tenorite

Irish Mag Mine, *850 level;* A cave 30 feet above the level contained as botryoidal material that is a mixture of tenorite and manganese oxides with calcite (Ransome, 1904).

Holbrook Mine, Tenorite was common in small amounts throughout the oxidized ores in this large mine where it typically occurred as a part of impure alteration rinds on cuprite nodules.

Lavender Pit Mine, *Holbrook Extension;* Large, light weight blocks of mixed impure tenorite, azurite, malachite, and chrysocolla were mined from the upper portions of this area. Many attractive specimens were recovered; however, desiccation has muted the color of the associated chrysocolla while making the specimens somewhat friable.

Lowell Mine, Tenorite was widely distributed in this mine, most typically as coatings on massive cuprite.
1000 level; Tenorite was found here as part of an earthy material mixed with manganese oxides forming ores that contained 5% copper (Ransome, 1904).

TETRADYMITE Bi_2Te_2S:

This hydrothermal mineral has been recognized in very small amounts two localities. In both cases, it was part of a complex mineral assemblage that was found as compound inclusions in pyrite as well as replacing granular pyrite (Alan Criddle, personal communication, 1992; Schumer, 2017).

The species associated with tetradymite are (Alan Criddle, personal communication, 1992):

chalcopyrite
djurleite
sphalerite
stützite
calaverite
cassiterite
melonite
wittichenite
bornite
covellite
galena
stannite
rucklidgeite
gold
kësterite
kiddcreekite
chalcocite
tennantite
altaite
mawsonite
sylvanite
goldfieldite
volynskite
digenite
pyrite
hessite
rutile
tellurium
kostovite
colusite

OCCURRENCES:

Campbell Mine, *2300 level, 125 stope;* Tiny amounts of tetradymite were found here as compound inclusions in pyrite and as part of a multi-mineral assemblage replacing granular pyrite (Alan Criddle, personal communication, 1992).

Higgins Mine, *Tunnel level;* Tetradymite was noted from here by Schumer (2017) in a gangue of fluorapatite, chlorite, and quartz in association with chalcopyrite, sphalerite, pyrite, and scheelite.

TETRAHEDRITE $Cu_6[Cu_4(Fe,Zn)_2]Sb_4S_{13}$:

This hypogene mineral was the most common sulfosalt in the district. It was widely distributed in many of the orebodies. However, tetrahedrite was never found in large amounts.

Typically, tetrahedrite was found as included masses in the common copper sulfides. For the most part, it occurred as small blebs or grains and rarely blades, often intermixed with other minor minerals, in copper, lead, and zinc sulfides (Tenney, 1913; Schwartz and Park, 1932). Masses of nearly pure tetrahedrite of up to 20 cm, while not common, were not unknown. Other sulfosalts and ore sulfides mineral were typically found as inclusions in these masses.

The more common species typically associated with tetrahedrite are:

chalcopyrite
covellite
galena
famatinite
bornite
tennantite
sphalerite
enargite
chalcocite
calcite
stromeyerite
quartz
pyrite
hematite
silver
freibergite

OCCURRENCES: Given the wide distribution and lackluster nature of tetrahedrite, only a small number of the typical occurrences will be noted.

Campbell Mine, Tetrahedrite was a common, widespread minor accessory mineral in the sulfides of the Campbell orebody (Schwartz and Park, 1932; Alan Criddle, personal communication, 1992).

Cole Mine, Massive material was produced from this mine as represented by USNMNH specimen 115,256.

Gardner Mine, *400 level, 11 drift;* Large patches of tetrahedrite were included in a chalcocite/bornite mixture with pyrite at this locality (Tenney, 1913).
900 level, 11 and 17 stopes; Minor amounts of tetrahedrite were associated with chalcopyrite/pyrite ores here (Tenney, 1913).

Holbrook Mine, *300 level, 400 level;* Intergrowths of tetrahedrite in pyrite and/or galena were common in several areas on these levels. Also, masses of nearly pure material were abundant with bornite, chalcopyrite, and pyrite in 56 stope on the 400 level (Tenney, 1913).

Junction Mine, Several areas in this very extensive mine contained minor tetrahedrite as inclusions in the ores.
2700 level; Abundant tetrahedrite was found in a high-grade stope on this level by one of the authors in 1972 as thin, vein-like inclusions in a bornite/chalcocite ore with pyrite and freibergite.

Oliver Mine, *1350 level;* Minor tetrahedrite was found here as rounded grains in bornite (Tenney, 1913).

Sacramento Mine, *1500 level;* Common in several places in small amounts as inclusions in sulfides particularly galena. Bornite, chalcopyrite, silver, and chalcocite were associated minerals (Tenney, 1913).

Spray Mine, *400 level, 500 level, 600 level;* Several areas on these levels produced tetrahedrite in minor amounts as inclusions in chalcocite and bornite with sphalerite, chalcopyrite, and pyrite (Tenney, 1913).

THOMSONITE $NaCa_2Al_5Si_5O_{20} \cdot 6H_2O$:

This hydrothermal species has been noted to occur in the district by Anthony, et al. (1995). However, no information regarding the mode of occurrence or the area where it occurred is provided.

TILASITE $CaMg(AsO_4)F$:

This rare supergene mineral has been recognized at a single locality in the district. Bladh, et al. (1972) used the Bisbee material to establish the crystal structure for this species.

The typical occurrence for tilasite is as small, complex crystals with other manganese and arsenic minerals in veinlets in limestone.

The species associated with tilasite are:

calcite
braunite
conichalcite

OCCURRENCES:

White Tail Deer Mine, A clean limestone surface outcrop near this mine contained calcite veinlets with complex, green tilasite crystals to 6 mm in size (Williams, 1970).

