MINERALS OF ARIZONA

TWENTY-THIRD ANNUAL SYMPOSIUM

Sponsored By

Flagg Mineral Foundation

March 27-29, 2015

Co-Chairpersons

Phil Richardson - Chair, Flagg Mineral Foundation

Ray Grant - Vice Chair, Flagg Mineral Foundation

Minerals of Arizona

Twenty-third Annual Symposium

Sponsored by the Flagg Mineral Foundation

Friday, Saturday, and Sunday
March 27, 28, and 29, 2015

Co-chairpersons:
Phil Richardson - Chair, Flagg Mineral Foundation
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Clarion Hotel at Phoenix Tech Center
5121 E. La Puente Ave, NW corner of Elliot Rd and Interstate 10.

Cover Design by Harvey Jong

Photo Credits

Upper left: Silver
Mineral Park, Cerbat Mountains, Mohave County, Arizona
Former Eidahl Collection specimen, current owner unknown
Tony Kampf photo

Upper right: Silver
Silver King Mine, Pinal County, Arizona
Former Gene Schlepp specimen, current owner unknown
Wendell Wilson photo

Lower left: Silver
Mohave County, Arizona
Evan Jones specimen & photo

Lower right: Silver
Lucky Cuss Mine, Tombstone Hills, Cochise County, Arizona
Flagg Mineral Foundation Collection specimen
Jeff Scovil photo

Friday, March 27
Micromineral Session – 2 PM to 5 PM

Friday afternoon 2 PM to 5 PM will be a mircomineral session. Some microscopes will be available to use and samples to give away. **Talk - 4 PM – Ron Gibbs**

Dealers selling at the Clarion 5 to 10 PM

Saturday, March 28
Minerals of Arizona Symposium
(program next page)

Evening Buffet

6:00 Buffet, auction and evening speaker Tony Potucek – Notable Native Silver Specimen Producing Localities in New Mexico and Arizona

Sunday, March 29
Mineral Identification - 9:00 to 11:00 AM

Erik Melchiorre, Geology Department, California State University, San Bernardino will use portable XRF to identify unknown minerals for symposium participants. Each person can bring one unknown sample.

Saturday March 28 –Symposium Program

8:00 - 8:45 - Coffee Hour

8:45 – 9:00 - Welcoming Remarks and Introductions

9:00 – 9:40– Crystallized Gypsum Deposits of the San Pedro River Basin - Barbara Muntyan

9:40 – 10:20 – Red Cloud Mine - the world's greatest wulfenite locality – Les Presmyk

10:20 – 10:50 - Break

10:50 – 11:30 – Silver Production and Mineralogy of the Silver King Mine, Calico, California - Tera Ochart and Chelsea Sheets-Harris

11:30 – 12:10 - The Apex Mine, Utah - A Colorado Plateau-type Solution-Collapse Breccia Pipe and a Tsumeb, Namibia Analogue – Karen Wenrich

12:10 – 1:30 - Lunch

1:30 – 2:10 – Mine Reclamation and Mineral Specimen Recovery Operation at the Blanchard Mine, Socorro County, New Mexico - Mike Sanders

2:10 – 2:50 – Origins of Azurite and Malachite - Erik Melchiorre

2:50 – 3:20 - Break

3:20 – 4:00 – History of the Freeport-McMoRan Minerals Mineral Collection – Will Wilkinson

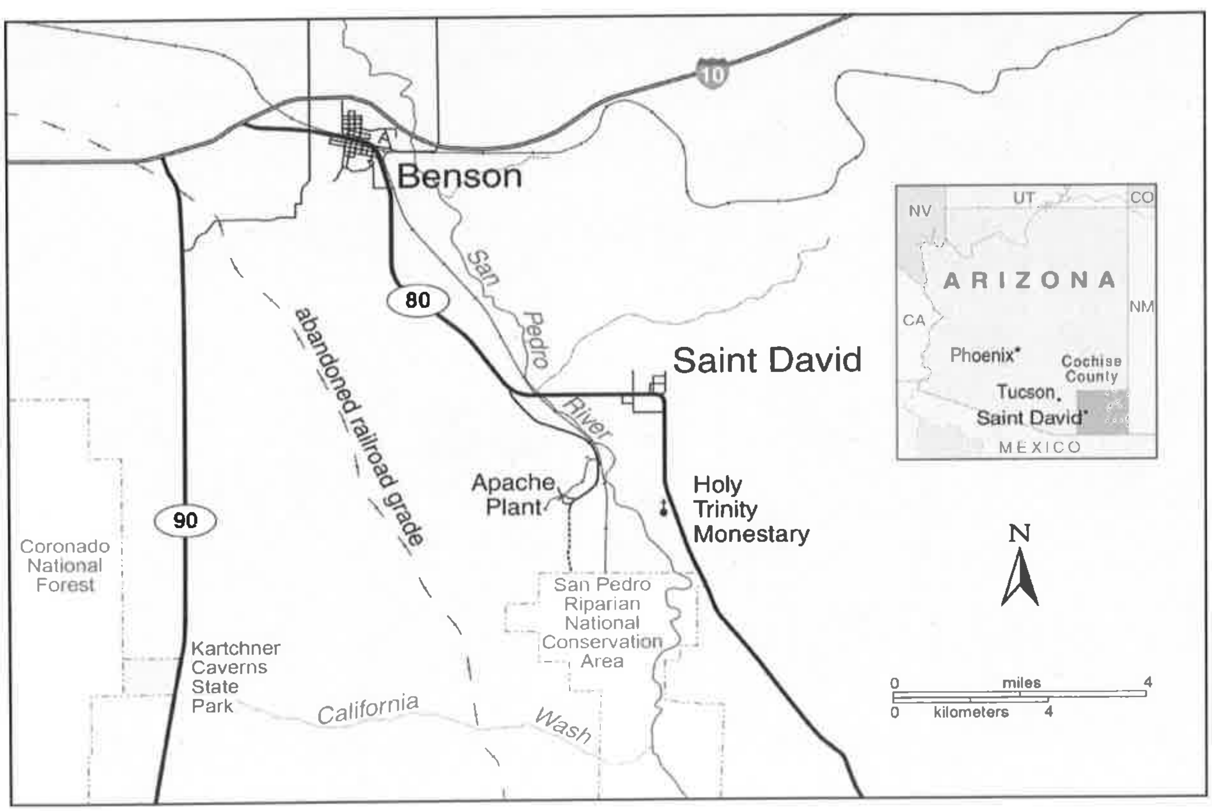
4:00 – 4:40 - Emus, 'Roos and Minerals and Mines at Broken Hill, NSW, Australia - Anna Domitrovic

Crystallized Mineral Deposits of the San Pedro River Basin, Arizona

Barbara L. Muntyan

The gypsum (selenite) deposits near the hamlet of St. David in Cochise County, Arizona, have been known to mineral collectors for more than fifty years. The collecting areas are located on the west side of the San Pedro river valley. This valley is a graben: a fault-block downed dropped valley, possibly associated with Basin and Range faulting. The river itself flows north out of Mexico and is one of the last free-flowing rivers in Arizona. Although it is a quiet stream for most of the year, the San Pedro can turn into a roaring torrent during the summer monsoons. The landscape in the collecting areas is high chapperal: sparse grasses, a few prickley pears, creosote bushes and occasional mesquite trees.

Pleistocene Ice Age erosion is found on many of the benches; some of them contain vertebrate fossils. The gypsum deposits cover a wide area. Although most collectors only know the area near St. David, crystals can be found in an area approximately 200 square miles.



Map by W. W. Besse

Gypsum is hydrated Calcium Sulfate: $CaSO_4.2H_20$. A monoclinic mineral, it is soft (only 2 on the Mohs Scale), and has a highly developed cleavage parallel to the C axis of the crystals. Gypsum crystals result from evaporation of saline waters. It is also soluble in water, which means that material exposed on the surface is etched, dull, and broken along cleavage planes.

Most field guides and most collectors are familiar only with small desert roses perhaps a half inch to 1 inch in diameter, and indeed there are literally thousands – probably millions -- of them found on the surface or near-surface throughout the collecting areas. Most of the area is Arizona State Trust Land. Access to the familiar collecting sites is from the Apache Powder Road; a former dynamite manufacturing operation to supply dynamite to the mines in Bisbee, the plant's ten-story tower is a prominent landmark visible from much of the collecting spots.

The best crystals are found *in situ* in a number of washes that run down to the San Pedro river to the east. On the correct horizons in some of these washes, roses can reach 8 inches in diameter. In addition, depending on the wash, fine monoclinic crystals up to 6 inches in length, fishtail twins, hoppered crystals, and crystals with movable bubbles have been found. Crystal color can be tan, red-brown, white, cream or clear, transparent selenite crystals.

Because of the potential for flash flooding during the summer monsoons, many of the washes are scoured or change channels. In addition, the ground is rock-hard bentonite and other clays, which are softened by the monsoons. Thus optimum collecting time is after the rains, but only after the trails dry out a bit to allow motor travel. Four-wheel drive and high clearance is definitely required.

