15th annual

# NEW MEXICO MINERAL SYMPOSIUM

November 12 & 13, 1994


NMIMT Campus, Socorro, New Mexico

Welcome to

# THE FIFTEENTH ANNUAL

# NEW MEXICO MINERAL SYMPOSIUM

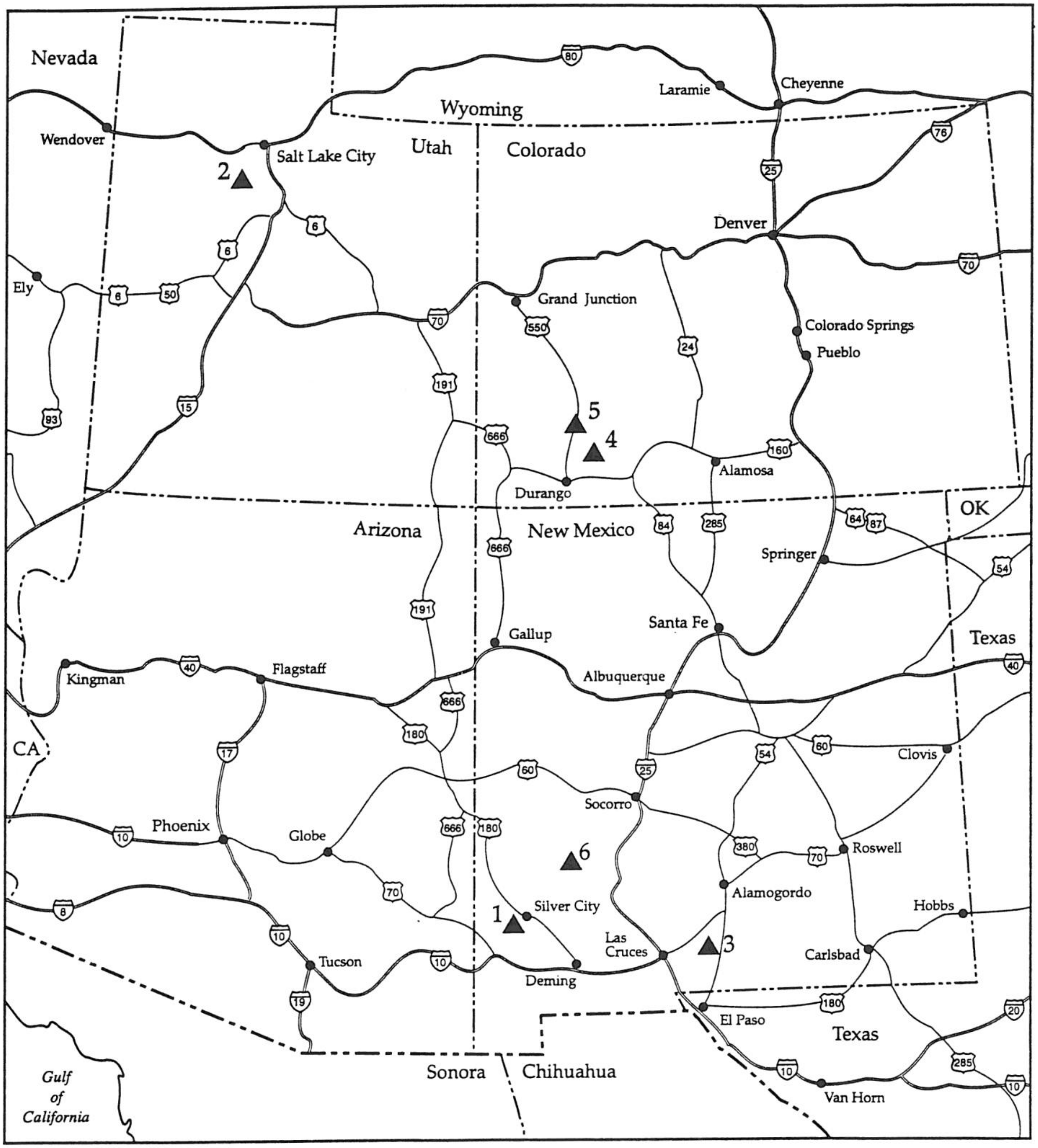
November 12 and 13, 1994

Macey Center Auditorium
New Mexico Institute of Mining and Technology
Socorro, New Mexico

sponsored by
New Mexico Bureau of Mines and Mineral Resources
Albuquerque Gem and Mineral Club
Los Alamos Geological Society
New Mexico Geological Society
Chaparral Rockhounds

The purpose of the New Mexico Mineral Symposium is to bring together for an exchange of ideas both professionals and amateurs interested in mineralogy. The sponsors hope that the Fifteenth New Mexico Mineral Symposium will give both groups a forum to present their cumulative knowledge of mineral occurrences in the state. In addition to the formal papers, informal discussions among mineralogists, geologists, and hobbyists should benefit all.

Cover—MINERALS OF THE FOUR-CORNERS STATES. Scepter quartz from Kingston, New Mexico; rhodochrosite from Silverton, Colorado; topaz from the Thomas Mountains, Utah; and barite from Superior, Arizona represent the four-corners states in the cover design by Teresa Mueller.