TITANITE $CaTiSiO_4$:

This hydrothermal species has been recognized as a minor accessory mineral in several of the intrusive units. Also, titanite was noted in the limited skarn development adjacent to the Sacramento Stock Complex. It is probably more common in the productive area of the district than the few confirmed localities would suggest.

Typically, titanite occurred as scattered tiny grains in the intrusives or as granular masses in a skarn assemblage. In some places in the Juniper Flat granite, it occurred as well-formed crystals in vugs (Anthony, et al. 1995).

The species associated with titanite are:

quartz
muscovite
pyrite
orthoclase
calcite
chlorite
plagioclase
“biotite”
hematite

OCCURRENCES: Titanite is a common accessory mineral in the Juniper Flat granite on the western edge of the district with occasional pockets of well-formed crystals with chlorite and quartz (Anthony, et al. 1995).

Gardner Mine, *900 level, 9 drift;* Titanite was abundant in samples from here as granular masses with pyrite and hematite in altered limestone (Tenney, 1913).

Lavender Pit Mine, Minor anhedral grains of titanite occurred in the younger porphyry unit of the Sacramento Stock Complex.

TOLBACHITE $Cu^{2+}Cl_2$:

This is a very rare mineral in the district. The Bisbee occurrence is the first New World find. Under humid conditions, tolbachite alters to a fluffy, greenish-white paratacamite.

Tolbachite, like all of the other copper-chlorine minerals from the district, is found associated with cuprite. The typical mode of occurrence is as patches of a yellow-brown material in fractures in massive cuprite. On rare occasion, tolbachite is found as an extremely thin coating of microcrystals, again on cuprite.

The minerals associated with tolbachite are:

cuprite

atacamite

paratacamite

nantokite

OCCURRENCES:

Southwest Mine, *5th level*, *14 stope*: Tolbachite was found in minor amounts here as yellow-brown, filmy patches on massive cuprite and as partial coverings of cuprite crystals where it occurred as small patches of light brown microcrystals associated with nantokite and atacamite.

TORBERNITE $Cu^{2+}(UO_2)_2(PO_4)_2 \cdot 12H_2O$:

A supergene mineral that is very rare in the district. It is known only from a few specimens from a single locality.

The species associated with torbernite are:

azurite

smithsonite

pyrolusite

OCCURRENCES:

Junction Mine, *770 level;* Torbernite occurred here as a few transparent, apple-green crystals to 2 mm scattered across bright blue, botryoidal azurite with minor smithsonite and pyrolusite.

TREMOLITE $\square\{Ca_2\}\{Mg_5\}(Si_8O_{22})(OH)_2$:

The tremolite-actinolite minerals series is defined as one of the calcium amphiboles with A(Na+K+2Ca)<0.5 apfu and with C(Al+Fe3++2Ti)<0.5 apfu with (OH), F or Cl occupying the W position (Black, 2018). This mineral was formed as part of the modest contact metamorphism surrounding the Sacramento Stock Complex and the underground intrusive dikes. Tremolite was perhaps the most common of the minerals that formed in this environment (Ransome, 1904; Bonillas, et al. 1916; Galbraith, 1947). As such, it was abundant as well as widely distributed. Ransome (1904) noted that most of the limestone in the Spray mine below the 400 level and in the Irish Mag mine below the 850 level exhibited some degree of alteration to tremolite. This alteration ranged from minor to nearly complete replacement.

Typically, it was found as aggregates of minute radiating prisms or as a fibrous material that were white to pale green in color. For the most part, the fibers were short, but on occasion it occurred as thick, asbestiform material.

The species associated with tremolite are:

actinolite
dickite
calcite
epidote
diopside
edenite
quartz
forsterite
chalcopyrite
wollastonite
chlorite
grossular
chalcocite
vesuvianite
sphalerite
pyrite
andradite

OCCURRENCES: Tremolite is so abundant and widely distributed that only a few of the typical occurrences are noted.

Gardner Mine, *900 level, 44 drift;* The limestone in this area was almost completely replaced by light green massive tremolite with minor pyrite and sphalerite (Tenney, 1913). Elsewhere on this level it was found associated with epidote, minor zoisite, and apatite replacing limestone as well as the fringe of an intrusive dike.

Lowell Mine, *1100 level, 9 drift; Massive* gray, asbestiform tremolite with quartz was abundant here as a replacement of limestone adjacent to a dike (Tenney, 1913).

Sacramento Mine, *1600 level;* Tremolite as small fibers in calcite with dickite had largely replaced limestone in an area of this level (Tenney, 1913).

TUNGSTENITE WS_2

This hypogene mineral has been recognized in very small amounts in a single mine within the district. In this occurrence, tungstenite was a minor inclusion in the complex, multi-mineral assemblage that was associated with common sulfides in the Campbell orebody.

The species associated with tungstenite are:

chalcopyrite
gold
sphalerite
bornite
wittichenite
kiddcreekite
chalcocite
tennantite
galena
digenite
colusite

OCCURRENCES:

Campbell Mine, *1600 level;* Found here as laths in bornite associated with kiddcreekite, colusite with Te-rich tennantite (Schumer, 2017).

TURQUOISE $Cu^{2+}Al_6(PO_4)_4(OH)_8 \cdot 4H_2O$:

This abundant mineral was of secondary origin within the district. Cook (1994), noted *"The famous turquoise of the Bisbee district came from the base of the Glance Conglomerate. Thus, either copper enrichment or diagenesis of older supergene mineralization must have occurred after deposition of the base of the Glance conglomerate."*

However, only three mines produced this mineral with the Lavender pit producing all but a very small amount of the turquoise that came from here. Bisbee has produced some of the world's finest gem turquoise.

