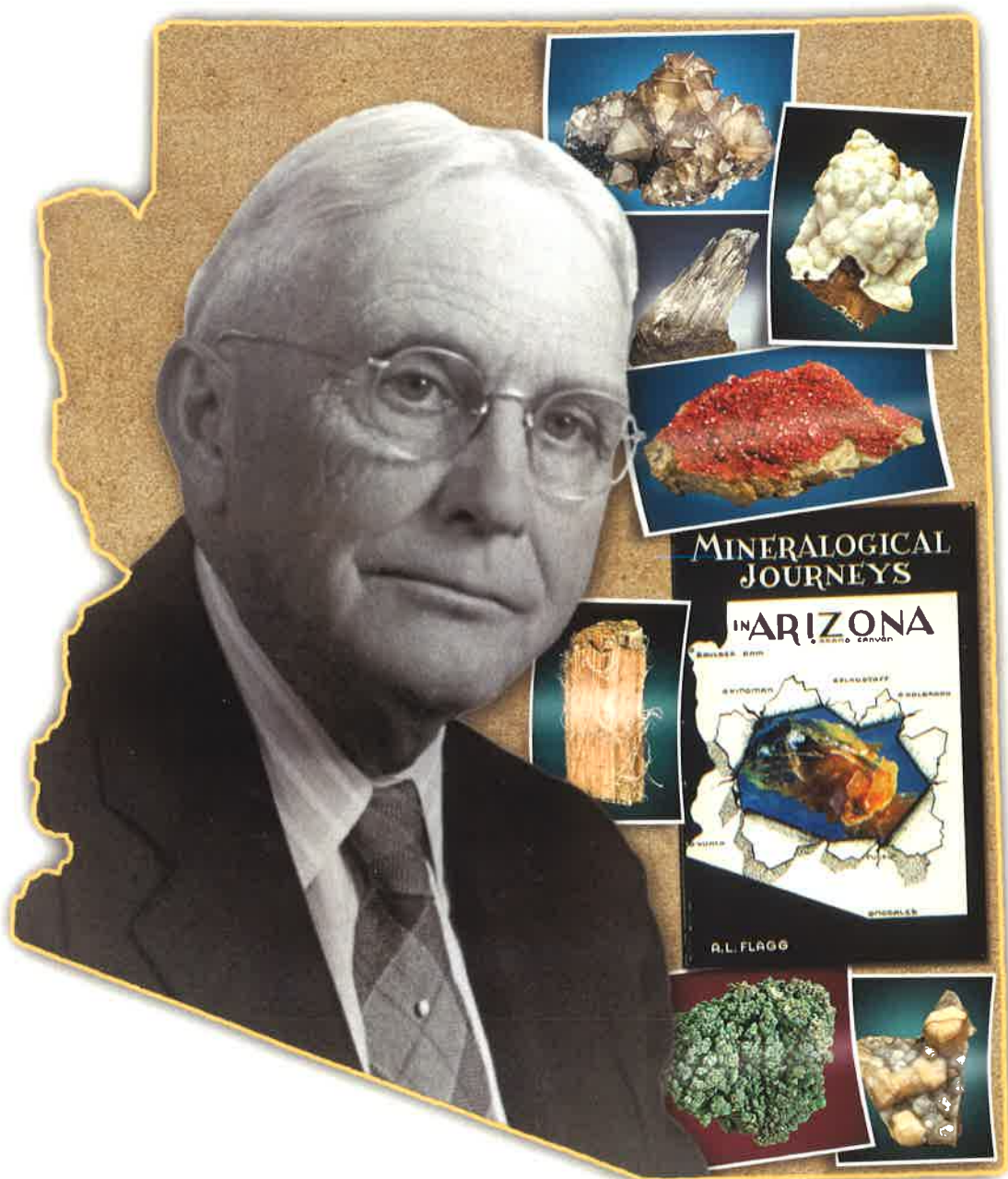


# MINERALS OF ARIZONA

## TWENTY-FIRST ANNUAL SYMPOSIUM



Sponsored By  
Flagg Mineral Foundation  
April 5-6, 2013

Co-Chairpersons

Phil Richardson - Chair, Flagg Mineral Foundation

Ray Grant - President, Mineralogical Society of Arizona

Williams  
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# **Minerals of Arizona**

**Twenty-first Annual Symposium  
Dedicated to Arthur L. Flagg**

**Sponsored by the Flagg Mineral Foundation**

**Friday, Saturday, and Sunday  
April 5, 6, and 7, 2013**

**Co-chairpersons:**

**Phil Richardson - Chair, Flagg Mineral  
Foundation**

**Ray Grant – President Mineralogical Society of  
Arizona**

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

This Minerals of Arizona Symposium is dedicated to Arthur L. Flagg (1883 – 1961). Over his lifetime he contributed a great deal to the knowledge of Arizona Minerals. He continues to add information today through his mineral collection and collection catalog that were recently made available for study.

After the abstract on the Arthur Flagg Collection by Phil Richardson, there are some sample pages of the Flagg catalog, photographs of the Flagg cases in Tucson, 2013, and a copy of the Mineralogical Society of Arizona Bulletin published right after Flagg's death in 1961

Cover design: Harvey Jong

Arthur Flagg photograph, courtesy Flagg family  
Mineral specimens are from the Arthur Flagg collection.

Top left: Quartz on Hematite, England, Jeff Scovil photo

Top right: Opal, Bagdad, Arizona, Jeff Scovil photo

Top middle left: Asbestos, Woonsocket, Rhode Island  
(Flagg's home town), Jeff Scovil photo

Top middle right: Vanadinite, Apache mine, Arizona, Jeff  
Scovil photo

Bottom middle left: Asbestos, Sierra Ancha, Arizona, Jeff  
Scovil photo

Bottom middle right: Mineralogical Journeys in Arizona  
dust jacket cover, Publisher: Fred H. Bitner, 1958.  
Scanned image courtesy of Marcus Origlieri

Bottom left: Malachite on Copper, Bisbee, Arizona, Jeff  
Scovil photo

Bottom right: Quartz Coating over Pseudo-hexagonal  
Aragonite, Bloody Basin, Arizona, Jeff Scovil photo

## **Friday, April 5**

### **Micromount Session – 2 PM to 4 PM**

Friday afternoon 2 PM to 5 PM will be a micromount session. Some microscopes will be available to use. The Flagg Foundation has a lot of micromount material that will be available free for the participants. Everyone is welcome, even collectors of big rocks.

### **Talk - 4 PM - New Western United States Mineral Species**

By Joe Marty

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[jmmicros@msn.com](mailto:jmmicros@msn.com)

Joe Marty will discuss new minerals recently found in the Western United States. His Power Point presentation will be illustrated with locality pictures, maps, and photomicrographs, many of which were taken with stacking software to improve depth-of-focus. His talk will concentrate on locations in the western United States with emphasis on the Colorado Plateau. Collecting status and mineral associations at these localities will also be discussed.

Joe Marty: Joe is an active field collector of minerals in the West. He is a retired medical technologist and maintains a business for cleaning and servicing microscopes. His field collecting has enabled him to build up a collection of over 13,000 catalogued micromounts. He is a member of the Micromounters Hall of Fame. Other hobbies include fishing in Alaska and bird watching.

### **Dealers selling at the Clarion 5 to 10 PM**

## **Saturday, April 6 – Symposium Program**

- |                 |   |
|-----------------|---|
| 8:00 - 8:45 -   | <b>Coffee Hour</b>  |
| 8:45 – 9:00 -   | <b>Welcoming Remarks and Introductions</b>  |
| 9:00 – 9:40–    | Minerals of Bagdad, Mohave County – Barbara Muntyan   |
| 9:40 – 10:20 -  | The Ben Williams Collection, a Lost Trove from 19 <sup>th</sup> Century Bisbee – Evan Jones |
| 10:20 – 10:50 - | <b>Break</b>  |
| 10:50 – 11:30 - | Rare Earth Elements in Arizona – Karen Wenrich  |
| 11:30 – 12:10 – | Arizona's Fabulous Sulfates – Les Presmyk   |
| 12:10 – 1:30 -  | <b>Lunch</b>  |
| 1:30 – 2:10 –   | Formation of Arizona Minerals through Geologic Time – Jan Rasmussen                         |
| 2:10 – 2:50 –   | New Ideas on the Origin of Oil: A Herkimer Diamond Case History from New York– Stan Keith   |
| 2:50 – 3:20 -   | <b>Break</b>  |
| 3:20 – 4:00 –   | Mineralogy along Route 66 in Northern Arizona - Anna Domitrovic                             |
| 4:00 – 4:20     | - The Arthur L. and Richard W. Flagg collection – Phil Richardson                           |
| 4:30 – 6:00 -   | Happy hour, visit dealers   |

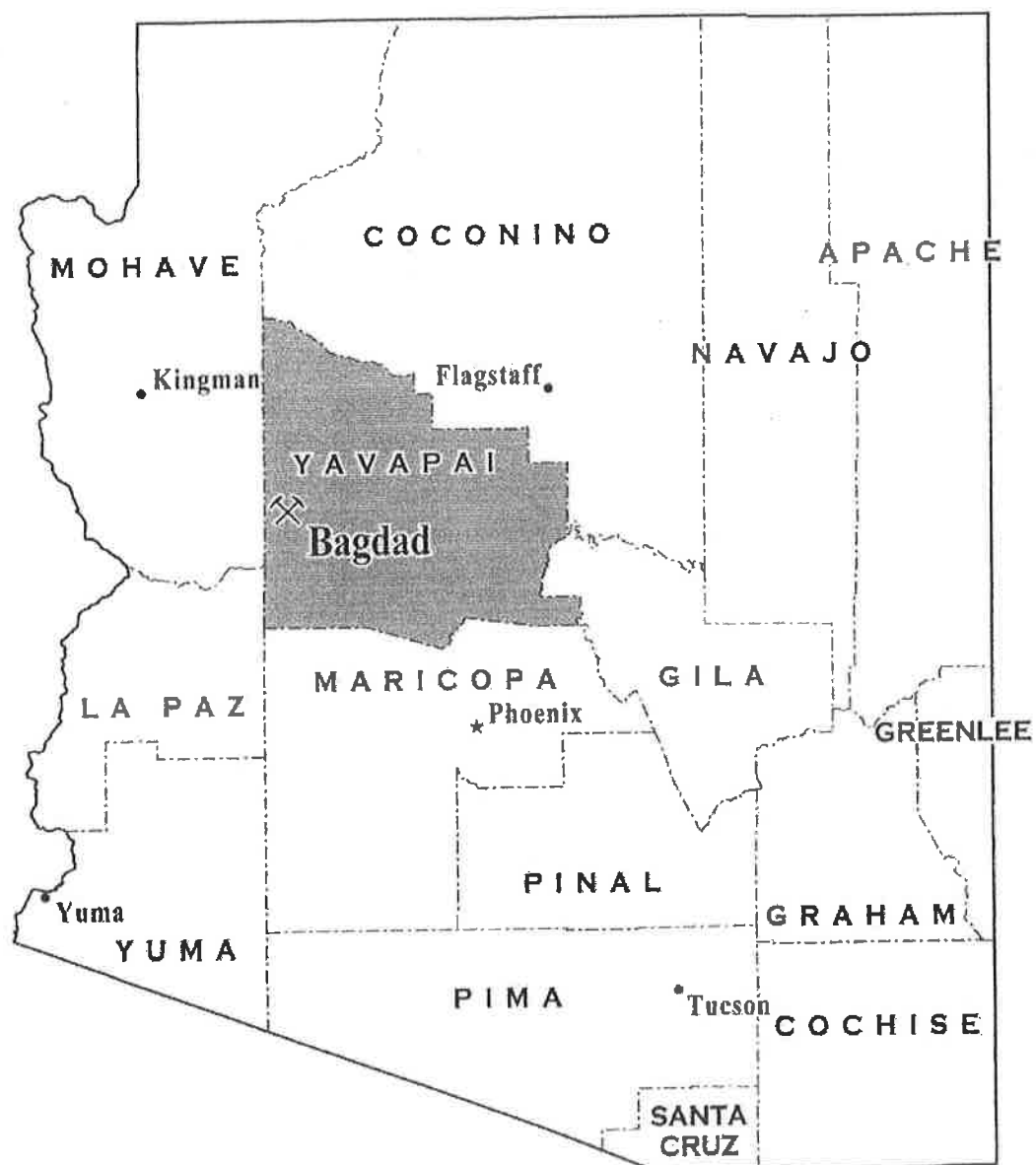
### **Evening Buffet**

- |      |   |
|------|---|
| 6:00 | Buffet, auction and evening speaker Jeff Scovil – The best Arizona minerals I have photographed and an auction of donated items |
|------|---|

# MINERALS OF THE BAGDAD COPPER MINE

Barbara L. Muntyan

The Bagdad Copper Mine is the last major porphyry copper deposit in Arizona which has been developed largely without the support of a major mining company. The mine is located in west-central Yavapai County, approximately 100 miles from Phoenix.



Map by William W. Besse

The first claims were staked between 1878 and 1882, with the Bagdad Copper Company formed in 1911. Originally operated as an underground mine, using block-caving methods. It became an open pit operation in 1945. The first mill was constructed in 1928 and the state's first SXEW plant was constructed at Bagdad in 1970. Cyprus Mining acquired the mine in 1973, later merging with Phelps-Dodge, which operated the mine until 2007; in that year Bagdad was acquired, along with all other PD assets, by Freeport MacMoRan, the present owner. The mine currently produces about 25 million pounds of copper annually.

Because of its remote location (the highway literally ends at the company town), Bagdad is not as well-known as Morenci or Ray, but this mine has produced its share of exceptional mineral specimens, in particular beautiful, gemmy calcite clusters and fishtail twins, sprays of malachite pseudomorphs after azurite, deep blue chrysocolla covered with druzy quartz and surrounded by banded malachite, fine groups of quartz crystals, chalcopyrite, and several other species for the collector. The lapidary material from Bagdad is truly noteworthy.

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Parsons, A. R. The Porphyry Coppers in 1956. (1957). AIME.

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## THE BEN WILLIAMS COLLECTION A TROVE FROM 19<sup>th</sup> CENTURY BISBEE

By Evan A. Jones

### BEN WILLIAMS BORN IN LONDON

Ben Williams was born in London in February 1852, the youngest son of John and Leah Williams, a prominent family of Welsh metallurgists from Swansea. His father John developed the world's first water-jacket smelting furnace, used successfully in Norway for the first time in 1853, which allowed for more uniform temperatures resulting in much improved smelting of metallic ores. This type of furnace was later used throughout the American West. In 1855, the Williams family moved to the United States and settled in Connecticut, then the American center of brass and copper refining.

By the 1860's, the family moved to Michigan where the elder Williams worked in the copper refining works at Hancock, across Portage Lake from Houghton. It was here that Ben Williams first found employment as a clerk, and later as a bookkeeper, in the late 1860's while a teenager. Then, in 1874, the Williams family moved to San Francisco with one D.W. Bisbee, who had married Ben Williams' sister, ultimately organizing the mining firm of Bisbee, Williams & Company. This company would later become critical to the development of the Copper Queen mine in Bisbee.

### BEN WILLIAMS IN ARIZONA

After gaining further experience in the 1870's working at mines and smelting operations in California, Montana and Nevada, Ben Williams first went to Arizona Territory in September 1878. Riding by train to Fort Yuma and crossing the Colorado River by ferry, he then traveled up the Gila River by stage through Maricopa Wells and eventually to Tucson. His first job in Arizona Territory was as superintendent of the San Xavier mine in the Pima district. However, he left the following year and moved to Charleston, a smelter town along the San Pedro River, to prospect in the Huachuca Mountains.