Red Cloud Mine – The World's Greatest Wulfenite Locality by Les Presmyk

Flagg Mineral Symposium – March 2015

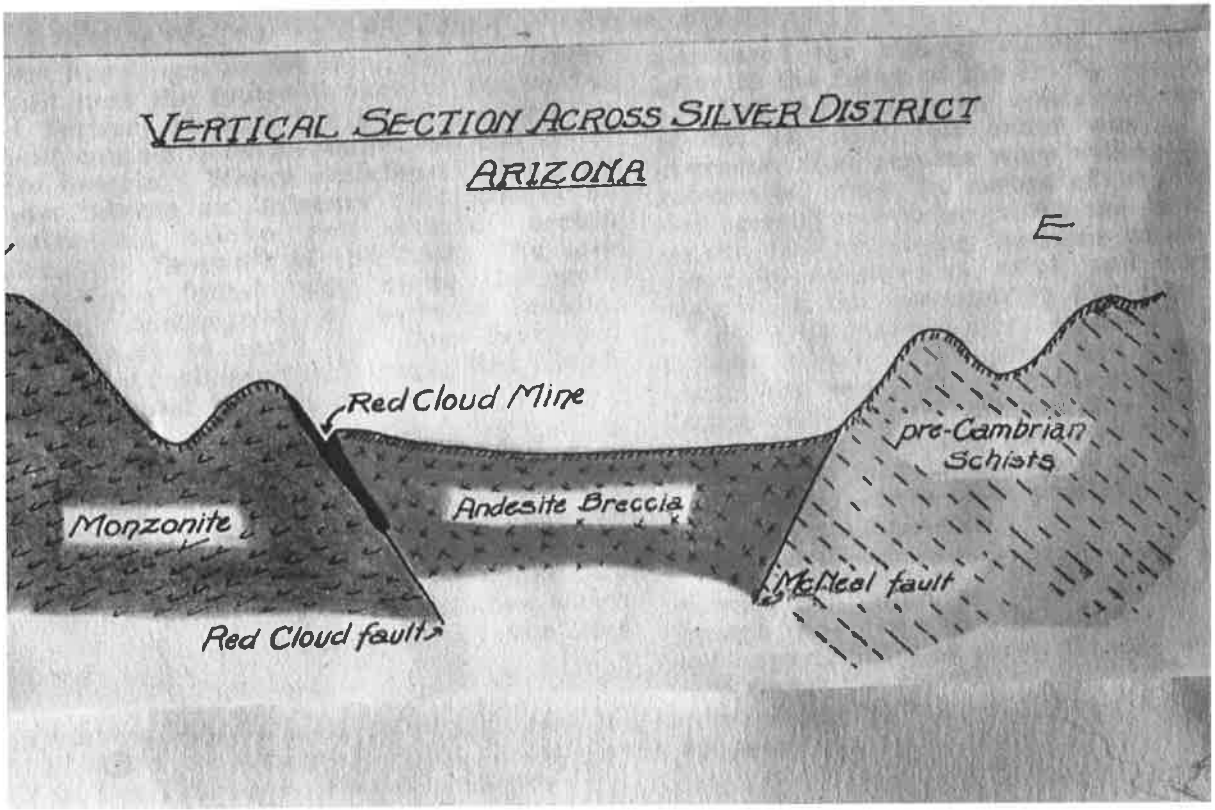
The Red Cloud mine is in the southwest corner of Arizona, about 180 miles from Phoenix. It is one of a dozen or so mines in the Silver District. Today, most of that 180 miles is by paved freeways and highways and only the final 15 miles or so is on dirt and sandy roads. There was a railroad planned from Yuma into the Silver District but the mines did not last long enough to make that dream come true.

When the area was first being prospected travel in Arizona was limited to staying fairly close to water and the Colorado River provided transportation for people and supplies. The Red Cloud was originally claimed in 1862 and was named after a nearby Spanish/Indian trail, not anything related to the red wulfenite scattered on the surface.

Mining History

The most intensive mining took place between 1878 and 1885. From 1900 to 1955 there was minor mining efforts and the dumps and tailings were reprocessed. The Ed Over pocket was collected in 1938. From 1955 to 1978 the major mining activity was from field collectors. When the price of silver spiked to $54 per ounce, an effort was made to start mining again. A mill was built and the stopes were completely cleaned out. With the precipitous drop in the price of silver, all mining activity came to a halt. But, the collecting activity intensified from 1983 to 1995. In that year, Wayne Thompson and associates purchased the mine and open pitted the vein. Collector's Edge took over ownership in 1999 and continued the open pit mining until 2003. The mine is currently privately owned and some exploration is taking place.

Geology



The basement rock to the west, forming the footwall of the red cloud vein, has been described as granite, granodiorite and quartz monzonite. This has been estimated to be of Cretaceous or Tertiary age, around 65M years. The east side of the district is underlain by a pre-Cambrian metamorphic series of quartzite, argillite, and quartz-mica schist.

The center of the district consists of a series of beds of volcanic breccia, agglomerate, lava flows and tuff. There are even sandstones and thin-bedded limestones, indicating incursions of water during Tertiary times.

Mineral deposition was controlled by the two main faults in the area, the Red Cloud on the west and the McNeal on the east. Sulfide mineralization was emplaced later in the Tertiary. The entire exposed vein in the Red Cloud is oxidized. Deeper diamond drilling did not encounter sulfide minerals except for the occasional galena pod.

Specimen Production

By the mid to late 1970's no one could call themselves a serious field collector in the southwest without spending time at the Cloud. Specimen production was sporadic and mainly dependent on how much effort one was willing to put into digging. Fine specimens came from the open cut on the surface as well as 400 feet underground.

Specimen is 8cm wide

Besides the author, the list of those who collected at the Red Cloud reads like a who's who of field collecting. Wayne Thompson, Gary Fleck, Ray Grant, Dave Shannon, Graham Sutton, Mike Smith, Dick Jones, Tom McKee are just a few from Arizona. New Mexico collectors like Tony Potucek, Mike Jaworski and Mike Sanders would travel over from their studies to try their luck in Arizona. Southern California collectors like Garth Bricker spent nearly every school break at the Cloud.

When we started open pitting the vein I asked Wayne to allow me to host field trips. We invited and encouraged field trips by various groups and clubs including the Mineralogical Society of Arizona, the Flagg Mineral Foundation, the Albuquerque Gem & Mineral Club, The Tucson Gem & Mineral Society and the Los Angeles Gem & Mineral Guild. Collector's Edge continued this tradition. The number of people who can now say they collected at the Red Cloud number in the hundreds.

The largest pocket ever found at the Cloud was initially discovered on April 1, 1996. Initially, it appeared to be about 10 feet long. When it was finished it was nearly 40 feet long. All types of collecting equipment were used to extract the specimens. From screwdrivers and rock picks to sledgehammers, 8 foot pry bars, gas-powered diamond saws to jackhammers and backhoes, everything was employed to expose the pockets but to extract the specimens in the safest possible way.

The mineralogy of the Red Cloud mine is fairly simple, with a small number of collectable species. Wulfenite is the most notable species with reasonable cerussite and mimetite specimens. Although vanadinite is reported from here, most likely any specimens are from one of the other mines, such as the Pure Potential/North Geronimo/Romaldo Pacheco. In all of the vein material moved by the open pitting operations, no vanadinite was ever found.

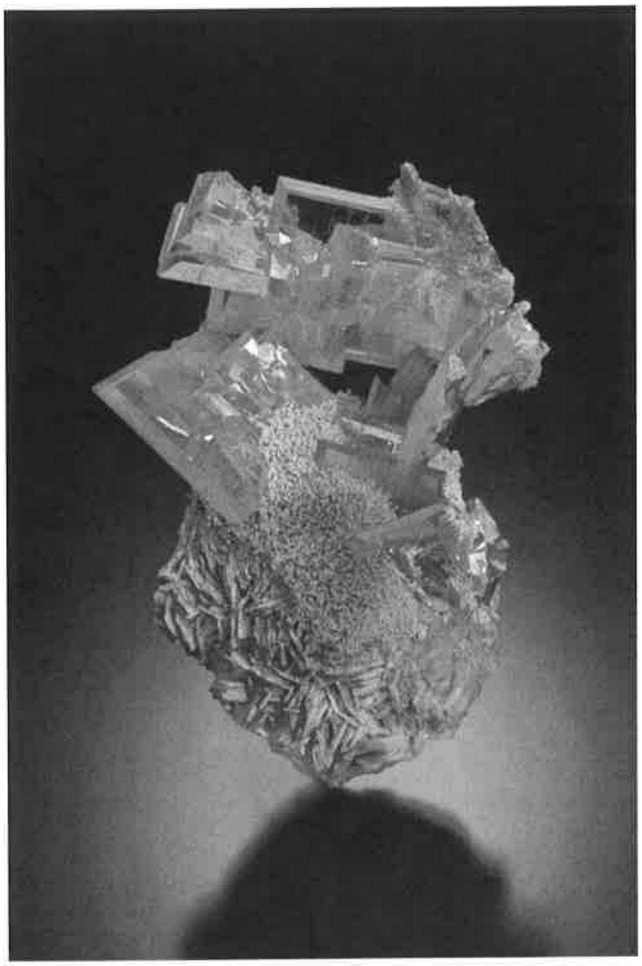
The World's Greatest Wulfenite Locality

1. How famous is the locality? The Red Cloud is world famous.
2. Color – Red is the most desired color for wulfenite with yellow probably a close second.
3. Quality – Crystals up to 2", clusters of crystals up 12" across with orange-red to red crystals.
4. Valuable Specimens – Red Cloud specimens have sold for more money than any other locality with prices over $250,000 for specimens less than 6" across.
5. Longevity – The Red Cloud has produced over three centuries and 140 years.
6. Quantity and Quality – greatness is defined by large numbers of fine specimens.
7. Gemstones – Red Cloud produces material clear and large enough to cut gemstones.

Here are the other contenders.

United States Localities are pretty much Arizona with one in New Mexico and include the following:

79 and the Rowley mines. While each locality has produced beautiful and desired specimens, specimens larger than 3" across are rare and the number of great specimens are limited.



Rowley Mine – 2" tall, Dick Morris Collection, Jeff Scovil Photo

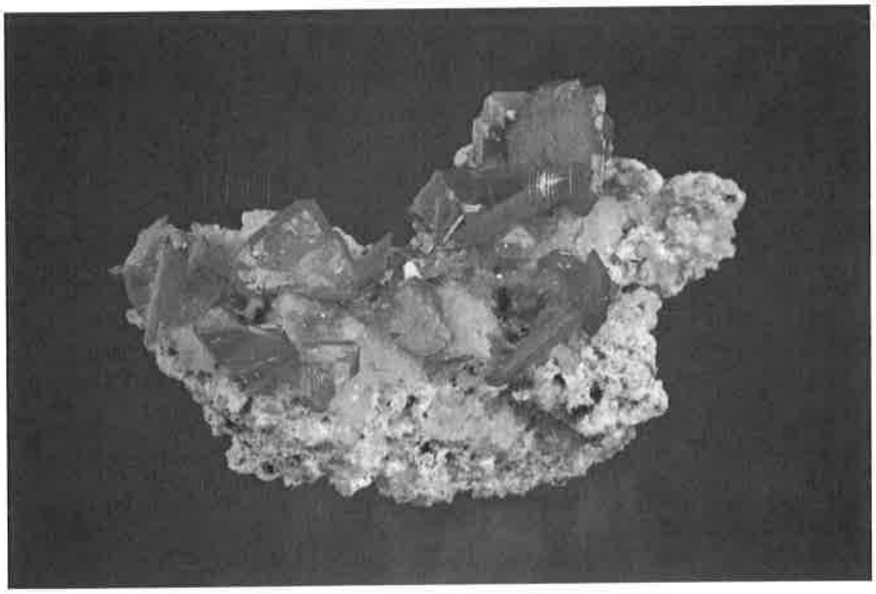
Defiance mine has produced both quantity and quality of large crystals and large clusters of crystals. The orange to brownish orange is not the most desirable color.