The first turquoise recognized from the district was found in 1951 during part of the overburden rock waste pre-stripping program for the Lavender pit. In 1955, a modest amount of light green to pale blue/blue-green turquoise was found in one of the underground mines.

All of the turquoise found in the Lavender pit came from the post-mineral Glance conglomerate along the eastern side of the pit. In this unit, the turquoise occurred as veins, open-space fillings, and, less often, as a replacement of pebbles within the conglomerate. The turquoise-filled fractures in the conglomerate were typically discontinuous, seldom over a meter in length, and usually less than 3 cm at the thickest point. Parallel, closely-spaced, small fractures were occasionally filled by turquoise, creating exceptionally handsome material. Quartz-crystal-lined voids and fractures in small quartz veins were commonly filled by turquoise as well.

Apparently random replacement of small pebbles by turquoise, while uncommon, was a feature that was evident throughout the whole of the turquoise-bearing area in the Lavender pit. Rinds on pebbles within the conglomerate were common, as were irregular, partial replacements. Complete replacement of the pebbles was far less common.

The color of the turquoise from the Glance conglomerate ranged from nearly white to blue to sky-blue as well as to a light blue-green to, very rarely, an apple-green. Color variations within the same small piece were common. A modest amount of the sky-blue material was sub translucent in nature.

The minerals found with turquoise in the district are:

hematite
pyrite
malachite
goethite
quartz

Turquoise has been recognized here as pseudomorphs after tiny apatite crystals.

OCCURRENCES:

Cole Mine, *1200* level; Turquoise was found here as thin veinlets to minute stringers of pale green to blue-green material with minor, 2 mm, euhedral pyrite crystals in a pyrite-rich intrusive dike (University of Arizona specimen 1243). The supergene origin of this turquoise is questionable given the fresh appearance of the associated pyrite. Pseudomorphs of turquoise after 0.2 mm apatite crystals have been observed in the dike rock.

Dallas Mine, ***1400 level, 10-D stope;*** A small number of specimens from this stope contained a bluish, microcrystalline crust of a member of the chalcosiderite-turquoise series which is either a copper-rich chalcosiderite or an iron-rich turquoise. Quartz, goethite and later cuprite are associated with these specimens (Whitley-Smith, 2017).

Lavender Pit Mine, Turquoise came from this mine in large amounts in veins, void fillings, and nodules of often very fine blue material in a brown to reddish brown conglomerate. In some instances, the veins of turquoise were up to 7 cm in thickness.

TYROLITE $[Ca_2Cu^{2+}_9(AsO_4)_4(OH)_8(CO_3)(H_2O)_{11}](H_2O)_x(x\sim0\text{-}1)$:

This supergene species is apparently quite rare at Bisbee, as it has been recognized in only in small amounts on but a few specimens. The species associated with tyrolite at Bisbee are:

azurite
kaolinite
malachite
andradite
hematite
quartz
goethite

OCCURRENCES:

Tyrolite was confirmed on a single specimen by Anthony J. Nikischer (personal communication, 2005) as sprays of 3 mm crystals on goethite with azurite and malachite. No information on the exact location at Bisbee was available.

Shattuck Mine, A few specimens of azurite and malachite in a quartz/andradite skarn adjacent to the Shattuck Dike contained very small amounts of tyrolite as bluish green sprays of 3 mm crystals.

Southwest Mine, *6th level;* Sparing tyrolite occurred in vugs in supergene hematite as single bladed greenish, tabular crystals. Abundant kaolinite was present in the area were the specimens were collected.

TYUYAMUNITE $Ca(UO_2)_2V_2 O_8 \cdot 5\text{-}8H_2O$:

This is an uncommon mineral in the district that is always of supergene origin. It typically occurs in small amounts in the limestones adjacent to supergene chalcocite orebodies (Hutton, 1957).

The species associated with tyuyamunite are:

chalcocite
calcite
malachite

OCCURRENCES:

Campbell Mine, The occurrence of tyuyamunite at this mine is known only through specimen number 21108 in the American Museum of Natural History collection.

Cole Mine, *1100 level;* This is the area that produced most of the tyuyamunite from the district. It occurred as bright yellow patches on often slickensided limestone or rarely as 2 to 4 mm fan-shaped crystal clusters in small voids with calcite in limestone.

U

URANINITE UO_2:

This hypogene mineral was found in very small amounts as a minor accessory mineral associated with the primary sulfides in several of the mines. Bain (1952) describes the typical occurrence for uraninite. Using specimens from an unspecified mine, it was noted as cubic microcrystals fringing pyrite crystals in a massive sulfide matrix that included galena and sphalerite. He believed that uraninite was the first mineral deposited during mineralization at Bisbee.

The species associated with uraninite are:

pyrite
hematite
zippeite
quartz
galena
chalcopyrite
sphalerite
uranopilite
johannite

OCCURRENCES:

Cole Mine, Uraninite was recognized in a few specimens from an unspecified level in this mine that were collected in the late 1940's. Here, it was found as tiny, black anhedral inclusions in pyrite with minor chalcopyrite. The sulfide/uraninite mixture was partially altered and contained uranopilite as well as minor zippeite and johannite.

Czar Mine, *400 level;* Uraninite was found here as scattered, corroded, black cubes to 4 mm on and included in fine-grained pyrite.

URANOPILITE $[(UO_2)_6(SO_4)O_2(OH)_6(H_2O)_6 \cdot 8H_2O$:

This is an uncommon mineral in the district that has been found only as an efflorescence on decomposing pyrite with a very minor amount of uraninite.

