MINERALS OF ARIZONA

TWENTY-FOURTH ANNUAL SYMPOSIUM

Sponsored by
Flagg Mineral Foundation
April 15 - 17, 2016
Quality Hotel
5121 E. La Puente Ave
(NW corner of Elliot Rd and
I-10 in Phoenix)

FLAGG MINERAL FOUNDATION

Co-Chairpersons
Flagg Mineral Foundation
Phil Richardson
Ray Grant

Minerals of Arizona

Twenty-fourth Annual Symposium

Sponsored by the Flagg Mineral Foundation

**Friday, Saturday, and Sunday
April 15, 16, and 17, 2016**

Co-chairpersons:
Phil Richardson
Ray Grant

**Quality Hotel at Phoenix Tech Center
5121 E. La Puente Ave, NW corner of Elliot
Rd and Interstate 10, Phoenix.**

Arizona Quartz on Cover

Top left: Quartz, Japan law twin, Holland mine, Washington Camp, Santa Cruz County, Arizona, Flagg Mineral Foundation Collection, Jeff Scovil photograph.

Top right: Quartz on andradite garnet, Stanley Butte, Graham County, Arizona, Les and Paula Presmyk collection, Jeff Scovil photograph.

Bottom left: Quartz, Fat Jack mine, Yavapai County, Arizona, Marshall Sussman collection, Jeff Scovil photograph.

Bottom right: Quartz after chrysocolla, after malachite, after azurite, Live Oak mine, Miami, Gila County, Arizona, Les and Paula Presmyk collection, Jeff Scovil photograph.

Thanks to Bo Ochse for the cover design, to Les Presmyk for supplying the photographs and to Jeff Scovil for permission to use them.

New Flagg Mineral Foundation Logo

FLAGG MINERAL FOUNDATION

About the Flagg Mineral Foundation:

The Foundation was formed in 1962 with the goal of establishing a mineral museum in the Phoenix area. Through the dedication and hard work of its members, a world-class collection of minerals was on permanent display in downtown Phoenix. Unfortunately, due to Arizona House Bill HB2251, the museum was closed in 2011. Currently, the better part of the collection is on exhibit at the Flandrau Museum at the University of Arizona in Tucson, and other loans have been made to the Superstition Mountain Museum and the Pinal Geology and Mineral Museum. The Foundation holds the following annual mineral events:

A. L. Flagg Gem and Mineral Show in January
Minerals of Arizona Symposium in the spring.

[handwritten notes:] ICO store . net

April 1st. Desert Museum

Friday Program

2 to 4 PM -trading session, microminerals, 4 PM talk
"What's new in Arizona Minerals", Ron Gibbs and
Ray Grant

Saturday Program

Continental Breakfast 8 AM, talks from 9 AM to
4 PM followed by a Dinner at 6 PM. Speaker will be Bob
Jones and History of the Tucson Gem and Mineral Show.

Sunday Program

9 AM to 11 AM, Portable XRF for analyzing gold and
other minerals for their chemistry,
trading or selling by individuals.

Saturday, April 16 - Symposium Program

8:00 - 8:45 - **Coffee Hour**

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

9:00 – 9:40– Arizona Fluorite Locations – Barbara Muntyan

9:40 – 10:20 - The Moss Mine an Arizona Original - Anna Domitrovic

10:20 – 10:50 - **Break**

10:50 – 11:30 - Arizona Quartz - Les Presmyk

11:30 – 12:10 – Formation of Quartz Scepters – Richard Zimmerman

12:10 – 1:30 - **Lunch**

1:30 – 2:10 – Unique Occurrences of native Lead in Arizona – Brian Beck

2:10 – 2:50 – Miarolitic Pegmatites of Southern Nevada – Steve Scott

2:50 – 3:20 - **Break**

3:20 – 4:00 – Formation of Stichtite - Erik Melchiorre

4:00 – 4:20 - Photographs from Richard Bideaux's Collection – Phil Richardson

4:30 – 6:00 - Happy hour, visit dealers

6:00 Buffet and evening speaker, Bob Jones on The History of the Tucson Gem and Mineral Show and an auction of donated items

FLUORITE LOCALITIES IN ARIZONA

Barbara L. Muntyan

Tucson, Arizona

Fluorite is a widespread mineral in Arizona, occurring in at least 390 localities in twelve counties, according to MINDAT. Although perhaps less admired than specimens of wulfenite or azurite, fluorite can nevertheless be found in fine, euhedral crystals to 2" on edge, in hues of spruce green, pale green, lavender, dark purple, and bi-colored crystals. Associated minerals species include quartz, calcite, galena, and wulfenite. .

The finest Arizona fluorite specimens have certainly come from the Oatman mining district, Mohave County in recent years, first from the Hardy mine and then later from the Homestake and Skinner. Mined by Mark Hay and Dick Morris, these mines have provided a steady flow of octahedral fluorite, colored grass-green, spruce-green, or raspberry/green combos on white drusy quartz matrix, and with occasional rosettes of clear quartz on top.

The Santa Teresa wilderness area, Graham County, has recently produced fine octahedral purple fluorite on clusters of white to clear quartz crystals. The best fluorite crystals have been found up to 2" on edge and are usually grape-jelly purple, but may also be lavender or zoned shades of purple.

Another locale exploited commercially in the last few years is located at the eastern extent of the Tombstone Hills, Cochise County. Named "La Fluorite Dulcita" claim by the most recent owner, the deposit has been known for many years and has produced both pale green and dark purple octahedral fluorite on druzy quartz casts which have formed upon earlier depositions of yellow calcite in both scalenohedra and rhombohedral crystal forms.

A recent find near Deluge Wash toward the eastern side of the Huallapai Mountains has produced pale green fluorite crystals in complex cuboctahedra more than 2" across, perched on milk-white quartz crystals. This mining area has molybdenite and hiseringerite, as well as other contaminants, which make successful cleaning very challenging.

Other, older, localities for Arizona fluorite specimens include the mines of the Castle Dome area, including the Hull, where it has been found associated with galena, calcite and wulfenite. Other locales include the Hesson mine in LaPaz County, the Empire and Toughnut mines at Tombstone, the Neptune mine at the north end of the Sierrita Mountains in Pima County, the Prism (Rainbow) mine in Maricopa County, the Lucky and other mines in the Duncan area, the Ten Strike mine near Klondyke, and various locales in the Buckskin Mountains and Artillery Mountains,

BIBLIOGRAPHY

Anthony, J.W. et.al. Mineralogy of Arizona. 3rd edition. Tucson, AZ., University Press (1995).

Domitrovic, A. M., Wilson, W. E., and Hay, M. "The Castle Dome District, Yuma County, Arizona," Mineralogical Record, vol. 29, 437-458 (1998).

Elevatorski, E. A. Arizona Fluorite. Phoenix. Arizona Department of Mineral Resources (1971).

Hay, M. and Morris, D. "Fluorite from the Oatman District, Mohave County," Mineralogcal Record, vol. 46, 569-581 (2015).

Jackson, B. "La Fluorita Dulcita prospect, Cochise County, Arizona," Rocks and Minerals, vol. 88, 148-151 (2013).

Lausen, C. Geology and Ore Deposits of the Oatman and Katherine Districts, Arizona. Arizona Bureau of Mines Bulletin 131 (1931).

Ross, C. P. Geology and Ore Deposits of the Aravaipa and Stanley Mining Districts, Graham County, Arizona. U.S. Geological Survey Bulletin 763 (1925).

Schrader, F.C. Cerbat Range, Black Mountains, amd Grand Wash Cliffs, Mohave County, Arizona. U.S. Geological Survey Bulletin 397 (1909).

Simons, F. S. Geology of the Klondyke Quadrangle, Graham and Pinal Counties. U.S. Geological Survey Professional Paper 461 (1964).

Wallace, T.C., editor. Collecting Arizona: State of Mines, Legacy of Minerals. Denver, CO., Lithographie (2012).

THE MOSS MINE, MOJAVE COUNTY: AN ARIZONA ORIGINAL

Anna M. Domitrovic

Arizona-Sonora Desert Museum

Tucson, Arizona

One hundred fifty years ago, John Thomas Moss ventured into the mountains west of Kingman. After several years exploring the hills in what is now known as Silver Creek Canyon, he discovered what would be Arizona's first patented gold claim. Some say that it was as early as 1863, but historical records show it was probably in 1865. Still, it remains the first and the oldest known patented gold claim in what was Arizona Territory. Moss claimed to have found "free visible gold" in outcroppings. The remains of a shaft and headframe still stand near his discovery. Moss's glory hole was only about ten feet in diameter and depth. But from that hole, Moss apparently removed over $200 thousand in gold. A 1939 letterfrom E. R. Householder of Kingman to T. E. Campbell in Prescott described movement of ore in the 1870's first by burros packing the ore to the Colorado River, then by steamer to Port Isabel on the Gulf of California, to Port Arena on the Pacific Coast, to San Francisco and finally to England for treatment. While there was considerable activity on what was eventually named the Moss Vein in the early years after initial discovery, it was not long-lasting. Moss was born in 1839 in Utica, Iowa and died in San Francisco in 1880, a poor man.

It would be nearly thirty years before any more work was done on the Moss Vein after its first decade of production, but that work also included other mines in the District surrounding Oatman. In the early 1900's, gold was discovered in the Gold Road Vein east of the Moss, more than likely on a similar strike and trend as the Moss. At that time, it was owned by the Gold Road Mining & Exploration Company. Mining was "hit-and-miss" in the District through World War I and then sporadic into the 1940's. Other mines in the area that will be mentioned in this presentation include the Hardy and the Homestake, both known for fine, pale green and purple/blue crystalline fluorite. Currently, Northern Vertex Mining Corporation, a Canadian company, and Patriot Gold Corporation based in Las Vegas teamed up in 2011 to explore and develop the new Moss Mine Project. More than 15,000 feet have been drilled. Phase I, a Pilot Plant to recover gold, is complete. The companies anticipate a five-year mine life with anticipated recovery of about 80% gold and 65% silver.