Then a fateful event occurred. Hearing of rich copper strikes, in February 1880 he visited Mule Gulch, then a ramshackle prospector's camp, and saw the Copper Queen and other properties. Claims had first been staked in the area in 1877, but no serious mining had taken place. Samples were taken and word of the promising copper deposit soon reached Bisbee, Williams, and Co. in San Francisco.

### THE BEGINNINGS OF THE COPPER QUEEN

In June of 1880 a group of investors named W.H. Martin, John Ballard, and Edward Riley bought the Copper Queen claim and, through the firm of Bisbee, Williams & Company, erected a water jacket smelting furnace placing Ben Williams in charge of general operations and Ben's older brother Lewis in charge of smelting. The Williams brothers built a house directly across the gulch from the mine site. By April 1881, Ballard, Martin, and Riley incorporated the Copper Queen Mining Company and mining commenced in earnest. Despite primitive conditions, bandits and Apache raids, the Copper Queen soon became the first (and only) successful mine in the district. In 1883 the town was incorporated and named Bisbee after Ben Williams' brother-in-law. That same year the company built a toll road over Mule Pass, affording easier access to the fledgling mining town.

### THE COPPER QUEEN CONSOLIDATED MINING COMPANY

But by 1884, ore at the Copper Queen was running out. Then, and quite fortuitously, the fabulous Atlanta ore body was discovered simultaneously by the Copper Queen Company and the Phelps Dodge Company, owners of the adjacent Atlanta Claim. Partly to avoid expensive apex-law litigation, in August of 1885 the two companies consolidated, forming the Copper Queen Consolidated Mining Company. Dr. James Douglas of Phelps Dodge became president while Ben Williams remained in charge of general operations and Lewis Williams remained in charge of smelting. A new shaft was dug, the Czar, to exploit the fabulously rich new ore body and a new smelter was blown in.

*Gibbs*

## THE QUEEN OF COPPER CAMPS

In 1888, the C.Q.C.M. Co. built the Arizona and South Eastern Railroad from Fairbank to Bisbee, finally connecting the mining district to the outside world by rail. What followed was a period of great success and prosperity for the company, the town, and its citizens. New ore bodies were discovered and mines developed. Schools, hospitals, hotels, a company store, and a library were built. By the time of Ben and Lewis Williams' retirement from the company in December of 1899, Bisbee had assumed its position as "The Queen of Copper Camps" in no small part due to Ben's exemplary and capable leadership. By all accounts, he was well-loved by everyone in the mining company and by the citizens of Bisbee, especially due to his kindness and generosity towards all of the Copper Queen employees. Upon his retirement he was presented with a large engraved silver loving cup by the people of Bisbee to show their appreciation.

## THE RETIREMENT YEARS

After retirement from the C.Q.C.M. Co., Ben and Lewis Williams moved to Milton, California in the Sierra Nevada and purchased the old Napoleon mine in Calaveras County. The Napoleon was the oldest copper mine in the state and was first worked in the 1860's. The brothers dewatered the mine and extracted about 3000 tons of ore before finally settling in Los Angeles in 1903. Lewis Williams died in 1907 at age 62.

In addition to retaining business interests in Arizona as a director of the Bank of Bisbee, Ben Williams became a director of the Citizen's Trust and Savings Bank of Los Angeles and Treasurer of the Los Angeles Hospital Association. In 1911 Ben married Miss Bessie M. Reid, daughter of Detroit plate glass magnate William Reid and in 1912 a son, Ben Williams, Jr., was born. The family lived in a large home near what is now the intersection of I-10 and Normandie Avenue in West Los Angeles.

A successful angler by this time, Ben was a member of the Tuna Club on Catalina Island where his name is engraved on many cups and trophies. He was also a Knight Templar, a Shriner, and a member of several country clubs in both Los Angeles and Phoenix. He returned to Arizona often due to his business and social connections in Phoenix and Bisbee. Interestingly, he was a member of the El Zahirah Temple in downtown Phoenix, which later housed the Department of Mineral Resources and the Arizona Mining and Mineral Museum.

## AN ARIZONA PIONEER PASSES

On September 1, 1925, Ben Williams passed away at the age of 73 of respiratory illness. His funeral was attended by members of the Copper Queen management, with several acting as pallbearers. He was cremated and is interred at Forest Lawn Cemetery in Los Angeles. Ben Williams will always be remembered as an important Arizona pioneer and father of the Copper Queen mine in Bisbee, Arizona.

## THE MINERAL COLLECTION

As General Manager of the Copper Queen (Consolidated) Mining Company from 1880 to 1899, Ben Williams oversaw the development of most of the important early mines in the Warren district, including the Copper Queen, the Czar, the Holbrook, the Spray, and the Gardiner. All of these produced thousands of finely crystallized specimens of azurite, malachite, calcite, copper, cuprite and scores of rare species. Thanks to Ben Williams, Dr. James Douglas, and others in the Copper Queen management, these found their way into museums and collections throughout the world, marketed by such dealers as A.E. Foote and George English.

Like most in the Copper Queen management, who considered mineral collecting to be practically a God-given birthright, we now know that Ben Williams assembled an incredible mineral collection during his time in Bisbee, perhaps rivaled only by that of Dr. James Douglas. As general manager, Ben was well positioned to obtain many wonderful specimens during the earliest, and arguably most exciting, chapter of mining and mineral collecting at Bisbee. Since most of the early mines exploited carbonate and oxide ores almost exclusively, specimen production was spectacular and prolific.

## THE COLLECTION IS DISCOVERED

The Ben Williams collection was not known to exist until its discovery at auction in California the summer of 1998. Ben Williams, Jr., who had been living near Sacramento, had died a few years earlier and the estate was cashing out all assets. Bill Larson, a mineral and gemstone dealer in southern California, learned of the auction and made inquiries requesting further information. Needless to say, when it was discovered who had originally assembled the collection, excitement was palpably high. At auction, Larson placed the winning bid and secured the entire mineral collection which also included Ben Williams' books, photos, papers and personal effects.

The mineral collection was packed in fifteen large wooden crates, each specimen having been carefully wrapped in cotton and newspapers before being crated and nailed shut. Upon further inspection, it was discovered the newspapers were dated 1937-1938, about 13 years after Ben Williams' passing. This meant the collection had not seen the light of day for 60 years. Presumably it had been crated up by Ben Williams' wife and son in 1938 and the collection stayed in the family, unknown to the mineral collecting community, until the auction took place in 1998. It is not known why the collection was never unpacked during those 60 years.

The Ben Williams collection contained hundreds of specimens, ranging from small ore samples to spectacular museum pieces up to two feet across. Nearly every specimen was in superb condition due to the excellent packing job. It is estimated that about 95% of the collection was from Bisbee, the rest consisting of a few coppers and calcites from Michigan and assorted specimens from Arizona, California and Mexico. Unfortunately, none of the minerals were labeled. Had the specimens been labeled with specific mine names, levels, stopes and dates collected, it would have provided a wealth of knowledge to collectors and researchers (let that be a lesson to collectors everywhere). In any event, the Ben Williams collection turned out to be the most important group of Bisbee minerals to surface in decades, much to the delight of collectors and Bisbee specialists.

The collection also contained many fascinating items including books, photos, ledgers, newspaper articles and Ben's personal photo album dating from his years in Bisbee. This album contained many never before seen shots of life in the fledgling copper camp. It also contained what could be the most significant artifact ever discovered related to Bisbee mining and the Warren Mining district.

## THE COPPER MATTE

The most exciting artifact in the Ben Williams collection is a drab, irregular chunk of copper matte, obviously crudely smelted, to which a faded paper label is affixed. The label, written in Ben Williams' own hand, reads "First copper smelted in Mule Gulch by George Warren". It is well known that the first crude smelter in Mule Gulch was set up by George Warren near Castle Rock in 1878, barely a year after the first claim was located by an Army scout who stumbled across ore while looking for water. The ore smelted by Warren was not from the Copper Queen, but likely from claims in nearby Hendricks Gulch.

Who could have predicted there still existed an example of copper matte from the very first crude attempt at smelting by the man who the entire district would later be named after? By the miner who is pictured on the official State Seal of Arizona? Could this artifact have been given to Ben Williams by George Warren himself?

**BEN WILLIAMS (1852-1925)**  
**General Manager, Copper Queen Mining Company**  
**(1880-1885) and Copper Queen Consolidated**  
**Mining Company (1885-1899)**



## Rare Earth Elements in Arizona

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### Introduction to Rare Earth Elements

The knowledge that the supply of rare-earth elements (REE) will not be able to keep up with the new and ever growing demand has been no secret in the geological community for years. However, it was not until it was presented to congress as a “potential shortage that could impact US *renewable energy* sources, communications and defense industries” that politicians and the public tumbled to how critical these metals are, and just how vulnerable the US currently is.

With over 97% of the world's supply presently produced by China, and with the Chinese domestic demand for REE soon matching, if not eclipsing, its own internal supply, the US could soon be left in the cold. Starting in 2005 China put export taxes on REE of 15-20% and put restrictions on the amount of export. Forecasts predicted a critical shortage for the rest of the world outside of China by as early as 2012. So, REE prices went up. In 2008 China produced 97% of the worlds REE, India 2.2%, Brazil 0.5% and Malaysia 0.3%.

***Geochemical Properties & Abundances:*** These strategic, multi-use elements, which are neither “rare” nor “earths”, are known to occur in very few economic deposits around the world. They acquired the term rare because when they were first recognized in the 18<sup>th</sup> and 19<sup>th</sup> centuries they were identified from within “rare” minerals. In fact, cerium (Ce) is actually more common than Copper (Cu).

The REE, lanthanum to lutetium (atomic numbers 57-71) are members of Group IIIA on the periodic table, and all have similar chemical and physical properties. This uniformity arises from the nature of their electronic configurations, which results in a particularly stable 3+ oxidation state, accompanied by similar ionic radii that have a small but steady decrease with increase in atomic number for a given co-ordination number. However, the wide variety of types and sizes of the REE cation co-ordination polyhedra in rock-forming minerals does provide a means for these elements to be separated by chemical fractionation. Although the elements Sc and Y (atomic numbers 21 and 39) are also Group IIIA elements for which the REE happily substitute (the radii for Sc is significantly smaller and hence is not as good a substitute for the REE whereas Y is), they are not technically REE despite sometimes included in REE lists. The REE have been divided into “heavy” and “light”. REE, with the light generally including the lighter elements, La to Eu, and the heavier ones, Gd to Lu. The heavy REE are less abundant and, in general, significantly more expensive/valuable than the lighter ones.

***Rare Earth Element Mineralogy:*** The REE are rarely concentrated in mineable deposits. Principal concentrations of REE are associated with uncommon varieties of igneous rocks, specifically alkaline igneous rocks and carbonatites. Monazite-bearing placers have been a steady producer of REE for the past 50 years (fig. 1), although <3% in today's total world production. As many as 300 minerals contain REE. Table 2 shows the list of 54 that have been found in REE deposits. Yet, only 9 are considered to be the major rare earth minerals: Bastnasite, parisite, synchysite, Ba-REE

fluorocarbonates, monazite, xenotime, churchite, fergusonite, and loparite. Bastnasite is by far the most important REE ore-bearing mineral particularly in the Mountain Pass, CA and Bayan Obo, China deposits that have produced over 95% of the total world REE production to date.

**Rare Earth Element Uses:** REE are indispensable in a wide variety of clean energy technologies (Table 1). They are used in the advanced nickel-metal hydride (NiMH) batteries, which are found in most modern hybrid cars. Powerful neodymium (Nd, a light REE) magnets enable the new generation of wind turbines, electric and hybrid electric cars (Prius), and generators. REE phosphors illuminate compact fluorescent light bulbs. In the defense sector REE are required for military electronics, communications and surveillance equipment, and missile guidance systems. Tomahawk cruise missiles use REE magnets in tail control fins; and samarium-cobalt magnets are used for flight control surfaces on missiles, sidewinders, Phoenix, etc. Cerium has been used to treat water, particularly arsenic-rich waters. In essence, it can be safely said that with the past decade of advanced technology US energy and national security are heavily dependant on REE.

**Rare Earth Element Color Doping of Gemstones:** REE such as cerium (Ce) and neodymium (Nd) have been used for decades as coloring agents in synthetic gemstones and glass, and Ce has been used as a polishing compound for over a half century. Cerium produces yellow, orange, and red cubic zirconia. When cubic zirconia are doped with Neodymium they acquire a lovely purple color that changes to a blue depending on the wavelength of the light. Erbium produces a pink colored cubic zirconia. Holmium is another of the colorants used for cubic zirconia and glass, providing yellow or red colors.

**Rare Earth Element Mines:** There are essentially two world class REE mines in the world: (1) Bayan Obo, China that produces 97% of the world's REE (fig. 1), and (2) Mountain Pass, located less than 50 miles west of the Arizona border in California (fig 2). Up until 2002 it produced about 5% of the world's REE supply. Both deposits are hosted in carbonatites. The Mountain Pass Mine is the only deposit in the Western Hemisphere with any hope of significant production in the near future, and it has been plagued by environmental hindrances, nothing abnormal for the State of California. Because of those issues it closed in 2002 after operating for 50 years.. According to Cranstone (1981) "The ore, mined in a small, low-cost open pit, grades 8-10% rare-earth oxide. The rare earth distribution as oxides, in percent is cerium 50.08%; lanthanum 33.0%; neodymium 12.0%; praseodymium 4.08%; samarium 0.5%; gadolinium 0.2%; europium 0.1%; and yttrium group 0.2%." The Mountain Pass deposit contains light REE, but very little of the heavy, less abundant and hence, more valuable, REE. It is only 1 in 10 global rare-earth element mines, and it employed 450 people. It was expected to produce 19,500 tons of REE oxide material/year by mid 2013. According to Ginger McLemore as of January 2013 Mountain Pass was producing ore that was now 12% bastnasite (up from the 8-10% from 20<sup>th</sup> century production). The current owner, Colorado-based Molycorp, started the reopening process of the mine in 2010 and it's stock price soared to \$80/share. However, in 2010 I predicted that the Chinese would prevent Mountain Pass from success by raising their "export quota" (and causing REE prices to drop) just as the company was ready to go into full production. Asia Business Report just announced "China's government eased its restrictions on rare-earth exports for the first time since 2005 in an apparent nod to a trade fight over Beijing's tight global grip on production of the strategically important minerals". That was a thinly veiled disguise, supposedly bowing to the US government's requests, but in actual fact, intended to prevent their only major competitor from succeeding. The result has been a drop in REE prices. Molycorp's stock price fell to just over

\$2.00/share in March 2013 just as they need more capital to continue their mining and processing plant rebuild. With stock dropping from \$80 to \$2.00 in 2 years it may be difficult to attract investors.

This drop in REE prices and controlling of the market by the Chinese has a direct impact on any potential exploration for REE in Arizona. Lowered REE prices and the constant threat of China running the market into the ground is a deterrent to any investor and mining company. It certainly guarantees China control of the REE industry.

**Rare Earth Element Production from Uranium Mines:** Rare earth elements were extracted as a by-product of uranium mining in Canada during 1966-1970 and 1973-1977. The ore mineral, uraninite, contained sufficient REE to make it profitable to extract REE from the raffinate fluids. From 1966 to 1970, uranium mines in the Elliot Lake district of Ontario were the world's major source of yttrium concentrate. All rare earths except promethium have been detected in these ores. The Elliot Lake ores contains about 0.11% uranium oxide ( $U_3O_8$ ), and 0.028% rare-earth oxides (Cranstone, 1981). The beauty of this occurrence is that the REE are concentrated in the uraninite, which was already being concentrated from the ore. The REE were a bonus in the ore. "For a short period of time HREE were extracted from the raffinate fluids that emanated from the chemical processing of uraninite at Blind River, Ontario." (Mariano and others, 2010). REE are significantly concentrated within the uraninite from breccia pipes in northern Arizona.