The species found associated with uranopilite are:

pyrite
zippeite
johannite
uraninite
gypsum

OCCURRENCES:

Cole Mine, Uranopilite has been recognized on a few specimens from an unspecified level in this mine that were collected in the late 1940s or early 1950s. It was found as an efflorescence on decomposing sulfides. Uranopilite from here is highly fluorescent and composed of bright lemon-yellow globular aggregates of tiny lath-like crystals with gypsum and minor zippeite as well as johannite.

V

VANADINITE $Pb_5(VO_4)_3Cl$:

This supergene mineral is of very limited distribution within the district.

The arsenic-rich variety, endlichite, is the only form of vanadinite known from here. It occurred as long, thin, brown, prismatic crystals of up to 2 cm in length. The crystals were intergrown in "jackstraw" fashion often filling the voids in a calcite cemented, jarosite/plumbojarosite breccia in which they grew. Some of the crystals were cavernous.

The only associated species were, as noted, calcite, jarosite, and plumbojarosite.

OCCURRENCES:

The material is known only from a few dump specimens recovered as a new access road was cut through the waste dump in 1973.

Shattuck Mine; The variety endlichite was found here as acicular 2 cm, brown crystals in "jackstraw" fashion often filling voids in a jarosite/plumbojarosite breccia with calcite.

VARISCITE $AlPO_4 \cdot 2H_2O$:

This species has apparently formed under both hypogene and supergene conditions in the district. Typically, variscite was massive with occasional crystal-lined vugs in the supergene material.

The species associated with variscite are:

pyrite
cuprite
chalcopyrite
pickeringite
copper
pseudomalachite
scorzalite

OCCURRENCES:

Cole Mine, *1200 level;* Veins of hypogene variscite were found in a pyrite/chalcopyrite orebody on this level in 1956. It occurred as a massive, apple-green to pale green material that graded into a gray/white rind at the edges. Minor pyrite is often included in the rind material. Compact in nature, pieces up to 15 kilos were recovered.

Lavender Pit Mine, *Holbrook Extension;* Supergene variscite has been found in the altered sediments adjacent to the Sacramento Stock Complex. Here it occurred in large masses that were pale blue, green, brown, black to white in color. Microcrystals were noted in some of the small vugs in the massive material (David Garske, personal communication, 1998). Copper and cuprite coated by pseudomalachite, in minor amounts, as well as scorzalite and pickeringite (Rob Bowell, personal communication 2004) were associated with variscite from here.

VELIKITE Cu_2HgSnS_4:

This rare hypogene species is quite uncommon within the district with only very small amounts found at a single locality. Here, velikite was identified as micro-phases in the complex ores associated with the Campbell orebody.

OCCURRENCES:

Campbell Mine, This species was found in small amounts as micro-inclusions in sulfides with a diverse assemblage of copper/tin species (Sid Williams, personal communication, 1992).

VESUVIANITE $Ca_{19}(Al,Mg,Fe)_{13}Si_{18}O_{68}(O,OH,F)$:

This hydrothermal mineral is widely distributed in modest amounts throughout the district. Vesuvianite occurs as part of a multi-mineral, contact-replacement assemblage (Ransome, 1904; Bonillas, et al. 1916).

Typically, vesuvianite occurred along with other calc-silicate minerals replacing limestone. In these occurrences it was found as an impure, fine-grained, massive material or as compact, granular masses of small crystals. Vesuvianite was colorless to white to pale green in color.

The species associated with vesuvianite are:

tremolite
edenite
wollastonite
actinolite

quartz
grossular
epidote
magnetite
chlorite
pyrite
zoisite
sphalerite
hematite
pectolite
calcite
chalcopyrite
diopside

OCCURRENCES: Vesuvianite was so widely distributed and nondescript that only a few of the typical occurrences are noted.

Gardner Mine, Massive, impure, greenish vesuvianite was found here in an intrusion breccia as a replacement of limestone with other calc-silicate minerals.

Irish Mag Mine, Tiny, colorless crystals of vesuvianite were found in several samples from here studied by Ransome (1904).

Sacramento Mine, Vesuvianite was relatively abundant in this mine as a constituent of a calc-silicate mineral assemblage replacing limestone adjacent to the Sacramento Stock Complex.

VOLBORTHITE $Cu_3^{2+}V_2^{5+}O_7(OH)\cdot 2H_2O$:

An uncommon supergene mineral in the district, volborthite has been recognized on a small number of specimens from one locality. Here, it occurred as a minor, late-stage overgrowth on a 4 mm crust of mottramite that was, in turn, on highly supergene-altered Martin limestone.

The species associated with volborthite are:

mottramite
calcite
pyrolusite
goethite

OCCURRENCES:

Shattuck Mine, *600 level, 8 stope;* Volborthite occurred in the "vanadium cave" on the 9th floor (78 feet) above the level. It was found here in small amounts as tiny, yellowish-green crystals of pseudohexagonal form on mottramite with minor calcite.

VOLKONSKOITE $Ca_{0.3}(Cr^{3+},Mg,Fe^{3+})_2(Si,Al)_4O_{10}(OH)_2\cdot 4H_2O$:

This hydrothermal species is apparently quite rare within the district. Volkonskoite has been found in small amounts from a single mine. It occurred as massive material filling small voids in a quartz/pyrite matrix.

The species associated with volkonskoite are:

pyrite
quartz
chalcopyrite

OCCURRENCES:

Campbell Mine, Ore stockpiles from this mine contained minor amounts of volkonskoite as a waxy, green material in massive quartz/pyrite ores. Euhedral, cubic pyrite crystals to 2 mm occurred in this material as well.