Geographic Index Map
15th New Mexico Mineral Symposium

## SCHEDULE

Numbers in parentheses refer to geographic location on map.

**Friday, November 11**

6:00 pm Informal tailgating and social hour, individual rooms, Super 8 Motel

**Saturday, November 12**

8:30 am Registration; coffee and donuts

9:30 *Opening remarks,* main auditorium

9:40 (1) *A New Mexico fluorite dig*—Ramon S. DeMark and Michael R. Sanders

10:10 (2) *Mineralogy and geochronology of the Mercur gold deposit, Utah—Paula* N. Wilson and James R. Wilson

10:40 Coffee break

11:10 (3) *Geology and mineralogy of the Jarilla (Orogrande) mining district, New Mexico—Philip* C. Goodell and Virgil W. Lueth

11:40 (4) *Theisite and associated minerals from near Durango, Colorado—Patrick* Haynes

12:00 pm Lunch, Museum tours

2:00 *Update of the* Mineralogy of Arizona—Raymond Grant

2:30 *Minerals of Utah—James* R. Wilson and Paula N. Wilson

3:00 Coffee break

3:30 (5) *Zunyite and other minerals of the Zuni mine, San Juan County, Colorado—Paul* F. Hlava, Arnold G. Hampson, and William P. Moats

4:00 *The "precious" gems: where they occur, how they are mined—Fred* Ward, featured speaker.

5:30 Sarsaparilla and suds: cocktail hour (with cash bar)

6:30 Dinner at Macey Center followed by a brief presentation by Fred Ward, *Jade,* and an auction to benefit the New Mexico Mineral Symposium.

**Sunday, November 13**

9:00 am Welcome to second day of symposium and follow-up remarks

9:10 *New Mexico garnets: mineralogical beauty and economic potential-* Virgil W. Lueth

9:40 (6) *Bixbyite: a re-examination of material from New Mexico and Utah—Paul* F. Hlava and Eugene E. Foord

10:10 Coffee break

10:40 *Fluorite mining, Castleton, Derbyshire, England—Dale* Wheeler

11:10 *Open forum on minerals in the four-corners states*

12:00 pm Lunch

1:15-3:00 Silent auction, upper lobby, Macey Center, sponsored by the Albuquerque Gem and Mineral Club

# A New Mexico fluorite dig

(Location 1 on index map)

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The Pine Canyon fluorspar deposit is in the Burro Mountains about 16 mi southwest of Silver City, Grant County, New Mexico. Claims on this deposit were first located in the early 1940s, although no ore was ever shipped (Gillerman, 1952). The deposit is currently under claim as the "Judith Lynn" and was located in April 1983. Thoughts of a significant fluorite recovery effort from the Pine Canyon deposit have intrigued us for the last ten years.

Fluorite from the Pine Canyon deposit has fascinated collectors since the 1970s when it first appeared on the mineral specimen market erroneously labeled as originating from Catron County, New Mexico. This bit of misinformation was corrected in an article by North and DeMark in the New Mexico issue of the *Mineralogical Record* (v. 20, no. 1, 1989). Digging with hand tools on the claim over the years had about reached an end as the trenches dug on nearly vertical veins became too deep to work effectively. We decided that the time had come for a mechanized fluorite dig.

Mike New of Top-Gem Minerals (Tucson, AZ) was contacted at the Denver Show in September 1993 about suggestions for equipment. He recommended the use of a tracked, 40-ton Caterpillar 320L excavator, which had been used very successfully at Morenci, Arizona to collect azurite and malachite. An agreement was reached between ourselves and Mike New and Joe Kielbaso of Top-Gem Minerals to commence the operation with the excavator on the 1st day of July, 1994. The operation was scheduled for two-weeks duration pending approval of the U.S. Forest Service as the mining claim was located within the Gila National Forest. Prior to operations commencing, however, the Forest Service required a detailed Notice of Intent that described the proposed mining plan, an archaeological survey, and clearance. In a good example of cooperation between the U.S. Forest Service and claim owners, Forest Service personnel (Mr. Robert Schloss) volunteered to accomplish the archaeological survey so that we could meet our start-up date of 1 July. A Notice of Intent was submitted to the Forest Service in mid-June that described in detail the scope of the digging to be accomplished. The Notice included the possibility that some drilling and blasting might be needed. We also advised that we would backfill all excavation and restore the surface topography to the degree possible to its original configuration. With all of the necessary steps completed, the Forest Service authorized us to proceed with the dig.

It was determined that most of the fluorite occurred in three primary veins that had a northeast-southwest strike and dipped about 70° northwest. Veins would pinch and swell along strike and dip with maximum width of about 20 cm. The host rock at the surface is an eroded Precambrian granite, and the fluorite mineralization is generally considered to be Tertiary (Gillerman, 1952). The working area for the excavation was roughly a north-south rectangle about 75 m long and 50 m wide. Fluorite crystals were found as fracture fillings lining granite walls and, between clay seams in the veins, usually in plates.