Glove mine – the one other Arizona locality that could challenge the Red Cloud for this title. Glove specimens are certainly valuable and mine production was prolific but the Glove remains Arizona's #2 locality.

North Geronimo and the Old Yuma have produced fine specimens but just not very many.

World-wide localities:

Iran has produced truly red wulfenites but never in much quantity and crystal size has been under 3/4" across.

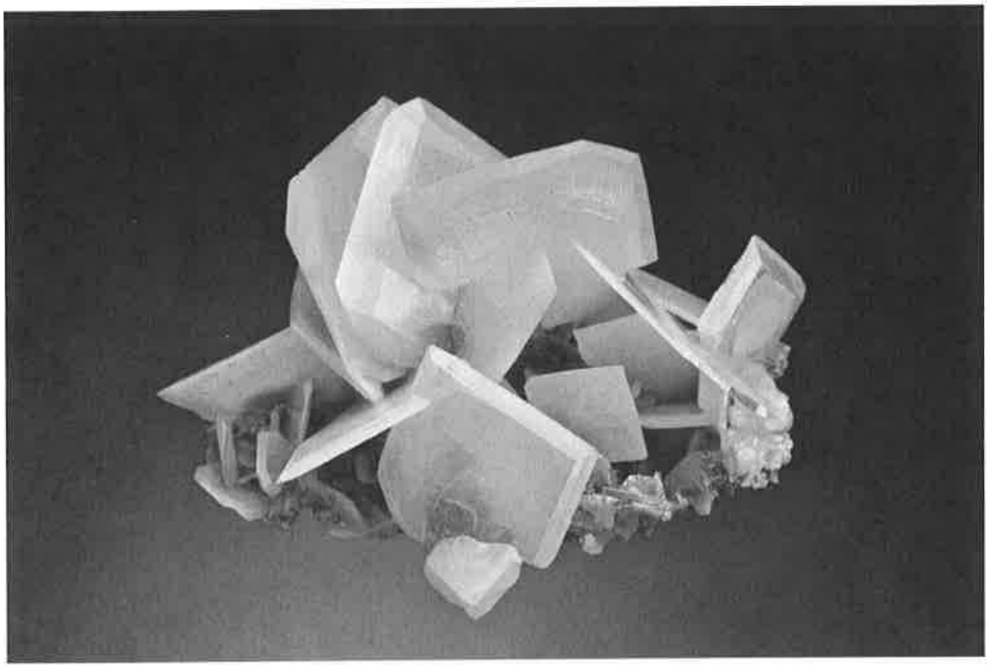


Nakhlak Mine, Iran – 2-1/8" tall, Crystal Classics/Kristalle Specimen, Jeff Scovil Photo

China's Jianshan mine produced large specimens of fine crystal but nothing with the sharpness and color of the Red Cloud.

Africa – M'Fouati and Tsumeb have produced notable wulfenite specimens. The quantity is not large and in the case of Tsumeb, the best specimens are bright yellow and the few specimens collected are in Desmond Sacco's collection. Morocco has two localities, Mibladen and Touissit.

Mexico has three localities to be considered, starting with Mapimi and Los Lamentos. Of the two, only Los Lamentos has produced the quantity and quality of specimens to be considered a great wulfenite locality. Probably the strongest contender is the San Francisco mine in Sonora. Over a period from 1972 to 2000, 7 or 8 pockets were discovered, each one producing large quantities of quality specimens.



Touissit, Morocco. Neil Prenn Collection. Jeff Scovil Photo.

Europe - Mezica, Slovenia is distinctive and probably Europe's finest locality. But the crystals do not display the color, sharpness and luster of the Red Cloud.

Silver Production and Mineralogy of the Silver King Mine, Calico, CA

Tera Ochart and Chelsea Sheets-Harris, *Geology Department, California State University, San Bernardino, CA 92407*

Historical data for silver and gold production from mines in the American Southwest are notoriously inaccurate and often represent a minimum value. US Mint records only record production which was received by the mint. Many remote mines found ready markets for their products in or through neighboring Mexico. Companies back then were as honest as those today. In some mines, "high-grading" was substantial, and in others "tribute miners" removed undisclosed amounts of ore. However, forensic geology can be used to estimate the production of these mines by measuring the volume of ore removed, and measuring the metal content of ore pillars and remnants of ore within stopes. Mapping of the extensive workings of the Silver King Mine at Calico, CA, and measurements of ore density, suggest removal of over 42,000 tons of ore from the stopes. Measurements of ore grade in pillars ranged from 20 to 600 ounces of silver per ton, consistent with historical values (e.g., Lindgren, 1887). It is calculated that at least 16 million ounces of silver were produced from the Silver King Mine, far more than the reported total of 15 million ounces from the whole district. This calculation does not consider the effects of bonanza pockets, and assumes that only paying ore was removed from the stopes.

The main silver mineral of the Calico District is reported in the literature as chlorargyrite. We have obtained samples of rich silver ore from ore pillars in the Silver King Mine, and performed XRF and EDS elemental analyses to determine the exact chemistry of the silver halide minerals. Our data for 20 samples suggest the silver halides range from bromian chloragyrite to bromargyrite. Color ranges from pale yellow to vivid lime green, and efforts are underway to measure the color index of samples, and determine if there is correlation with bromine content. These samples have very low iodine content, consistent with experimentally determined limits of solid solution (Chateau, 1959).

Chateau, H., 1959a. Proprietes thermodynamiques des cristaux mixtes d'halogenures d'argent. Comptes Rendus, Academie des Sciences, Paris 248: 1950-1952.

Lindgren, W., 1887, The silver mines of Calico, California: Transactions of the American Institute of Mining Engineers, vol. 15, p. 717-734.

THE APEX MINE, UTAH – A COLORADO PLATEAU-TYPE SOLUTION-COLLAPSE BRECCIA PIPE AND A TSUMEB, NAMIBIA ANALOGUE

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ABSTRACT[1]

The Apex Mine is located on the east flank of the Beaver Dam Mountains, Washington County, 1.1 mi. south of Jarvis Peak, in southwestern Utah. It was mined intermittently between 1884 and 1962 for Cu, Pb, Ag, and minor Zn. In addition, Ga and Ge were recovered during 1985-1986.

The ore consisted of limonitic breccia derived from silty and sandy carbonate rocks of the Pennsylvanian Callville Limestone and overlying Pakoon Dolomite. This breccia collapsed into the Mississippian Redwall Limestone, which is part of the thick Paleozoic carbonate sequence in the southern Beaver Dam Mountains. Although the breccia was previously interpreted as the result of faulting, this study shows instead that it is a nontectonic, polymictic breccia that formed by collapse of overlying rock, as high up in the section as the Queantoweap Sandstone, into solution caverns, and that both brecciation and mineralization predate all faulting in the area. Similarities in mineralogy, geochemistry, and structure demonstrate that this deposit is an analogue of the world-class Tsumeb Cu-Ge-Ga Mine. Both deposits occur in solution-collapse breccia pipes. The Tsumeb ore deposit contains both oxidized and primary ore, whereas the Apex orebody is essentially the oxidized remnants of a uranium-rich, polymetallic (base metal) orebody that is typical of northern Arizona.

Additional mineralized solution-collapse breccia pipes have been identified in the Beaver Dam Mountains, which implies that the underlying Mississippian Limestone provided such an extensive karst system that favorable ground for ore deposition was created far westward beyond the Colorado Plateau Province, into the Transition Zone and Basin and Range Province.

Mineralization at the Apex Mine likely occurred during at least two separate events: (1) 200-260 Ma when the initial uranium and base metals mineralized the breccia that presumably bottoms in the Mississippian Redwall Limestone (similar to thousands of breccia pipes in the southwestern corner of the Colorado Plateau that formed with Pangean time, events, and mid-continent MVT ores), and (2) 4-6 Ma when the primary ore was oxidized during Basin and Range extension in southern Utah. The oxidation likely removed the uranium and enriched the Fe, Ge, and Ga in the Apex orebody.

The analogy between the Tsumeb and Apex mines extends further than just the mineralogy and geochemistry in that they both lie in a similar underlying extensive karst network. Tsumeb is also part of a large mining district of base metal (Zn-Cu-Pb) sulfide mines, in the Otavi Mountainland, Namibia, which formed in collapse breccias and solution cavities related to a karstic network associated with the post-Gondwanaland surfaces in carbonate rocks of the Neoproterozoic Otavi Group. The base metal sulfide ores have been oxidized to late stage ores, 24-33 Ma, rich in Ga-Ge-V, similar to the Apex Mine.

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[1] A full paper version of this abstract can be found at Wenrich and Verbeek, 2014.

Mining for Ge and Ga at the Apex Mine lasted only briefly during 1985-1986. Previous publications and metallurgical studies suggested that the Ga and Ge resided in jarosite and goethite, respectively. However, geochemical results from this study indicate that this is not the case, and that originally both Ga and Ge likely occurred in sulfide minerals within the primary ore, and probably currently reside in oxidized minerals richer in Co and Ni than in Fe-rich minerals. If this mineralogical scenario is true it would explain why the company had metallurgical problems and could not recover the amount of Ga and Ge from the ore that they had expected.

The recently formed open caves within the orebodies in the Beaver Dam Mountains are a result of complete oxidation of the sulfide replacement ore, which created a reduction in volume of the limestone host rock. The caves contain considerable jarosite and goethite, together with graded bedding of dissolution residue in some parts of the caves.