The geology of the gold/silver deposit is a brecciated epithermal vein system of Au-Ag stock work. Geologic reconnaissance by Patriot described the geology in the project area as "Tertiary quartz monzonite ... intruding Tertiary-age volcanics" underlain by PreCambrian rocks. The vein itself is up to 45 feet thick, tracing at or near the surface for more than a mile.

REFERENCES

On-site Research

- Kingman Historical Society, Mojave Museum, Kingman, Arizona; Reference stacks.

Publications

- Anthony, J.W., Williams, S.A., Bideaux, R.A., and Grant, R.W.; Mineralogy of Arizona, 3rd Edition, 1995.
- Arizona Atlas & Gazetteer, 1993.
- Ransome, F.L., Geology of the Oatman Gold District, Arizona, USGS Bulletin 743, 1923.
- Schrader, F.C., Mineral Deposits of the Cerbat Range, Black Mountains and Grand Wash Cliffs, Mojave County, Arizona, USGS Bulletin 397, 1909.

Websites

- MinDat.org
- Northernvertex.com
- Patriotgoldcorp.com

Acknowledgements

I would especially like to acknowledge and thank Kenneth Don for photographing the mineral specimens for this presentation.

Arizona Quartz

Les Presmyk

Quartz has played a role in the various civilizations that have lived in Arizona over the millennia. Starting with such utilitarian use of agates and amethyst for arrowheads, and quartz crystals for medicinal and ornamental uses, these uses are evident having been found in prehistoric excavations. In the past 100 years or so, quartz and its various forms have been preserved for lapidary and specimen beauty.

It is worth noting the significant agate, fire agate, jasper and petrified wood localities in the state but this paper will deal with the crystallized quartz locales.

Although Arizona's copper and lead minerals generally overshadow everything else, Arizona possesses fine quartz localities and some of them are unique or nearly so. A few result from the mining for copper and other metals and many are surface localities, mainly discovered by rockhounds and mineral collectors. The Four Peaks amethyst mine produces world-class faceting amethyst and the locale is almost visible from all of Phoenix. This discussion will include Arizona's copper mines, smaller underground mines, and a number of the surface localities.

Although Ajo had lots of quartz and silica in the orebody and a suite of copper silicate minerals, including shattuckite, ajoite and papagoite, virtually no specimen quartz is known from here. The mines of Bisbee are much the same situation except for the occasional pocket of amethyst or amethystine quartz crystals, sometimes associated with white bladed calcite. All of the drusy quartz on malachite or chrysocolla specimens I have seen labeled from Bisbee have turned out to be from the Live Oak mine in Miami.

Drusy quartz crystals covering chrysocolla are known from several Arizona copper mines, starting with the Old Dominion in Globe, the Live Oak in Miami, the Ray mine and Bagdad. As an aside, the area in and around the Bagdad mine have produced quartz crystal clusters and Japan-Law twins. A few specimens were recovered in Morenci in the 1990's but very few. The Twin Buttes mine south of Tucson and even the Mammoth-St. Anthony mine has produced some attractive quartz on chrysocolla specimens. There are also some small but important localities, including the Blue Angel prospect in western Arizona, that have produced good specimens. The material can make for attractive specimens as well as being used in jewelry.

Chrysocolla in quartz (chalcedony) or gem silica was first noted by Ransome at the Old Dominion but it is the material from the Live Oak mine, both underground and open-pit, which made Arizona world famous for this beautiful gem material. Gem silica has also come from the Ray mine and Bagdad. Some of the Ray material was quite attractive when it first came out of the ground but as it lost water, it turned white.

No discussion of Arizona quartz localities could exclude the Holland Mine and the various surface deposits in and around Washington Camp and Duquesne. The Holland Mine has produced Japan-Law twins up to 10" on a side and individual doubly-terminated crystals to 14" long. Some of Arizona's best amethyst scepters have been found around the Santo Nino mine. Numerous pockets of normal quartz crystals and groups of Japan-Law twins have been encountered throughout the area. Most of the twins are frosted white but an occasional pocket has produced lustrous, clear heart-shaped twins.

Quartzsite, Arizona is named after its quartz locality at Crystal Hill, not the metamorphic rock. Years ago, Rock Currier decided to make up tee-shirts for sale at his booth at the Quartzsite show. They became gifts when it was pointed out to Rock his error in assuming the town was named after the rock, not the nearby quartz crystal locality. Crystal Hill has produced clear and lustrous quartz crystals up to 10 inches long and in clusters to 12 inches across. Some of the crystals have included chlorite and other minerals. It is now a state park and only hand digging is allowed. South and slightly west of Quartzsite is the Crystal Gallery/Veta Grande/Big Bertha/Purple Cow Ledge claim. Since the 1950's it has produced high quality hematite crystals up to 3 inches across standing on white quartz and associated quartz crystals. The quartz crystals, with and without hematite, are also quite interesting. Some of the crystals exhibit curving of up to 30 degrees. Arizona's best faden quartz comes from this locality.

Date Creek Ranch, between Wickenburg and Kingman, has produced colorless, amethyst and smoky quartz crystals and clusters for decades. It is entirely a surface accessible locality although a few years ago collectors went in with a back-hoe and dug out a number of specimens.

The Fat Jack mine just outside of Crown King is also known for its colorless, amethyst and smoky quartz crystals and scepters. Stolzite crystals are also found here, with a few being very bright yellow and occurring on quartz crystals. Over the past 20 to 25 years, pockets have been sporadic and the claim has been owned by a half dozen different people. The claim is now held on behalf of the Mineralogical Society of Arizona.

The Huachuca Mountains south of Sierra Vista have several areas for collecting quartz. Starting with the Wakefield mine, which produced clusters of clear, lustrous crystals to various surface pits, rock crystal, amethyst and smoky quartz can still be collected here. There are a series of hiking trails throughout the mountains with lots of hummingbirds and other wildlife if one cannot find any of the quartz crystal locales. The Hamburg mine produced Japan-Law twins with associated malachite or yellow calcite.

For decades, deer hunters, rockhounds and people hiking the hills and lower slopes of the Mongollon Rim country from Payson to Tonto Village and Diamond Point have picked up these sparkly and clear "Payson or Arizona Diamonds". This is a locality similar to the famous Herkimer diamonds of New York. These crystals occur in vugs in limestone. In the mid-1990's there was a lot of collecting activity in the area, which prompted the Forest Service to withdraw 7000 acres from mineral entry and set it aside for recreational collecting. While most of the crystals found here appear to be colorless, a lot of the crystals exhibit a slight amethyst color to them.

There are two notable quartz specimen areas in Graham County. The first is around Stanley Butte south of San Carlos Lake. This was part of the Mineral Strip area that was deeded back to the San Carlos Apache Tribe almost 50 years ago. From 1950 to 1980, the area was open to collectors and is probably best known for its andradite crystals. Quartz crystals up to 12" were collected in association with andradite and a number of notable pockets were excavated. Clear crystals with a tan chalcedony coating, amethyst and colorless crystals associated with andradite all come from this area. Probably the best include a pocket dug in 1984 with clear, slender quartz crystals on green andradite coated matrix. This region is no longer open to collecting.

The second area is the Santa Teresa Mountains in Graham County which represents a locality known during World War II days to a more recent incarnation in the past 10 to 15 years. During World War II the northern end of the Santa Teresas were prospected for optical grade quartz crystals for the war effort. Fred Rhodes had smoky quartz crystal with small epidote crystals scattered across the surface. This intrigued Tony Potucek and others to spend time exploring the area around 15 years ago. In the past 10 years several collectors have been hiking into the south end of the mountain range and discovered a number of cavities in the granite, which have contained quartz, fluorite, hematite, beryl and ilmenite.

FORMATION of PHANTOMS and SCEPTERS

Dick Zimmermann   24th Flagg Mineral Symposium   April 16, 2016

Abstract

Mineral collector and rock hound publications offer little insight into the origin of phantoms and scepters. Usually, both are explained with vague descriptions of two stages of crystal growth with a significant period of time between the two stages of growth. Phantoms are said to be the result of dirt, bubbles or inclusions deposited on the surface during the interruption. More obscure explanations are offered for the formation of scepters. Related scientific literature is very limited, and theories that have been published are not generally correct.

A review of the basic chemical processes governing crystal growth, and close examination of cut and polished crystal sections presented in the literature, show that no interruption in growth is necessary. Many phantom features can be explained by rhythmic or oscillatory precipitation, where the concentration of impurities in the solution varies in a cyclic manner. Others can be explained by a progressive change in impurity concentrations. An interruption in growth may have occurred, but is not necessary. Most scepter growth can be explained by progressive changes in impurity concentrations and other environmental factors, along with different chemical energy levels on different crystal faces. Relative increases or decreases in the ratios of impurity ions can cause changes in the relative growth rate of different crystal faces, and cause scepter growth.

Introduction

Mineral collectors have limited opportunity to explain the formation of phantoms and scepters, because they are reluctant to destroy the specimen to study the internal structure. Even if they are willing to damage a specimen, they may not have the necessary equipment or scientific background. If they search the limited scientific literature directly related to phantoms and scepters, they find little helpful information.

However, there are geologists (who are not mineral collectors) that study crystals very carefully in search of information on the geological processes that formed the surrounding mineral deposit. They do not hesitate to destroy the specimen in the laboratory to reveal the internal information it contains. At times, they even favor scepters over normally-formed crystals, because they know that a greater amount of data about the history of the mineral deposit will be obtained. That is because the very existence of the scepter indicates a change in growth conditions. Their research is not associated with mineral collecting, and the literature they publish has apparently not previously attracted the attention of mineral collectors. Review of the data they produced, and the basics of crystal face growth rates, reveals rather simple scepter formation processes.

Occurrence of Phantoms and Scepters

Many quartz crystals display phantoms and/or scepters features, which are not mutually exclusive. Phantoms appear to occur more frequently than scepters, but quartz crystals with one or the other (or both) of these features are collected at many different locations. Although not seen as often, these features form in many other minerals as well, including beryl, calcite, fluorite, fluoroapatite, sapphire, selenite, tanzanite, tourmaline, and vanadinite. Staples reported austenite scepters from Gold Hill, Utah; Whitlock reported pyrite scepters from Rodout, Colorado; and Hildebrand reported montroydite scepters from Terlingua, Texas.