The mining plan was to dig as deep as possible parallel to the veins and as close to the vein as practicable with the machine. Next, the vein material would be extracted using hand tools. Vein material was then collected in buckets (between 6 and 15 buckets) that were transported to the washing area at the end of each day. The heavy clay and organic material enclosing the fluorite made it impossible to evaluate the specimens without some cleaning. A windmill and stock tank in Pine

Canyon directly below the mining area was a ready source of water and proved to be invaluable to the cleaning and sorting effort. The buckets of vein material were soaked overnight, and the following day clay/fluorite chunks were broken apart and scrubbed with brushes so that the fluorite could be evaluated. Specimens were then graded in three categories: A (high quality), B (medium grade), and "54s" (student/beginner specimens).

In general, the two most southerly (upslope) veins produced the curved, scallop-faced, purple octahedrons most often associated with the Pine Canyon fluorite. The most northerly (downslope) vein produced fluorite that was markedly different. The octahedrons were much smaller but were very sharp and often associated with light green cubes less than 1 cm. Virtually all of the fluorite from both areas was coated with a druse layer of quartz up to 1 mm thick. On the last day of excavating, a small section of the center vein produced some unusually sharp octahedrons that, upon cleaning, proved to have exceptional clarity. Some of the crystals also had a more prominent zone of green in the interior. These were the only crystals found that were suitable for faceting.

The maximum depth to which the excavator could break rock and remove material was 2.5-3 m. To reach deeper on the veins, drilling and blasting were used. Mark Kielbaso, our expert excavator operator, was also our premier driller and blaster. A series of 8 to 11 holes 3-ft-deep were drilled parallel to the veins. These were loaded with ANFO (ammonium nitrate-fuel oil) "bombs" (two 15-cm charges) and a Kinepac "trigger" and were set off simultaneously using det cord and a fuse and cap. This method allowed us to reach a maximum depth of about 4 m on the veins.

We commenced reclamation of the area in the afternoon of the 14th of July. All trenches were filled, and the slope was contoured to its original configuration. A U.S. Forest Service agent (Bob Schloss) inspected the area that afternoon and proclaimed that the reclamation effort was satisfactory. That evening, the specimens were divided according to our pre-arranged contract, and the packing of specimens for transport began. Everything but breaking camp was complete. All agreed that the dig was a great success. No one had been hurt, the equipment worked perfectly, we all got along well, and most importantly, a large number and volume of superb fluorite specimens had been recovered. It doesn't get better than that!

Reference

Gillerman, Elliot, 1952, Fluorspar deposits of Burro Mountains and vicinity, New Mexico: U.S. Geological Survey, Bulletin 973-F.

**Mineralogy and geochronology of the Mercur gold deposit, Utah**

(Location 2 on index map)

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The Mercur gold deposit is a sediment-hosted disseminated gold deposit in the southern Oquirrh Mountains of north-central Utah. The mine area consists of folded and faulted Paleozoic sedimentary rocks that were intruded by small igneous bodies during the Oligocene. Mineralization occurs in the Mississippian Great Blue Limestone. The upper half of the lower member of the Great Blue hosts most of the gold mineralization and is locally known as the Mercur Mine Series.

The deposit is characterized by the presence of As-, Fe-, TI-, Sb-, and Hg-minerals that occur in the unoxidized ore as sulfides and sulfosalts. Minerals at Mercur include realgar, orpiment, pyrite, marcasite, and the Tl-minerals lorandite, raguinite, gillulyite, and fangite. Both gillulyite, $Tl_2(As,Sb)_8S_{13}$, and fangite, $Tl_3AsS_4$, are new species identified at Mercur, and raguinite, $TIFeS_2$, is known from only one other locality. Cinnabar has been found at the deposit but has not been seen in recent mining activity. The Tl-Hg mineral christite has supposedly been found at Mercur as well. Other minerals found here include calcite, quartz, barite, and various antimony oxide pseudomorphs of stibnite.

Pyrite occurs as (1) euhedral grains, (2) irregular or rounded zoned grains, and (3) fine-grained "filigree" pyrite. Chemically pyrite can be divided into non-arsenian, moderately arsenian, and strongly arsenian categories. Gold is found in highest concentrations (avg. 0.1 wt %) in strongly arsenian pyrite. Realgar is common in the deposit and is usually observed being replaced by orpiment. Orpiment is common and can be divided into two geochemical groups based on relative content of minor elements: orpiment with low Tl-high Sb and orpiment with high Tl-low Sb.

K/Ar dating of hydrothermal illite, including ammonium-illite and tobelite, resulting from argillic alteration of limestone and shale throughout the Mercur district has resulted in dates ranging from 99 to 226 Ma. This age range is interpreted as resulting from a series of overprinted Mesozoic hydrothermal events. The age of gold mineralization is still not adequately determined but current data suggest about 150 Ma. The age data do not support a Tertiary age or a Tertiary intrusive model for gold mineralization. Combination of the age data with structural analysis by Kroko (1992) suggests that mineralization may have occurred during formation of the Ophir anticline.

Supplemental reading

Kroko, C. T., and Bruhn, R. H., 1992, Structural controls on gold distribution, Mercur gold deposit, Tooele County, Utah: Utah Geological Survey, Miscellaneous Publication 92-3, pp. 325-332.