### **Rare Earth Element Localities in Arizona**

Minerals bearing rare earth elements have been recognized in Arizona for almost a century. However, there has been no REE production from Arizona with the possible exception at the Rare Metals Mine (fig. 2) for which Adams & Staats (1969) state that several tons of Ytterbiantalite were obtained during intermittent mining of the deposit. It is possible that Arizona just doesn't have the geological terrane for such deposits, but with the second largest REE deposit in the world located 50 miles to the west of its border, and with New Mexico along the eastern border with 5 REE producing areas (Table 3), that is doubtful. Alkaline rocks and pegmatites similar to those that host New Mexico REE deposits also exist in Arizona. The major difference in exploration successes between the two states might lie more with the major REE research survey that New Mexico funded at a rate of \$50,000 to \$100,000/year since 1985. The greatly improved analytical techniques for REE may also facilitate the discovery of REE deposits in Arizona. This push for exploration, can also lead to overly zealous ventures, which promote targets containing REE that are marginally above average crustal abundance, such as the La Paz prospect (Table 4)

**Kingman Feldspar Mine, Mohave Pegmatite District, NW Arizona (fig. 2, locality 6, fig. 3).** A very large pegmatite that outcrops 5 miles north of Kingman has been mined for feldspar for over 70 years. It intrudes into 1.7 Ga Proterozoic granitic rocks. The pegmatite is composed almost entirely of microcline and fine-grained quartz. The wall zone ranges in thickness from 9 to 18 ft and is composed predominantly of quartz and white microcline with lesser biotite and accessory allanite, magnetite, zircon, titanite, bastnasite, uraninite, apatite, hematite, ilmenite and rutile. Two large pods of monazite were found in a satellite pit. In 1944, 20 tonnes of allanite were excavated and sent to an unknown buyer (Heinrich, 1960). There is no indication if the allanite was ever processed and if the REE were produced. The allanite in the pegmatite is enriched in the light REE, but extremely depleted in the heavy REE (Table 4), similar to Mountain Pass (data deposit comparison shown in Table 4). Bastnasite occurs as an alteration product along the rim of the allanite grains (Hanson et al., 2012).

**Rare Metals Mine (fig. 2, locality 9 on fig. 3).** “Several tons of yttrotantalite were obtained during intermittent mining of the deposit. Other rare-earth and thorium minerals such as monazite, gadolinite, euxenite, allanite, and chevkinite have been found in pegmatites in the Aquarius Cliffs area “ (Adams & Staatz, 1969).

**Other pegmatites, vein deposits and fossil placers.** “A pegmatite on the Mineral X claim (#7, Fig 3) contains one of the few localities in the US in which the rare yttrium silicate, thalenite, has been found. A black multiple oxide mineral, possibly euxenite, is found in small pegmatites in granite about 5 miles south of buckeye (#19, fig. 3). This mineral is found as minute crystals associated with smoky quartz, feldspar, biotite, magnetite, and sparse xenotime. Rare-earth-bearing pegmatites have also been found about 8 miles southwest of Buckeye.” (Adams & Staatz, 1969) Other pegmatite localities reported to contain rare-earth-bearing minerals are shown in figure 3. Vein deposits containing rare earths are known at eight localities (fig. 3). Fossil placers have been a steady source of REE in many parts of the world. In Arizona all known placers are small. Three are shown in figure 3. In northern Arizona two places north of the Black Mountain Trading Post (#2, fig. 3) contain black sand laminae as much as 6” thick exposed in sandstone of the Toreva Formation. These laminae are similar to the much larger titaniferous fossil placers occurring to the east in New Mexico (table 3), which also contain minor monazite.

**REE in Breccia Pipes in Northern Arizona (localities 25-31, fig.3):** Although the bulk rock does not contain particularly anomalous concentrations of the REE, the uraninite contains concentrations of Neodymium (Nd) that are between 15-20% of the Nd concentrations in the bastnasite of Mountain Pass, CA. Considering that the bastnasite has to be mined strictly for the REE at Mountain Pass, but the uraninite is already processed in the breccia pipe mines for the uranium alone, the Nd and other REE collected from the raffinate fluids should be mostly profit. The more valuable HREE are enriched in the uraninite ores, whereas the Mountain Pass ore contains essentially no significant HREE.

**Summary:** Arizona has not had the extensive exploration for REE that New Mexico has had, so there is a reasonable expectation that REE occurrences similar to those in NM could be found in Arizona. However, most are in alkaline rocks and pegmatites. No producing REE mines are in alkaline rocks – all are in carbonatites. The metallurgy for alkaline rocks is far more complex and difficult than that for carbonatites. Hence, the close proximity of the world class Mountain Pass REE carbonatite deposit to the Arizona border is of considerable significance.

The REE that are in the alkaline rocks and pegmatites in Arizona are depleted in the more valuable heavy REE. The only exception to this is the uraninite in the northern Arizona breccia pipes. Here there is a very significant heavy REE enrichment that even Mountain Pass does not have (Table 4). Because these uraninite orebodies are already being mined for uranium there would be no mining costs for REE production, just the processing costs to collect REE from the raffinate fluids. However, with the million acres of northern Arizona containing the breccia pipes being removed from mineral entry by the federal government in 2012, those mines that are currently allowed to continue to produce are not likely to spend money to alter their mill circuit to process the REE. Yet, for economic REE production that includes the valuable heavy REE, Arizona’s greatest REE treasure is in the uraninite structure within high grade uranium deposits of northern Arizona.



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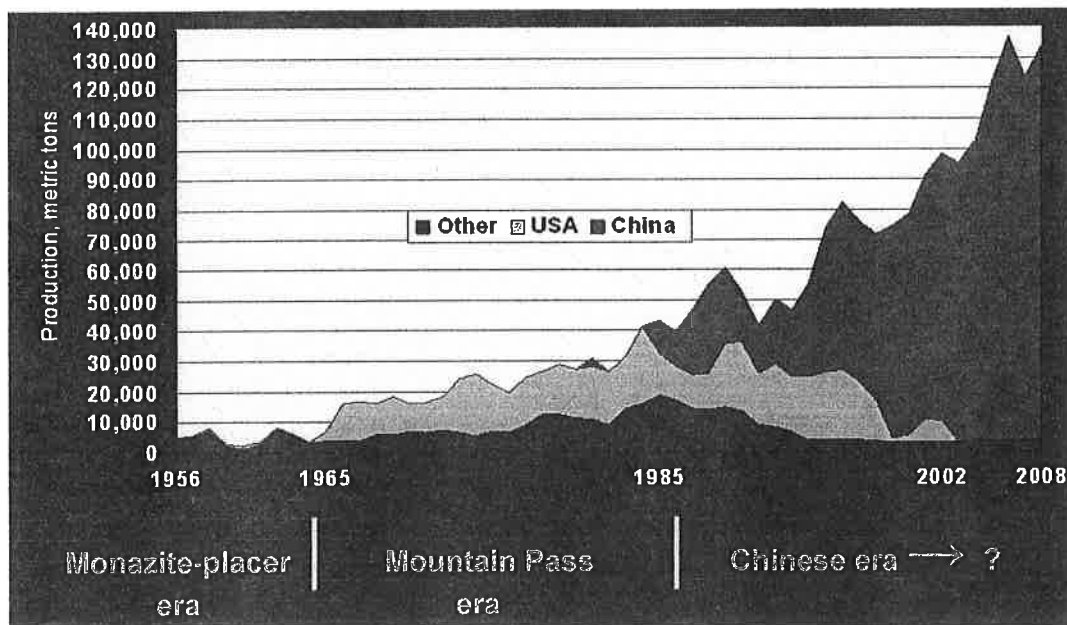


Figure 1. Graph showing the current total dominance of the Chinese REE deposit Bayan Obo, in world REE production. However, there was a time when the US, Mountain Pass deposit, was the world's primary producer. Diagram from Tse, 2011.

**Table 1. CHEMICAL CHARACTERISTICS, CRUSTAL ABUNDANCES, AND USES OF RARE EARTH ELEMENTS**

RARE EARTH ELEMENT	Atomic Number	Average Crustal Abundance	2012 (4th Quarter) US \$/kg	OXIDE	Uses
Lanthanum (La)	57	35.0	\$28.00	La <sub>2</sub> O <sub>3</sub>	The production of specialized steel and other metals alloys, fiber optic, and optical glass, rechargeable batteries, including those used in consumer electronics and electric and hybrid cars, misch-metal "sparking" alloys such as are used in lighters, re-chargeable batteries, catalysts
Cerium (Ce)	58	65.0	\$25.00	Ce <sub>2</sub> O <sub>3</sub>	A polishing agent for optical and other glass products, as well as for metal (including jewelry) and other materials that require precision surfaces. The production of catalytic converters to reduce toxic and reactive emissions from vehicle exhaust, a catalyst, re-charge batteries.
Praseodymium (Pr)	59	9.1	\$120.00	Pr <sub>2</sub> O <sub>3</sub>	The production of permanent magnets, in high performance magnesium alloys, as a glass and a ceramic colorant, in some batteries and catalytic converters, and in high intensity lighting and misch-metal sparking alloys.
Neodymium (Nd)	60	37.0	\$115.00	Nd <sub>2</sub> O <sub>3</sub>	The manufacturing of high strength types of permanent magnets. The most commonly manufactured neodymium magnets, and the most commonly used rare earth permanent magnets overall, are neodymium-iron-boron magnets. They are used in lasers, and glass.
Samarium (Sm)	62	7.0	\$55.00	Sm <sub>2</sub> O <sub>3</sub>	High strength permanent magnets. Additional (non-magnet) applications of samarium include anti cancer drugs, lasers, including some specialized lasers used in analytic equipment. Also used because of its exceptional ability to absorb...
Europium (Eu)	63	2.0	\$2,150.00	Eu <sub>2</sub> O <sub>3</sub>	TV color phosphors; used to produce red phosphors that are key to the manufacture of energy efficient (white) compact fluorescent light bulbs, as well as to the function of most computer and television screens.
Gadolinium (Gd)	64	6.4	\$210.00	Gd <sub>2</sub> O <sub>3</sub>	For radiation shielding and to slow rates of reaction in nuclear reactors. Also used as a contrasting medium in medical MRI, imaging, as a phosphor in medical X-Ray imaging, to create temperature tolerant and oxidation resistant alloys of iron, magnets, superconductors.
Terbium (Tb)	65	1.1	\$2,500.00	Tb <sub>2</sub> O <sub>3</sub>	In solid state electronics, in potentially environmentally important fuel cell technologies, in a variety of precision sensors and actuators, and in sonar systems. Currently used in the production of energy efficient fluorescent and compact fluorescent light.
Dysprosium (Dy)	66	5.8	\$1,100.00	Dy <sub>2</sub> O <sub>3</sub>	The production of very strong magnets that are critical to a wide range of emerging high tech instruments (cell phones, computers, ipods, etc) and environmentally sustainable technologies such as hybrid cars and wind power generators.
Holmium (Ho)	67	1.3	\$945.00	Ho <sub>2</sub> O <sub>5</sub>	The production of very powerful magnets and in nuclear control rods, due to its ability to absorb large quantities of stray neutrons; Holmium lasers are used as surgical lasers in the medical and dental fields, as well as in fiber optics, and dope lasers used in eye surgery.
Erbium (Er)	68	3.9	\$275.00	Er <sub>2</sub> O <sub>3</sub>	The production of amplifying lasers for fiber optic cable communications. Erbium in glass cables reduces signal loss sustainability. Lasers made with this element are used widely in medical, dental and dermatological applications.

Thulium (Tm)	69	1.1	\$595.00	Tm <sub>2</sub> O <sub>3</sub>	Medical and other lasers, as well as to make safer medical X-ray equipment. The element also shows potential in the development of superconductive materials.
Ytterbium (Yb)	70	3.1	\$586.00	Yb <sub>2</sub> O <sub>3</sub>	Technologies such as solar electric cells, high performance steel alloys, high powered lasers, anti-forgery inks, night vision technology, and stress measuring instruments. Its potential market demand for applications as an alloy component as a fiber optic.
Lutetium (Lu)	71	0.5	\$2,200.00	Lu <sub>2</sub> O <sub>3</sub>	As a small scale chemical catalyst and in the petroleum refining process. It also has important current medical applications including use in cancer treatment and as a sensor material in PET scans.
Yttrium (Y)	39	30.0	\$120.00	Y <sub>2</sub> O <sub>3</sub>	The production of phosphors such as those necessary to create the red colors on CRT displays (television screens). Currently, used for high powered lasers, energy saving white LED lights, to increase the strength and durability of aluminum and other alloys.
Scandium (Sc)	21	21.0	\$15,000.00	Sc <sub>2</sub> O <sub>3</sub>	High performance aluminum and titanium alloys for sports equipment and for the aerospace industry. It is also used in some specialized high intensity and "true color" light source.

**Table 2.** Rare earth elements, thorium, and uranium content of minerals found in rare earth elements deposits.—

[—, not available; REO, rare earth minerals may be found in deposits that are or have been mined or in unmined deposits] From Long et al., 2010

Mineral	Formula	REO	ThO <sub>2</sub>	UO <sub>2</sub>
Allanite (Ce)	(Ce,Ca,Y) <sub>2</sub> (Al,Fe <sub>3+</sub> ,Fe <sub>2+</sub> ) <sub>3</sub> (SiO <sub>4</sub> ) <sub>3</sub> (OH)	3 to 51	0 to 3	—
Allanite (Y)	(Y,Ce,Ca) <sub>2</sub> (Al,Fe <sub>3+</sub> ) <sub>3</sub> (SiO <sub>4</sub> ) <sub>3</sub> (OH)	3 to 51	0 to 3	—
Anatase	(Ti,REE)O <sub>2</sub>	—	—	—
Ancylite (Ce)	SrCe(CO <sub>3</sub> ) <sub>2</sub> OH·H <sub>2</sub> O	46 to 53	0 to 0.4	0.1
<b>Bastnasite (Ce)</b>	(Ce,Lu)(CO <sub>3</sub> )F	70 to 74	0 to 0.3	0.09
<b>Brannerite</b>	(U,Ca,Y,Ce)(Ti,Fe) <sub>2</sub> O <sub>6</sub>	—	—	—
Britholite (Ce)	(Ce,Ca) <sub>2</sub> (SiO <sub>4</sub> ,PO <sub>4</sub> ) <sub>3</sub> (OH,F)	56	1.5	—
Brockite	(Ca,Th,Ce)(PO <sub>4</sub> )·H <sub>2</sub> O	—	—	—
Calcio-ancylite (Ce)	(Ca,Sr)Ce <sub>3</sub> (CO <sub>3</sub> ) <sub>4</sub> (OH) <sub>3</sub> ·H <sub>2</sub> O	60	—	—
Cerianite (Ce)	(Ce <sub>2</sub> ,Th)O <sub>2</sub>	—	—	—
Cerite (Ce)	Ce <sub>3</sub> Fe <sub>3+</sub> (SiO <sub>2</sub> ) <sub>6</sub> [(SiO <sub>3</sub> )(OH)](OH) <sub>3</sub>	—	—	—
Cheralite	(Ca,Ce,Th)(P,Si)O <sub>4</sub>	—	=30	—
Chevkinite	(Ca,Ce,Th) <sub>4</sub> (Fe <sub>2+</sub> ,Mg) <sub>2</sub> (Ti,Fe <sub>3+</sub> ) <sub>3</sub> Si <sub>4</sub> O <sub>22</sub>	—	—	—
Churchite (Y)	YPO <sub>4</sub> ·H <sub>2</sub> O	—	—	—
Crandallite	CaAl <sub>3</sub> (PO <sub>4</sub> ) <sub>2</sub> (OH) <sub>5</sub> ·H <sub>2</sub> O	—	—	—
Doverite	YCaF(CO <sub>3</sub> ) <sub>2</sub>	—	—	—
Eudialyte	Na <sub>4</sub> (Ca,Ce) <sub>2</sub> (Fe <sub>2+</sub> ,Mn <sup>2+</sup> ,Y)ZrSi <sub>8</sub> O <sub>22</sub> (OH,Cl) <sub>2</sub>	1 to 10	—	—
Euxenite (Y)	(Y,Ca,Ce,U,Th)(Nb,Ta,Ti) <sub>2</sub> O <sub>6</sub>	—	—	—
Fergusonite (Ce)	(Ce,Lu,Y)NbO <sub>4</sub>	—	—	—
Fergusonite (Y)	YNbO <sub>4</sub>	—	—	—
Florencite (Ce)	CeAl <sub>3</sub> (PO <sub>4</sub> ) <sub>2</sub> (OH) <sub>6</sub>	—	1.4	—
Florencite (La)	(Ce,Lu)F <sub>3</sub>	—	—	1.4
Fluocerite (Ce)	(La,Ce)F <sub>3</sub>	—	—	—
Fluocerite (La)	(La,Ce)F <sub>3</sub>	—	—	—
Fluorapatite	(Ca <sub>2</sub> REE)F	0 to 21	—	0 to 0.01
Fluorite	(Ca <sub>2</sub> REE)F	—	—	—