Most of the scepters described in this paper are quartz, and quartz has a very complex structure. While the most common form is usually described as a hexagonal prism terminated with a pyramid, quartz does not belong to the hexagonal crystal system. That is because it does not have six positions of rotational symmetry. Quartz is trigonal, and the primary unit cell is a rhombohedron. The common form is actually pseudo-hexagonal, and the terminations are formed by the faces of rhombohedrons. Much of the literature refers to the positive rhombohedron and the negative rhombohedron faces, as well as others. For simplicity and brevity, this paper will only refer to the pseudo-hexagonal prism and the terminating pyramid when describing quartz crystals. The components of scepters will be referred to as cap and stem.

Origin of Phantoms

Sources such as Mindat state that phantom crystals are formed by multiple stages of growth with dust, inclusions, or bubbles deposited on the crystal surface during an interruption in growth. However, careful examination of a variety of phantom specimens, and related literature, reveals that there are additional ways for phantoms to form. Growth need not necessarily be interrupted and phantom features may or may not be obvious. Phantoms formed by dust, inclusions, or bubbles are usually obvious under visual examination, but phantoms formed by variations in impurity concentration are often more subtle. They may only be apparent when the crystal is examined with laboratory equipment. Perhaps a better definition of a phantom would be a crystal that preserved an earlier growth stage, whether or not optically visible.

Growth conditions may experience chemical oscillation that produces crystal zones. Mindat defines oscillatory zoning as "repetitious concentric compositional variation in minerals resulting from cyclical changes in the chemical environment during crystal growth". Shore defined oscillatory zoning in a crystal as "multiple compositional growth shells". Shore reported that oscillatory zoning has been observed in over 75 different minerals from every major mineral class, and may be caused by either an extrinsic or intrinsic process. Extrinsic processes include oscillatory changes in the pressure, temperature, or chemical composition of the mineral solution. Intrinsic processes include oscillatory chemical changes near the growing crystal surface. They may involve varying adsorption of impurities, or fluctuating ratios of major solution constituents.

There are many examples of phantom features formed by zoning in the scientific literature. For example, Kempke showed that oscillatory zoning (forming phantom features) in apatite crystals

from Germany was due to variations in Fe and Mn concentrations. Long photographed luminescent calcite with rhythmic variations in color (phantom lines) caused by varying concentrations of Fe and Mn. Goetz (2002) showed that quartz crystals displaying no phantom lines, under natural or polarized light, may display many distinct phantom lines when examined under cathodoluminescence.

Since changes in solution concentrations can cause phantoms, and environment determines form, it is possible for a phantom to have a different form than the exterior faces of the crystal. Heyl described calcite crystals that changed form during growth.

Origin of Scepters:

Attempts to explain scepter growth usually assume two stages of growth, with a thin layer of clay or other debris (masking theory) covering much of the initial growth, before secondary growth begins. The clay, or other debris, then prevents secondary growth on the portion of the crystal that is covered. For quartz crystals, the explanation assumes the prisms are more likely to be covered or coated than the pyramids; therefore the secondary scepter formation (cap) grows only on the pyramid. The masking theory is also used to explain why scepters sometimes only form on the tallest crystals in a cluster. However, it fails to explain why there is often such a clean transition between the stem and the cap. If random coatings of clay are the answer, then secondary growth should frequently occur on a portion of the prism as well as the pyramid. Usually, it does not. Nevertheless, the masking theory has gained credibility in recent publications.
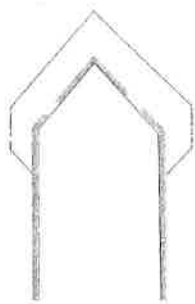

Figure 1: Masking

Sunagowa published a refined version of the masking theory. It claims there is an interruption in growth during which time portions of the crystal are coated with foreign material. Figure 1 illustrates the masking and scepter growth process. The grey area in the figure represents foreign material (not quartz) which masks the original crystal and may prevent unit cells of quartz from bonding to it. It may be clay or another mineral. Later, epitaxial crystal growth on the two still exposed small tip areas of the original crystal surfaces causes the scepter to form. Secondary growth begins in the two gaps in the mask, and then grows laterally over the surface of the mask. The prism on the cap grows beyond the prism on the stem because the cap is chemically isolated from the stem. Epitaxial growth produces common unit cell alignment so that the old and new growths have parallel crystal axes. However, the presence of the stem faces does not influence the growth of the scepter cap.

Takahashi (2004) published one of the most rigorous studies promoting the masking theory. He also postulated that scepters grow due to epitaxial lateral overgrowth (ELO), where a mineral grows over another material (same or compatible mineral), while maintaining common crystal

axis alignment. Natural and synthetic quartz crystals were masked and placed in sodium hydroxide solution, with synthetic quartz nutrient crystal, to produce additional growth. Portions of the crystals were coated with silver to provide masking. The experiment produced a single crystal point from growth through two holes in the silver mask. In another experiment, both the natural and synthetic quartz test crystals produced scepter growth. While the experiments clearly showed that ELO *can* produce scepter growth, they did not establish that it is the *only* means of scepter development or even that it is the most common.

While some natural scepters may indeed form by ELO, and the process could cause the cap and stem to have different-sized prism cross sections (in the a-b plane), the theory does not explain why so many scepters have caps that are symmetric with the stem. Intuitively, the stem and cap would often have a different (but parallel) c-axis if the masking theory is correct. The quartz page (www.quartzpage.de/cr/scepter.png) illustrates four different types of scepters. It shows a symmetric scepter, an asymmetric scepter, a reverse scepter, and a symmetric scepter with reversed lower pyramid. The asymmetric scepter cap has unit cells that are in alignment with those of the stem, but the c-axis of cap and stem are not coincident (parallel, but not coincident). Masking and ELO growth would appear to produce many more asymmetric scepters than symmetric ones. Collectors may favor symmetric scepters over asymmetric ones, but it seems unlikely that large numbers of unsymmetrical scepters are simply thrown away. If the majority of naturally-grown scepters are symmetric, there must me another scepter growth process besides the ELO process demonstrated by Takahashi. The usually clean transition between stem and cap is also unexplained. Masking may cause some scepter growth, but it seems unlikely that there would almost always be 100 % masking on the stems. Yet, many (perhaps most) scepters have absolutely no secondary growth on the stem.

Based on studies of scepters from the Entia Mountains of Central Australia, McColl proposed a variation of the masking theory. In this variation, the material surrounding the growing crystal is another mineral rather than clay. At Entia Mountain, quartz and calcite precipitated simultaneously. McColl presumed that calcite was deposited around the quartz, preventing the quartz prisms from growing while the pyramids did continue growing. Then, at some point, the calcite nutrients were depleted, while there were still quartz nutrients in the solution. Scepter caps then grew on the quartz stems. Later, the stems may have become elongated as some of the calcite was removed by erosion or dissolution. Exactly why the quartz crystals would develop scepter caps, rather than simply elongate, is not explained. The argument simply established that space would become available for prism growth, if the growth environment were to induce such growth. McColl also reported a second type of scepter that appeared to develop from point nucleation on the tips of the quartz crystals. Those crystals were not associated with calcite deposits.

Frazier and others attempted to explain scepter growth as a less extreme form of hopper growth. It is well known (Berg Effect) that, when a mineral solution becomes highly saturated, crystal growth on points and edges becomes more rapid than growth on the centers of faces. This effect

is a plausible explanation for hopper crystals, but fails to explain the flat crystal faces on most scepters. Joshi showed that impurity concentrations can also make nucleation more probable on pyramid edges of quartz than at the centers of faces, but did not indicate any reason to suspect that the process produces scepters. Although highly-saturated solutions can promote crystal growth on tips and corners, as well as on the tallest crystals, scepter growth does not necessarily favor any particular crystals. Jackson reported that 80% of the quartz crystals in some vug systems at Spruce Ridge, Washington were sceptered. Since so very many scepter caps have flat faces, and scepter caps do not always appear on only the tallest crystals, there must be some processes other than the Berg Effect, or edge anomalies, causing scepter growth.

Relative growth rates of crystal faces

Inspection of cut and polished scepter cross sections suggests that scepter growth may often be caused by a much more basic process than any suggested in the literature. It may simply result from different growth rates on different crystal faces. Varying growth rate ratios cause changes in crystal form, and it is known that changing environmental conditions can cause the growth rate ratio to change. Balitzsky conducted laboratory experiments documenting how the chemical composition, density, and saturation level of the solution can all affect the growth ratio of quartz crystal faces.
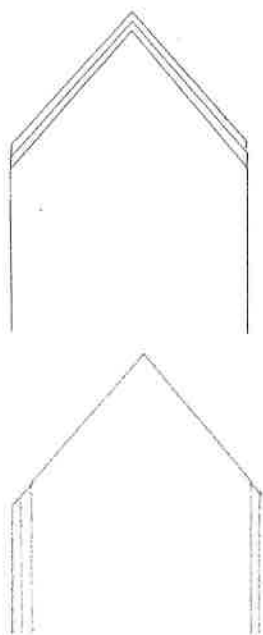

Figure 2: KOH rich (top) and KOH poor (bottom) growth

Ihinger analyzed quartz crystals and showed that the growth rates of the different faces are dependent on three different types of point defects caused by hydrogen impurities: AlOH, LiOH, and water. Steltz conducted laboratory analysis of impurities in quartz crystals, and showed that solution chemistry affects growth direction (which face grows fastest). Figure 2 illustrates the effect of KOH concentrations on the face growth velocity of quartz crystals. Jourdan conducted laboratory analysis of quartz crystals from Alpine fissures, and determined that growth rate was dependent upon traces of Al and Li. Quartz crystals from vugs in hydrothermal veins were shown to have grown most rapidly on either the prism faces or on the pyramid faces, depending upon the relative concentrations of AlOH and KOH. An initial growth rate in an AlOH-rich environment produced most rapid growth on the pyramid faces. Secondary growth in a KOH-rich environment produced growth on only the prism faces.