Wilson, J. R., and Wilson, P. N., 1992, Sulfide and sulfosalt mineralogy at the Mercur gold deposit, Tooele County, Utah: Utah Geological Survey, Miscellaneous Publication 92-3, pp. 343-348.

Wilson, P. N., Parry, W. T., and Nash, W. P., 1992, Characterization of hydrothermal tobelitic veins from black shale, Oquirrh Mountains, Utah: Clays and Clay Minerals, v. 40, pp. 405-420.

Wilson, P. N., and Parry, W. T., 1993, Characterization of argillic alteration and K/Ar dating of illite at the Mercur gold mine, Utah: further evidence for a Mesozoic age of gold mineralization: Utah Geological Survey, Miscellaneous Publication 93-5, 26 pp.

# Geology and mineralogy of the Jarilla (Orogrande) mining district, New Mexico

(Location 3 on index map)

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Virgil W. Lueth (signed)
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The Jarilla or Orogrande mining district is in the Jarilla Mountains in south-central New Mexico. The district is near the town of Orogrande, 46 mi northeast of El Paso, Texas and 35 mi south of Alamogordo, New Mexico on US-54. The district has been the site of modest metal production but has always held a lure for mineral collectors, exploration geologists, and promoters. The name Orogrande (Spanish for large gold) alludes to a tale about the origin of serious exploration in the district after a large nugget was found by placer mining. It is still not clear if the 6-7-oz nugget was actually found in place or if the place was salted with the nugget to stimulate mining activity in the district. The nugget is reported to still exist in a private collection.

The district is in a horst block in the center of the Tularosa Basin. The district consists of an elongate structural dome centered about a granite stock of Tertiary age. Flanking the dome are sedimentary rocks of Paleozoic age, mainly shales and carbonates. Igneous dikes are most common in the northern and southern parts of the range and intrude both the stock and sedimentary rocks. Contact metamorphism is common at the contacts of the granite stock and limestones. This metamorphism hosts most mineralization thus far discovered in the district. The district has been the target for porphyry copper mineralization in the main intrusive mass. Basin and Range-type faulting has produced minor complications in the geologic structure of the district and exposed the horst block that forms the Jarilla Mountains. The mountains were later dissected by streams that produced a number of arroyos and small canyons and led to the formation of the placer deposits.

More than 41 minerals have been identified in the district. Each is associated with a particular episode of ore mineralization. In addition to the primary minerals commonly found in limestones, shales, and granites, many contact metamorphic, skarn, and ore sulfide minerals are found. Weathering of the ore deposits produced secondary minerals, mainly copper types that display striking color contrasts with their matrix material.

Primary minerals, formed directly from crystallization of igneous rocks, include fine orthoclase crystals. The crystals can be found as single crystals or as complex twins from the unit mapped as orthoclase adamellite by Schmidt and Craddock (1964). These crystals can be found in pod-shaped bodies near the Little Joe workings. In addition, a large dike of the granite porphyry is found through the center of the range in a north-south orientation. The best collecting is along this dike, which displays a distinct chill zone on the margin and large megacrysts of orthoclase in the center.

Interactions of magmatic fluids with carbonate host rocks produced large-scale metamorphism of the limestones. Minerals from the contact metamorphic suites include euhedral specimens of both garnet and magnetite that can be found mainly in the southern part of the district. Euhedral magnetite crystals (2.5 cm on edge) replaced by hematite (as "martite" pseudomorphs) can be collected on the hill above the Lucky mine workings. Euhedral, but discolored garnets with numerous inclusions of calcite and pyroxene can also be found at this location. South of the Lucky mine, immediately across the road at the Lincoln workings, are prospects where small hematite roses (0.3 cm diameter) can be found on the dumps or underground. Reddish-brown grossular to andradite garnets can be separated from calcite at the Cinco de Mayo, Iron Duke, Iron Queen, and Iron King mines. The garnets occur as individual grains or as complex intergrowths.

Secondary minerals, formed by the weathering of earlier-formed species, are common in the district. The district is renowned for turquoise, which is still produced from the "turquoise workings," part of the old Iron Mask workings. Chrysocolla and malachite form lovely specimens on black manganese oxides and tenorite from the large stope in the Lucky mine. Often, clear scalenohedrons of calcite formed over the chrysocolla or malachite.

The easy access to the mines makes the Jarilla district a favorite of weekend collectors and geology students. Many collectors visit the area annually and still manage to find good material. Recently reported finds of quartz crystals with chlorite inclusions continue to add lure to the district. Some workings in the district are rarely visited by the "weekenders" and represent a good prospecting target for the more adventurous. Prospectors should have in hand the publication of Schmidt and Craddock (1964), the NMBMMR Open-file Report 370 by Robert North, USGS Orogrande North 71/2-min quadrangle map, and plenty of water.

References

North, R. M., 1982, Geology and ore deposits of the Orogrande mining district, Otero County, New Mexico: New Mexico Bureau of Mines and Mineral Resources, Open-file Report 370, 18 pp.

Schmidt, P. G., and Craddock, C., 1964, The geology of the Jarilla Mountains, Otero County, New Mexico: New Mexico Bureau of Mines and Mineral Resources, Bulletin 82, 55 pp.