VOLTAITE $K_2Fe_5^{2+}Fe_3^{3+}Al(SO_4)_{12}\cdot 18H_2O$:

This is a relatively common mineral that was widely distributed and locally abundant. It has been recognized in post-mining occurrences only. Voltaite is one of the more recognizable of the multi-mineral crusts that occur in many of the moist, pyritic areas of the underground mines (Merwin and Posnjak, 1937).

Usually, voltaite is found as sharp, black to green-black octahedral or cubic crystals, to 1 cm in size. For the most part it is found growing on other post-mining iron sulfates such as rhomboclase and copiapite. Porous aggregates of small crystals to 12 cm have been found. This is one of the few post-mining, hydrated iron sulfate species, which survives reasonably well after removal from the mine.

The species associated with voltaite are:

rhomboclase
chalcanthite
copiapite
kornelite
coquimbite
pyrite
römerite
paracoquimbite

OCCURRENCES:

Campbell Mine, Voltaite was common throughout this large mine as part of the multi-mineral crusts that were found in the warm, moist, pyritic zones.
2100 level; Exceptional crystals of voltaite came from this level. They were sharp, lustrous, black octahedrons to 1 cm with rhomboclase and copiapite on oxidizing pyrite.

Cole Mine, This is a common post-mining mineral in many parts of the mine.
700 level; Porous aggregates of voltaite to 12 cm composed of small, bright crystals occurring on and partially encased by copiapite with coquimbite were found in abundance at a waste transfer raise by one the authors in 1968.

Junction Mine, Many areas of this sulfide-rich, large mine contained voltaite as part of the post-mining crusts found lining mine openings.

Lavender Pit Mine, Voltaite is a common constituent of the post-mining assemblage that forms on pit walls in pyritic areas during moist periods. It is most often found as 1 mm or less euhedral crystals on and encased in römerite.

Sacramento Mine, The material studied by Merwin and Posnjak (1937) almost certainly came from this mine. It was an extremely abundant mineral that was found in many areas as part of the multi-mineral, post-mining crust that formed throughout the warm, moist, pyritic zones of this mine.

VOLYNSKITE $AgBiTe_2$:

This hypogene mineral was noted in modest amounts at two localities in one mine. In these occurrences it was part of a complex assemblage included in pyritic sphalerite ores or as inclusions in pyrite as well as replacing pyrite.

The species associated with volynskite are (Sid Williams, personal communication, 1987; Alan Criddle, personal communication, 1992):

pyrite
altaite
tellurium
gold
cassiterite
kiddcreekite
sphalerite
melonite
rucklidgeite
kostovite
stannite
calaverite
rhodostannite
stützite
goldfieldite
kësterite
galena
hessite
mawsonite
colusite
“wolframite”

OCCURRENCES:

Campbell Mine, *2200 level;* Volynskite was recognized in relatively moderate amounts as micro-phase inclusions in a pyrite-sphalerite ore with calaverite, altaite, melonite, and rhodostannite (Sid Williams, personal communication, 1987).
2300 level, 125 stope; Volynskite was one of the many species in a very complex mineral assemblage that was found both as inclusions in pyrite and replacing pyrite (Alan Criddle, personal communication, 1992).

W

WILLEMITE Zn_2SiO_4:

This mineral is of supergene origin at the several recognized localities within the district. It is not particularly abundant at any of these occurrences, except the 2100 level Campbell Mine occurance.

Willemite was typically found as disseminated 1 to 2 mm, rice-grain-shaped crystals in altered limestone or as distinct, free-standing crystals in voids in goethite. In all occurrences in the district, willemite is highly fluorescent, giving the typical intense yellow-green response to ultraviolet light. The material from both Higgins mine localities is also strongly phosphorescent.

The minerals found with willemite are:

calcite
quartz
shattuckite
cuprite

anglesite
plancheite
goethite
copper

OCCURRENCES:

Campbell Mine, *1500 level;* Willemite was reported from here as highly fluorescent material by Anthony et al. (1995).
2100 level; Massive, green fluorescent willemite with highly red, fluorescent iron-stained calcite was relatively abundant in a stope on this level and highly collected during the last years of the 1940s (Melvin Elkins, personal communication, 2016).

Higgins Mine, *Twilight claim*; Willemite occurred in the open-cut manganese workings 300 feet above the tunnel level as 1 mm prismatic crystals in altered limestone along with irregular blebs of a shattuckite and plancheite mixture. This material is intensely fluorescent.
Tunnel level, "Cuprite stope"; Willemite was abundant as highly fluorescent and strongly phosphorescent, massive material with calcite, cuprite, and copper in a post-mineral breccia. Colorless willemite crystals to 2 mm. on braunite were found in a different part of the Cuprite stope as well.

Southwest Mine, *3rd level*; Willemite was noted here as clusters of 0.2 mm hexagonal crystals on a mixture of goethite and plumbian calcite.
6th level; It occurred at a location on this level as white, 0.5 mm spheroids and 0.1 mm hexagonal prisms on goethite.

WITTICHENITE Cu_3BiS_3:

This hydrothermal mineral has been recognized in small amounts at a single mine. Here, wittichenite was noted as a very minor accessory mineral in a complex, silver- and bismuth-rich, diverse mineral assemblage. This assemblage occurred as micro-phase inclusions in a siliceous hematite matrix associated within a highly altered dike of undetermined composition (Alan Criddle, personal communication, 1992).

The species associated with wittichenite are (Alan Criddle, personal communication, 1992):

jalpaite
djurleite
spionkopite
galena
digenite
hematite
bismite
chalcopyrite
bismuthinite
bornite
acanthite
copper
sphalerite
covellite
gold
stromeyerite
quartz
chalcocite
silver
matildite
emplectite
cuprite

It is worth noting that the chalcocite associated with this locality contained 6% silver.