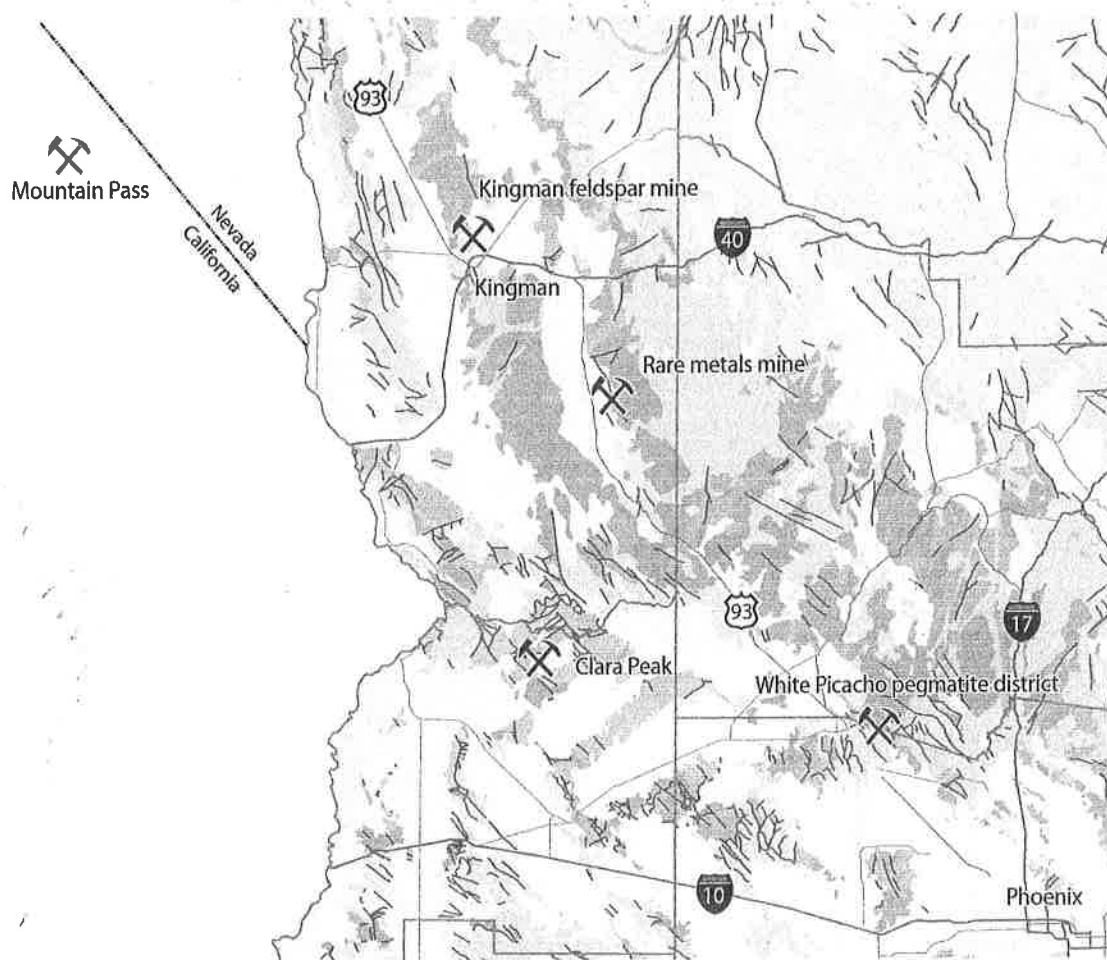
Gadolinite (Y)	$Y_2Fe_{2+}Be_2Si_2O_{10}$	40	--	--
Gagarinite (Y)	$NaCaY(F,Cl)_6$	--	--	--
Gerenite (Y)	$(Ca,Na)_2(Y,REE)_3Si_6O_{18} \cdot 2H_2O$	--	--	--
Gorceixite	$(Ba,REE)Al_3[(PO_4)_2(OH)_5] \cdot H_2O$	--	--	--
Goyazite	$SrAl_2(PO_4)_2(OH)_5 \cdot H_2O$	--	1.4	--
Hingganite (Y)	$(Y,Yb,Er)_2Be_2Si_2O_8(OH)_2$	--	--	--
Imortite (Y)	$Y_2(SiO_4)(CO_3)$	--	--	--
Kainosite (Y)	$Ca_2(Y,Ce)_2Si_4O_{12}(CO_3) \cdot H_2O$	--	--	--
Loparite (Ce)	$(Ce,Na,Ca)(Ti,Nb)O_3$	32 to 34	--	--
Monazite (Ce)	$(Ce,Lu,Nd,Th)PO_4$	35 to 71	0 to 20	0 to 16
Parisite (Ce)	$Ca(Ce,Lu)_2(CO_3)_2F_2$	59	0 to 0.5	0 to 0.3
Perovskite	$(Ca,REE)TiO_3$	=37	0 to 2	0 to 0.05
Pyrochlore	$(Ca,Na,REE)_2Nb_2O_6(OH,F)$	--	--	--
Rhabdophane (Ce)	$(Ce,Lu)PO_4 \cdot H_2O$	--	--	--
Rhabdophane (La)	$(La,Ce)PO_4 \cdot H_2O$	--	--	--
Rinkite (rinkolite)	$(Ca,Ce)_4Na(Na,Ca)_2Ti(Si_2O_7)_2F_2(O,F)_2$	--	--	--
Samaraskite	$(REE,Fe_{2+},Fe^{3+},U,Th,Ca)(Nb,Ta,Ti)O_4$	--	--	--
Sphene (titanite)	$(Ca,REE)TiSiO_5$	=3	--	--
Steenstrupine (Ce)	$Na_4Ce_6Mn_2Fe_2(Zr,Th)(Si_6O_{18})_2(PO_4)_7 \cdot 3H_2O$	49 to 52	1.6	--
Synchysite (Ce)	$Ca(Ce,Lu)(CO_3)_2F$	--	--	--
Synchysite (Y) (doverite)	$Ca(Y,Ce)(CO_3)_2F$	--	--	--
Thalerite (Y)	$Y_3Si_5O_{10}(F,OH)$	--	--	--
Thorite	$(Th,U)SiO_4$	=3	--	10 to 16
Uraninite	$(U,Th,Ce)O_2$	--	--	--
Vinseite (Ce)	$Na_3(Ce,Lu,Nd)(PO_4)_2$	--	--	--
Xenotime (Y)	$YPO_4$	52 to 67	--	0 to 5
Yttriofluorite	$(Ca,Y)F_2$	--	--	--
Zircon	$(Zr,REE)SiO_4$	--	0.1 to 0.8	--

**Table 3.** Production of REE in New Mexico as of 2011. Note that only the Gallinas Mountains have had REE production from bastnasite, which is considered to be more economic than the more resistate monazite, tantalite/columbite, or samarskite.

DISTRICT NAME	PRODUCTION
Gallinas Mountains	146,000 lbs of bastnasite concentrate
Petaca	112 lbs of samarskite, few hundred lbs of monazite, 12,000 lbs of Ta-Nb-REE ore
Elk Mountain	500 lbs of Ta-U-REE concentrate
Rociada	Several thousand tons of REE-Ta ore
Tecolote	\$10,000 worth of beryl, tantalite-columbite and monazite
Gold Hill	REE production in the 1950's

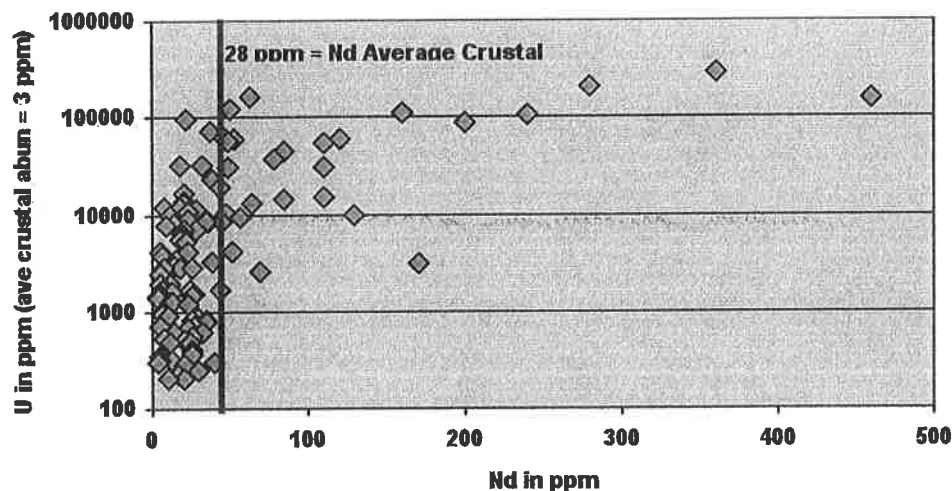
**Table 4.** REE content of ore minerals for Arizona REE occurrences and the 2 world class REE deposits.

REE (ppm)	Bastnasite Mountain Pass, CA (Castor, 2008)	Bastnasite Bayan Obo, China (Hedrick, 2004)	Uraninite Sage Breccia Pipe Ore, AZ (Wenrich, 2011)	Uraninite Pinenut Breccia Pipe Mine, AZ (Wenrich, 2011)	Allanite-(Nd) Kingman Feldspar Mine, AZ (Hanson, 2012)	Allanite-(Ce) Kingman Feldspar Mine, AZ (Hanson, 2012)	Yttrio-tantalite Rare Metals Mine, AZ (Adams & Staatz, 1969)	Bulk Rock La Paz Prospect (Average for Lower Plate rocks), AZ (Boyer, 2012)	Average Crustal Abundance
La	338000	230000	52	24	230	240		59.0	35.0
Ce	496000	500000	409	638	430	610	98000	126.8	65.0
Pr	41000	62000	127	208	110	70		14.8	9.1
Nd	112000	185000	922	1188	510	410		57.7	37.0
Sm	9000	8000	588	397	70	30		11.0	7.0
Eu	1000	2000	189	124	0	0		2.7	2.0
Gd	2000	7000	837	415	0	0		9.7	6.4
Tb*	0	1000	120	59	n/d	n/d		1.4	1.1
Dy	0	1000	583	317	0	0		7.5	5.8
Ho*	0	trace	90	47	n/d	n/d		1.5	1.3
Er*	0	trace	201	108	n/d	n/d		4.0	3.9
Tm*	0	trace	19	12	n/d	n/d		0.5	0.5
Yb	0	trace	104	74	10	10		3.2	3.1
Lu*	trace	trace	12	7	n/d	n/d		0.5	0.5
Y	1000	trace	2425	928	20	10	306000	38.2	30.0

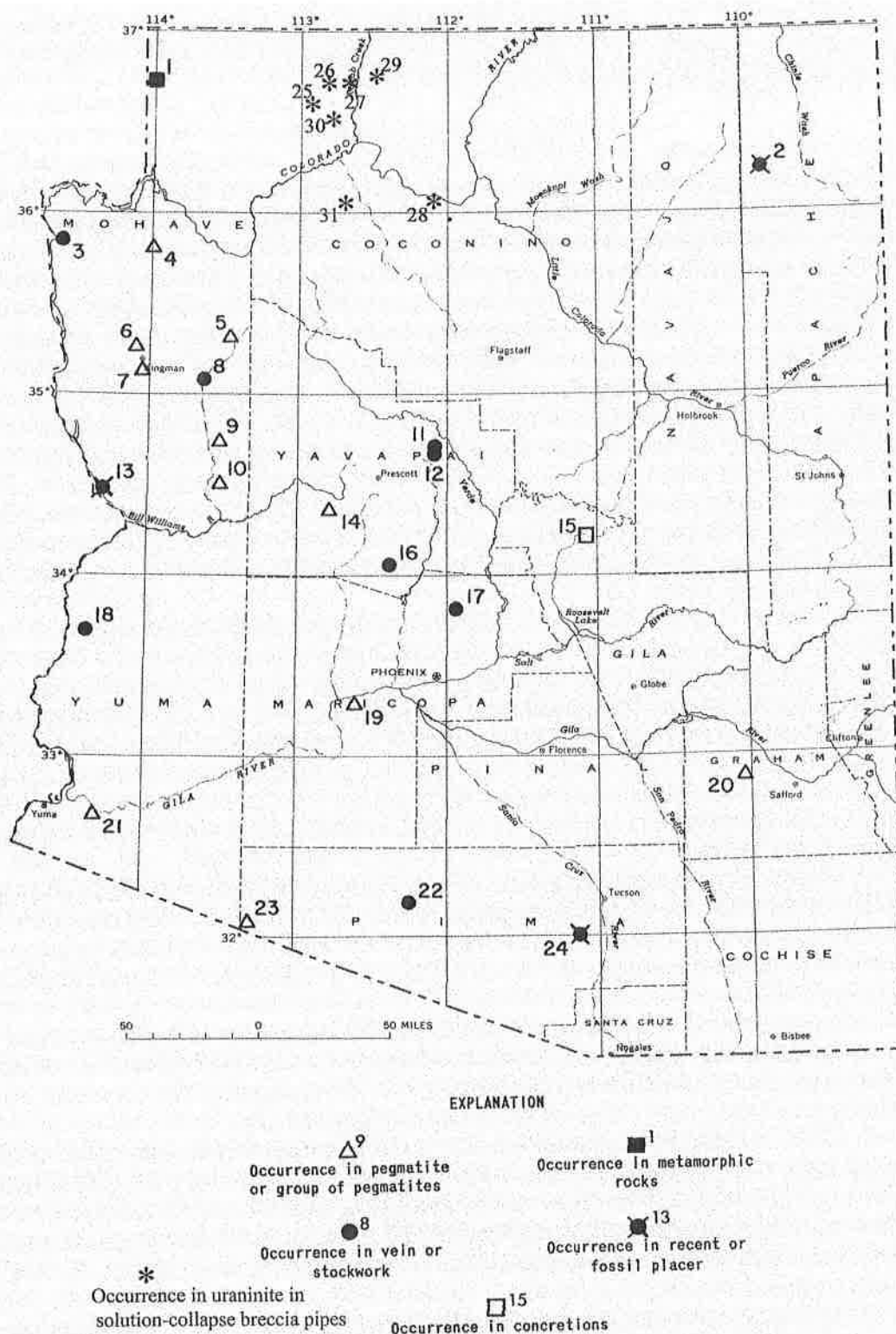


**Figure 2.** Map showing the world's second largest REE mine, located less than 50 miles west of the Arizona border in a carbonatite. Base map is the Geological Map of Arizona. Other mines shown on the map are REE mines containing REE minerals, but without any REE production. Map from Jon Spencer, AZGS, written commun., 2013.