## Theisite and associated minerals from near Durango, Colorado

(Location 4 on index map)

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In 1980 Joe Taggart and Eugene Foord identified austinite, beta-duftite, and conichalcite from Tucker's tunnel in Hinsdale County, Colorado. In 1981 Nick Theis and Mike Madson discovered what turned out to be a new mineral at this locality. Material was sent to Sid Williams for analysis, and he identified the new mineral theisite, along with several other minerals. The other minerals were adamite, anglesite, azurite, barite, calcite, cerussite, chalcocite, chrysocolla, covellite, cuprite, duftite, galena, hemimorphite, kolwezite, malachite, partzite, quartz, sphalerite, tenorite, tetrahedrite, uraninite, and zeunerite.

Later investigations by Robert Cobban and Jack Murphy found the mineral aurichalcite. More recently, the author has collected numerous samples and sent some of them to Paul Hlava for analysis. This work has resulted in the addition of still more species. These include cinnabar, olivenite, tennantite, and willemite. This brings the species tally up to 30.

The locality is on the USGS Granite Peak 71/2-min quadrangle map in NE1/4NE1/4 sec. 13 T37N R6W. It is reached by taking Middle Mountain Road from the northeast edge of Vallecito Reservoir to Tuckerville, and then south 1 mi to the mine. The tunnel is collapsed, but samples with microscopic crystals can be found sparingly on the small dump. All theisite needs to be tested with acid to distinguish it from aurichalcite.

Special thanks to Paul Hlava for his analysis.

Supplemental reading

Schmitt, L. J., and Raymond, W. H., 1977, Geology and mineral deposits of the Needle Mountains district, southwestern Colorado: U.S. Geological Survey, Bulletin 1434, 40 pp.

Smith, D. A., 1982, Song of the Hammer and Drill: Colorado School of Mines Press, pp. 174-175.

Steven, T. A., Schmitt, L. J., Jr., Sheridan, M. J., and Williams, F. E., 1969, Mineral resources of the San Juan Primitive Area, Colorado: U.S. Geological Survey, Bulletin 1261-F, 113 pp.

Taggart, J. E., Jr., and Foord, E. E., 1980, Conichalcite, cuprian austinite, and plumbian conichalcite from La Plata County, Colorado: Mineralogical Record, v. 11, no. 1, pp. 37-38.

Theis, N. J., Madson, M. E., Rosenlund, G. C., Reinhart, W. R., and Gardner, H. A., 1981, National Uranium Resource Evaluation, Durango quadrangle, Colorado: Bendix Field Engineering Corporation, Grand Junction, Colorado. Williams, S. A., 1982, Theisite, a new mineral from Colorado: Mineralogical Magazine, v. 46, no. 338, pp. 49-50.

## Update of the *Mineralogy of Arizona*

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There are 810 mineral species described from Arizona in the second edition of the *Mineralogy of Arizona* (Anthony, Williams, Bideaux, and Grant, in press). The first edition published in 1977 had 584 mineral species listed for Arizona; 226 minerals, an average of 14 minerals per year, have been added for the last 16 years. There are several reasons for this increase in the rate of identification and discovery of new minerals in Arizona. They include better techniques for mineral identification with the use of equipment like the electron microprobe, a high level of interest in rare minerals by mineral collectors, and the detailed study of some unusual mineral deposits found in Arizona. These deposits include the pegmatites of the Basin and Range, the breccia pipes of the Colorado Plateau, and the Campbell sulfide deposit at Bisbee.

Granite pegmatites are widespread throughout Arizona. They are abundant in the older Precambrian terrain of the Grand Canyon and in the Precambrian rocks of the Arizona pegmatite belt. This area, from the northwest corner of Arizona trending 250 mi southeast to the Phoenix area, encompasses part of the Transition zone and the Basin and Range Province. More than 120 different minerals have been reported from pegmatites in Arizona. Many of these minerals are the result of a complex sequence of alteration of the primary pegmatite minerals.

The Hack 1, Hack 2, Hack 3, Hermit, Pigeon, and Kanab North breccia pipes were all brought into production as uranium mines in the 1980s. These breccia pipes are concentrated on the Colorado Plateau between the Grand Wash Cliffs and the Echo Cliffs and along both the north and south sides of the Colorado River. The uranium concentrations in the ore can be high: 0.3 to 0.6% uranium oxide or higher. Other elements that are enriched in these deposits include Sb, As, Ba, Cd, Cr, Cs, Cu, Co, Ga, Ge, **Pb,** Hg, Mo, Ni, Se, Ag, Sr, V, and Zn. The concentration of so many elements and the subsequent oxidation of some of these deposits have resulted in the formation of a large number of minerals. More than 100 minerals have been reported from these deposits.

Since mining began in the Bisbee area in 1877, more than 290 minerals have been found, making it the locality with the most mineral species in Arizona. Recent research in the area has been concentrated on the Campbell orebody. This orebody is a replacement of a limestone breccia by massive sulfides. The sulfide body—mainly pyrite with either chalcopyrite or bornite—contains small amounts of many rare Au, Ag, Bi, Cu, Hg, Ni, Sn, and Zn sulfides and tellurides.