OCCURRENCES:

Campbell Mine, *1600 level;* Silver-rich (7%) wittichenite was recognized from this part of the Campbell orebody in the work of Criddle and Stanley as part of a high-silver/bismuth mineral assemblage (Alan Criddle, personal communication, 1992).

“WOLFRAMITE” $(Fe,Mn)WO_4$:

This is a series name; the end species are ferberite (iron-rich) and hübnerite (manganese-rich). It has been included here for completeness only where the distinction between the two species was not made and to allow for the work of previous studies to remain available. “Wolframite” was found in several localities in two of the mines in the district. Typically, it occurred in small amounts as inclusions in sulfides along with a number of tin, tungsten, and vanadium minerals. Often, it is part of a diverse assemblage that was replacing pyrite. An additional locality is represented by University of Arizona specimen 6091, noted as having been collected one mile north of Bisbee.

The species associated with “Wolframite” are (Sid Williams, personal communication, 1987; Alan Criddle, personal communication, 1992):

kiddcreekite
chalcopyrite
nolanite
mawsonite
kostovite
magnetite
scheelite
goldfieldite
colusite
tennantite
altaite
pyrite
chalcocite
galena
tetradymite
sphalerite
bornite
gold
stannite
tellurium
cassiterite

OCCURRENCES:

Campbell Mine, *2300 level 125 stope; “*Wolframite” was found here in very small amounts as a minor component of the compound inclusions in pyrite and as part of a complex mineral assemblage replacing granular pyrite (Alan Criddle, personal communication, 1992).
2566 level; ‘Wolframite” was part of a very complex assemblage of tin, tungsten, and vanadium mineral found here replacing pyrite (Alan Criddle, personal communication, 1992).

Cole Mine, *1300 level;* “Wolframite” came from this level in minor amounts with kiddcreekite, scheelite, pyrite, bornite, and chalcopyrite; all in specimens that have a crust of chalcocite crystals and some elemental gold (Sid Williams, personal communication, 1987).

WOLLASTONITE $CaSiO_3$:

This mineral was formed as part of the modest contact metamorphism surrounding the eastern part of the Sacramento Stock Complex and to a lesser degree, some of the underground intrusive dikes. Wollastonite was one of the several minor minerals that formed in this environment (Bonillas, et al. 1916). Ransome (1904) looked for wollastonite but did not find it in the samples from the western part of the district, which he studied. It was, however, widely distributed in small amounts, particularly in the intrusion breccia on the edge of the Sacramento Stock Complex as well as the Martin and Abrigo limestones along the eastern portion of this intrusive.

Typically, it was found as a fibrous crystals or as compact, massive material that were white to pale gray in color.

The species associated with wollastonite are:

- tremolite
- quartz
- chlorite
- chalcopyrite
- pectolite
- edenite
- chlorite
- grossular
- epidote
- diopside
- actinolite
- sphalerite
- pyrite
- muscovite
- magnetite
- vesuvianite
- calcite
- hematite
- zoisite

OCCURRENCES: Wollastonite was so widely distributed and nondescript that only a few of the typical occurrences are noted.

Gardner Mine, Wollastonite was relatively common as a white, fibrous material with a number of other typical contact-metamorphic minerals in the intrusion breccia type ores developed by this mine.

Lowell Mine, At this mine, wollastonite was found as needle-like crystals with pectolite, epidote, and chlorite, with pyrite replacing limestone adjacent to a dike in Martin limestone (Tenney, 1913).

Spray Mine, 500 *level, 103 drift;* Nearly pure, massive wollastonite was found here replacing limestone (Tenney, 1913). Also on this level it occurred as a minor component of a contact-mineral assemblage replacing limestone with abundant sericite, substantial amounts of pyrite, and minor zoisite (Tenney, 1913).

WULFENITE $PbMoO_4$:

This supergene species has been recognized in only a few locations in the district and never in any quantity. For the most part, wulfenite from here occurs as small, tan to colorless crystals commonly associated with supergene copper and/or lead minerals. Typically, this is a very late stage mineral as no specimens are known from here with any other species deposited on the wulfenite.

The species associated with wulfenite from the district are:

- malachite
- smithsonite
- cerussite
- azurite
- copper
- mimetite
- goethite
- anglesite
- calcite
- hematite
- galena

OCCURRENCES:

Campbell Mine, The Campbell orebody between the 1700 level and the 2566 level produced wulfenite specimens with small crystals that were associated with copper, malachite, cerussite, azurite, and mimetite (Anthony, et al. 1995). All of the occurrences listed below are from parts of the Campbell orebody.

1800 level, 59 stope; Wulfenite was moderately abundant in this lead stope as zoned, tabular crystals to 8 mm on a soft goethite. These crystals ranged from a straw color to colorless and were associated with calcite and minor anglesite.

Another stope on this level, east of the Campbell fault, produced a small number of attractive specimens of yellow-orange crystals to 1.5 cm on hematite with malachite-coated copper and very minor yellow mimetite.

2566 level; A very few specimens of 2 cm bright orange crystals on hematite were recovered from an oxidized fault zone on this level.

Cole Mine, *700 level;* Gemmy, colorless wulfenite crystals to 8 mm occurred on goethite and on decomposing galena from this level. Anglesite, cerussite, and minor malachite were associated with the wulfenite on galena.

Holbrook Mine, Wulfenite came from here in very small amounts as 3 mm yellow-brown crystals on azurite and malachite.

Lavender Pit Mine, *Holbrook Extension;* This part of the pit mined much of the Holbrook mine area, so similar specimens were produced. Wulfenite was found here as rare caramel-colored crystals to 8 mm on blocky azurite crystals with malachite.