Fischer conducted very detailed analysis of three sequential growth stages of quartz crystals in hydrothermal veins. The first stage of growth had no optically discernable defects, the second had feathery lamellae, and the third had interstices and skeletal growth. The three growth stages were respectively associated with slow growth and low supersaturation, rapid

growth and moderate supersaturation, and very rapid growth and very high supersaturation. Further, precise measurement of cut crystal cross-sections showed that the pyramid face growth rate far exceeded prism face growth rate, especially in the last two stages.

Wenk analyzed fluid inclusions in quartz crystals from Swiss Alp fissures to determine growth conditions. He showed that four different solution chemistries were associated with four different crystal morphologies. A solution high in hydrocarbons produced doubly-terminated crystals with steep pyramids. A solution high in methane produced crystals with skeletal and scepter overgrowths. (The methane came from the hydrocarbons as temperature rose and gas was released due to pressure drops.) A relatively pure water solution produced classical symmetric-prismatic rhombohedral quartz crystals (prism and pyramid). Finally, a high CO_2 concentration produced stepped crystals in the tessin habit.

In 1906, Spezia truncated a common quartz crystal, and placed it in a sodium metasilicate and water solution. Normal pyramids grew on both ends of the truncated prism. There was no growth on the prism faces. Hale grew quartz in sodium carbonate ($NaCO_3$) solution, using a polished quartz sphere as the seed crystal. That produced a quartz crystal with the common pseudo-hexagonal form, as the pyramid faces grew outward from the sphere but the prism faces did not. Maleev, experimenting with NaOH solution, reported that man-made quartz seed crystals grew on only the pyramid, but natural quartz seed crystals grew on the hexagonal prism as well. Stephen confirmed that the prism faces of quartz crystals have zero growth in NaOH solution, but reported they do experience some growth in $NaCO_3$ solution.

Seager studied barite crystals from the Silver Band in England, and found there were five different forms that appeared in succession, as growth conditions changed. The crystals displayed the a,b,c,d,m, and o faces. Rapid growth, on only some faces at a time, caused sequential form changes. Initial growth was primarily on the m and d faces. Then yellow-brown barite was deposited on the o faces, followed by blue barite on the o faces. Following that, there was growth on the m faces again, and then on the d faces. The exact environmental changes that caused these changes were not determined, but analysis of the crystals determined that both gradual and abrupt environmental changes were involved.

The role of surface energy

Crystal faces grow at different rates under different environmental conditions because faces with different lattice planes have different chemical bonding energies. The complex physics of surface energy were explained by Kondrashow. Simply stated, faces with higher surface energy grow faster. Hartman theorized that the higher growth rates on surfaces with higher surface energy is caused by the higher bonding energy released when a unit cell is attached to the crystal surface. The attachment time is less for higher energy bonds. Therefore, growth is faster on the face with greater surface energy.

Using X-ray diffraction, Bragg and Gibbs determined the complex structure of quartz in 1925. Using the known positions of the atoms in the crystal, Sakensa then calculated the relative surface energies of the different faces of quartz, and showed that the predominant pyramid faces (z faces) have greater surface energy than the prism faces. Therefore, under most conditions, the length of a quartz crystal will grow faster than the width.

Using an early computer simulation that modeled the atomic structure and growth of crystals, Dowty (I) evaluated the effect of atoms slightly below the surface, as well as those on the surface. Also using experimental methods, he measured the surface energies for the pyramid and prism faces of quartz. Using that experimental data, the computer simulation predicted the growth rate of quartz crystals. The surfaces with higher surface energy produced the higher growth rates.

Two decades later, Rohl developed a more sophisticated simulation that considered the distorted atomic structure at the crystal surface (called relaxation), as well as the effect of atoms further from the surface. The simulation predicted the slowest growth on faces with the greatest atomic spacing (least surface energy). The simulation evaluated the growth of eleven different possible faces on a quartz crystal, and showed that the faces with the lowest surface energy became those with the largest area. This verified early work by Gibbs and Wulff that predicted a crystal will tend to grow in a way that minimizes total surface energy. That is because rapid-growing high-energy surfaces tend to grow out of existence, as lower energy surfaces expand.

Another two decades later, Suzuki developed techniques to measure both surface energy and crystal face growth rate. For quartz, he experimentally proved that the prism faces have less surface energy than the common pyramid faces. Therefore, in the most common forms, quartz crystals grow in length faster than they grow in width. Suzuki's experiments also showed that, for synthetically grown quartz, there is a nearly linear relationship between free-surface energy and growth rate.

Examination of scepter cross sections

Ramseyer (1988 & 1990) studied quartz crystals to determine how crystallography and physical and chemical conditions influence the cathodoluminescence of α quartz grown under hydrothermal conditions. Scepters were favored as specimens, because they indicated a greater change in physical and chemical conditions during growth. The specimens were cut along the c-axis, polished, and examined under cathodoluminescence. The samples showed abrupt changes in growth conditions shortly prior to, and again during, scepter formation. Some of the samples clearly showed that scepters formed because the change in growth conditions caused growth to stop on the six pseudo-hexagonal prism faces. Meanwhile, growth continued on the pyramid faces, causing the pyramid to enlarge and form a scepter.

Pirney studied the effects of trace elements on cathodoluminescence in quartz crystals. Scepters were chosen because they indicated major changes in growing conditions. The scepters were cut

along the c-axis, and thin sections were then cut and polished, so the crystal structure could be observed. Then, microprobe analysis determined the trace element concentration at various points on the cross sections. The results showed huge changes in trace element concentration, especially Al, when scepter formation began. On one of the specimens, prism growth did continue for a time after scepter growth began on the pyramid, but at a much lower rate.

Rakovan (1995) analyzed amethyst-capped scepters from Hopkinton, Rhode Island, and determined they formed in meteoric water-based fluids, rather than hydrothermal fluids, as originally thought. The analytical techniques included cathodoluminescent examination of cut crystals, as well as chemical analysis of fluid inclusions and trace elements in the crystal structure. He concluded that distinct changes in the environmental conditions and the chemistry of the solution were primarily responsible for scepter growth. However, he also concluded that the surface texture of the stems had some influence on scepter formation. The stems have smooth pyramid faces but very rough prism faces. Amethyst growth always ended at the interface between the smooth and rough faces, and Rakovan concluded that the topography of the stem also influenced scepter growth.

Observing unusual yellow cathodoluminescence in quartz, Goetz (2013) revealed sector zoning in a scepter cap, which was not present in the stem. This zoning revealed an abrupt change in solution chemistry, as scepter growth began. The yellow luminescence is believed to be due to rapid crystallization in an oxygen-deficient environment. Voudouris described scepters with tessin stems from Greece. The crystals formed in hydrothermal fissures, and the growth of the scepter caps is believed to be due to changes in temperature, pressure, and solution concentrations, as meteoric or sea water entered the fissures.
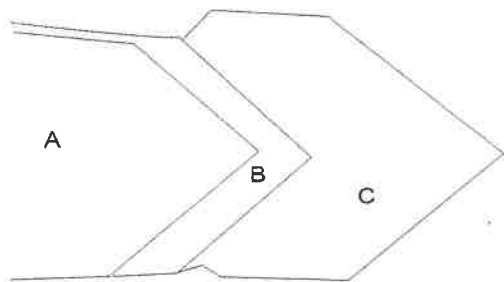

Figure 3: Two stage transition to scepter growth (Ramseyer)

Ramseyer published a cathodoluminescent image of a quartz scepter cross section cut along the c-axis. The different colors show a two-stage growth ratio transition due to changes in impurities.. Figure 3 illustrated the three stages of crystal growth. First, the light blue layers (B) grew over the dark purple (A), with the pyramid growth greatly exceeding the prism growth. In the second stage, the pale yellow layers (C) grew only on the light blue pyramid faces, forming a scepter.

Figure 4 illustrates scepter growth stages observed by Perney. Perney's photo of a scepter cross section shows scepter formation due to large changes in growth ratios, but with the prism growth not abruptly going to zero. A very low rate of prism growth continued, forming the tapered transition region between the stem and cap the upper left portion of the photo. Growth continued on all faces for a time, but the change to a much higher growth rate on the pyramid faces caused a scepter to form. Figure 4 illustrates regions of pyramid face growth (1py and 2py), prism face
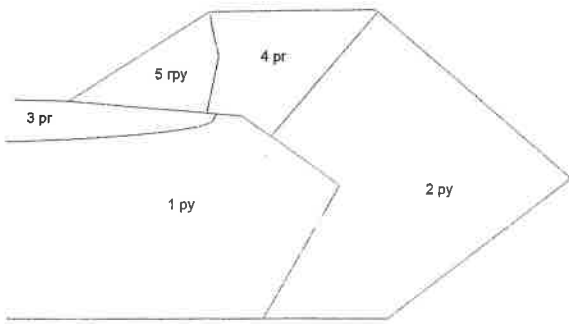
Figure 4; Layers Parallel to Prism and to Pyramid – (Perney)

growth (3pr and 4pr), and reverse pyramid growth (5rpy) as evidenced by phantom lines in Perney's photo.

Figure 5 illustrates different growth regions in a scepter cross section photo published by Jourdan. The top and bottom portions of the photo indicate different conditions. In the top portion, prism growth suddenly went to zero, and scepter growth proceeded on the pyramid faces. The process was similar to that in the Ramseyer photo. In the bottom portion, there was a gradual transition, as the prism growth lagged way behind the pyramid growth, but did not go to zero. The growth in the bottom of the photo is similar to that in the Perney photo. The reason for the different growth conditions on the opposite sides of the prism may have been due to sector zoning in the prism, or to different conditions in the mineral solution, caused by fluid flow, density stratification, or other factors.
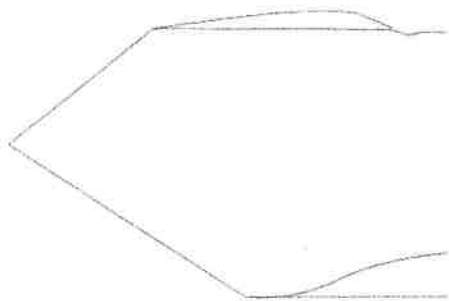

Figure 5: Regions of pyramid and prism face growth on scepter head (Jourdan)

The references documenting examination of cut scepters contain many photos showing (by distinct phantom lines) the progression from normal growth to scepter growth, as conditions change. Collectively, they suggest face growth rate ratio change is a common, and perhaps the most common, cause of scepter growth.