**Minerals of Utah**

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Mineral collectors have been very active in Utah over the past decade, resulting in many new species and new discoveries at old locations. New species resulting from this collecting activity include gillulyite, fangite, tooelite, and haynesite. In addition, there are several other potential new species currently being characterized. Many more species new to Utah have also been discovered.

Traditionally Utah has been famous for the topaz, bixbyite, and red beryl that occur together in the Thomas Range and the gem-quality red beryl in the Wah Wah Range. The Thomas Range has recently produced the rare mineral durangite, red beryl with a rosette habit, and large lustrous garnets (5 cm or more). One or more new species are being described from the area.

New material and resurfacing old material has reached collectors from the famous mining sites of the Bingham open-pit copper mine (faustite, wavellite, okenite, and zeolites) and Park City (pyrite and tetrahedrite). Processing of the old ore dumps in the Tintic district is yielding many micro- to thumbnail-size specimens of arsenates, including some new species. Likewise, the Gold Hill district is still providing arsenates and other material to collectors, including a new locality for phillipsburgite and the new mineral tooelite.

Claimholders in the Dugway geode beds have excavated many geodes recently, showing that there are significant quantities of material still available, albeit too deep for most individual diggers. Another geode locality in Utah is along the east side of the San Rafael Swell where agate nodules in shale are often found to contain crystals of celestite, barite, and quartz.

Other traditional localities for Utah collectors such as the iron mines near Cedar City, the uranium mines of southeastern Utah, and the jasper-bearing gravels from Green River to Moab are still producing specimens.

An illustrated article on recent collecting can be found in *Rocks and Minerals* (Richardson et al., 1993) and a new book on collecting localities in the state will be available soon (Wilson, in press).

References

Richardson, P. D., Wilson, J. R., and Wilson, P. N., 1993, An overview of recent mineral collecting in Utah: Rocks and Minerals, v. 68, no. 6, pp. 381-393.

Wilson, J. R., in press, The collector's guide to rocks, minerals, and fossils of Utah: Utah Geological Survey, Miscellaneous Publication, Salt Lake City, Utah.

## Zunyite and other minerals of the Zuni mine, San Juan County, Colorado

(Location 5 on index map)

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The Zuni mine is about three mi northwest of Silverton in the San Juan Mountains of southwestern Colorado and is the type locality for zunyite and guitermanite(?). Both of these minerals were described in 1884 by Hillebrand although the validity of guitermanite(?) as a mineral species is presently uncertain. The mine is near timberline on the south face of Anvil Mountain at elevations ranging from about 11,800 to 12,000 ft. Collecting is limited mainly to the summer months, from early July to late September, because of winter snow accumulations.

The Zuni mine lies in a geologically complex region referred to as the western San Juan caldera complex that locally includes the Silverton, San Juan, Uncompagahgre, and Lake City calderas. The entire caldera complex developed in the Oligocene-Miocene in a large cluster of earlier intermediate-composition stratovolcanoes that, at minimum, include the Cow Creek, Larsen, Carson, and Cimarron centers (Sanford, 1992). The mine is near the 26-27 Ma Sultan Mountain stock that intruded along the ring-faulted margin forming the southern and southwestern edges of both the San Juan and Silverton calderas (Hon and Lipman, 1989). Hydrothermal solutions rising along the faulted rim belt have extensively altered the volcanic rocks forming the southern slopes of Anvil Mountain (Molenaar et al., 1968).

The Zuni was originally located in 1881 as a silver mine. The property consists of five patented claims covering approximately 50 acres (Groben, 1976). Workings consist of an upper and a lower adit, a shaft, and a small open cut near the portal of the upper tunnel. Upper and lower workings are separated by about 200 vertical ft with no connection between them (Ransome, 1901). None of the underground workings are presently accessible. This mine exploited a small Ag-Pb-Cu orebody trending N15°W and dipping 75-80° westward (Ransome, 1901). The deposit, possibly a small breccia pipe (Hillebrand, 1884), is hosted by lathes and andesites of the Silverton Volcanic Series (Ransome, 1901). Country rock adjacent to the deposit has been subjected to advanced argillic alteration and contains ubiquitous disseminated pyrite.

Zunyite, quartz, pyrite and possibly enargite occur in attractive crystals of interest to micromount collectors. At the end of this abstract, we have included a page of drawings illustrating the wide variety of morphologies exhibited by the zunyite and pyrite crystals. Other minerals previously reported from the Zuni mine include anglesite, barite, bournonite, cosalite, dickite, galena, guitermanite(?) (presently under re-investigation), jordanite, kaolinite, pearceite, and native sulfur. To this list we can add acanthite, alunite, anatase(?), apatite, bornite, kuramite (first recorded occurrence in Colorado), sphalerite, stibnite, and an unknown Pb-As sulfide, which were all observed during micromount or microprobe studies.

| Native Elements | Sulphosalts | Sulfates |
|---|---|---|
| sulfur | bournonite | alunite |
| | cosalite | anglesite |
| | enargite | barite |
| **Sulfides** | guitermanite(?) | |
| acanthite | jordanite | **Phosphates** |
| bornite | kuramite | apatite |
| galena | pearceite | |
| pyrite | sartorite | **Silicates** |
| sphalerite | unknown Pb-As sulfide | dickite |
| stibnite | | kaolinite |
| | **Oxides** | quartz |
| | anatase(?) | zunyite |

**Acknowledgments**

The authors thank Patrick E. Haynes of Cortez, Colorado for helpful discussions of the mineralogy of the Zuni mine and for the donation of several specimens examined in this study. We also wish to thank Jack Murphy of the Denver Museum of Natural History for the loan of a piece of sample DMNH#547 for analysis and for discussions of the mineralogy of this mine and the area around it. The crystal drawings were produced using the SHAPE° crystal drawing program (copyright by Eric Dowty and R. Peter Richards, 1987 & 1988).