Mining History

The Apex Mine is also known as the Dixie Mine, and should not be confused with the Apex Mine near the Bingham Canyon Mine. The main adit is located at an elevation of about 5600 feet. Copper was discovered in the area in 1872. The Tutsagubet Mining District was formed on 2 June 1883 at the camp of the Mountain Chief Mine. The boundaries were established for the district, which included ten square miles in the Beaver Dam area in the southwest corner of Washington County. This district included the Apex Mine, which was a particularly active copper producer in the 1890s (Fig. 1). A number of small mines were developed and mined intermittently until the end of World War II. The property consists of 22 patented and 9 unpatented mineral claims. During its 78 years of production, the Tutsagubet mining district yielded over 7900 tons of copper, 475 tons of lead, 11 tons of zinc, and 180,000 troy oz of silver, along with minor amounts of gold (Perry and McCarthy, 1977, p. 516-525). Most of the production was from the Apex Mine, with minor production from the Paymaster, Black Warrior, Jessie, Westside, and "unknown" mines. The presence of significant amounts of gallium and germanium in the Apex ores was recognized in the 1950's.

Such extensive oxidation produced colorful copper (Fig. 2), lead, and zinc oxide minerals that have attracted the curiosity of local mineral collectors for over 100 years. Mineral specimens have been salvaged from the dumps and inside the mines (when available to the collectors) almost from the beginning of mining at the Apex. Some azurite specimens from the Apex Mine compare favorably to azurite that has been preserved from the world-class locality of Bisbee, Arizona. If it weren't for the persistence and dedication to mineral preservation of mineral collectors, much Apex Mine data that is currently available might have been lost.

Kinkle (1951) provided a brief history of the mine prior to 1951: "The Apex Mine has had a varied history of production since 1900, and reached its peak production by 1905. At that time it was supplying ore for a smelter, which has long been dismantled, at St. George. According to old-timers in the district, the mine reached the 1100-foot level by means of an inclined shaft from the upper tunnel, and most of the ore above the 1100-foot level was mined out when the workings and shaft caved in 1905 [fire destroyed mine buildings, maps, and records]...As far as could be ascertained, the mine was not operated from 1905-1914, but was operated continuously from 1914 to 1921 when it again was shut down. It was reopened from 1929-32 [1672 tons averaging 32.90% Cu], and from 1936-38 [365 tons averaging 19.69% Cu], most of the operation being by leasers. Mr. Cox and Mr. Paterson, the present owners [as of 1951] began work in October 1941, and the mine has operated continuously [5,247 tons averaging 17.00% Cu][to 1951]."

Although from 1947 until 1983 there was activity on the property, little ore was removed from the mine. A total of 8835 feet of exploration boreholes was drilled at the Apex Mine from February to August 1983 (Fig. 3). A continuous, well-mineralized, Ge-Ga iron-oxide zone was defined from 80 feet above the 250-foot level down to the 600-foot level. The iron-oxide zone consisted of (1) massive, soft limonite, (2) limonite-goethite zones, and (3) limonitic dolomite breccia that were concentrated along steeply dipping subsidiary fault zones in the footwall of the Apex fault (Lalonde, 1983). Musto Exploration's geological reserve calculation, based on the 8835 feet of drilling, shows "that a total of 242,758 tons averaging 0.032% Ga, 0.064% Ge, and 1.63% Cu was defined" (Lalonde, 1983).

When processing of Ge and Ga ore began at the Apex in 1985, it became the world's first primary producer of these two metals. In addition, Ag, Cu, and Zn were recovered as by-products. The Musto Explorations operation shut down sometime in 1987, because of milling problems that resulted in disappointing ore recovery. It appears from the sign on top of the main portal to the mine that it was subsequently owned by Teckcominco (written commun. from Steve Scott).

Geologic Setting

The Paleozoic rocks in the Apex Mine area of the Beaver Dam Mountains can be traced eastward onto the Colorado Plateau. The Beaver Dam Mountains are located in the transition zone between the Colorado Plateau and Basin and Range provinces of the western U.S. There is little change in stratigraphy other than that the rocks are gently tilted, and the carbonate sequence thickens to the west. The Pennsylvanian Callville Limestone (~1500 ft thick) and Pakoon Dolomite (~600-800 ft thick) are exposed in the immediate area of the Apex Mine and dip eastward at roughly 10° to 20° (Hintze, 1985; Hammond, 1991). The Mississippian Redwall Limestone (~600 ft thick) is exposed about 1 mi. west of the mine and dips back under the Callville Limestone at the mine. The Apex Fault, discussed by Bernstein (1986) in his Apex Mine study, is shown only in the immediate area of the Apex Mine by Hintze (1985) and extends less than 1 mile.

The Callville Limestone in the immediate area of the mine consists of "massive beds up to 20 ft thick interbedded with many thinner beds of limestone and subordinate shale and sandy limestone members. The prevailing dip is 5° to 10°E on the east side of the mines, and 10° to 30°E. on the west side of the mines. The dip gradually steepens westward until the beds are dipping 60° to 80°E. at the Black Warrior Mine, a mile and a half west of the Apex Mine.... Many local warps in the bedding are present, and some of the mine levels in the Apex show some crumpling of the limestone... No connection is obvious between the warps in the limestones and the location of ore in the vein.... The limestones have very little fracturing,... and show no alteration except for a small area northwest of the Paymaster shaft" (Kinkel, 1951).

In contrast to the flat-lying rocks on the Colorado Plateau, according to Hintze (1985, Biek and others, 2009), these units in the Apex Mine area have been subjected to two principal deformations: (1) a late Mesozoic compressional phase, and (2) a late Cenozoic extensional phase.

Extensive karst in the Callville and Redwall limestones continues across the Beaver Dam Mountains, as evidenced by numerous prospect pits. However, only the Apex, Paymaster, Black Warrior, and Surprise Mines appear to have had any significant production. In the Black Warrior Surprise mines to the west of the Apex Mine, the Pb and Cu ore occurs as a filling of preexisting caves and show little tendency to replace the walls of the cave.

Most of the historic Grand Canyon copper mines tapped the oxidized zone of uranium- and base-metal-bearing breccia pipes that formed by collapse of overlying sedimentary rocks into solution caverns within the Mississippian Redwall Limestone. Primary sulfide and uranium ore, widely present southeastward on the Colorado Plateau in the uranium-rich breccia-pipe district, is sparse at the Apex Mine. Where faulting and oxidation have been more severe, some of the breccia-pipe orebodies, such as those of the Grand Gulch and Ridenour mines on the western edge of the Colorado Plateau, also are heavily oxidized, although not quite to the extent of the Apex Mine. Within the Colorado Plateau's breccia pipes, most of the uranium ore occurs within the sandy breccia matrix formed by comminution and decementation of Pennsylvanian and Permian sedimentary rocks. Similarly, the Apex Mine is in a collapse breccia formed by solution, also presumably of the underlying Redwall Limestone. The major difference between orebodies in the Beaver Dam Mountains and those on the Colorado Plateau is that the Apex type tends to be oxidized extensively, with enrichment of Ga and Ge, and lacks uranium-bearing ore.

Masses of broken and recemented rock in the vicinity of the Apex and Paymaster mines have long been interpreted as fault breccias due to movement along the Apex Fault (Bernstein, 1986) a NNW-trending fault of steep westerly dip, with an estimated displacement (Kinkel, 1951) of about 75 feet. This study shows that fault breccias at the Apex and Paymaster mines are only locally developed and are volumetrically insignificant, and that the preponderance of breccia seen in and near these mines is a solution-collapse breccia (Fig. 4) that predates the Apex Fault, early basin-range extension along low-angle detachment faults, and regional thrusting in the area.

Mineralogy of Mine Ore

The ore consists of malachite, azurite, and other secondary copper minerals in cemented, but very porous, masses. Massive black and yellow iron oxides are abundant, and a few small patches of lead oxide (plattnerite and possibly plumbojarosite) that still contain specks of galena can be found on the dump. The Ga and Ge ore was believed by Musto Explorations to be jarosite and goethite. However, geochemical results from this study suggest that is not the case.

The Apex Mine hosts a wide assortment of Cu, Pb, Zn, and As minerals, for which the Apex has long been popular with mineral collectors. Azurite and malachite specimens from the mine are spectacular, with some forming stalactites within the cavernous areas. The azurite and malachite also form beautiful replacements of fossils in the Callville Limestone, including the colonial corals Chaetes and Syringopora (Fig. 5), and the gastropod, Bellerophon.

Most of this mineral suite is similar to that of the world-class Tsumeb solution-collapse breccia pipe in Namibia. Tsumeb, also rich in Ga and Ge, has been mined for those metals along with Cu. Every mineral identified at the Apex Mine has been found at the Tsumeb Mine, including all 29 of the minerals listed above and an additional 9 identified from the Apex Mine by Steve Scott (written communication, 2014).

In addition, the suite of base-metal elements that is contained in these oxidized minerals is similar to that contained in the reduced ore of the Colorado Plateau breccia pipes. Primary unoxidized ore minerals of these base metals at the Apex Mine, such as galena and chalcopyrite, are rare but present, and are suggestive of the composition of the original unoxidized sulfide orebody.

Table 1. Minerals found at the Apex Mine. *Recently identified by Steve Scott

Adamite	Galena
Allophane	Goethite
Anglesite	Halloysite
Aurichalcite	Hematite
Azurite	Hemimorphite
Brochantite	Jarosite
Cerusite	Malachite
Chalcopyrite	Native Copper
Chrysocolla	Plattnerite
Cobaltian Adamite	Plumbojarosite
Conichalcite	Rosasite
Covellite	Wulfenite *
Cuprian Adamite	Zincian oliventite
Cuprite	
Duftite	

An Analogue of the Tsumeb Mine, Namibia

The Tsumeb Mine in Namibia is perhaps the closest analogue of the Apex Mine, in that it is also one of the few mines in the world to be mined for Ga and Ge. According to Boni and others (2007), the Tsumeb deposits "occurred in collapse breccias and solution cavities related to a karstic network associated with the post-Gondwana land surfaces in carbonate rocks of the Neoproterozoic Otavi Group, which already contained primary sulfide orebodies." The Tsumeb mine contained economic concentrations of Pb, Cu, Zn, Ag, Cd, Ge, and As (Lombaard and others, 1986) similar to mines in the unoxidized ores of the Colorado Plateau breccia pipe district. Tsumeb is also part of a large mining district of base metal (Zn-Cu-Pb) sulfide mines, in the Otavi Mountainland, Namibia.