Discussion

While scepters may be caused by different growth rates on different crystal faces, the same is obviously not true for reverse scepters. However, reverse scepters may be caused by different growth rates on different portions of the same crystal face. Research by Seager (1953) determined that layers on a crystal surface do not even grow in all directions (in plane) at the same velocity. If the crystal is concentrically zoned, the pyramid may have annular regions with different surface energy. Then, certain environmental conditions may cause reverse scepter growth to occur on only the center portions of the pyramid. The fact that reverse scepters appear to always be symmetric supports this idea. Alternately, reverse scepters may result from epitaxial growth on the crystal tip only. Conversely, growth on only an outer annular area of a crystal face may provide an alternate explanation for the growth of hopper crystals. All hoppers may not be the result of the Berg Effect.

Dowty (II) defined sector zoning as "the existence of different compositions in different growth sectors of a single crystal". Possible causes are local variations in liquid composition near the surface, and partial incorporation of an adsorption layer of various impurities. Under either

condition, high-and low-energy surfaces react differently, to produce sector zoning. Rakovan (2009) also offered explanations for the origins of sector zoning.

For a quartz crystal with sector zoning, the pyramid faces may not all have the same surface energy, and scepter growth may occur on only a few of the pyramid surfaces, producing an asymmetrical scepter. The environment, as well as differing surface energies, is an important variable. For example, Dhanaraj described how the growth rate of the different pyramid faces on quartz depends upon pH.

Asymmetrical scepters have a cap c-axis that is parallel to the stem c-axis, but the two axes are offset. As discussed previously, the masking process might produce asymmetrical scepters. ELO might also produce a reverse quartz scepter, if exposed areas are only on the center of the pyramid. However, properties of the crystal itself, such as sector zoning, might also cause asymmetrical sector growth. Different growth rates on different crystal faces may cause asymmetrical, as well as symmetric scepters..

Many scepters from various locations have amethyst caps. That implies that the impurities causing the color may be associated with scepter formation. However, Henderson reported recovering both amethyst and clear scepters from nearby pockets in a road cut, suggesting some other factor initiated scepter growth. Henderson also described the extreme asymmetry of scepters collected from the site and cited literature claiming fluid flow and gravitational settling may cause such features.

Among the many environmental factors effecting crystal growth, it might be presumed that electrical charges, due to the pyroelectric effect, might also be included. Charges might develop on certain faces during cooling in a hydrothermal environment. However, Miers reported that quartz only becomes charged on alternate prism faces. That suggests pyro-electricity is not involved in the growth of quartz scepters.

Abbona documented the origin of crystal shapes in detail. Beginning with a description of the theoritical equilibrium shape of a crystal growing in a pure solutions, he subsequently discussed all possible internal and external factors that can alter the shape of the crystal. A comprehensive discussion of the effect of impurities and other environmental factors begins on page 33 of his paper.

Clifford described how Vlad Klipov is growing quartz crystal specimens in the laboratory. The laboratory work confirms that different crystal faces grow at very different rates. Klipov has been growing collector-quality quartz specimens, which are being sold at the Tucson show. The article displays twins, and states that Klipov hopes to grow scepters as well. Recent photos appearing on the internet, as well as a recent display at Tucson, show he is beginning to have some success with laboratory- grown scepters. Klipov will not disclose how the laboratory grown crystals are developed, but he did state that masking in not involved. That suggests that ELO is not the primary scepter-growing process in nature..

Many scepter crystals have uneven or incomplete lower pyramid faces on the cap. That may be because growth stopped on the prism faces, and there is no significant bonding between the lower pyramid of the cap and the faces of the prism. Lower pyramid growth then only occurs from the cap down as the cap grows laterally beyond the prism, and it is not well bonded to the scepter stem (prism).

In general, the cut cross sectional photos in the cited literature show a progression in scepter development. First, pyramid face growth becomes predominant, causing the tip of the crystal to enlarge. Next, prism faces develop on the enlarged tip. These are independent of the prism faces on the original crystal stem. They have different impurity concentrations and different growth rates. Finally, the lower pyramid faces grow downward from the scepter head prism faces. They may or may not be bonded to the original stem prism faces, depending upon impurity concentrations and other environmental factors. This process may explain why many scepter heads have high quality upper pyramid faces but incomplete or otherwise flawed lower pyramid faces.

Conclusions:

Phantoms can certainly form in accordance with the commonplace explanation of dirt, bubbles, or inclusions adhering to the crystal surface during an interruption in growth. However, many phantoms form without interrupted growth, and the cause is variations in solution impurities, rather than discreet pieces of foreign material adhering to the crystal surface. Variations in impurity concentrations, or lattice defects, cause phantom lines. Many crystals that do not show any phantom features under natural light do display many phantom features when examined in other ways. They do not have large defects such as bubbles, inclusions, or dirt on the phantom surfaces, but distinct phantom lines are there.

Published explanations for scepter growth generally assume two stages of growth with partial obstruction of the crystal surfaces, by clay or another mineral, occurring between them. These explanations are probably correct for only a small percentage of scepters. Also, as in the case of phantoms, scepter growth does not necessarily require two stages of growth at different times. Laboratory tests showed that masking and ELO can produce scepters, but did not demonstrate that those factors are necessary conditions for scepter growth. It is unlikely that most scepters form by masking and ELO, because that process does not explain the high percentage of symmetric scepters.

The claim that scepter growth is similar in some way to hopper growth, because edges can promote growth under highly saturated conditions, is perhaps closest to the truth, but still not correct. The Berg Effect explains hopper growth, but not scepters growth. Scepter growth does not require high solution saturation, but only changes in the concentrations of the solution impurities.

As revealed by many published images of cut scepter cross sections, most scepter growth is caused by a simple fact of crystal growth -- all of the faces do not grow at the same rate. That is what causes different specimens of the same mineral to display different forms. The ratio of the growth rates is determined by the concentrations of impurities in the solution, among other environmental factors. As the concentrations of those impurities change, the relative growth rates of the faces change, and the form may change. All that is required, for a quartz scepter to develop, is for the prism faces to quit growing, and for the pyramid faces to continue growing and to dominate edge growth. Eventually, the tip will get wider, as well as longer, as tip growth extends beyond the edges of the prism. The relative change in growth ratios that causes this is due to a change in solution impurities. That explains why the tips of so many scepters are a different color than the stem.
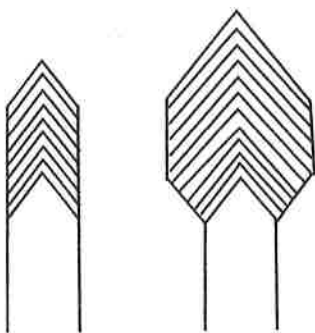

Figure 6: Alternate growth profiles

Finally, there is one additional requirement for scepter growth. As prism growth approaches zero, and pyramid growth continues, edge conditions must favor scepter development. Figure 6 illustrates the two possibilities. With growth occurring only on the pyramid faces, the crystal can simply grow longer, with the extended prism faces defining the form. Alternately, it can develop a scepter, with pyramid faces defining the form. Environmental conditions have to favor development of the scepter form.

Most reverse scepters probably develop due to epitaxial growth extending from the tip of the crystal, because of unique chemical conditions at that point. Sector zoning may also be involved in the formation of reverse scepters. Presumably, if there is sufficient prism growth on a reverse scepter, it might grow into a normal scepter. Once the normal scepter is formed, only c-axis cuts, and laboratory examination, could determine if the scepter formed as a common scepter, or developed from a reverse scepter.

Finally, the literature reports attempts to grow synthetic quartz scepters, and a recent internet posting presents a photo of one. Such laboratory work may eventually unlock the complete secrets of scepter growth.

References:

Abbona, Francesco, and Aquilano, Dino, Morphology of crystals grown from solution, Springer Handbook of Crystal Growth, ISBN 978-3-540-74182-4. Springer-Verlag Berlin Heidelberg, 2010, p. 53 01/2010; DOI: 10.1007/978-3-540-74761-1_3
https://www.academia.edu/6437479/Morphology_of_crystals_grown_from_solutions

Balitsky, V.S., et al, Experimental and computer simulations of morphology of quartz crystals in connection with conditions of their growth, Crystal Growth, structure and physical properties of crystals, IEM Library, Vol. 7, No. 2, http://library.iem.ac.ru/exper/v7_2/crystal.html

Brown, C, S, et al., The growth and properties of large crystal of synthetic quartz, GE Research Laboratories, January 24, 1952

Clifford, Janet H., and Klipov, Vlad A., A Marriage of Science and Art, Creating quartz specimens in the laboratory, Rocks and Minerals, Jul/Aug 2015, Vol 90, N0. 4, pp 379-384

Dhanaraj, Govindhan, et al, Springer Handbook of Crystal Growth (2010), p 632

Dowty, Eric, Crystal structure and crystal growth I, The influence of internals structure on morphology, American Mineralogist, Volume 61, p 448-459, 1976

Dowty, Eric, Crystal structure and crystal growth II, sector zoning in minerals, American Mineralogist, Volume 61, pages 460 -469, 1976

Fischer, Miriam, Evolution of the Fossil Hydrothermal System at Long Valley Exploratory Well, Mammoth Lakes, California, USA, Dissertation, Ruhr-University Bochum, February 2003

Frazier, Si, Scepters Rule, Lapidary Journal, January 1998, pp 52-59

Götze, J., Origin and significance of the yellow cathodoluminescence (CL) of Quartz, CORALS–2013 (Conference on Raman and Luminescence Spectroscopy in the Earth Sciences), pp 31-32