Y

YARROWITE Cu_9S_8:

This hypogene species is quite rare within the district with only very small amounts found at a single locality. Here, yarrowite was identified as micro-phases in the complex ores associated with the Campbell orebody.

OCCURRENCES:

Campbell Mine, Yarrowite was found here in small amounts as micro-inclusions in sulfides (Sid Williams, personal communication, 1992).

Z

ZINCOBOTRYOGEN $(Zn,Mg)\ Fe^{3+}(SO_4)_2\ (OH)\cdot 7H_2O$:

This is an uncommon mineral in the district that was always post-mining in origin. It occurred as massive reddish-orange material with a greasy appearance. The general similarity of zincobotryogen to other post-mining minerals and a general lack of interest in these minerals as a whole may well have caused it to go unrecognized at other occurrences.

The species associated with zincobotryogen are:

- sphalerite
- gypsum
- pyrite
- calcite
- hydrozincite
- goslarite

OCCURRENCES:

The occurrence of this species in the district was first based on specimen number 97,317 in the collection of the American Museum of Natural History (Joe Peters, personal communication, 1992). The locality for this specimen was unrecorded, but it was not from the one noted below.

Higgins Mine, *Tunnel level;* Patches of red-orange zincobotryogen to 2 mm occurred on iron-rich sphalerite pieces left underground during mining. It occurred here with hydrozincite, goslarite, gypsum, and smithsonite, all of which were post-mining in origin.

ZINCOCOPIAPITE $ZnFe_3^{3+}(SO_4)_6(OH)_2{\cdot}18H_2O$:

This species has only been recognized in small amounts in a single post-mining occurrence. In this occurrence, it was found as a minor component of a multi-mineral crust on broken sphalerite/pyrite ore.

The species associated with zincocopiapite are:

- pyrite
- melanterite
- sphalerite
- römerite
- copiapite
- smithsonite

OCCURRENCES:

Higgins Mine, *Tunnel level;* Fractures in broken sphalerite/pyrite ore left in place underground had tiny, clusters of tabular, amber crystals of zincocopiapite with copiapite, melanterite, and römerite.

ZIPPEITE $K_3(UO_2)_4(SO_4)_2O_3(OH)^{\cdot 3\cdot}H_2O$:

This is an uncommon mineral in the district. At the single recognized occurrence, it was formed as the result of the decomposition of pyrite with a very minor uraninite present.

The species associated with zippeite are:

- pyrite
- uranopilite
- uraninite
- gypsum

OCCURRENCES:

Cole Mine, Zippeite is known only by a few samples collected in the 1940s from an unspecified level in this mine. It occurred as very tiny orange/yellow, globular, efflorescence on decomposing sulfides with gypsum and uranopilite.

ZIRCON $ZrSiO_4$:

This hydrothermal species was a common accessory mineral in several of the intrusive units within the district and the Pinal schist. The two intrusives that are part of the Sacramento Stock Complex contained zircon (Ransome, 1904; Bryant and Metz, 1966) as did the Juniper Flat granite (Ransome, 1904). It was also recognized as an accessory mineral in the Pinal schist (Ransome, 1904). In all cases, zircon occurred in small amounts as either tiny anhedral grains or equally small crystals.

The species associated with zircon are:

apatite
magnetite
quartz
orthoclase
rutile
ilmenite
chlorite
“serpentine”
“tourmaline”
“oligoclase”
fluorapatite
pyrite
muscovite

OCCURRENCES: Only a couple of typical occurrences will be noted because of the wide distribution and nondescript nature of zircon in the district.

In his study of the Pinal schist, Ransome (1904) noted zircon as small crystals with tourmaline, chlorite, and "oligoclase". The Juniper Flat granite contained zircon as a minor accessory mineral with muscovite, apatite, tourmaline, and magnetite (Ransome, 1904).

Holbrook Mine, *500 level;* Zircon was noted as an accessory mineral along with fluorapatite in one of the porphyry units of the Sacramento Stock Complex in a matrix of orthoclase, "biotite", and quartz with pyrite (Tenney, 1913).

ZOISITE $Ca_2Al_3(SiO_4)(OH)$:

This hydrothermal alteration species is widely distributed within the district, but always in small amounts. It has been recognized as an alteration product in the porphyry units (Bonillas, et al. 1916; Schwartz, 1956; Lowell and Guilbert, 1970) and in the sediments (Tenney, 1913; Bonillas, et al. 1916). It is possible that much of the reported zoisite is actually clinozoisite.

Zoisite occurred as a minor constituent of a calc-silicate alteration assemblage in both the porphyry and the contact-altered sediments, particularly the Abrigo limestone (Bonillas, et al. 1916). In all instances it formed as tiny anhedral grains and rarely as small compact masses.

The species associated with zoisite are:

epidote
wollastonite
rutile
calcite
forsterite
hematite
pyrite
sericite
clinozoisite
tremolite
apatite

OCCURRENCES: Only a few representative occurrences are noted below because of the nondescript nature of the species in the district.

Gardner Mine, *900 level, 9 drift;* Calc-silicate altered limestone at this locality contained grains of zoisite with tremolite, epidote, clinozoisite, and apatite (Tenney, 1913).

Holbrook Mine, *500 level;* An altered porphyry dike on this level contained minor zoisite with rutile and pyrite (Tenney, 1913).

Lavender Pit Mine, Zoisite occurred in the porphyry units of the Sacramento Stock complex, usually in the less sericitic portions.

Spray Mine, *500 level;* Several places on this level contained zoisite in altered limestone as grains or very small compact masses with wollastonite, forsterite, tremolite, pyrite, and very minor sericite (Tenney, 1913).