At the Tsumeb Mine much of the primary ore remains unoxidized, although a significant amount was oxidized 24-33 Ma to a Ga-Ge-V-rich ore (Lombaard and others, 1986), as it has at the Apex Mine. The oxidized ore is located at depths between 0-900 ft and between 2250-3400 feet, with primary ore between these two horizons and additional ore extending down to 5150 ft [the depth of the mine at the time of the Lombaard and others (1986) paper]. The mineral assemblage at the Tsumeb Mine contains over 200 minerals, with a significant number of them having their type locality at Tsumeb, which makes it one of the world's premier mineral localities. In comparison, mineral collector Steve Scott has found and identified 38 minerals from the Apex Mine, every one of which also occurs at the Tsumeb Mine. With more collecting and careful mineral identification by collectors such as Steve, the Apex Mine list may grow to approach that of Tsumeb.

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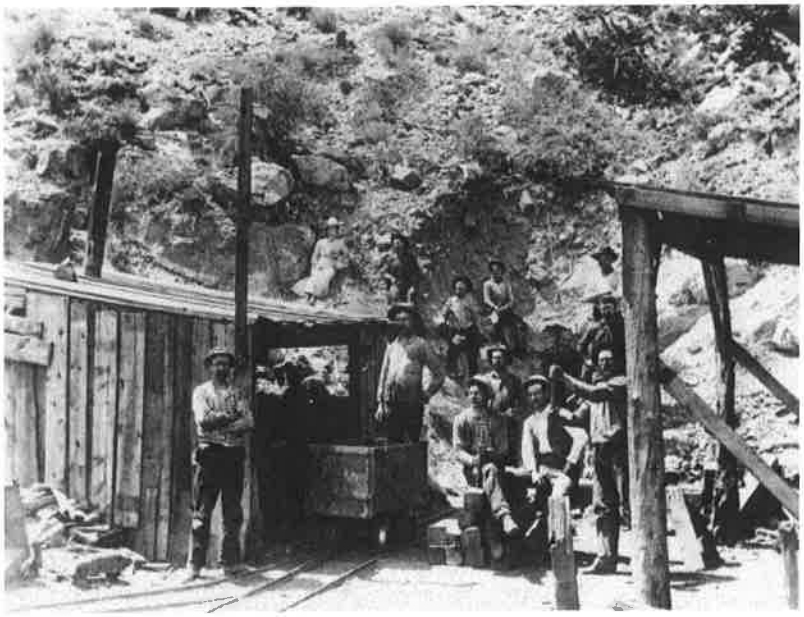

Figure 1. Miners at the entrance of the Apex Mine. Date unknown, but probably late 1800's. Contributed by James E. Kemple on March 2, 2012 to Washington County Historical Society Photo Collection.

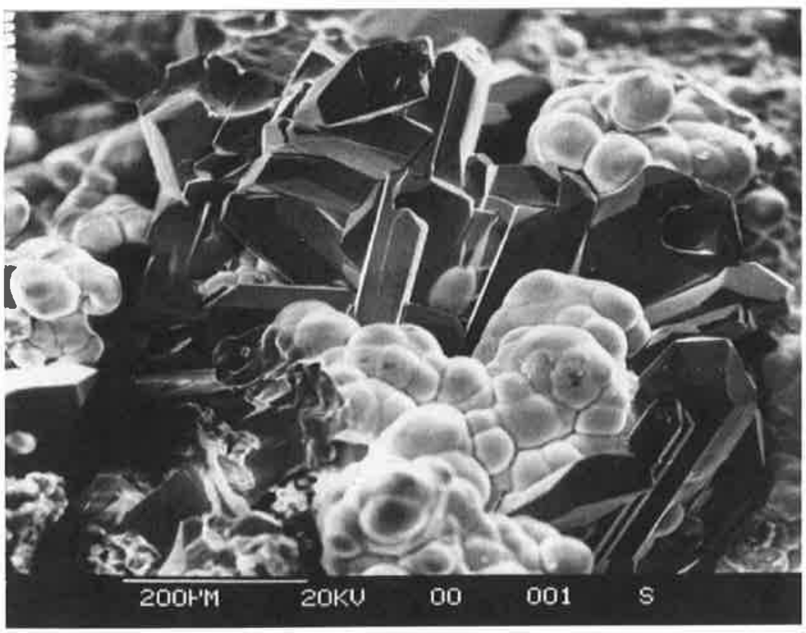

Figure 2. Electron backscatter image of conichalcite [$CaCu^{2+}(AsO_4)(OH)$] and azurite [$Cu_3(CO_3)_2(OH)_2$] showing remarkably perfect crystallization of the azurite in the Apex Mine. Photo and specimen of Karen Wenrich.

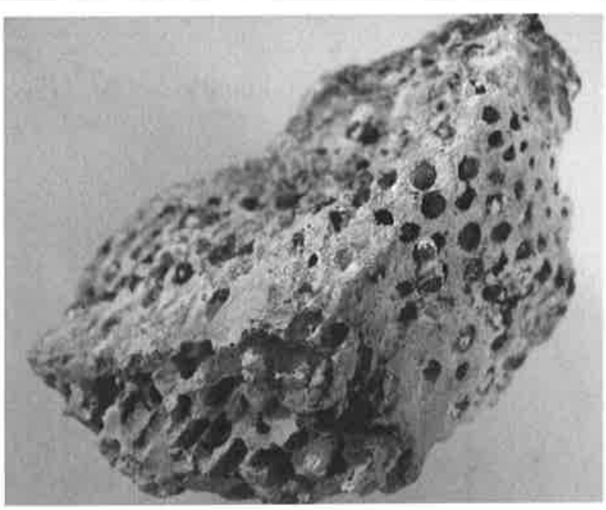

Figure 5. Fossil coral, Syringopora, replaced by malachite and azurite in the Callville Limestone. Steve Scott specimen and photo.

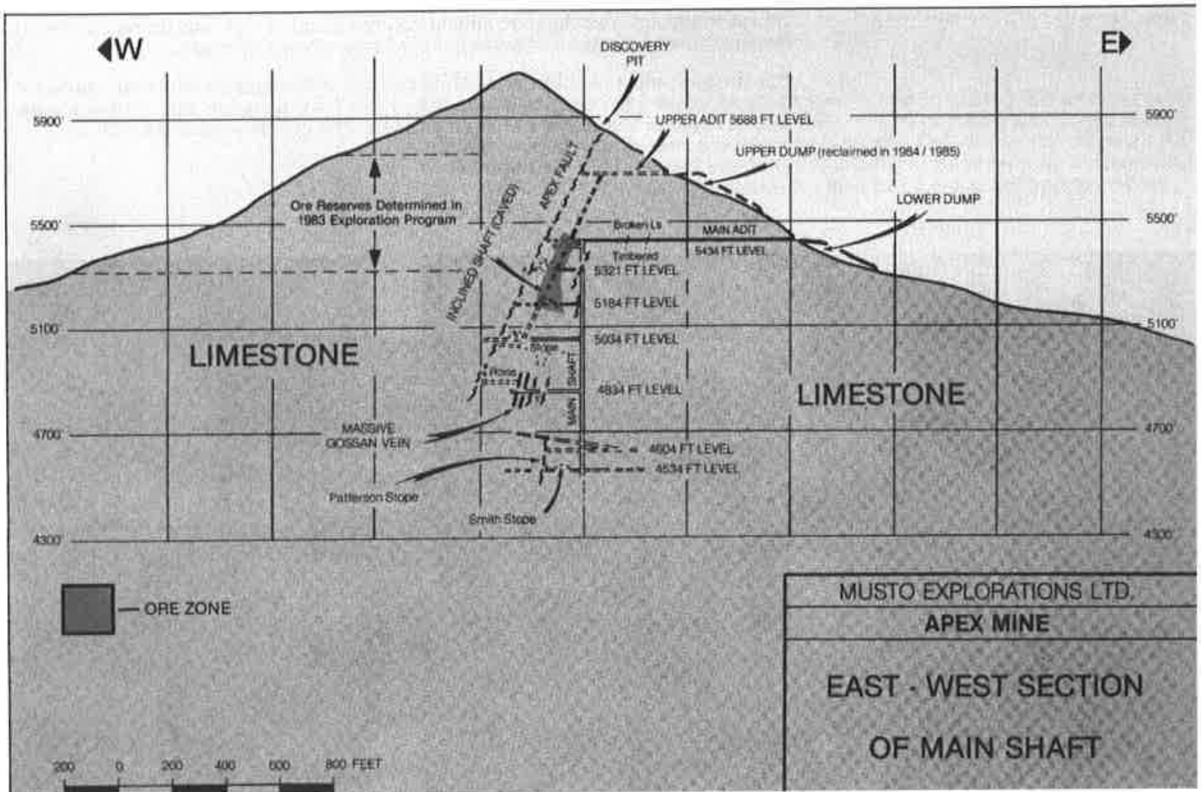

Figure 3 East-west cross section of the main Apex Mine shaft showing the ore zone extending from 5185 ft to 5434 ft above sea level. Musto Explorations Ltd. Apex Mine.