Gotze, Jens, Potential of cathodoluminescence (CL) microscopy and spectroscopy for the analysis of minerals and materials, Anal Bioanal Chem (2002) 374 :703–708 DOI 10.1007/s00216-002-1461-1

Hale, Danforth R., and Hurlbut, Cornelius S. Jr., 1949: Quartz sphere grown into a faced crystal. American Mineralogist 34(7-8): 596-599

Hartman, P., and Perdok, W.G., On the Relations between Structure and Morphology of Crystals. I, Acta Crystallographica, Vol 8. Part I, January 1955, p 49-52

Henderson, William A., and Haritos, Michael, Amethyst scepters, Salem, New London County, Connecticut, Rocks and Minerals, November, December 1989, pp 456-461

Heyl, Allen V., et al, Nickle Minerals from near Linden, Iowa County, Wisconsin, American Mineralogist, *Volume 44, pages 995-1009, 1959*

Hildebrand, W.F., and Schaller, W.T., The Mercury Minerals from Terlingua Texas, Bulletin 405, U.S. Geological Survey, 1909, page 82

Ihinger, Philip D., and Zink, Stephen I, Determination of the relative growth rates of natural quartz crystals, Nature, Vol. 404, 20 April, 2000

Jackson, Bob, Spruce Ridge Washington, Mineral Treasurers of the United States, p 89-95 http://www.geologyadventures.com/images/stories/Spruce.pdf

Jourdan, A.L., et al, Oxygen isotope sector zoning in natural hydrothermal quartz, Mineralogical Magazine, vol 73, no. 4, 615-632, 2009

Jourdan, A.L., et al, Sector Zoning of trace elements and oxygen isotopes in natural quartz crystals, University of Lausanne, Switzerland (online)

Joshie, M.S., et al, Surface structures of trigonal bipyramidal faces of natural quartz crystals, American Mineralogist, Volume 62, 122-126. 1977

Kempke, U., and Gotze, J., Cathodoluminescence (CL) behavior and crystal chemistry of apatite from rare-metal deposits, Mineralogical Magazine, February 2002, Vol. 66(1), pp. 151–172

Kondrashov, Dmitry, Geometric Theory of Crystal Growth, May 12, 1998

Long, J, V, P, and Agrell, S. O., The cathodoluminescence of minerals in thin section, Department of Mineralogy and Petrology, Cambridge

Maleev, M. Chr., and Kostov-Kyten, V., On the Growth of the Hexagonal Prism on Crystals of α Quartz, Comptes rendus de,l'Acadamie bulgare des Sciences, Tome 53, No 8, 2000

McColl, Don, Quartz scepter crystals from the Entia Valley, Harts Range, Central Australia, The Mineralogical Record, Vol.Vol.3, No. 6, November – December 2002, pages 515-521

Miers, Sir Henry Alexander, Mineralogy: An Introduction to the Scientific Study of Minerals, Page 116 of book I

Perney, Beat, and Eberhardt, Peter, Micro distribution of Al, Li, and Na is alpha quartz; possible causes and correlation with short lived cathodoluminiscence, American Mineralogist, Volume 77, pages 534-544, 1992

Rackovan, John, et al, Amethyst on Milky Quartz from Hopkinton, Rhode Island, The Mineralogical Record, Vol. 26, No. 2, Mar-Apr 1995, pp 83-89

Rakovan, John, Sectoral Zoning, Rocks & Minerals Volume 84, March/April 2009, pp 171-176

Ramseyer, K., et al., Cathodaluminiscent Colors of α quartz, Mineralogical Magazine, December 1988, Vol. 52, pp 669-677

Ramserer, Karl, et. al, Factors influencing short lived blue cathodoluminescence of α quartz, American Mineralogist, Volume 75, pages 791-800, 1990

Rohl, A.L., and Gay, D. H., Modeling the Morphology of Crystals by Computer, Mineralogical Magazine, Dec. 1995, Vol. 59. pp 607-615

Saksena, Bishambhar, Dayal, and Srivastava, Krishna Gopal, The structure and morphology of alpha quartz, 1948

Seager, A.F., The surface structure of crystals, The Mineralogical Magazine, March 1953, Vol. XXX, No. 220

Segar, A. F., and Davidson, W.S., Changes in Habit during the growth of barite crystals from the North of England, November 2, 1950

Shore, Mark, and Fowler, Anthony D., Oscillatory Zoning In Minerals: A Common Phenomenon, The Canadian Mineralogist, Vol. 34, pp. 1111-1 126 (1996)

Staples, Lloyd W. Austenite, a new Arsenate Mineral from Gold Hill, Utah, The American Mineralogist, Journal Of The Mineralogical Society Of America, February, 1935, pp 112 – 119

Steltz, Daniel J., How fast did that crystal grow? Quantifying the growth rates of natural quartz crystals, U of Wisconsin at Eau Claire : online at http://minds.wisconsin.edu/handle/1793/8337/browse?value=Steltz%2C+Daniel+J.&type=author

Stephan, V., and E.V. Zharikov, Crystal and Epitaxial Growth, Volume 2, Stepan University Press, November, 2001, p 54 (Google books)

Sunagawa, Ichiro, Crystals; Growth, Morphology, and Perfection, Cambridge University Press, 2005, p 140 and p 216

Suzuki, Takaomi, et al, Specific Surface Free Energy of As-Grown and Polished Faces of Synthetic Quartz, Journal of Crystallization Process and Technology, 2014, 4, 177-184 Published Online October 2014 in SciRes. http://www.scirp.org/journal/jcpt http://dx.doi.org/10.4236/jcpt.2014.44022

Takahashi, Yasushi, et. al., Epitaxial Lateral Overgrowth (ELO): The mechanism of formation of scepter, skeletal, cathedral and related quartz morphologies, Eur. J. Mineral. 2004, Vol.16, pages 1009-1017

Takahashi, Yasushi, Origin of Scepter Quartz, Journal of the Gemological Society of Japan 28(1-4), 15-30, 2008-03-30(alternate source in Japanese)

Voudouris, P., et al, Genesis Of Alpinotype Fissure Minerals From Thasos Island, Northern Greece. Mineralogy, Mineral Chemistry And Crystallizing Environment, Bulletin of the Geological Society of Greece, vol. XLVII 2013, Proceedings of the 13th International Congress, Chania, Sept.2013

Wenk, Hans-Rudolph, and Bulakah, Andri, Minerals; their Constitution and Origin, Cambridge University Press, 2006, p 284

Whitlock, H.P., Minerals from Roundout, Ulster County, New York State Museum, Bulletin 98, Mineralogy 4, Contributions from the Mineralogical Laboratory, New your Museum 59th Annual Report, 1905, page 6 and Figure 4

Unique Occurrences of Native Lead in Arizona

By Brian A. Beck, PG, CRS
Photography by Ron Gibbs

Native lead has been found in a previously undescribed occurrences at two placer gold mining projects in Yavapai County, Arizona, in the Weaver II Mining District and in the Humbug Mining District. The recovered native lead particles range in size from 0.01grams (g) to 22.4g. The shapes of the particles are highly varied, from flat paper-thin films, lumps, to apparent crystalline forms.

Historically, lead found in the area has been assumed to be of human origin, the result of hunting (buckshot and bullets) or industrial activity. Historical mining efforts in the past have excavated less than 20 feet below the ground surface, mainly to depths of 6 feet or less. With one of the recent projects, the excavation was mined in 6-foot benches and the material was processed separately, bench by bench. The new mining operation in the Weaver II Mining District has reached depths of nearly 100 feet. Material recovered from these depths suggests that the native lead found cannot be of human origin.

Sampling was carefully done on 440 tons of placer ore taken from benches from 30 to 60 feet below the surface. A total 2.28 kg of coarse concentrate from the initial gravity trap was recovered. This is approximately 14% of the total heavy metal recovered from the recovery operations. This concentrate was then separated into various mineral groups:

Feldspars and Quartz	847g
Iron Oxides (Hematite, Magnetite, Ilmenite)	623g
Lead	538g
Galena	10g
Titanite	3g
Chromite	1g
Native Copper	1g
Mercury (amalgam)	0.5g

Mineral samples were sent to Attard Minerals in San Diego, California for testing and confirmation and mineral identification. The majority of the feldspar is a high calcium-Albite. The native LEAD was found to be very pure with up to 5% iron. More than 50% of the lead particles contain some lead carbonate not as a coating, but as small crystalline pits within the surface. No sulfates were observed. The lead exhibits variations in its physical character with density ranging from 10.1 to 16.3 g/cm (pure Pb = 11.3 g/cm) and hardness ranging from 1.5 to 3.0 (pure Pb = 1.5). Assays of some of the lead particles found gold in concentrations of 22 ounces per ton of lead or 0.08% by weight. Gold appears to be tied to particles of LEAD with higher density and hardness.

This unique occurrence raises some interesting questions about the mode of formation of these lead particles and the source of the LEAD. Other placers in the area also contain LEAD particles of similar sizes and physical character.