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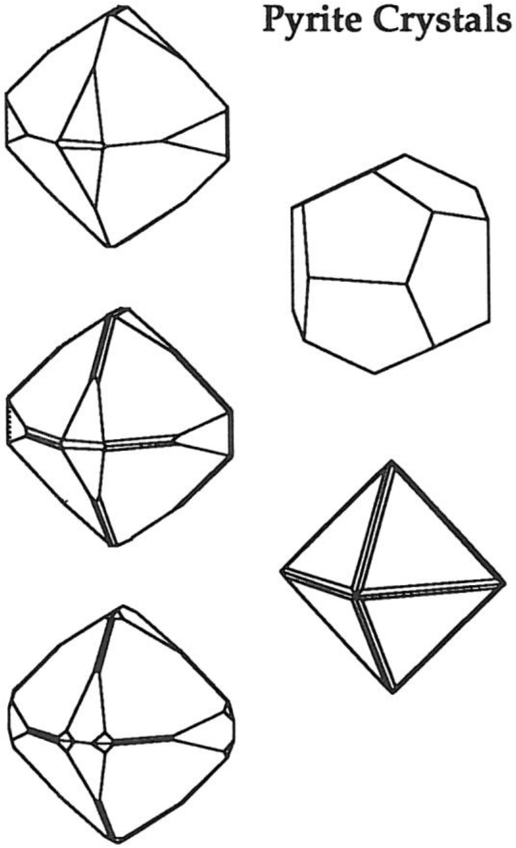
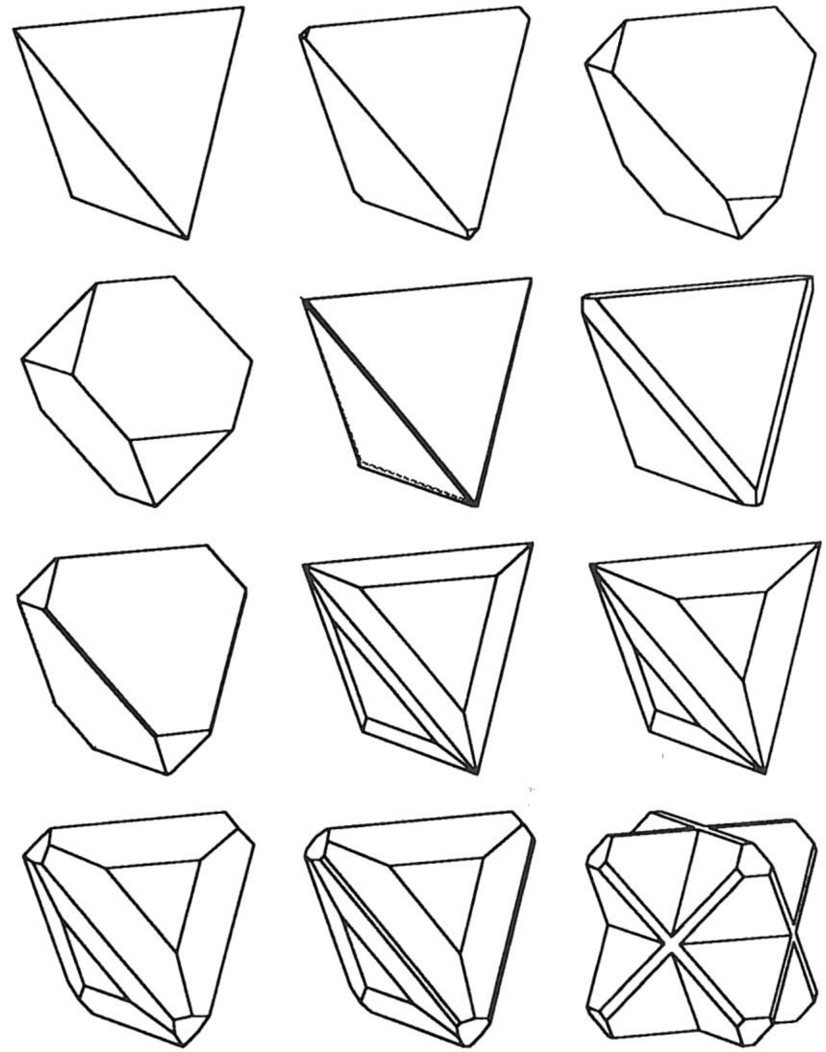
## Pyrite Crystals



## Zunyite Crystals



A series of drawings showing a selection of Zuni mine pyrite crystal morphologies and zunyite crystal morphologies. Most of the pyrites are dominated by the octahedron and are modified by a variety of small faces belonging to several pyritohedra, a trisoctahedron, the cube, and a trapezohedron. The zunyite crystals are dominantly positive tetrahedra which are usually modified by the negative tetrahedron, the cube, and a tristetrahedron.