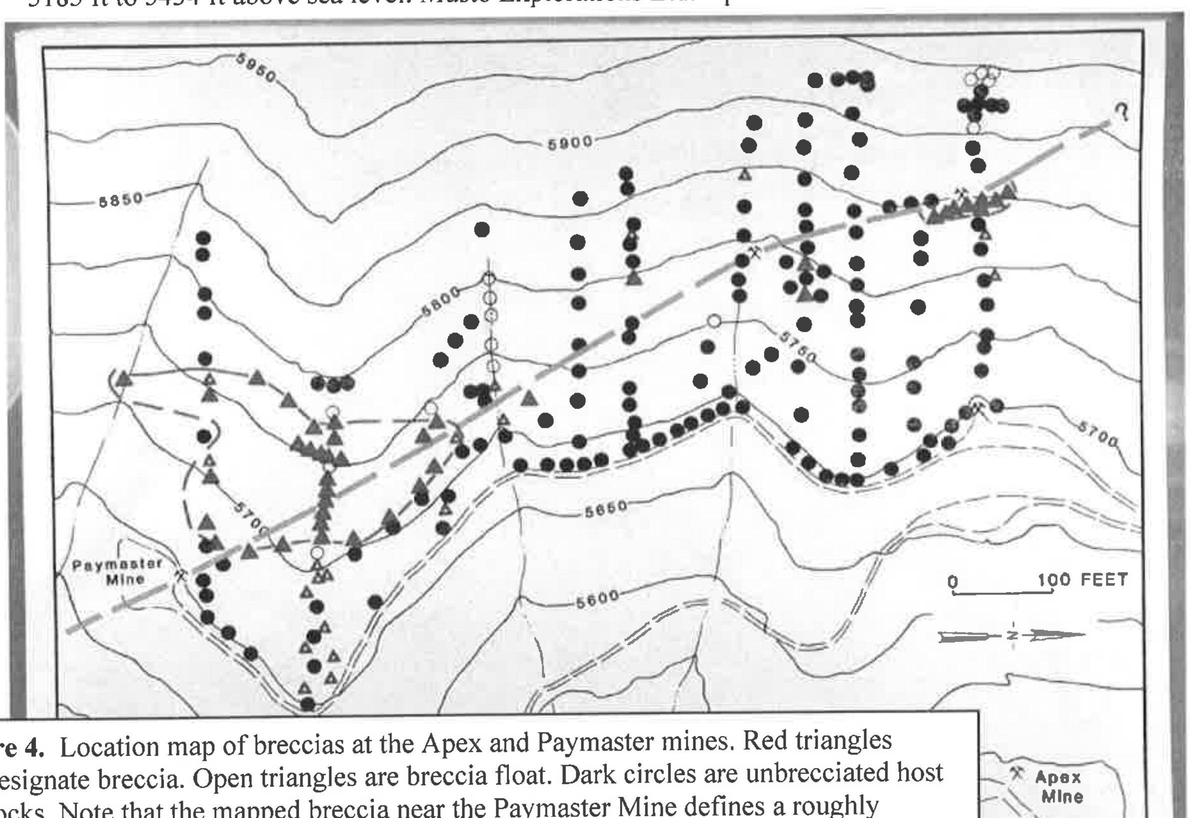

Figure 4. Location map of breccias at the Apex and Paymaster mines. Red triangles designate breccia. Open triangles are breccia float. Dark circles are unbrecciated host rocks. Note that the mapped breccia near the Paymaster Mine defines a roughly circular body, unlike a fault breccia, whereas an elongated fault breccia pattern along the fault zone would be expected. Although at the Apex Mine the breccia outcrop exposure is linear along the Apex Fault (dashed green line), underground it is not. The breccia exposure is more characteristically circular in pattern as at the Paymaster Mine outcrop shown in this figure

Table 2..Geochemical analyses of Apex Mine samples. Major oxides are in weight percent (%) and other elements are in ppm. ** Idicates some samples were determined by ICP and others by neutron activation.

Field ID	1181-E-C86	1181-H-C86	1181-J-C86	1181-V-C86R
Mine Level	5347			5330
Ag**	5	480	1	74
Al_2O_3** (%)	10.20	3.40	0.57	1.15
As**	2000	44000	14000	31000
Au**	<0.1	0.1	0.1	<8.0
B**	20	50	30	20
Ba**	680	330	260	111
Be**	<0.1	<0.1	<0.1	<0.1
Bi**	<10	300	<10	<10
C**	0.70	0.20	0.31	4.56
C (CRBNT PC)	0.55	0.01	0.21	4.49
C (ORG)	0.150	0.190	0.100	0.070
CaO**(%)	1.15	0.69	0.32	13.57
Cd**	24	560	49	26
Ce**	19.0	52.6	9.0	13.7
Co**	271.0	676.0	6860.0	721.0
Cr**	60.0	45.1	26.0	23.3
Cs**	0.900	1.850		0.227
Cu**	81000	46000	46000	65000
Eu**	0.65	1.33	1.00	0.52
Fe (%) (INAA)	22.0	23.3	47.3	3.5
F (PC)	0.11	0.08	0.03	0.05
Ga**	82	1200	240	460
Ge**	500	1500	10000	5000
Hf (INAA)	1.98	2.53		6.67
Hg (FL)	0.15	40.00	0.56	12.00
K_2O (%)	0.337	0.952	0.030	0.181
La**	9.01	41.20	4.73	10.80
Li**	12	19	3	16
Lu**	0.216	0.159		0.100
Mg (%)	0.28	0.30	0.12	7.46
Mn**	593.96	852.21	1291.23	335.72
Mo**	62	290	460	99
NaO**(%)	0.020	0.180	0.007	0.030
Nd**	9.00	30.80	2.40	10.50
Ni**	920	1000	3500	360
P (%)	0.070	0.240	0.007	0.180
Pb**	1300	11000	1600	280

Field ID	1181-E-C86	1181-H-C86	1181-J-C86	1181-V-C86R
S (TOTAL) PC	0.06	1.19	0.06	0.06
Sb**	9.9	2520.0	77.5	68.8
Sc**	2.380	1.500	0.337	0.879
Se (FL)	6.6	0.5	<10	<10
SiO_2 (%)	26.70	25.40	3.71	40.80
Sm**	2.94	5.09		2.27
Sr**	920	4000	150	1800
Ta**	0.108	0.269	1.600	0.094
Tb**	0.30			0.13
Th**	2.4	3.6		1.0
Ti** (ICP)	300	900	50	200
U (DN)	89	35	29	13
V**	33	86	21	35
W**	<20	<20	<20	<20
Y**	10	6	5	7
Yb**	1.200	0.740		0.567
Zn**	35900	40500	32100	2530
Zr**	30	70	30	150

Mine Reclamation and Mineral Specimen Recovery Operation in July 2013 at the Blanchard Mine, Socorro County, New Mexico

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In July 2013, Blanchard mine claim owners Ray DeMark, Mike Sanders, and Brian Huntsman joined forces with Arizona-based mineral specimen miners and mineral dealers Mark Kielbaso and Bruce Barlow for a three week mine reclamation and mineral specimen recovery project at the Blanchard mine.

The Blanchard mine is located approximately 5 miles south of Bingham, in Socorro County, New Mexico. The mine is located on the west side of the Sierra Oscura mountain range and is surrounded on three sides by the White Sands Missile Range. The mine is located on Federal (U.S. Department of the Interior, Bureau of Land Management [BLM]) property. Therefore, prior to the start of operations mining permits were obtained both from the BLM, and from the State of New Mexico Energy, Minerals and Natural Resources Department, Mining and Minerals Division (MMD). MMD regulates provisions and requirements specified in the New Mexico Mining Act. Permit requirements included paying a permit application fee to MMD, posting a land reclamation bond to the BLM, and backfilling and restoring the project area to pre-mining conditions to the degree possible at the end of the operation.

The goal of this project was two-fold:

1) A Blanchard mine underground working known as the Portales tunnel was opened to the surface and was actively caving in. It was considered to be very hazardous, and posed a substantial safety and health threat to unauthorized persons who chose to enter the underground workings. It was therefore determined that the Portales tunnel portal needed to be sealed to prevent unauthorized entry into the underground workings.

2) Previous specimen mining work indicated that the potential for high-quality fluorite and galena on quartz mineral specimens existed in and around the Portales tunnel portal, but the formerly productive ground had become buried by the collapsed rock and sloughed material that had collected at the portal entrance. It was therefore concluded that this sloughed material and overburden would be temporarily removed to uncover potentially productive ground, mineral specimens if found would then be recovered, and finally the Portales tunnel portal would be backfilled and sealed with sloughed material and previously-mined waste rock in the immediate vicinity of the portal.

Operations commenced in early July 2013, and were completed approximately three weeks later. Equipment utilized for the operation included two track-mounted excavators (trackhoes), portable rock saws and drills, mining hand tools, specimen packaging materials, etc. One of the trackhoes was equipped with a bucket (hoe), and the second machine was equipped with a large hydraulic rock-breaking hammer, utilized for removing fractured rock and for breaking up large slabs, etc.

This was a successful and enjoyable operation. Mine closure and reclamation costs were recovered as part of the potential value of mineral specimens that were obtained. The three mining claim owners and the two Arizona mining partners also obtained multiple boxes of high-quality mineral specimens that were "highgraded" from the general specimen material produced during the operation. The Portales underground workings were also closed and backfilled which eliminated that hazard and potential liability at the property. Equipment problems were minimal, and no accidents or injuries to project personnel occurred during the operation. Project participants were also treated to some spectacular July monsoon rainstorms that passed through the area during the project, and impromptu card games during the day and evening also helped pass the time!

The talk will focus on the various techniques and equipment utilized to extract mineral specimens, and complete the mine reclamation and land restoration work at the property. A representative sample of some of the high-quality mineral specimens recovered during the operation will also be shown.

Azurite and Malachite: The Origins of the Copper Carbonate

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Malachite and azurite have been used for pigments and adornment for at least 3000 years, and may have contributed to the discovery of copper smelting. Both minerals commonly exhibit fine-scale banding, indicative of rhythmic, seasonal deposition. These copper carbonates also occur in speleothem, mammary, and other concretion-like forms which hint at formation in the shallow subsurface. Yet the partial pressures of CO^2 required for the formation of azurite are orders of magnitude greater than atmospheric levels (Kiseleva et al., 1992). Carbon and oxygen stable isotope analyses of copper carbonates from around the world indicate formation occurs primarily between 10 and 30°C, with a robust biological component to the carbon source. This carbon source is strongly linked to both soil and chemosynthetic microbial CO^2. There is a strong association between azurite formation and white to red swelling clays within fault zones. The optimal conditions for copper carbonate formation appear to be within the shallow oxidation zone during periods of rapid exothermic bacterial oxidation of sulfides triggered by wet-dry precipitation cycles. Where the presence of swelling clays allows for CO^2 levels to greatly exceed atmospheric levels, azurite will form. As CO^2 slowly bleeds from the system, it may enter the malachite stability field. This explains the common occurrence of finely inter-banded azurite and malachite in copper deposits of arid regions around the world.