#### Uranium vs Neodymium



**Figure 4.** Uranium vs neodymium in bulk rock geochemical analysis of samples collected from 9 breccia pipe uranium mines. Note that where the Nd is greater than the average crustal abundance there is a direct correlation with higher uranium content of the rock. Laser oblate mass spectrometry/electron microprobe research has confirmed the Nd is in the uraninite with concentrations of 922 ppm and 1188 ppm in the Sage breccia pipe and Pinenut Mine uraninites.



**Figure 3 .** The numbers on the map correspond to the list below. Map modified from Adams & Staats, 1969.

- |                                   |                          |                                |
|-----------------------------------|--------------------------|--------------------------------|
| 1. Virgin Mountains               | 11. Bechetti Lease       | 21. Ligurta district           |
| 2. Black Mountain Trading Post    | 12. Fairview claims      | 22. Quijotoa Mountains         |
| 3. Bendina Claim                  | 13. Chemehuevis district | 23. Papago Wells               |
| 4. Hillside and Quartz Mtn Claims | 14. Peeples Valley mine  | 24. San Xavier Mission         |
| 5. Cottonwood Creek area          | 15. Diamond Butte        | 25. Hack Canyon Mine           |
| 6. Cerbat Range                   | 16. Willbanks prospect   | 26. Hermit Mine                |
| 7. Mineral X Claim                | 17. Valcarce claim       | 27. Kanab North Mine           |
| 8. Uranium Basin                  | 18. Scott Lode           | 28. Orphan Mine                |
| 9. Aquarius Cliffs                | 19. Buckeye area         | 29. Pigeon Mine                |
| 10. Signal district               | 20. Lucky Strike claim   | 30. Pinenut Mine               |
|                                   |                          | 31. Sage Breccia Pipe Prospect |



## Arizona's Fabulous Sulfates

Les Presmyk

### 2013 Arizona Mineral Symposium

Most every Arizona collector has encountered gypsum near St. David (roses) or the Camp Verde area (pseudomorphs after glauberite). If you are a bit more adventurous, or just plain crazy, you may have seen white fur lined walls in an underground drift composed of epsomite or halotrichite. Maybe you have even gotten lucky and found a recognizable barite crystal. Arizona also has a number of localities for which the conditions and the subsequent sulfates are unique or certainly one of a handful of such localities across the world. There are two distinct and widely varied groups of sulfate minerals gracing the cabinets of collections throughout the world. The first, of course, are those minerals occurring before the influence of man. Minerals like world class spangolites from Bisbee or linarites from the Mammoth-St. Anthony and Grand Reef Mines, a Magma mine barite or leadhillite from Tiger. The other group occur as the result of the intervention of man. These are the post mining minerals, some of which are quite astounding in their own right.

Thirteen new sulfate minerals were first described from Arizona, seven of which resulted from the burning of the orebody in the United Verde mine at Jerome. The pyrite and copper sulfides caught fire in 1894 and remained sealed until 1928. During that period numerous attempts were made to quench the fires, including the use of pressurized air, water, carbon dioxide and steam. It was the multiple surges of water and carbon dioxide that helped provide the environments in which seven new minerals formed, including native selenium, and over a dozen minerals were described. Access to these areas resulted when the United Verde open pit began intersecting cracks, thus allowing hot gases to escape. Three minerals are still unique to the United Verde and they are guildite, yavapaiite and lausenite. The other species are butlerite, ransomite, jeromite, and selenium, along with alunogen, copiapite, coquimbite, voltaite and claudetite.

The Mammoth-St. Anthony Mine hosts a significant group of rare and spectacular mineral species. The mine really came into its own as one of Arizona's premier localities during its last mining period from 1934 to 1953. Mine management recognized the value of its minerals and had one or more of their personnel collecting specimens for the company. There are two periods in which sulfate minerals formed, the first, referred by Dick Bideaux as the normal sequence, produced anglesite and devilline. The second, called the anomalous sequence, resulted in beaverite, brochantite, connellite, linarite and bobmeyerite. There are also sulfate/carbonate species in this second sequence which include leadhillite, susannite, plumbonacrite, caledonite and wherryite.

The mines of Bisbee comprise one of Arizona's great copper mining districts and is also its premier specimen producing locality. Two new sulfates were first described from Bisbee, chalcoalumite and spangolite and although the type specimen is labeled Tombstone, it is almost certainly from Bisbee. Additional and noteworthy sulfates include antlerite, anglesite, brochantite, connellite, cyanotrichite, leadhillite, and gypsum. The antlerite and connellite crystals from here are some of the world's finest.

Leadhillite is overshadowed by the Mammoth-St. Anthony Mine but is nicely crystallized with distinctive white bladed crystals.

Bisbee's other group of sulfate minerals are the ones forming in the mines. It is not uncommon to find chalcantite and halotrichite growing in a number of old mines throughout the state. What is unique to Bisbee is the suite of species occurring there. Dick Graeme and his two sons, Richard and Douglas are responsible for this information. As they explored the mines, not only did they extract numerous specimens, but they also preserved information about the depositional environments. Post-mining gypsum crystals adorn a number of collections. Miners would find these lining drainage ditches and iron pipes. The other species include melanterite, boothite, ransomite, halotrichite, coquimbite, copiapite, kornellite, voltaite, chalcantite, hydrobasalumnite, and goslarite. Due to the humid conditions these minerals form in, most remain where they were encountered and photographed.

One other notable locality for its sulfate minerals is the Grand Reef Mine. Most famous for its large linarite crystals, up to two inches long, it is also the type locality for two sulfates, grandreefite and pseudograndreefite. Caledonite, anglesite and creedite also occur here in crystallized specimens.

A number of other localities throughout the state have produced fine specimens. The barites from the Magma Mine at Superior are Arizona's best and range in color from white to golden to black and in crystals up to two inches across. Other barite localities include the Cerbat Mountains, the Rowley Mine with mimetite and wulfenite, the Old Reliable Mine, near Mammoth, and from the Puzzler Mine in the Castle Dome District. Gypsum crystals up to two inches occur on siderite from the Antler Mine, with azurite at the Castle Dome Mine near Miami, as crystal groups and with colorful copper inclusions from the Mission Mine and associated with both azurite and diopside from the Morenci Mine.

Cyanotrichite has been produced from the Maid of Sunshine Mine, near Courtland, and the Grandview Mine in the Grand Canyon. Brochantite in association with azurite is known from the Silver Hill Mine, north of Tucson and the Castle Dome Mine near Miami.

# Formation of Arizona Minerals through Geologic Time

Jan C. Rasmussen, Ph.D., R.G.

## Abstract

Numerous orogenic (mountain building) episodes generated mineralization when Arizona was on the leading edge of a continent. Arizona was subjected to volcanism and plutonism that rose from the plate that was being subducted under the westward-advancing North American continent. Deposition of minerals is associated with five orogenies (mountain building episodes) in the Proterozoic and five orogenies in the Mesozoic and Cenozoic. Three orogenies in the Paleozoic that affected the eastern United States influenced the deposition of sedimentary rocks in Arizona. The thirteen orogenies that affected deposition of collectible minerals and productive mining districts in Arizona are listed in Table 1.

The **Penokean (Hudsonian) orogeny (2000-1800 Ma [million years ago])** and its correlative Mohave belt in Arizona added to the margins of the Archean (4000 to 2500 Ma) cratons (central cores of the continents). An Arizona example of the banded iron formations (BIF) may be the Pikes Peak iron formation in northern Maricopa County.

The **Yavapai orogeny (1800 – 1775 Ma)** includes the Prescott-Jerome belt that developed as an intraoceanic island arc from 1800 to 1740 Ma. Mining districts that may have formed during the Yavapai orogeny include the Big Bug (Iron King mine) and Verde (Jerome) districts. These mines are volcanogenic massive sulfide (VMS) deposits that were formed as black smokers exuded zinc, lead, and copper sulfides from undersea hot springs related to volcanism.

The **Mazatzal orogenic belt (1750 – 1600 Ma)** was added to the southern margin of the Yavapai belt between 1775 and 1600 Ma. In Arizona, granodiorite plutons and associated mineralization and later submarine volcanoes were accompanied by undersea hot springs (black smokers). These rocks were later subjected to high-grade regional metamorphism. In southern Arizona, metasedimentary and metavolcanic rocks of the Pinal Schist (1710 to 1675 Ma) were intruded by granodiorite (1675 to 1625 Ma) of the Mazatzal orogeny. Examples of zinc-copper volcanogenic massive sulfide deposits of the Mazatzal orogeny may include the Old Dick mining district (Bruce mine).

The **Oracle/Ruin “anorogenic” orogeny (1440 – 1335 Ma)** records the intrusion of peraluminous granites that are characterized by large potassium-feldspar (orthoclase) crystals. Examples may include the Tungstona mining district in Yavapai County, pegmatite deposits in the White Picacho district in Maricopa-Yavapai counties, and possibly the Four Peaks amethyst deposit.

The **Grenville orogeny (1200 – 900 Ma)** of the eastern United States and Canada is expressed in Arizona by rift basins of the Grand Canyon Supergroup and the Apache Group of central and southern Arizona. The diabase dikes that intruded the limestones contact metamorphosed them and created chrysotile asbestos veins.

After a long period of erosion, the Proterozoic rocks were buried beneath sandstones and quartzite of Cambrian age. During the Paleozoic, Arizona was on the trailing edge (passive margin) of the North American continent from 542-251.5 Ma. The plate tectonic regime during the Paleozoic involved the North American plate moving eastward over a westward-subducting plate in at least three main orogenies with active volcanism, magmatism, and metamorphism along the east coast of the U.S. These orogenies included the Taconic orogeny (490-445 Ma), the Acadian (or Caledonian) orogeny (410-380 Ma), and the Alleghenian (or Ouachita) orogeny (325-220 Ma). The effect of these orogenies on southern Arizona was in the nature of the

sediments being shed from continental areas in the east. During lulls in the mountain building activity, shallow seaways encroached on Arizona from the west or south, depositing limestone.

The **Taconic orogeny (490-380 Ma)** of eastern U.S., in Arizona was characterized by deposition of Cambrian sandstone, shale, and limestone in a shallow seaway that advanced eastward.

The **Acadian/ Caledonian orogeny (410-380 Ma)** of eastern U.S., in Arizona consisted of sandstones, siltstones, and marine carbonates of Devonian age. In the lull between the Acadian and Alleghenian orogenies, much of the North American continent was inundated by shallow seas. In the Mississippian in Arizona, thick sequences of limestone and dolomite were deposited throughout the state. These thick, cliff-forming Mississippian formations are the sites of most of the caves in Arizona. Beautiful speleothems of calcite are the collectible minerals later deposited in caves in these formations. The Redwall and Escabrosa limestones are also the source of much of the limestone that is mined for cement in Arizona at Clarkdale and Rillito, north of Tucson.

The **Alleghenian (Ouachita) orogeny (325 – 220 Ma)** in Arizona is recorded in Pennsylvanian, Permian, and earliest Triassic rocks of continental, marine, and mixed sedimentary environments. During this orogeny, the Appalachian Mountains were uplifted when the northwest coast of Africa impacted the eastern U.S. and the north coast of South America impacted the south coast of North America in the formation of the supercontinent Pangea. The alternation between thin ledges of limestone and slopes of siltstone/shale in Arizona Pennsylvanian formations may reflect the sea level changes caused by advances and retreats of glaciation in the southern hemisphere, where the continents were massed at the south pole as Gondwanaland. Sporadic uplift and subsidence of local arches and basins may also reflect the influence of upwarps and basins associated with ancestral Rocky Mountain tectonic activity. Along the Mogollon Rim in the Payson area at Promontory Butte, some of these formations are host to small uranium deposits.

In the Mesozoic and Cenozoic, active mountain building returned to Arizona. After the major continent-continent collision of North America, Europe, and Africa created the supercontinent Pangea and the Appalachian-Ouachita Mountains, the tectonic plates were forced to reorganize. In the Triassic, as Pangea began to split apart separating the eastern North American plate apart from Africa, the western coast of North America became the leading edge of the northwestward moving North American continent. The resulting subduction of the northeast-dipping Farallon oceanic plate under the North American plate caused volcanism and accompanying mineralization throughout the western U.S.

The **Nevadan orogeny (205-145 Ma)** of **Triassic-Jurassic age** in the southwestern U.S. is indicated by increasing amounts of volcanic ash (indicated by the weathering product of bentonitic clay) in Triassic and Jurassic formations of northern Arizona and by abundant volcanic and plutonic rocks in southern Arizona. During the early Mesozoic, higher areas in southern Arizona may have allowed alkaline solutions to travel through groundwater from the alkaline, uranium-rich plutonic and volcanic sources in southern Arizona through the Pennsylvanian-Permian sandstones and then deposit uranium in reduced environments of the collapsed cave formations of breccia pipes or organic-rich areas in roll-front uranium deposits of the Jurassic sandstone formations. Examples of breccia pipe deposits include the Orphan mine and Grandview mine exposed in the Grand Canyon. In latest Middle to Late Jurassic time, alkaline volcano-plutonic complexes formed in southern Arizona. In southeastern Arizona, plutonic rocks of *metaluminous quartz alkalic magma chemistry* are known from Bisbee (Warren mining district) and from the Courtland-Gleeson area (Turquoise mining district). Another metaluminous quartz alkalic magmatic suite occurs at Sugarloaf Peak in the Dome Rock Mountains of La Paz County western Arizona.

The **Cretaceous Sevier orogeny (140-89 Ma)** of the **Early Cretaceous** consisted of a stable (non-migrating and non-flattening) magmatic arc, with back arc basins located in Arizona, such

as the Bisbee Group. A mid-Cretaceous shallow seaway transgressed from the southeast, depositing the Mural Limestone, which is a source of limestone for cement at Paul Spur east of Bisbee. Coal deposits formed in northern Arizona in the Black Mesa basin.

The **Laramide orogeny (85 – 43 Ma) (Late Cretaceous and Early Tertiary)** represents flattening subduction, in which the magmatic arc migrated eastward through geologic time. The Laramide orogeny has been subdivided into four phases: the earliest (Hillsboro), early (Tombstone), middle (Morenci), and late (Wilderness) phases.

The **Late Cretaceous, Earliest Laramide (Hillsboro) phase (85-80 Ma) consists of copper gold mineralization** related to metaluminous quartz alkalic magmatism, such as the Copper Flat stock at Hillsboro in New Mexico. Examples in western Arizona include the Madersbach pluton in the central Plomosa Mountains and examples in southern Arizona include native copper in the high potassium andesitic volcanics at La Colorado south of Arivaca.

The **Late Cretaceous, Early Laramide (Tombstone) phase (79-67 Ma) consists of lead-zinc-silver mineralization** associated with caldera development of alkali-calcic volcanism and plutonism in southern Arizona. The Tombstone Assemblage is characterized by large volcanic centers (calderas) that experienced large volumes of explosive volcanism and ash deposits. Large exotic blocks in a volcanic matrix are generally interpreted as caldera infill or moat deposits from the collapse of the volcanic edifice. Examples include the Tucson Mountain Chaos, the Claflin Ranch Formation in the Silver Bell Mountains, the lower Salero Formation in the Santa Rita Mountains, and the Bronco Volcanics in the Tombstone Hills. Numerous areas in southern Arizona contain the roots of this caldera volcanism in the form of monzo-dioritic to quartz monzonitic plutons that are locally associated with lead-zinc-silver mineralization. Examples of Tombstone Assemblage plutons include the Josephine Canyon Diorite in the Santa Rita Mountains, the Schieffelin Granodiorite and Uncle Sam Tuff of the Tombstone Hills, and the Silver Bell Dacite in the Silver Bell Mountains. Examples of the metaluminous alkali-calcic districts with lead-zinc-silver mineralization include the Tombstone, Tyndall (Glove mine), Washington Camp, Patagonia (Duquesne-Washington group) and Salero mining districts.