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THE AUTHORS

Left to right, Douglas L. Graeme, Richard W. Graeme III, and Richard W. Graeme IV with a very small part of the collection

Bisbee and the Graeme family: Our connection to Bisbee began in 1883, when Charles Keeler came to this young mining camp as a boy, seeking work, which he quickly found in the Copper Queen Mine. For most of the next 62 years, he would call Bisbee his home and mining his trade. He retired in 1945 but continued to live close to the Cole Shaft, where he had spent so many working days. Charles was our grandfather/great-grandfather. It was his many stories and reminisces that kindled a life-long interest within Richard Graeme III for all things Bisbee, most of all the minerals as he was a mineral collector. The legacy of Keeler's interest continues with unabated passion in Richard Graeme IV and Douglas Graeme. Together, we have assembled the largest and most complete collection of Bisbee minerals with some 7,000 specimens. This is supplemented with an extensive research library and a historical photograph collection of more than 6,000 images, all of which provide an unparalleled research basis.

And too, we have spent 10s of thousands of hours in the field, underground, and the laboratory over the last 70 years. The resources and experiences provide a unique platform for the telling of Bisbee's colorful past and its wonderful minerals.

Richard (Dick) W. Graeme III Born in Bisbee, Arizona, in 1941, and was an active collector of Bisbee minerals by the age of six. By his early teens, he had amassed a good collection of minerals and was well known to mineral dealers and other collectors as a source of specimens. In 1959, while looking for minerals in the Cole Mine, he collected a specimen that would later be recognized as a species new to science and which would be named graemite in his honor (Williams and Matter, 1974).

Dick went to work in the mines in 1960 as a laborer where he would remain for the next dozen years, during which he completed a BS in Geological Engineering in 1972 at the University of Arizona. The day after receiving his diploma, he was promoted to Resident Geologist of the Copper Queen Branch. With the closure of the mines, Dick left Bisbee but continued to study its mineralogy, geology, and history while writing about all of these aspects (Graeme, R.W., 1981, 1987, 1993, 1999, 2008, 2012a, 2012b), and (Graeme et al., 2015). After 55 consecutive years in the copper industry, much outside of the U.S. in senior management positions, he retired and lived in Lima, Peru until his death on June 2, 2021.

Richard (Rich) W. Graeme IV: Born in Bisbee, Arizona, in 1968, Rich was collecting underground with his father and twin brother by age six. Minerals and mining were the focal points of his youth, with many hundreds of hours underground in Bisbee and other western mining areas collecting minerals and mining artifacts. In 1986, along with his twin, he collected what is surely Bisbee's finest cuprite specimen along with exceptional examples of some of the rarest of copper minerals.

Rich has worked in the goldfields at Nome, Alaska, underground in the fabled Sunnyside Mine at Silverton, Colorado, and the Continental Mine near Silver City, New Mexico, as well as the Golden Queen Mine near Mojave, California, gaining first-hand experience in underground mining. Later, he worked in Bisbee at the Queen Mine Tours as a guide, where his knowledge base was put to full use.

Because of the difficult times for the domestic mining industry, Rich switched from a mining major to education and received his degree in education from the University of Arizona in1999. He now teaches science in nearby Sierra Vista.

Douglas (Doug) L. Graeme: Born in Bisbee, Arizona in 1968, Doug was underground and collecting minerals and artifacts by the age of six. From that point on, his focus has been on Bisbee, and its incredible mineralogy interspersed with mineral finds elsewhere. Most of his free time as a young boy was spent underground in a usually successful quest for minerals and mining-related memorabilia. The news and significance of his discoveries were shared with fellow collectors when, beginning at age 13, he and his brother made frequent presentations at the New Mexico Mineral Symposium.

While he collected many fine minerals in his teen years, nothing compares to the extraordinary cuprite he collected with his twin in the Southwest Mine. Along with what is one of the world's best cuprites, he also collected a diverse suite of rare and uncommon copper minerals, some of which remain the best examples known for the species.

By the time Doug had completed three years of university studies with a mining major, the U.S. mining industry was well into its decline. Nonetheless, he worked on the surface with the gold dredges of Nome, Alaska, and underground in the specimen-rich Sunnyside Mine near Silverton, Colorado, as well as in the Continental Mine in Fierro, near Silver City, New Mexico. Later he would work at the Queen Mine Tours as a guide then in Kartchner Caverns during its development using his mining experience. Now Doug has returned to work in Bisbee as the Manager for the Queen Mine Tours, where his passion and knowledge help keep the legend of Bisbee alive.

PUBLICATIONS:

Our publications include chapters in various books or periodicals over a 40-year period. More recently, we have taken important segments of Bisbee's geology, mining, and history and published' detailed overviews of these various aspects. All are listed below by year published.

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1987 - "Bisbee; Arizona's Dowager Queen of Copper Camps": A look at her first 50 years" (in *History of Arizona Mining*): By Richard. W. Graeme III

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2016a - *The Forgotten Caves of Bisbee, Arizona.* R.W. Graeme, III, D.L. Graeme, and R.W. Graeme IV, Copper Czar Publishing, Bisbee, Arizona, 175 p.

2016b - *An Overview of the Post- Mining Minerals Found at Bisbee, Arizona.* R.W. Graeme, III, D.L. Graeme, R.W. Graeme, IV, Copper Czar Publishing, Bisbee, Arizona, 36 p.

2016c - *Glossary of Mining and Mining Related Terms as used at Bisbee, Arizona*, R.W. Graeme, III, D.L. Graeme, R.W. Graeme, IV, Copper Czar Publishing, Bisbee, Arizona, 136 p.

2020 - *7---- Bells: Mine Safety & Accidents at Bisbee, Arizona*, Second edition:_by Richard William Graeme IV Copper Czar Publishing, Bisbee, Arizona, 589 p.