Kiseleva, I. A., Ogorodova, L. P., Melchakova, L. V., Bisengalieva, M. R., Becturganov, N. S., 1992, Thermodynamic properties of copper carbonates; malachite $Cu_2(OH)_2 CO_3$ and azurite $Cu_3(OH)_2(CO_3)_2$: Physics and Chemistry of Minerals, v.19, n.5, p.322-333.

History of the Freeport-McMoRan Inc. Mineral Collection

Freeport-McMoRan Center, Phoenix, Arizona

By

William H. Wilkinson

The true origins of the Freeport-McMoRan Inc. mineral collection are lost in the mists of time. But through historical documents, anecdotes and knowledge of the mineral specimens themselves, a consistent timeline has been established.

The Freeport mineral collection includes material from the heritage Phelps Dodge and Cyprus collections as well as some new additions made by Freeport and totals approximately 350 specimens. Currently, there are 135 specimens on display at the Freeport-McMoRan Center with an additional 10 pieces on display at the Cotton Center.

The core of the collection consists of a unique suite of rare and old specimens collected from the mines at Bisbee, Arizona, around the turn of the 20th Century. There are few other collections (museum or private collections) that can match the quality, size and historic representation of the specimens in the Freeport collection. Imminent mineralogist and mineral dealer, Lawrence Conklin, stated in his early appraisal of the collection that "the collection of the entire 41 pieces (the number of pieces at the time of his appraisal) is an absolutely unique holding, and the value for the same is therefore priceless".

The number and quality of specimens encountered in mining activities at Bisbee and an enlightened attitude toward specimen preservation by management has led to many specimens being preserved and forming the center pieces of numerous museum and private mineral collections around the world. A number of the Bisbee specimens in the Freeport collection were collected in the 1880s to 1890s and some were almost certainly displayed in the Arizona Pavilion at the World's Columbian Exposition in Chicago in 1893 (World's Fair). Several specimens have drops of candle wax on them from the only source of light underground in that era, attesting to their age.

Several years before the Columbian Exposition, the Copper Queen Consolidated Mining Company in Bisbee went to extraordinary lengths to collect mineral specimens to ensure that the Bisbee portion of the Arizona Pavilion at the Exposition was outstanding. Mineral specimens of exceptional size and quality were collected specifically for the Exposition under the guidance of Ben and Lewis Williams.

Following the World's Columbian Exposition, many of the Bisbee specimens that were on display in the Mining and Metallurgy Building at the Fair were donated by the Copper

Queen Consolidated Mining Company to museums throughout the US and Canada. A newspaper reference from 1901 notes that many of the specimens were returned to Bisbee and were put on display in the company's office there. This appears to be the origin of the collection.

These specimens were displayed for a while in the Bisbee office, but space constraints caused them to be packed and stored in the Lowell Mine warehouse prior to the merger of the Copper Queen Consolidated Mining Company into Phelps Dodge in 1917 (Richard A. Graeme, Oct. 6, 2010, email). A number of wooden crates, as well as a few large wooden barrels, all packed with very course sawdust, almost wood shavings, that contained large specimens were sent to New York when the offices were either relocated or remodeled during the 1920s. Phelps Dodge moved its offices from Cliff Street to 40 Wall Street around 1929 (Cleland, 1952). This then is probably the material that made up the bulk of the minerals displayed in the New York office and formed the core of the collection as we know it today.

Phelps Dodge moved offices again in November 1955 from 40 Wall Street to 300 Park Avenue. No records of moving the collection at that time have been found, but the minerals were displayed in large, glass-fronted cases in the Park Avenue office.

A significant collection of native cooper and related species from the Upper Peninsula of Michigan was added in 1981, although no documentation can be found to explain why this collection was purchased. What we do know is that the collection contained 773 pieces and was purchased for $10,000.00 from a collector in northern Michigan (retired professor?). There is a copy of a detailed catalogue of these specimens, but there is no mention of the previous owner or who prepared the catalogue from the original collection notes. If there were paper labels with the collection, none survived. In February 1982, all 773 specimens were loaned to the American Museum of Natural History in New York and the Michigan collection was accessioned in the AMNH collection on March 23, 1982.

In 1987, Phelps Dodge made the decision to close the New York office on Park Avenue after 150 years in that city and relocate to Phoenix, Arizona. According to Mark Mollison of Phelps Dodge (email dated 22 March 2014), many (most) of the samples in the collection were to be given to the second-hand furniture dealer who took much of the office furniture! Mark, along with Mike Nillsen, played a role in pointing out that the specimens should be saved. By the time of the move, he and Mike were the only ones in the NY office with a technical background who appreciated the specimens.

In preparation for this move, the display collection, consisting of 41 specimens at that time, was cleaned and appraised by imminent mineralogist and mineral dealer, Lawrence H. Conklin, in April 1987. He stated that "many of these specimens are unique, and his appraisal has placed prices on them that would prevail were they offered singly on the retail market; however, the collection of the entire 41 pieces is an absolutely unique holding, and the value for the same is therefore priceless". Conklin stated in an email dated July 12, 2010, "you can safely say that there is more than a million dollars in that lot".

Conklin remembers the appraisal and cleaning job very well. His father helped him because it was a really big job. Phelps Dodge gave him an executive bathroom and he cleaned the specimens in a shower in his bathing suit. The display was rather dull because of poor lighting in the simple but large glass front cases. There was no labeling of any kind on or with the specimens. He says that he cleaned away primordial mud from each specimen and the colors and surfaces exposed raised the appraised value by 100% (email from Conklin, 2010).

The collection was moved to Phoenix, Arizona, in 1987 and displayed in large, custom cases of the 2600 North Central Avenue office building. There were four, low glass cases on the 14th Floor containing 36 specimens. Four similar cases were located on the 15th Floor and housed the largest of the specimens for a total of 25 specimens. The Lobby Case was a long, rectangular glass case that contained 23 specimens and was the first thing a visitor saw upon entering the building.

In November 1991, the AMNH requested that Phelps Dodge permanently donate the Michigan copper samples acquired in 1981 so they could become part of the Museum's permanent ore deposit collections. Dick Moolick, former President of Phelps Dodge and at this point in time the Chairman of the National Mining Hall of Fame Museum (NMHFM) in Leadville, Colorado, requested that all of the specimens be donated to the NMHFM.

In June 1992, Phelps Dodge decided to divide the collection and requested that 200 specimens were to be sent to the museum in Leadville and that 173 were to be returned to the Phelps Dodge headquarters in Phoenix. The remaining 396 specimens were to remain with the AMNH. The portion retained by the AMNH is now part of the permanent ore deposit reference collection.

The 177 specimens that Phelps Dodge retained were shipped to Phoenix and promptly "lost" in storage. These were "rediscovered" in 2009 while going through historical files (they were stored in document file boxes), but the catalogue was lost at that time and there was no knowledge of where the specimens had come from other than recognition that they were from Michigan. The catalogue was subsequently discovered in another set of files.

In 1999, Phelps Dodge acquired Cyprus Minerals Corporation and the collection of minerals Cyprus maintained was added to the Phelps Dodge collection. They were packed and moved to 2600 N. Central Avenue and placed in temporary storage. No inventory was completed and there was no catalogue or locality information for the Cyprus specimens.

Prior to Phelps Dodge moving from 2600 North Central Avenue to One North Central Avenue (ONC) in 2001 and merging the Cyprus collection, all of the minerals on display were recorded and photographed. An inventory was generated with mineral names, floor location and dimensions of each specimen along with low quality photographs. These were put in a binder and the page numbers became the mineral number now used. These numbers stopped at 83.

In anticipation of this move, it was decided to have the collection cleaned and the appraisal updated by Les Presmyk, a prominent local mineral dealer and appraiser. Les noted in his report the earlier appraisal by Conklin but did not have access to it. During the cleaning by Presmyk, he compiled a spreadsheet using the page number as the identifier and added mineral name, locality information, dimensions, and appraised value in October 2001. There were a total of 104 specimens (so numbers 84-104 were not included in the 2600 North Central inventory).

In 2006 an art inventory was completed that included the minerals that were on display on the 19th and 20th floors in ONC. This inventory included name, locality information and dimensions along with decent digital color photographs. This inventory added a record number that was different from the page number of the Phelps Dodge inventory, but it did reference the PD page number. This inventory did not include the minerals on display on the 14th-18th floors and in the lobby of ONC.

The office was relocated to 333 North Central Avenue (Freeport-McMoRan Center) in 2010. All of the specimens have now been consolidated into the Freeport collection and are on display in newly designed, well lighted cases.

Detailed locality information for the majority of the specimens was missing, other than general location such as Bisbee, Morenci, etc. A significant part of the value of any collection is in knowing as much about the item as possible, a pedigree if you will. Because the collection has so many Bisbee specimens, prominent Arizona collectors Richard Graeme, Les Presmyk and Evan Jones were invited to view the collection. Their knowledge of both Bisbee minerals and history allowed them to identify specific mine locations and approximate the time frame in which the minerals were collected. The information provided by this august group is annotated in the collection catalogue.

In July 2010, most of the minerals were removed from the cases and professionally photographed by world renowned mineral photographer, Jeff Scovil. This is the first complete photographic inventory of the collection ever.

Specimens from the collection have been on long- and short-term loan to institutions on several occasions. From February 2010 through January 2011, the University of Arizona Mineral Museum in Tucson, Arizona, had a special exhibit of Bisbee minerals titled "Treasures of the Queen". Ten exceptional specimens from the collection were part of that exhibit. The exhibit resulted in a special Supplement of the Mineralogical Record magazine titled "Treasures of the Queen, The Bisbee Exhibition" and photos of three of the specimens are included in that Supplement.

In February 2012, to commemorate the Centennial of Arizona statehood, the theme of the Tucson Gem and Mineral Show was mineral districts of Arizona highlighting the best mineral specimens from Arizona mines. Specimens from the Freeport collection were the focus of two large cases representing minerals from Bisbee and the part the mines of Bisbee played in the World's Columbian Exposition in Chicago in 1893 and ultimately in the economic drive for statehood. A book titled Collecting Arizona was published to coincide with the Show and contains photos of eight Freeport specimens.