The **Early Tertiary, Middle Laramide (Morenci) phase (66-55 Ma) consists of porphyry copper mineralization** associated with porphyritic stocks of quartz diorite to granodiorite composition of metaluminous calc-alkalic magma chemistry in southern Arizona. Mineralization of the Morenci Assemblage consists of the porphyry copper deposits that are the major source of historic copper production in Arizona. Examples include the Pima district (Twin Buttes, Sierrita-Esperanza, and Mission-Pima mines) south of Tucson and the Silver Bell mine northwest of Tucson. Other examples of porphyry copper deposits of the Middle Laramide include Ajo, Ray, Christmas, San Manuel, Mineral Park, Bagdad, Globe-Miami, Morenci, and Superior.

The **Early Tertiary, Late Laramide (Wilderness) phase (54-43 Ma) consists of tungsten (W) mineralization** associated with garnet-muscovite granitoid stocks and pegmatite dikes of peraluminous, magma chemistry. In the Little Dragoon Mountains, the main phase of the Texas Canyon pluton was intruded by the peraluminous calc-alkalic Adams Peak leucogranite. In the Huachuca Mountains, tungsten mineralization is probably related to the muscovite-bearing peraluminous alaskites that locally occur in southwest-directed thrust faults. An example of the Wilderness Assemblage mineralization is probably the Bluebird leucogranite in the Texas Canyon area. Peraluminous granites of Laramide age in Arizona include the peraluminous calcic magmatism of Las Guijas tungsten deposit and the peraluminous calc-alkalic magmatism associated with tungsten deposits at the Little Dragoon Mountains Bluebird deposit in Texas Canyon at approximately 64 Ma, the Borianna tungsten deposit in western Arizona, and the mineralization in Oracle district associated with the Wilderness granite in the Santa Catalina Mountains. Additional possibilities in western Arizona for gold-rich, latest Laramide (Wilderness

assemblage) ore deposits include the Vulture gold mine at approximately 75 Ma, the Copperstone gold deposit associated with southwest-directed thrust faults, and the Gold Basin deposit in Mohave County associated with 2-mica granites.

The **Galiuro Orogeny (43-13 Ma)** of mid-Tertiary age records the steepening of the subducting slab so that the central axis of the magmatic arc moved from the east to the west. The Galiuro orogeny is subdivided into early (Mineta), middle (South Mountain – calc-alkalic and later Datil – alkali-calcic), and late (Whipple) phases.

The *Early Galiuro orogeny (Mineta phase) – 38-28 Ma* records the deposition of sediments and volcanics in local basins, with minor volcanics, local conglomerates and lacustrine deposits of carbonates and gypsum and clay. Mineral deposits consisted of minor uranium in sedimentary and volcanic rocks, secondary exotic copper deposits, and industrial mineral deposits. Examples of exotic copper deposits near the porphyry copper deposits from which they were derived include the Copper Butte exotic copper deposit derived from the Ray porphyry copper deposit and the Ajo Cornelia exotic copper deposits derived from the Ajo porphyry copper deposit.

The two phases of the *Middle Galiuro orogeny (South Mountain [30-22 Ma] and Datil [28-18 Ma])* record widespread volcanism and emplacement of small stocks of calc-alkalic and later alkali-calcic magma chemistry. The earlier calc-alkalic phase (called the South Mountain phase) contains epithermal gold-copper veins associated with microdiorite dike swarms. Examples of the calc-alkalic phase include the deposits in the Little Harquahala district and the mines in the Kofa district. The later alkali-calcic phase (called the Datil phase) contains lead-zinc-silver skarns and replacement deposits in contact zones of stocks and small batholiths, associated with large caldera systems. Examples of the alkali-calcic phase include deposits of the Silver (Red Cloud mine), Castle Dome, Stanley, and Aravaipa mining districts.

The *Late Galiuro orogeny (Whipple phase) – 18-13 Ma* consists of coarse clastics and local volcanics and stocks of quartz-alkalic magma chemistry. These deposits are associated with microdiorite dikes and sometimes are associated with large, low-angle, normal, “detachment” faults, although the detachment faults are commonly reactivated along earlier thrust faults. Mineral resources of the Whipple phase consist of copper-gold-silver specularite replacement lenses, veins and disseminations in faults. Syngenetic stratabound uranium deposits were also deposited in lake beds and tuffs. The best known examples of these metaluminous quartz alkalic districts are the Oatman, Mammoth, Rowley, and Swansea gold districts. The oxidized zones of these deposits have produced a very unusual set of secondary minerals that are highly desirable for collectors.

The **San Andreas orogeny (Basin and Range Disturbance) - 13-0 Ma** produced the present physiography of the Basin and Range Province. The down-dropped fault basins are a result of the subducting Farallon slab being cut off by the strike-slip action on the San Andreas fault/transform boundary. As the underlying slab continued to descend and was missing in places, the overlying slab foundered and parts sank along steep normal faults creating the Basin and Range topographic province. This break-up allowed the intrusion of mantle basalt, which is largely devoid of mineralization, although some industrial minerals were deposited in the basins. Igneous rocks of this assemblage consist of basalt with local rhyolites, particularly where the normal faults allow mantle-derived basalt to ascend, as in the San Francisco volcanic field. The cinder cones near Flagstaff that are mined for cinders are an example of industrial minerals obtained from this assemblage. Other industrial minerals that were deposited in the down-dropped fault basins include salt in the Luke Salt basin in Glendale, the gypsum deposits in the San Pedro Valley and the Verde Valley, zeolites near Bowie, and sand and gravel deposits. The San Carlos basalts that contain olivine are an example of gemstones that are obtained from this assemblage.

Orogeny	Orogenic Phase	Age (Ma)	Age (period)	Arizona Magmatism	Alkalinity	Resources	Mining districts
San Andreas	Basin & Range	13-0	Latest Tertiary	anhydrous basaltic volcanism	Metalum. Alkalic	Sand, gravel, salt, zeolites, gypsum	San Francisco volcanic field, San Carlos olivine, Emerald Isle exotic Cu
Galluro	Late (Whipple)	18-13	Late Tertiary	volcanics & local epizonal stocks	Metaluminous Alkalic	Cu-Au-Ag in veins; epithermal Au-Ag veins	Oatman, Mammoth, Rowley, Swansea
	Middle (Datil)	28-18	Mid-Tertiary	alkali-calcic ignimbritic volcanics & plutons	Metaluminous Alkali-calcic	Pb-Zn-Ag F veins, replace.; epithermal	Silver (Red Cloud), Castle Dome, Stanley, Aravaipa
	Early (South Mountain)	30-22	Mid-Tertiary	calc-alkalic volcanics & plutons	Metalum. Calc-alkalic	Au +/- Cu-W veins & disseminated	Little Harquahala, Kofa
	Earliest (Mineta)	38-28	Mid-Tertiary	mostly within "volcanic gap"	-	Uranium, clay, exotic copper	Ajo Cornelia, Copper Butte (from Ray)
Laramide	Late (Wilderness)	55-43	Early Tertiary	2-mica, garnet-muscovite granitic stocks, sills, dikes	Peralum. Calcic, Calc-alkalic	Au dissem. & qtz veins; W veins,	Oracle (Wilderness granite), Boriana, Las Guijas, Gold Basin, Copperstone
	Middle (Morenci)	65-55	Cretaceous-Tertiary	granodiorite - quartz monzonite porphyry stocks, NE to ENE-striking dike swarms	Metaluminous Calc-alkalic	large disseminated porphyry Cu systems, local skarns & veins, fringing Zn-Pb-Ag	Ajo, Ray, Christmas, San Manuel, Mineral Park, Pima, Bagdad, Silver Bell, Globe-Miami, Morenci, Superior
	Early (Tombstone)	85-65	Late Cretaceous	qtz. monz. porph. stocks; ash flows	Metalum. Alkali-calcic	Pb-Zn-Ag veins & replacement deposits	Tombstone, Tyndall (Glove), Washington Camp, Salero
	Earliest (Hillsboro)	89-85	mid-Cretaceous	Volcanics, small stocks	Metalum. Alkalic	Cu-Au hydrothermal	Hillsboro, NM
Sevier		145-89	mid-Cretaceous			Sedimentary rocks	Bisbee Group sediments
Nevadan	Late	160-145	Late Jurassic	volcanics			
	Middle	205-160	Late & Middle Jurassic	Canelo Hills volcanics; plutonic rocks	Metalum. Alkalic	porphyry Cu-Au at Bisbee, Gleeson	Warren (Bisbee mine), Turquoise (Courtland-Gleeson)
	Early	230-205	Late Triassic	Fluid flow thru sedimentary rocks	Metalum. Alkalic	Uranium, vanadium, copper	Orphan, Grandview, Monument Valley
Alleghenian (Ouachita)		325-220	Miss. - Triassic	None	-	U in sed. rocks	Payson uranium
Acadian/ Caledonian		410-380	Devonian	None	-	Limestone	
Taconic.		490-445	Cambrian - Ord.	None	-		
Grenville		1200-900	Late Middle Proterozoic - Early Late Proterozoic	basalt flows, diabase dikes	Metalum. Alkalic	Serpentine asbestos	Sierra Ancha uranium Chrysotile (Salt R. Canyon)
"Oracle/Ruin"		1440-1335	Middle Proterozoic	K-feldspar megacrystic or porphyritic granites	Peralum. Calc-alkalic, Alkali-calcic	Pegmatites & greisens - Be, Li, Ta-Nb, U & W	White Picacho, Tungstona, Four Peaks
Mazatzal		1750-1600	Late Early Proterozoic	Basalt & rhyolite metavolc., schist	Metalum. Calcic	Cu-Zn-Ag VMS	Old Dick (Bruce)
Yavapai		1800-1775	Late Early Proterozoic	Andesite, schist, metarhyolite	Metalum. Calcic	Cu-Zn-Au VMS, Cu-Zn-Ag	Big Bug (Iron King), Verde (Jerome)
Penokean/ Hudsonian		2000-1800	Middle Late Proterozoic	Schist, banded cherty iron formation	Metalum. Calcic	BIF (Banded iron formation)	Pikes Peak iron

Table 1. Mountain building episodes in Arizona

## HERKIMER DIAMONDS AND THE ORIGIN OF OIL

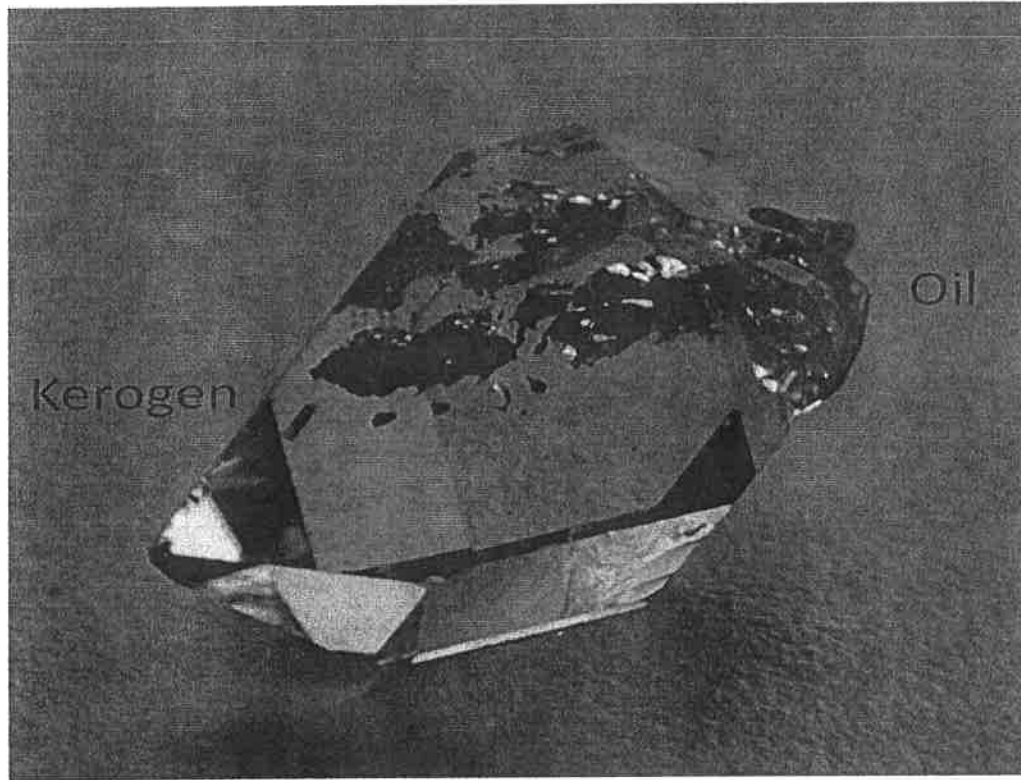
By Stan Keith

April 2013

Herkimer Diamonds (short 'c' axis stubby quartz) contain intriguing textures that suggest they are closely associated with the oil formation process and have in fact 'caught the petroleum generation in the act.' In addition to the well known association of Herkimer Diamond quartz with anthraxolite hydrocarbon occurrence in New York, it is now increasingly well recognized that 'Diamond' quartz from southern Pakistan has trapped oil as fluid inclusions. In some cases, Herkimer Diamonds have trapped the entire process of generation of petroleum from the anthraxolite kerogen precursor (see Figure 1 and Figure 2) to the liquid oil product. The association of Herkimer quartz and hydrocarbon formation is probably not accidental. When looked for, oil and kerogen inclusions in various kinds of quartz are relatively common in oil fields and in hydrocarbon-quartz/silica locations throughout the world. Relatively unreacted kerogen is typically found in early longer 'c' axis prismatic quartz whereas kerogen globulation and paraffinitic oil liquids and waxes characteristically appear in later Herkimer habit quartz which can overgrow earlier generation kerogen bearing quartz as scepters. Fluid inclusion data from the Herkimer, New York locality indicate oil was trapped under hydrothermal conditions between about 210 and 180° C, temperatures well above those of the conventional oil window which mainly ranges between 75 and 135° C. The consistent association with earlier forming hydrothermal dolomite and later forming calcite and co-evally depositing metal sulfides provides additional evidence for a oil generation in the context of hydrothermal processes.