Properties suggesting a natural origin for these particles:
1. Depth below surface
2. Placer ore undisturbed by previous mining activities
3. Obvious bullets recovered in first few feet only
4. Widely variable size and shape of the particles
5. Iron content of the lead
6. Gold content of the lead
7. Variation in the density and hardness
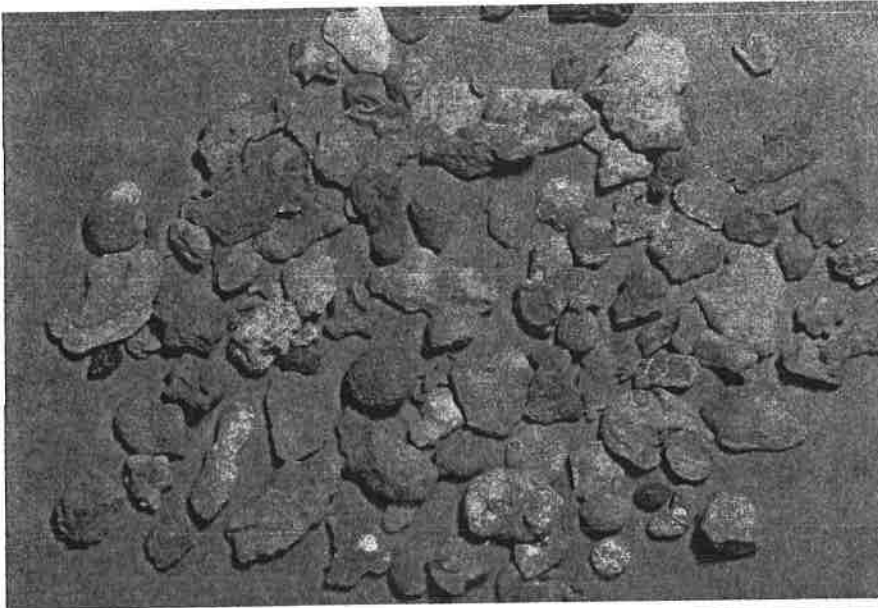
Example of LEAD particles
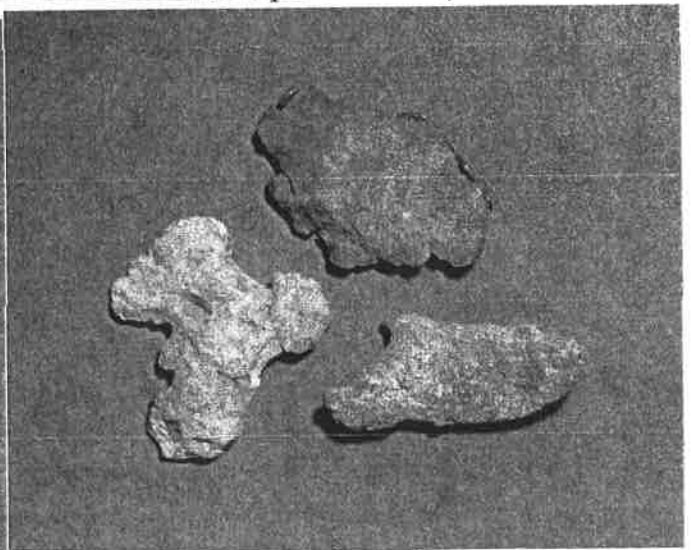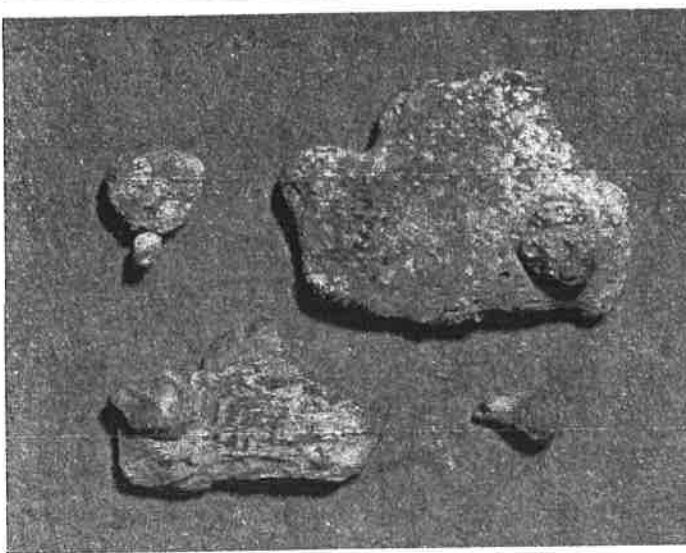
MIAROLITIC PEGMATITES
ALONG THE LOWER COLORADO RIVER VALLEY
CLARK COUNTY, NEVADA

By Steven W. Scott

BACKGROUND:

My first major mineral collecting trip took place in the Colorado Rockies collecting smoky quartz and amazonite microcline in the summer of 1981. While taking a summer class at the Colorado School of Mines, I was invited to go mineral collecting in the Lake George area west of Colorado Springs by Bob King. On this trip we found a large crystal pocket of smoky quartz and fluorite. Wow, this was a life changing experience. I did not realize that one could just go out prospecting and find such beautiful minerals. The technique used in finding crystal pockets in Colorado was challenging and fun. This experience provided me with the background needed to collect the miarolitic pegmatites in Southern Nevada.

DISCOVERY:
AREA 1:   ## SOUTH NEWBERRY MOUNTAINS

During the previous year (1979-1980) I had just started teaching Earth Science in Southern Nevada. It was now time to explore the local region for minerals. Around 1984, I met a local mineral collector, Walt Lombardo, at a mineral show in Las Vegas and he introduced me to other local collectors. This made exploring for new mineral locations easier as everyone was doing some sort of research. In April of 1985, at the local mineral show we were invited to collect minerals by a collector from Boulder City, Maury Morgenstein. He was collecting crystals in the Southern Newberry Mountains. So off we went. We had very poor results, finding just a few quartz crystal shards. The following weekend we explored some hills south of highway 163 near the intersection of highway 95. In a short period of time I had found a small fluorite pocket. The funny thing about this was I never found a fluorite pocket again. This area had large excavations and had been collected heavily in the past but was still producing some nice pockets. On one trip I met an eighty year old collector whose son was helping him collect. I asked if he had found anything and he showed me a beautiful, nicely striated, two inch square goethite pseudomorph after pyrite. I asked him how long he had been collecting the area and he said for over 20 years. That would put the collecting history in the area to the late 1950's to 1960's.

AREA 2:   ## ELDORADO MOUNTAINS

In June of 1986, the Clark County Gem Club was advertising a trip to collect garnet included quartz crystals from an area east of Searchlight. Seeing an opportunity to find a new pegmatite collecting area, my wife Dee and I signed up for the trip. The crystals were collected in a large sandy wash. These crystals that were found are called float as they eroded out of pockets higher up in the hills. I looked off in the distance a couple of miles and noted some granite outcrops that needed exploring, once the temperatures cooled down in the Fall. During the Fall my friend Don Arata

and I drove the extra couple of miles up a side wash to a ridge and started exploring. There was crystal float everywhere. Yea! A new collecting area! During May of 1987, the largest pocket of crystals that I had ever found was discovered in this area. The pocket roughly measured 8' X 2' X 8'. It took over two weekends to excavate the pocket. When the BLM was closing access roads in the area they made this route a designated road.

AREA 3:   **NEWBERRY MOUNTAINS**

In the Fall of 1988, I invited my dad who was visiting, to explore a new area in the Newberry Mountains near Christmas Tree Pass. This is a great memory as I had few times to share my collecting hobby with my dad. We drove up into the hills and parked my old Land Cruiser. In a short period of time we were finding float of small garnet included quartz crystals. We quickly discovered a small pocket.

LOCATION, TOPOGRAPHY, CLIMATE:

The mineral collecting areas are located in the Eastern Mohave Desert along the Colorado River. Most of the collecting sites are in the higher elevations ranging from 2-5 thousand feet. Creosote plants and cactus dominate the lower elevations and sparse pinon pine and juniper trees dominate the higher mountains. Rainfall varies with elevation and temperatures are hot in the summer and cold in the winter. Summer monsoons can cause flash flooding and Winter storms bring snow.

It should be noted this type of landscape is the fastest - constantly eroding landscape on Earth. Newly exposed crystal pockets occur yearly!

Springs and wildlife are quite abundant especially in the Newberry Mountains. There are herds of deer and big horn sheep occasionally seen. One must keep an eye out for rattlesnakes and gila monsters especially in the springtime when the temperatures reach 80 degrees.

The mountain ranges are typical of the western United States and trend in a north south direction and are parallel to the Lower Colorado River. The collecting area includes the Eldorado Mountains to the north, the Newberry Mountains and the Dead Mountains south into California.

On the west side of the mountains is Highway 95 running north and south. State Highway 163 to Laughlin splits the collecting area 1 & 3. The road to Cottonwood Cove takes you east of Searchlight into collecting area 2.

HISTORY:

The Newberry Mountains were a source of food, water, and a cool retreat from the summer heat for the Native Americans in the area. Evidence of their habitation is found all around the area: rock art, food grinding rocks, and projectile points. Spirit Mountain, the highest point in the region is 5639 feet and is a sacred mountain to the Native Americans. Some of the earliest mineral collecting was done just to the

west of Searchlight in the Crescent Peak area where the Native Americans were mining turquoise. The turquoise was traded throughout the Southwest. The turquoise mines were rediscovered in 1894 and became the Toltec and Morgan Mines.

The area was extensively explored by the Spanish in the 1700's. In Eldorado Canyon north of Searchlight, early gold prospectors discovered in the 1860's, old prospect pits and arrastres showing that the area was previously mined by the Spanish. Gold mining was widespread in the area during the late 1800's and early 1900's mining activity centered around the towns of Searchlight and Nelson.

ARIZONA TERRITORY:

For the Arizona mineral collector there is an Arizona connection to the area. After the Mexican American War, 1846-1848, this region was ceded to the United States. It became part of the New Mexico Territory. During the Civil War, 1861-1865, the New Mexico Territory was split forming the Arizona Territory along boundaries similar as today. One part of the Arizona Territory later became Clark County, Nevada. The northern half of Clark County was part of Piute County and the southern half part of Mojave County, Arizona Territory. This was for a short period of time as the region was added to the state of Nevada in 1866. Note this was after Nevada became a state in 1864.

COLLECTING HISTORY:

Even though the area showed signs of past mineral collecting there is little documentation of it. There is some inferred documentation that Arizona Collector Guy Hazen frequented the area after World War II. Also, Milton Speckles (Micromounters Hall of Fame) collected the area in the late 1940's and early 50's. Milton was an engineer at the nearby Davis Dam. At this time, Milton became a collecting friend of Guy Hazen. This information came from the Mineralogical Record Label Database. California collector Bob Reynolds has a Milton Speckles mineral specimen label of a Baveno Twin Feldspar crystal from the Dead Mountains in California from 1949. The Dead Mountains are south of the Newberry Mountains. During the 1980's and 1990's the two major collectors in the area were Maury Morgenstein and Jeffrey Jarrell. One time in the 80's Maury called me and said he had found a topaz pocket. At the time he was living in Boulder City, NV. Needless to say Dee and I quickly went to see the crystals. One of the topaz crystals Maury collected is posted on Mindat and was posted by collector/dealer Cal Graber. Another collector was the late Jeffrey Jarrell of AZ. His name was given to me by noted California collector/dealer John Siebel. I never met him but was told he had a great collection of minerals from the area. The Kingman Dailey Miner newspaper had a Feb. 21, 1995 article about a lecture he gave at the Laughlin Library on collecting the Tri State area. He had found a number of aquamarine beryl collecting sites in the area.