The collection includes some specimens that are of a more historical note, such as the first slag, blister, and anode from the Playas, New Mexico, smelter built in 1976 and an ancient copper ingot from the Isle of Cyprus (perhaps 2,000 years old). One case also holds a portion of the first cathode from the Tenke-Fungurume Mine in the DRC and other items from the DRC.

The collection continues to grow with special focus on the mines operated by Freeport-McMoRan Inc. around the world.

EMUS, 'ROOS and MINERALS and MINES OF BROKEN HILL, NSW, AUSTRALIA

Anna M. Domitrovic

Tucson, Arizona

The minerals deposits in the Broken Hill District, New South Wales, Australia, have often been described as "old ore in old rocks". The rocks are those of the Curnamona Craton, 2.5 – 3.1 billion years old. The deposit includes Pb-Zn-Ag with some Ur in granites and pegmatites, Pb-Ag in veins and suites of Cu minerals with minor Au, although no specimens of Au have been noted, until a find of micro Au crystals in the Kintore Pit in 2000. Minerals were deposited about 1.7 billion years ago.

During the Paleozoic, what now includes the Broken Hill District, the area of concern was a continental land mass. In the Mesozoic, terrestrial sediments were deposited and currently host artesian water, oil and gas. Shallow marine sediments deposited during this Era, formed the opal dirt of Coober Petty. Finally, during the Cenozoic Era to the present day, the current basins of NSW were taking shape.

Mineralization in the Broken Hill District is sometimes compared to that of Bisbee. While copper was an important commodity, much of the district's mined ore was related to silver, lead and zinc. As noted previously, gold was extremely rare.

The town site of Broken Hill dates to 1844, but was originally known as Willyama. Silver was discovered in 1883 and mining began in earnest about that time. Broken Hill Proprietary Company (BHP), now BHP Billiton, was founded in 1885 to mine ore in the district. Some mining continues to the present day, yielding about two million tons of ore annually.

While Broken Hill proper is the main topic of interest, several other mines in the district will be considered briefly. This presentation is the result of a mineral/museum conference held in Melbourne in 2000, with a pre-meeting trip to the mines in the Broken Hill District.

MINERALS of BROKEN HILL, NEW SOUTH WALES, AUSTRALIA

There are more than 350 known minerals from the mining properties at Broken Hill. The list below consists of minerals, in **bold,** that I personally acquired/collected during a 2000 conference and pre-meeting field trip. Those in *italics* are minerals from the Desert Museum's micro mineral collection. ***Bold*** are minerals in both collections. For a more comprehensive list of minerals, please go online and refer to the MinDat data base.

Anglesite (casts & pseudos)

Azurite

Bromargyrite

Cerussite

Chlorargyrite

Cuprite

Copper

(Embolite)

Garnet

Gold

Hematite

Iodargyrite

Malachite

Marshite

Mimetite

Pyrite

Pyrolucite

Pyromorphite

Raspite

Rhodochrosite

Scholzite

Silver

Smithsonite

Stolzite

Turgite

REFERENCES

4th International Mineralogy in Museums Conference Field Guide Broken Hill District, 2000

Arizona – Sonora Desert Museum permanent Mineral Collection

MinDat Data Base, 2015

Adamite
Arsenopyrite
Arsentsumebite
Atacamite
Agardite
Anglesite
Antlerite
Aragonite
Arsenosiderite
Aurichalcite
Azurite
Barite
Bayldonite
Beraunite
Beudantite
Brianyoungite
Brochantite
Bromargyrite
Calcite
Carminite
Cerussite
Cerussite
Chalcanthite
Chalcocite
Chalcopyrite
Chlorargyrite
Chrysocolla
Conichalcite
Connellite
Copper
Corkite
Coronadite
Covellite
Cumengite
Cuprite
Cyanotrichite

Devilline
Dolomite
Dufrenite-Natrodufrenite
Fluorapatite
Fluorite
Gahnite
Galena
Goethite
Gordaite
Graphite
Greenockite
Gypsum
Hemimorphite
Hinsdalite
Hopeite
Hydrocerussite
Hydrozincite
Ilmenite
Iodargyrite
Jarosite/natrojarosite
Kintoreite (?)
Koettigite
Ktenasite
Leadhillite
Leucophosphite
Libethenite
Linarite
Malachite
Mawbyite
Metatorbernite
Microcline
Miersite
Mimetite
Molybdenite
Nadorite
Namuwite

Niedermayrite
Olivenite
Paratacamite
Parnauite
Pharmacosiderite
Phosgenite
Pseudomalachite
Pyrite
Pyrolusite
Pyromorphite
Pyrrhotite
Quartz
Rhodonite
Rockbridgeite
Rosasite
Rutile
Sampleite
Schulenbergite
Scholzite
Scorodite
Segnitite
Serpierite
Silver
Smithsonite
Spangolite
Spessartine
Sphalerite
Stolzite
Strengite
Sulphur
Synchysite-(Ce)
Tsumcorite
Tsumebite
Variscite
Wulfenite
Zdenekite

Figure 6: **Minerals recorded from the Kintore and Block 14 Open Pits, Broken Hill (from stockpiled ore at the Pinnacle Mine; compiled by Jack Leach and Peter Elliott)**

Notable Native Silver Specimen Producing Localities in New Mexico and Arizona

By Tony L. Potucek

New Mexico and Arizona have both been significant silver producers during the mining history of both states. While copper is certainly the king of metals in both states, silver could be considered a candidate for queen, particularly in Arizona. Early exploration by Spanish focused on both of the precious metals—gold and silver. For the purposes of this presentation, however, we will focus our attention on native silver specimen producing localities and not on localities producing silver-bearing minerals. In addition, localities which produced micro-sized native silver specimens are not considered. These limitations considerably shorten the locality lists for both states.

Within the state of New Mexico, the Black Hawk Mining District has two significant macro-sized native silver specimen producers—the Alhambra Mine and the Black Hawk Mine. Alhambra mine native silver specimens typically have a Christmas tree appearance-branching dendritic limbs coming off trunks at right angles, the silver coated by Ni-skutterudite. Specimens are delicate but can be up to 10 cm in size. Virtually all of the rather delicate specimens have been acid cleaned to remove the carbonate matrix enclosing them. The amount of native silver produced by these mines is legendary with numerous glowing descriptions of the material observed in the mines.

The Crow Mine in Lincoln County, New Mexico is not generally known to produce a large number of native silver specimens. Specimens occur up to 6.5 cm or so, and are composed of flattened plates of native silver in a lighter altered vein material, as well as short, compact stout wires associated with white clay.

Other New Mexico native silver specimen producers are centered around the Silver City-Chloride Flat areas in Grant County. The silver is usually well crystallized, showing nice elongate spinel twins and cubic crystals of silver in groups of branching aggregates. A number of specimens are known from these unspecified mines. The Chino Mine, located in the Santa Rita mining area, produced native silver specimens during at least two periods: 1969 and circa 1980. Both discoveries occurred during open pitting for copper and specimens are known in a number of collections. The finds produced similar but slightly different styles—branching nicely crystallized silver specimens, usually off matrix and exhibiting a herring bone pattern.

Another locality from New Mexico which produced native silver are the mines near Hachita in Hidalgo County, which produced silver wires in the range of 1-1.5 cm. Finally, Catron County also produced some nice native silver as wires and clumps of small wires packed into cavities in cockscomb quartz veins from the Mogollon District.

Relegated to the lost locality in New Mexico, or yet-to-be-rediscovered category, is the Little Buck Mine in Dona Ana County which is reported to have yielded "ore the size of two fists…with wire silver from size of matches down…"

The state of Arizona appears to be more prolific in producing native silver specimens. The Silver King mine near Superior in Pinal County is undoubtedly the most well-known among mineral collectors, because of the number of documented silvers found in many collections. Groups of arborescent spinel crystals are the most common habit, but groups of wires associated with an altered granitic/quartz monzonite matrix are also well represented.

Gila County produced divergent habits of native silver at several localities. Notably, the namesake of the town of Globe, a large rounded silver nugget weighing 448 troy oz. most likely came from Richmond Basin, although placers only 4 miles north of Globe were also known to have produced silver nuggets. Often confused with native silver from the Silver King Mine near Superior, the Stonewall Jackson Mine at McMillenville also produced native silver, in association with a siderite gangue and acanthite and chlorargyrite. The native silver in documented Stonewall Jackson specimens is loose, arborescent fern-like masses and wires in a brown siderite matrix, as well as oxidized loose blebs.

Mineral Park in the Cerbat Mountains of Mohave County has produced equally fine native silver specimens, almost always as stout wires in singles and groups. They are known as beautiful coils and thick wires arising from a quartz matrix, or in coiled thick masses. Another Mohave location which produced beautiful ornate wires is attributed to the Gold mining District. The location is unknown at this time, as no such district exists. However, a couple of different possible locations in the County are the Gold Basin district and the Gold Hill district. They may also be from a locality with no known specimens called the Buckeye Mine, which produced native silver wires described by W.H. Newhouse in the American Mineralogist. Given the spectacular nature of the specimens, further research is needed.

The copper mines of Bisbee and Morenci also produced native silver. In Bisbee, the native silver occurs as a supergene product. Most notably, the Cole and the Junction Mines produced attractive hackly sheets and flakes in and on massive bornite and chalcocite, as well as fault gouge. However, other mines which produced native silver include the Campbell, Czar, Holbrook, and the Lavender pit. At Morenci, an occurrence of native silver in a brown to white kaolin produced small sheets and foils of native silver in the old Morenci pit at the location most collectors refer to as the Crystal Zone, producer of the best single crystals of lustrous azurite. The landmark to find this site on a bench in the pit was marked by an isolated telephone pole, and the locality produced native silver in the late 1980's and early 1990's.

The Lucky Cuss Mine in Tombstone, Cochise County has one very notable native silver specimen which resides in the Flagg Collection. No other significant silvers are known from here. However, the founder of the Tombstone district, Ed Schiefflin, described the initial outcrop of the Lucky Cuss claim, such that he could leave the impression of his pick head and coins in the ore, which leads one to believe the veracity of the occurrence of this native silver specimen.

While other native silver localities in both New Mexico and Arizona are cited in literature, this presentation focused on localities which produced macro-sized specimens for the mineral collector.