ZARO MNTNS





**Figure 1: Oil bearing 'Diamond' Quartz from the Zard Mountain area, Roskoh, Kharan region, Balushistan, Pakistan. This Herkimer shows the entire oil forming sequence which proceeds from left to right along the 'c' crystallographic axis. Photo from Raven Crystal website.**

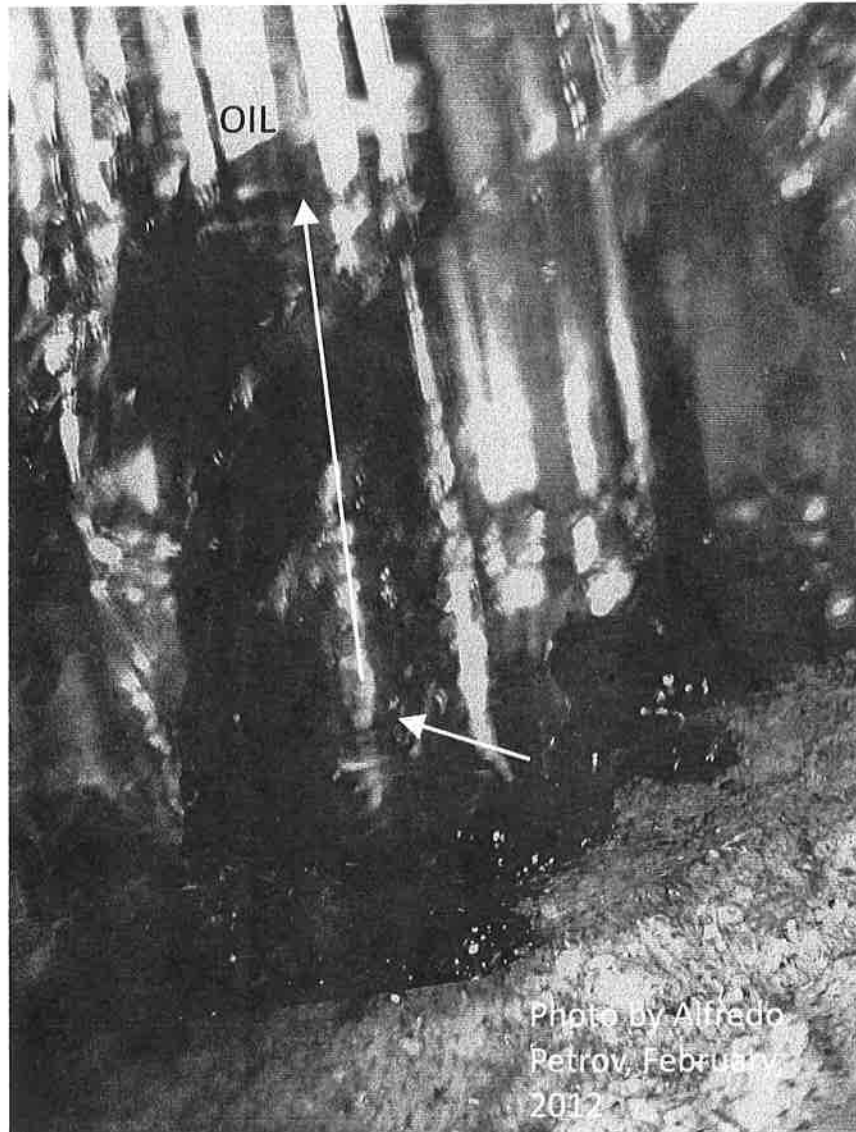
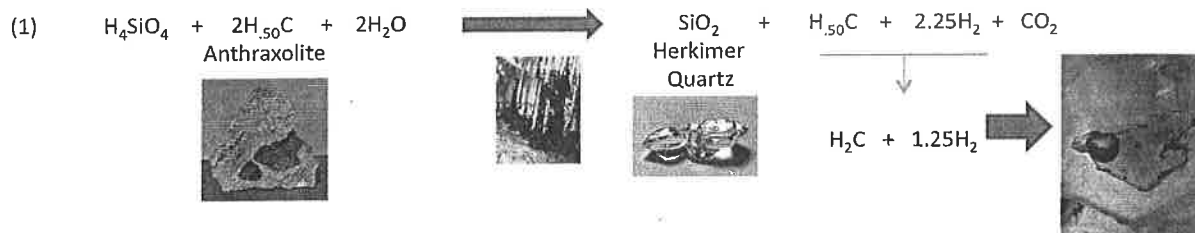


Figure 2: Globular kerogen hydrocarbon trapped in the base of a Herkimer quartz crystal and being converted to oil in tubular columns which rise above the base of the crystal. From a large Herkimer quartz crystal collected by Rob and Muriel Cristofar at the Ace of Diamonds Mine in 2011. Photo by Alfredo Petrov, February 2012.

The textures in the Herkimer reaction vessels indicate that hydrothermal oil formation was induced by hydrogenization of initial more hydrogen poor kerogen material by hydrogen donation from the hydrothermal fluids from which the quartz precipitated. A specific reaction which may have formed hydrothermal oil is proposed by which oil is formed during quartz precipitation from kerogen-bearing silicic acid in hydrothermal solutions as per the equation below.

## CHEMISTRY OF COINCIDENT FORMATION OF HYDROTHERMAL OIL AND HERKIMER 'DIAMOND'

During quartz formation hydrothermal water component (here shown as silicic acid) breaks down and donates oxygen to make quartz and carbon dioxide. The water breakdown simultaneously hydrogenates and decarbonizes anthraxolite kerogen to make hydrothermal oil plus carbon dioxide.



The anthraxolite kerogen material contains high nickel contents (up to 260 ppm) and locally contains platinum in basement hosted anthraxolite veins near Fonda, New York (Parnell, 1988). As such, coincident oil and Herkimer quartz formation occur as components of a much larger, regional scale hydrothermal petroleum which may be sourced as saline brines derived from ultramafic rocks such as serpentinite in the basement beneath the hydrothermal dolomite horizons in the upper Cambrian Little Falls Dolomite in the Herkimer county Herkimer diamond-anthraxolite district of east central New York state. The top of the petroleum system in this area is the Utica Shale, which may be a chemical sedimentary black shale lithocap above the 'oil field' associated with the Herkimer Diamonds that formed about 450 million years ago during upper Ordovician time. In this regard, it is very significant that hydrothermal monazite from horizons below the Herkimer zone have yielded radiometric dates which are the same age as the overlying Utica Shale (Selleck, 2010).

The hydrothermal hydrocarbon model in which various forms of silica are closely allied with oil formation presents a radically new model of hydrothermal oil formation. Like any other mineral, oil forms in the reservoir as part of the mineral depositional or paragenetic sequence and is especially tied to the quartz or silica depositional part of the sequence. The hydrothermal fluids which brought the kerogen starter, originated as crustal scale magnesium rich brine products derived from serpentinization of ultramafic peridotites and, after deposition of massive amounts of dolomite, subsequently evolved to silica rich brines which attended quartz deposition, minor sulfide precipitation, and oil formation via kerogen hydrogenization in carbonate reservoirs in the upper crust. The final reaction in the sequence involves the precipitation of calcite from excess calcium generated from the dolomitization and carbon dioxide generated during kerogen hydrogenization. The reaction sequence is very similar to that observed in Mississippi Valley Type lead-zinc deposits.

The strong association and perhaps dependence of oil generation on silica deposition and Herkimer diamond formation in particular strongly hints that diamond quartz may provide an exciting new prism from which to view the origin of oil.

## MINERALOGY ALONG NORTHERN ARIZONA'S ROUTE 66

Anna M Domitrovic  
Arizona-Sonora Desert Museum  
Tucson, Arizona

The first road to traverse the US from the east coast to the west coast was the Lincoln Highway. Conceived in 1911 and dedicated in 1913, it stretched across 13 states from Times Square in New York City to Lincoln Park in San Francisco. But the first paved road was Route 66, also known by such colorful names as the Will Rogers Highway, the Mother Road and Main Street America. Route 66's eastern end was in downtown Chicago, with its western terminus in Los Angeles. Completed in 1938, Route 66 provided the means for migrant workers of the 1930's Dust Bowl Era to safely travel west in search of better lives.

Some of the best preserved and longest stretches of this historic highway are in northern Arizona. Much of the original road in eastern Arizona is broken into bits and pieces in populated areas off I40. It continues westerly to Flagstaff and Kingman where it underlies the majority of the interstate. A good, long stretch of the original road takes off from I40 at Ash Fork, continues through Kingman, then picks up again through the Black Mountains west of the city, to Oatman and into Needles where I40 once again takes over.

Points of interest and the minerals found therein include Monument Valley and the Painted Desert and the uranium minerals on the Navajo Indian Reservation in northeastern Arizona. The Navajo call Monument Valley *Tse Bii' Ndzisgaaí* or Valley of the Rocks. Buttes, very popular in early western movies out of Hollywood, rise about 1000' off the valley floor. Rocks are shales and sandstones stained with iron oxide. Mining activities in Monument Valley from 1948-1967, recovered uranium, copper and vanadium.

The southern end of Monument Valley is the Painted Desert. It gets its name from early Spanish Colonialists who called it *El Desierto Pintado*. The rocks are siltstones, mudstones and shales of the Triassic age Chinle Formation. Iron and manganese stain the rocks various hues that give the Painted Desert its name. This approximately 7500 square mile area was named a national landmark in 1906 and later raised to national park status. Mineralization and fossilization in the Painted Desert are similar to that found in the Petrified Forest to the south.

Route 66 forms the boundary between the Painted Desert in the north and Petrified Forest in the south. Petrified Forest is about 146 square miles. It was named a national monument in 1906 and a national park in 1962. Like the Painted Desert, the rocks of Petrified Forest, the Chinle Fm, are about 225 my. Fossils include ferns, cycads and ginkoes. The fossil trees are the species *Araucarioxylon arizonicum*, *Woodworthia arizonica* and *Schilderia adamanica*. Actually, nine different species of trees have been identified in Petrified Forest, all of them extinct. *Phytosaurs* (fossil crocodiles), *Buttneria* (fossil amphibians) and early dinosaurs have also been found along with the fossilized flora. Silica, in the form of agates and crystallized quartz permeated the fallen trees, the result of volcanic eruptions, thus preserving them in the form of petrified wood. Fe, Mn and Cu stained the silica resulting in the rainbow of colors in the fossilized wood.

Baringer Crater, aka Meteor Crater and Canyon Diablo, was named after mining engineer Daniel Baringer, who was the first to recognize it as a meteor impact. About 50 thousand years old, the impact formed in Pleistocene rocks. The crater is 4000' in diameter, 570' deep, with a 150' rim. In 1903, Standard Oil Co. staked claims on 640 A around the center of the crater, estimating Fe reserves up to 100 million tons. While the mining operation did not progress, remnants of the Ni-Fe meteorite have made their way into collections world-wide.

The Grand Canyon is a bit off the beaten track of Route 66, but mining interests drew several miners and prospectors to Arizona Territory in the mid- to late-1800's. In the late 1800's, John Hance attempted to mine asbestos in the Canyon. Louis Boucher, who arrived in northern Arizona and the Grand Canyon about 1889, mined copper until 1912. And in the 1890's, Ralph Cameron opposed the Grand Canyon's national park status in an attempt to open a platinum mine near the south rim. Some notable mines include the Cameron, the Grand View and the (Old) Orphan. A recent contribution to Arizona's type minerals, grandviewite, was located at the Grand View Mine. John Wesley Powell was the first to lead an expedition down the Colorado River in the Grand Canyon in 1869. He served as Director of the USGS from 1881 - 1894.

A side trip north of Kingman takes one to the mines at Mineral Park and Chloride, and unique specimens of native gold on wulfenite, vanadinite and mottramite at Gold Basin. Mineral Park is considered the oldest camp/town in Arizona. A post office operated from 1872-1912. Copper was the first mineral of choice mined at Mineral Park, but Ag, Au, Mo and Pb were also recovered from the Precambrian crystalline rocks. Mining peaked between 1876 and 1882. Modern open pit mining began with Duval in 1963, followed by Cyprus in 1986 and Equatorial Mining of Australia in 1997. In 2003, Canada's Mercator Minerals, LTD., acquired the property from Equatorial in 2003. In 2012, Mercator determined that the ore reserves provided for a 22 year mine life.

Continuing north of Mineral Park brings us to Chloride, the oldest continuously inhabited town in Arizona. It was originally a silver camp established in 1863 but mining did not commence until the 1870's, even though mineral resources were first located in the 1840's. Further north in the Gold Basin District, wulfenite, vanadinite and mottramite occur at the historic mines, with gold occurring as micro crystals on wulfenite.

Finally, the last to consider on this mineralogical journey along Route 66 are the mines and minerals in the mountains and canyons surrounding Oatman. The Oatman District, in the Black Mts, is also known as the San Francisco and the Union Pass District. The Moss Mine, located in 1863, the first and oldest patented claim in Arizona, was also the first located in the district, followed shortly thereafter by the Hardy and the Homestake. Lode gold occurs in a quartz-monzonite-porphyry vein. Currently, Patriot Gold Corporation, in February 2013, announced a three-phase mining operation at the Moss Mine. The open pit, heap leach operation is scheduled to begin commercial production by mid-2014 and continue through 2017. Mining at the Hardy and Homestake mines began in the mid- to late-1860's and continued to the 1920's. These mines, and others in the district, are most notable for occurrences of green fluorite. Gold Road joins the Moss Mine as another lode gold occurrence in the district. It produced intermittently from 1902 to 1949. Gold and silver with trace beryllium occur in a vein in Tertiary volcanics. Current owners operate public tours of the mine.

Tourist attractions continue along Route 66 from the Gold Road Mine to and through historic Oatman. Oatman started as a gold mining camp in 1906. Centrally located in the Oatman District on the western flanks of the Black Mts, the town served as a supply point for the mines in the district. At its peak, Oatman had a population of nearly 3500. Currently, the town's population is about 150. The town caters to tourists travelling historic Route 66 and those seeking early history of northwestern Arizona. Nearby Bullhead City and Laughlin are also sources of interest to visitors to the area.

**Arthur Leonard Flagg, (1883 - 1961), Personal Mineral Collection**  
Phil Richardson, Flagg Mineral Foundation Chairman

Arthur L. Flagg was a practicing mining engineer, an accomplished author, and an Arizona mineral locality aficionado. Above all else, he was an enthusiastic unbridled "rockhound" who undauntedly promoted the earth sciences. Through his personal passion and involvement of forming both the Mineralogical Society of Arizona and the Rocky Mountain Federation of Mineralogical Societies, Flagg inspired generations of future collectors and earth scientists. As the first curator of the Arizona Mineral Museum, originally located on the State Fairgrounds in Phoenix, he held the public exhibition of minerals supreme. Contained within this presentation is a glimpse into the personal mineral collection of Arthur Leonard Flagg.

Arthur's personal mineral collection, held by his son, Richard, had been in storage for several decades until being donated to the Flagg Mineral Foundation this past November. It was packed into approximately 40 wooden crates and wrapped in 1929 to 1932 era newspaper. Unfortunately the newsprint showed extreme brittleness and yellowing from years of Arizona heat, and in most cases, had to be peeled away from the bulk of the specimens unwrapped.

Arthur meticulously hand numbered every specimen, from 1 to 5,086, and crafted a catalog entry for each instead of individual labels. (Flagg Mineral Foundation volunteers have transcribed these catalog entries onto replica Arthur L. Flagg mineral tags, from blanks which were found in one of the crates.) A majority of numbers are represented with more than one specimen, and the collection contains an estimated 8,500 pieces. The vast majority are modest mineral samples, what most would consider reference pieces, with approximately 700 plus being separately numbered rock specimens. Mineral specimen number 1 is a calcite from Joplin, Missouri, and the last number, number 5,086, is an emmonsite from Moctezuma, Sonora, Mexico. (The specimen information was transcribed exactly as it was listed in the catalog entry, with no corrections or additional information added.)

Arthur was the consummate collector, pursuing everything from display quality pieces to reference specimens, from vials of elements to glass tubes of worldwide sands, from mineral oddities to ore samples, and from lapidary

29 W. HOLLY ST., PHX



arts items to rock, gem, and mineral periodicals. His collection contains an incredible glimpse of early Arizona mining history, of the material available at that time, and of his desire to be able to spot identify minerals. We have uncovered typical period Bisbee azurites and malachites, New England classics, a magnificent Arizona manganite, a rare flagstaffite, and evidence of Arizona crocoite, just to mention several.

This donation has presented an unique opportunity, allowing the Flagg Mineral Foundation the chance to incorporate Arthur's personal collection, as a sub-collection, into the Foundation's long held mineral collection. A number of the important, representative specimens were recently exhibited in two cases at the TGMS 2013 Show. One case highlighted 22 of the 'best' display quality specimens from Arthur's collection. The second case highlighted Arthur's earth science paraphernalia and ephemera, and gave a glimpse of his passion for the hobby. The May/June Mineralogical Record magazine Arizona Collections supplement will also feature this important collection, and surplus material is available here at the symposium in the Flagg Mineral Foundation room. Please take the time to look through the extra collection material, add something into your own personal collection, and share Arthur's passion for minerals.

Sample pages from A.L. Flagg's specimen catalog that he typed in the summer of 1953. The first, last, and a random page of the 52 page catalog are reproduced here.