GEOLOGY SUMMARY:

The Miarolitic Pegmatites are found in Miocene (15-18 M) granite that formed in the outer margins of the granite plutons. Miocene plutons and volcanoes formed along the north south trending mountain ranges throughout the Basin and Range Region of California and Nevada. One of the last regions in the Basin and Range Region to experience widespread volcanism , plutonism, and extensionalism was this region. These plutons formed during the continental extension of the western part of the North American Plate. This region is known as the Northern Colorado River Extensional Corridor. The Southern Nevada plutons intruded older PreCambrian - Paleozoic granite and metamorphic rocks. These are notably darker rocks and finer textured than the Miocene granite.

When the intruded magma cooled in the plutons, volatile gases and liquids escaped to the outer margins forming voids for larger crystals to form. These pegmatites are simple, having mostly quartz and feldspar mineralization.

The Pegmatite Classification is NYF for Niobium, Yttrium, Fluorine enrichment.

Common minerals found in Miarolitic Cavities:

MICROCLINE, feldspar group, crystals are common a lot of them showing twinning (baveno, manebach, parallel, chevron & carlsbad).
ALBITE, feldspar group, white and sometimes blue tinted
PERTHITE, consisting of intergrowths of potassium rich feldspar microcline and sodium rich feldspar albite
QUARTZ (smoky), dark black to gray color, there are a wide variety of inclusions; spessartine inclusions are much sought after.

OTHER MINERALS COLLECTED:

ARAGONITE	BERYL	BIOTITE	BROOKITE **
CALITE	MANGANOCOLUMBITE – TANTALITE **		
EPIDOTE	FLUORITE		
GOETHITE pseudomorphs after pyrite			
HELVITE **	HEMATITE	MAGNETITE	MUSCOVITE
PYRITE	SCHORL	SPESSARTINE	
TITANITE **	TOPAZ ***	ZIRCON	

Also noted By Uni. New Orleans,

THORITE	MAGANOCOLUMBITE	ILLMENITE-PYROPHANITE
MONAZITE-Ce	BASTNAESITE-Ce	POLYCRASE-Y

** University of New Orleans, Microbeam Laboratory, 12-22-89
*** Not self collected

MINERAL COLLECTING NOTES, SITE 1:   Bat Ears, Newberry Mts.

Best clear and root beer colored smoky quartz
Most common area to find spessartine included quartz
Only area where I have found fluorite, helvite and magnetite in pockets

MINERAL COLLECTING NOTES, SITE 2:   Eldorado Mountains

Most smoky quartz is gray in color, somewhat opaque, some showing radiation damage
Spessartine included quartz crystals are clear
Only area where I have found calcite and aragonite in pockets
Nice microcline twinning

MINERAL COLLECTING NOTES, SITE 3:   Christmas Tree Pass, Newberry Mts.

Excellent microcline and microcline twinning
Nice epidote and manganocolumbite crystals
Some of the pockets have biotite crystals
Only area where I have found beryl crystals

Common in all areas are: spessartine included quartz, goethite pseudomorphs, quartz, microcline and albite

COLLECTING:

Like in all public collecting areas in our country over the past 30 years, rules and areas where you can collect minerals have changed. Many areas that were open to collecting in the past have been closed or access has been restricted. Today road closures, wilderness areas, wilderness study areas, endangered desert tortoise habitat, and National Recreation Areas are found in all the collecting areas 1-3. However there are still large areas you can go collecting. Be sure to check out where you can collect before going.

In the collecting areas look for the light colored granite outcrops and hike until you find crystal float. Try to follow the float uphill. When the float disappears a pocket is usually buried in the area. Dig around until you find it. Many pockets are found in the solid rock and boulders. Look along areas eroded in the granite. If you find one pocket usually there are many more in the area. There have been a few times where the pockets have been isolated with no other pockets found in the area but it's rare. Most of the crystal pockets are collapsed with many of the crystals showing damage. Rare are the special crystals that show no damage.

Tools and things you might need are:

Pick, rock hammer, chisel, long screw driver for probing, gloves, wrapping material, safety glasses, sun screen, long pants, sturdy shoes, long sleeved shirt, hat, backpack, water, food, maps.....

The long handle pick is the most important tool as you try to find a pocket. Small crystal shards and sometimes a reddish color of dirt indicate you are close to a pocket. When you see crystal faces on the shards, STOP. Then carefully start probing around for crystals with your screwdriver and glove covered hands.

Keep in mind most pockets are small and good quality crystals are rare. Hard work and spending time exploring will most likely pay off in finding good minerals.

The Nevada Bureau of Mines and Geology has a publication for sale with good information (but old) and a geologic map of the area

> Bulletin 80, Geology of the Granite Complex of the Eldorado, Newberry, and Northern Dead Mountains, Clark County, Nevada
> By Alexis Volborth, Univ. of Nevada Reno, Nevada 1973

Also:

Pegmatology , Pegmatite Mineralogy Petrology & Petrogenesis (book), University of New Orleans, 2003 Karen Webber, Willliam Simmons & Alexander Falster ISBN: 097406130-1

Miarolitic Pegmatites and Granites from The Searchlight District, Colorado River Extensional Corridor, Nevada, USA, (paper) 2011 Karen Webber, Willliam Simmons & Alexander Falster,
University of New Orleans, Karen Webber, Willliam Simmons & Alexander Falster

Stichtite Formation Within Methane-Rich Serpentinizing Environments

Dr Erik Melchiorre
Department of Geology
California State University, San Bernardino
5500 University Parkway
San Bernardino, CA 92407

Abstract

Stichtite $Mg_6Cr_2[(OH)_{16}|CO_3]$ $4H_2O$ is a rare purple mineral from the hydrotalcite group. It is commonly associated with Cr-rich serpentinites found within ophiolite or greenstone belts and has been long thought to be a weathering product of oxidizing chromium ore bodies at shallow depths. However, stichtite is not found as a weathering product at chromite mines, and at only 42 documented localities around the world (midat.org, 2014). The two most famous and productive stichtite localities are located in Tasmania, Australia, and Barberton, South Africa.

Stichtite in Tasmania, Australia occurs within mid-Cambrian serpentinite bodies (Petterd, 1914; Bottrill and Graham. 2006). Samples from Tasmania for this study came from all reported localities, including the Stichtite Hill and Tunnel Hill sites. Stichtite is mined at the Stichtite Hill locality for use as decorative carvings and for ornamental use. Stichtite also occurs at five lesser localities in Tasmania (Burrett and Martin, 1989; Bottri II and Graham, 2006).

Stichtite from South Africa occurs within the Archean Barberton greenstone belt (Cairncross and Dixon, 1995; Dann. 2000). Stichtite samples were collected from a road cut, near a turnoff to the New Amianthus Mine (Kaapsehoop asbestos mine) in Barberton, South Africa. South African stichtite is mined on a limited basis for collectors and museums in small specimen mines, but is mostly discarded from asbestos mines exploiting these deposits.

Recent work on stichtite from Tasmania and South Africa has shown that stichtite is often cut by serpentinite veins, suggesting stichtite formation is contemporaneous with serpentinization. The specific serpentinite mineral observed is low-temperature (50°C to 300°C) lizardite. Chromium and magnesium numbers from chromites associated with stichtite indicate formation occurs only within fore-arc serpentinization environments. Carbon and hydrogen isotope values of stichtite suggest stichtite forms in an abiogenic thermogenic methane-rich environment. Mineral associations such at aragonite indicate pressures can be quite high when stichtite forms.

References

Bottrill RS. Graham IT (2006) Stichtite from western Tasmania: Australian Journal of Mineralogy: 12:2: p. 101 - 107.

Burrett CF, Martin EL (editors) (1989) Geology and Mineral Resources of Tasmania: Special Publication, Geological Society of Australia: v.15: p. 574.

Cairncross B, Dixon R (1995) Minerals of South Africa Geological Society of South Africa: 296 pages.

Dann JC (2000) The 3.5 Ga Komati Formation, Barberton Greenstone Belt, South Africa: Part I: New maps and magmatic architecture: v. 103, p. 47-68.

Mindat web site (20 14) Mineral data for stichtite: http://www.mindat.org/min-3784.html

Petterd, WF (1914) Description of the mineral. *In*: Twelvetrees, W.H. (ed.), Stichtite: a new Tasmanian mineral: Tasmania Department of Mines: Geological Survey Record: 2: p. 3-4.

Photographs from Richard Bideaux's collection
Phil Richardson

A large collection of slides from Richard Bideaux has been given to the Flagg Mineral Foundation thanks to the efforts of Jim McGlasson and Shirley Wetmore. The Foundation plans to digitize the slides and make them available.

The following is the biographical information about Bideaux from the last edition of the *Mineralogy of Arizona* of which he was a coauthor.

Richard A. Bideaux, a University of Arizona graduate in geological engineering, received his master's degree in geology from Harvard University. He has discovered and helped to identify several new Arizona minerals. For many years he has been associated with the Tucson Gem and Mineral Society Show and served as assistant editor and columnist for the Mineralogical Record. Bideaux has been a collector and dealer in fine mineral specimens. Since 1980 he has served as a general partner of Mineral Data Publishing, which produces the *Handbook of Mineralogy*, a text he has also coauthored. Bideaux is a fellow of the Mineralogical Society of America.

Richard Bideaux (1935-2004) was also a very active participant in the Minerals of Arizona Symposiums until his death. The Thirteenth Annual Symposium was dedicated to him and the proceedings contain more information about his contributions.