- 1 Calcite, Joplin, Missouri
- 2 Stibnite, Pribram, Bohemia
- 3 Alabaster, Italy
- 4 Quartz and iron, Frizington, England
- 5 Quartz, Harris Lime Rock, R.I.
- 6 Aquacrepitite, Strodes Mill, East Bradford,
- 7 Barite, Mowbrow, England.
- 8 Bitumen,
- 9 Green Prase, Sneece Pond, Cumberland, R.I.
- 10 Andalusite, Lancaster, Mass.
- 11 Fluorite, England
- 12 Garnet, Ft. Wrangel, Alaska
- 13 Chalcedony
- 14 Dolomite, Old Maid's Quarry, Woonsocket, R.I.
- 15 Green Mica
- 16 Salt,
- 17 Gypsum, Ellsworth, Ohio.
- 18 Hornblende Schist, Cumberland, R.I.
- 19 Itacolumbite, Stokes county, North Carolina.
- 20 Molybdenite, Leadville, Colorado.
- 21 Dendrites, Lynn, Mass.
- 22 Jasper, Diamond Hill, R.I.
- 23 Magnetite, Copper Mine Hill, Cumberland, R.I.
- 24 Silver,
- 25 Clay Concretions, Connecticut River
- 26 Garnets, near Worcester, Mass.
- 27 Corundum, Newlin, Chester county, Pa.
- 28 Bowenite, Harris Lime Rock, R.I.
- 29 Asphaltum
- 30 Talc (?), Dexter Lime Rock, R.I.
- 31 Quartz enclosing tourmaline, Silver Star, Jefferson county, Montana.
- 32 Pyrite, Cat Swamp, (Now Elmgrove Ave.,) Providence, R.I.
- 33 Argentite, Durango, Mexico.
- 34 Titaniferous Iron Ore, Cumberland, R.I.
- 35 Soapstone, New Hampshire.
- 36 Orthoclase, Lincoln county, Nevada
- 37 Molybdenite, Okanogan county, Washington
- 38 Carnelian,
- 39 Fibrous Serpentine, West Goshen, Chester county, Pa.
- 40 Quartz, Old Maid's Quarry, Woonsocket, R.I.
- 41 Bog Iron Ore, Dexter Lime Rock, R.I.
- 42 Lime on leaves, Whirlpool, Niagara Falls, New York.
- 43 Porphyritic Trap, Old Maid's Quarry, Woonsocket, R.I.
- 44 Lignite, Washburn Mine, Brunswick, North Dakota
- 45 Clinchlore, Westtown, Chester county, Pa.
- 46 Quartz, Suttrop, Germany
- 47 Jeffersonite, Westtown, Chester county, Pa.
- 48 Asbestos, Canada
- 49 Porcelanite
- 50 Serpentine, West Chester, Pa.

- 1701 Vanadinite, near Kingman, Arizona.
- 1702 Cuprodescloizite
- 1703 Vanadium Ore, Ahumada, Chichuhua, Mexico.
- 1704 Iridium, Saws Bar, Siskiyou county, California.
- 1705 Thorianite, Yuma county, Arizona.
- 1706 Vanadium Ore, Carrizo Mts, New Mexico. (Hewettite, see 2444)
- 1707 Vanadinite, Black Hawk Mine, Vulture district, Maricopa county, Arizona.
- 1708 Copper Ore, Nokai Canyon, Arizona.
- 1709 Vanadinite, GVRM Mine, Cochise county, Arizona.
- 1710 Gypsum, Little Treasure Mine, Saddle Mt district, Pinal county, Ariz.
- 1711 Fused Vanadium Oxide
- 1712 Mineral Wax, Oro Belle Mine, Hart, California,
- 1713 Carnotite, Aguila, Arizona.
- 1714 Silver Ore, Tonopah, Nevada
- 1715 Durion Alloy
- 1716 (a) Ore (b) country rock, Vulture Mine, Maricopa county, Arizona.
- 1717 Jamesonite, GVRM Corp Mine, Cochise county, Arizona.
- 1718 Gold Ore, Wahls Well, near Gunsight, Arizona.
- 1719 Psittacinite, GVRM Property, Cochise county, Arizona.
- 1720 Nitrate deposit, near Winkelman, Arizona. *Decomposed - Discarded.*
- 1721 Wulfenite, GVRM Property, Cochise county, Arizona.
- 1722 Gold Ore, Bunker Hill Mine, Tombstone, Arizona.
- 1723 Gold Ore, Unity Mine, Warren, Idaho.
- 1724 Wulfenite & Cerussite, Stella claim, GVRM Property, Cochise county, Ariz.
- 1725 Gold Ore, 100 west stope, Unity Gold Mine, Warren, Idaho
- 1726 " 2 500 " " " " "
- 1727 Titaniferous Iron Ore, Tejunga Mts, Los Angeles county, California.
- 1728 Gangue rock, Spec. 1727
- 1729 Endlichite, GVRM Property, Cochise county, Arizona.
- 1730 Wulfenite " " " " "
- 1731 Peacock Ore, Springfield Mine, Crown King district, Arizona.
- 1732 Iron and copper sulphides, " " " "
- 1733 Lead Vanadate, Maria Mine, Cochise county, Arizona.
- 1734 Lead-zinc Ore, Adjust Mine, Saddle Mt district, Pinal county, Arizona.
- 1735 Wolframite, 3 mi west of Arivaipa creek, Pinal county, Arizona.
- 1736 Malachite, Bisbee, Arizona.
- 1737 Galena, Blanket Claim, GVRM Property, Cochise county, Ariz.
- 1738 Silver Ore, Maria Mine, Tombstone district, Cochise county, Ariz.
- 1739 " " " " " " " "
- 1740 Vanadinite " " " " " "
- 1741 Vanadinite Blanket No. 5, GVRM Property, Cochise county, Arizona.
- 1742 Laurence shaft, 80-ft HMCo Saddle Mountain district, Pinal county, Arizona.
- 1743 Black xls (?) Maria Mine, Tombstone district, Cochise county, Arizona.
- 1744 " " " " " "
- 1745 Wolframite, between Superior & Miani, Arizona.
- 1746 Telluride Ore, Cripple Creek, Colorado (Roasted)
- 1747 Vanadinite, Blanket No. 5 GVRM Property, Cochise county, Arizona.
- 1748 Vanadinite, near Charleston, Arizona (Across river)
- 1749 Pyrite, Springfield Group, Crown King district, Arizona.
- 1750

- 5051 Red Native Selenium, Sec.28 Ambrosia Lakes Dist,Nr Grants,New Mexico.  
 5052 Rosasite, Mina Ojuela,Mapimi, Durango,Mexico.  
 5053 Atacamite in Chrysocolla, San Manuel Mine,Pinal County,Arizona.  
 5054 Zippeite, Homstead Mine,Sec.23,Ambrosia Lakes Dist,Nr Grants,New Mexico.  
 5055 Sodalite in nepheline seyenite,York River,Ontario,Canada.  
 5056 Sodalite,Ontario, Canada (Bancroft?)  
 5057 Silver Ore,near Cleator,Arizona.  
 5058 Cloanthite, Cobalt,Ontario,Canada  
 5059 Native Silver, " " "  
 5060 Cone-in-cone, Pennsylvania.  
 5061 Zunyite, Zuni Mine, Silverton, Colorado.  
 5062 Hureaulite-vivianite,on Triphylite & Graftonite,Bull Moose Mine,Custer,S.Dakota  
 5063 Beraunite & Laubmannite,Buckeye Mt.,Polk County,Arkansas.  
 5064 Hureaulite,Mithridatite,~~Triphylite~~,Vivianite,Bull Moose Mine,Custer,So.Dak Tavorite  
 5065 Rockbridgeite,Tavorite,Bull Moose Mine,Custer, So.Dakota  
 5066 Tavorite,Hureaulite,Triphylite,Bull Moose Mine,Custer,So.Dakota  
 5067 Mithradite,Gypsum,Barboselite,Bull Moose Mine,Custer,So.Dakota  
 5068 Rockbridgeite,Vivianite,Tavorite, " " " " "  
 5069 Vivianite on Triphylite, " " " " "  
 5070 Mithridatite,Rockbridgeite etc " " " " "  
 5071 Reddingite,vivianite, triphylite. Hagendorf  
 5072 Vivianite,phosphorferite, ludlamite, Hagendorf  
 5073 Phosphophyllite, Hagendorf  
 5074 Strengite, Plegstein  
 5075 Hureaulite, Hagendorf  
 5076 Strangite, Stewearite, Hagendorf  
 5077 Strunzite, Hagendorf  
 5078 Reddingite, Hagendorf  
 5079 Phosphorferite, Hagendorf  
 5080 Phosphorsiderite, Plegstein  
 5081 Hagendorffite, wulfeite, Hagendorf  
 5082 Zincrockbridgeite, hureaulite, Hagendorf  
 5083 Wulfeite, Hagendorff//  
 5084 Laueite, Hagendorf.  
 5085 Rattle Stone, Sicily Island, La.  
 5086 Emmonsite, Mina Candalaria, Moctezuma, Sonora,Mexico.  
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# Flagg Memorial Cases

## Tucson Gem and Mineral Show, 2013



# ROCKHOUND RECORD



## MINERALOGICAL SOCIETY OF ARIZONA

MEMBER OF  
AMERICAN FEDERATION OF MINERALOGICAL SOCIETIES, ROCKY MOUNTAIN FEDERATION OF  
MINERALOGICAL SOCIETIES, ROCKS AND MINERALS ASSOCIATION

### A. L. FLAGG MEMORIAL BULLETIN

#### A Tribute to a Great Man

"He alone is worthy of the appellation who either does great things, or teaches how they may be done, or describes them with a suitable majesty when they have been done; but those only are great things which tend to render life more happy, which increase the innocent enjoyments and comforts of existence, or which pave the way to a state of future bliss more permanent and more pure." --- John Milton

There truly is no death for him who's life  
has ever touched the lives of other men  
With fingers sowing seeds of knowledge or of joy  
Which grow to spread and then to grow again.

He lives forever through his myriad friends  
Who cherish in their hearts his memory;  
And deeds of kindness and his fruits of work  
Are stamped upon the earth for all eternity.

Just as the ripples ever wider grow,  
Reflect and multiply from every shore---  
A single pebble cast is like a life  
Upon the sea of men forevermore.

Arthur L. Flagg (Mr. Rockhound) passed away in Phoenix, Arizona on April 27th. He is survived by his widow, Mary his sons Edward of Phoenix, Arizona and Richard of Denver, Colorado, and his daughter Anne, Mrs. Lenard Hines of Tucson, Arizona. His friends and acquaintances, though grieved by his death are left richer for having known him; all other sustain an unknown loss for having missed the benefit of his presence.



IN LIEU OF FLOWERS, the family requests that those persons wishing to express their sympathy in a concrete form make a contribution to the Heart Fund in the name of A. L. Flagg or to a Mineralogy Memorial Fund, Box 902 - Phoenix, Arizona.

ARTHUR LEONARD FLAGG was born on June 29, 1883, the son of Charles Welford and Anna R. (Daley) Flagg. His mother passed away when the boy was only 1½ years old. He received his education at Friends School in Providence, R. I. and later achieved his Bachelor's degree, majoring in geology at Brown University in 1906.

As a young mining engineer, Arthur Flagg followed Horace Greeley's advice and came west. He worked at assaying, surveying, and mining in Yavapai County, Arizona during the remainder of 1906 and 1907. From 1908 to 1912 he held a position as mine examiner in Durango, Mexico.

In 1910 Arthur L. Flagg was married to Mary Harkness White and thus began a union which was to flourish for over 50 years. They were blessed with two sons: Edward Carlton, and Richard Welford as well as a daughter: Anne Bailey. In later years he was to take great pride in his nine grand-children.

1912 found Arthur Flagg in private practise as consultant engineer in the states of Washington and Idaho. In 1913 he became manager of the Kelvin Sultana Copper Company which position he held until taking over as Receiver of the company in 1916. He resumed his private practise in Arizona in 1919. He has also held the position of director of the Ace Mineral and Development Company, consulting engineer of the Gallagher Vanadium and Rare Mineral Corporation, and Vice-

President of the Mines Holding Company.

Mr. Flagg took over as superintendent of the Mineral Department of the Arizona State Fair in 1946. In 1949 he became connected with the State Department of Mineral Resources. Upon reaching the age of retirement (70) in 1953, the mining companies combined to keep him in the position of curator of the mineral museum as he could no longer be employed by the state.

He contributed as a member to many organizations the first of which was the Sigma Chi fraternity to which he belonged in his college days. He was a member of Sigma Xi; (F) American Association for the Advancement of Science; the American Institute of Mining Engineers; the Arizona Academy of Sciences; the American Institute of Mining, Metallurgical and Petroleum Engineers; Arizona Small Mine Operators, and the Heard Museum Board. He was a licensed Mining Engineer for the State of Arizona.

In 1948 he served as president of the A.A.A.S. He was also president of the Mineralogical Society of Arizona, the Rocky Mountain Federation of Mineralogical Societies and the American Federation of Mineralogical Societies. He was co-founder of the Arizona Society and the Rocky Mountain Federation.

Mr. Flagg was the author of many valuable contributions to Mineral and Mining publications. He has had two books published: "Rockhounds and Arizona Minerals" and "Mineralogical Journeys in Arizona".

In 1960 as part of the celebration of the 75th Anniversary of the State of Arizona Mr. Flagg was awarded a special medallion

with the citation: "Graduate of Brown University with the degree of Bachelor of Arts in 1906; registered mining engineer and curator of the Arizona State Mineral Museum; author of "Mineralogical Journeys in Arizona", recognized as a national authority by gem & mineral societies; enthusiastic sponsor of Rock Hound Clubs and other groups, who has stimulated interest in the natural wonders of Arizona on the part of both young and old; distinguished geologist and mineralogist who has contributed much to his community and to the state, Arthur L. Flagg".

Mr. Flagg has also been honored by having been selected as worthy of appearing in "American Men of Science" and "Who's Who in Engineering".

During July of 1960 he suffered a severe heart attack which forced him to retire from the active functions of his office. However, to the last he maintained an interest and contrivuted as much as was physically possible.

At 5:30 on April 27th he died quietly in the Good Samaritan Hospital where he had been since the 2nd of March. The cause of death was heart disease combined with arteriosclerosis.

As a young boy Arthur Flagg was tremendously impressed by a teacher who seemed to have limitless information concerning the natural sciences. Not only was he inspired to work toward a career in the field of geology; but he spent the rest of his life emulating the kindness of the man of science who took the time to encourage a small boy. His love and understanding of nature was surpassed only by his feeling for children of all ages.

In the field of mineralogy he fostered many societies for amateur "Rockhounds" always stressing the importance of including children in their program of ad-

venture through the field of minerals, gems, and rocks. The A.L. Flagg Trophy was set up to encourage young people to exhibit their findings at the Arizona State Fair. Mr. Flagg also worked closely with the public schools, presenting programs for the pupils and enlightening the teachers on the possibilities in the earth sciences.

Fascinated by the western part of the United States after his first trip to Arizona, he made a career of exploring the many natural facets exposed in the Baby State. He is said to have known personally more about the area of Arizona than any other individual. Much of this information he has made available to others through his books and his articles in such publications as Arizona Highways Magazine.

Although Arizonans would like to claim him as their own, Mr. Rockhound belongs to the world. He is noted as the dean of mineralogists of the United States and respected for his contributions in this field throughout many of the other countries on the globe.

Several years ago a six year old boy gave a talk before the Mineralogical Society of Arizona on the occasion of their annual Junior Program. His speech was entitled, "How to Start a Rock Collection". In its entirety the contents were: "First you find a cigar box. Then you put in some cardboard dividers. Then you go pick up some rocks---- anywhere. Then you ask Mr. Flagg what they are."

This simple revelation expresses the faith held not only by children but by all persons who came in contact with Mr. Rockhound. It was a faith not only in his knowledge but in his kindly understanding of people. To those same children their one consolation is that now St. Peter can:

"ASK MR. FLAGG".