**The "precious" gems:**
**where they occur—how they are mined**

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Although today the gem trade encourages jewelers and the public to consider all gems precious, four gems historically stood above the others with special allure, beauty, and value. Throughout the world, diamonds, emeralds, rubies, and sapphires are known as precious. They are the gems against which all others are measured.

While writing and photographing the *National Geographic* gemstone series for 14 years, I had the opportunity to make field trips to and do extensive work around the major mines for all four precious gems. Those experiences emphasized the similarities and differences in exploration, in the deposits themselves, and in extraction. Of the four, only rubies and sapphires, which are both corundum crystals with trace-element-induced color variations, occur together.

Diamonds are unique, not only for their unprecedented hardness and heat conductivity but because of their delivery system to the earth's surface. No matter where they were formed under the earth's crust, they have to be propelled to or near the surface via a volcano for us to ever find them. Diamonds can be profitably mined either by locating the primary source, the diamond-bearing volcanic pipe, or by locating alluvial deposits where the gems have washed. South Africa's inland mines and those in Botswana, Russia, and Australia are examples of primary deposits whereas the Namibian coast, Angola, and the Ivory Coast illustrate secondary, or alluvial, deposits.

Although tunneling is sometimes used for gems (South African diamond mines, two or three tunnels at Colombia's Muzo emerald mine, and a pair of ruby tunnels in Mogok, Burma), the vast majority of gems are extracted in opencast mines or from small operations in river or stream beds. This is in sharp contrast to ore mining and illustrates the differences between gem crystal deposits and precious metals, for instance.

Also in contrast to diamond mining, which is often done by large companies or governments, individuals and small operators mine most colored stones. In fact, to assure this occurs and that its gem deposits provide income to local workers for decades, Sri Lanka prohibits the use of machinery. In Brazil, the world's largest volume producer of emeralds, claims are only 10 x 10 m, 100 $m^2$. In Zambia, Pakistan, Afghanistan, Kenya, Tanzania, Thailand, Cambodia, and a host of Third World counties, picks, shovels, and buckets are the means for bringing gems to market.

## New Mexico garnets: mineralogical beauty and economic potential

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Six species of garnets are reported in New Mexico in a wide range of geologic environments. Garnets are most commonly found in metamorphic rocks as almandine, andradite, or grossular. Igneous-formed garnets, as the species pyrope, almandine, and spessartine, are also found in the state. Clastic sedimentary rocks also contain garnets as detrital grains, but these garnets are not found in any significant concentration. Mineralogical and geological descriptions of individual garnet species are presented along with specific collecting locations.

**Almandine** [$Fe_2^{+2}Al_2(SiO_4)_3$]—Almandine garnets are most commonly found in mica schists and gneisses in the Proterozoic rocks in the northern part of the state. Crystals are typically isolated, euhedral, and embedded in mica schist. Most often the crystals contain many inclusions of mica, quartz, and feldspar that detract from their appearance. Tedious physical removal of the host rock by scraping is often required to expose the grains. The best collecting localities for almandine include the schists of Mora and San Miguel Counties. Fine crystals are found in the Picuris Range of Taos County. Igneous occurrences of almandine include the Capitan Mountains of Lincoln County and the pegmatites of the Petaca district in Rio Arriba County. Igneous-formed garnets are rarely of specimen grade because of the difficulty in removing host rock material and the poor condition of the material. The dispersed nature of the garnets along with their small size prevents mining of these types of garnets in New Mexico.

**Spessartine [**$Mn_3^{+2}Al_2(SiO_4)_3$]—Spessartine garnet ranging from yellow to black is most often found in igneous rocks. Topaz rhyolites of the East Grants Ridge district host very fine red to brown microspecimens along with topaz. Yellow to red spessartine garnets are found in the Petaca district as large masses in pegmatite and as individual grains in the host schists immediately adjacent to the pegmatites. Euhedral crystals up to a centimeter diameter are found in the bordering schists. Spessartine exhibits a complete solid solution with other garnets and is found as a significant component in the andradite garnets associated with the zinc skarns in the Central district of Grant County. The rarity of this species precludes any practical utilization of this mineral.

**Pyrope** [$Mg_3Al_2(SiO_4)_3$]—Pyrope garnets are derived from mafic to ultramafic rocks and represent New Mexico's most famous gemstone other than turquoise. These stones have been collected on the Navajo Reservation of northwestern New Mexico since before the arrival of the Spaniards. Commonly known as "Arizona rubies," many fine stones have been found and are described in a number of gemstone publications. The garnets are found as loose grains, often on ant or scorpion mounds. The garnets are weathered from mafic breccia dikes and further concentrated by eolian processes in the desert. The concentrations are not great, and the stones are small and fractured. However, facetable material can still be found in McKinley and San Juan Counties. The volume of pyrope garnet in the state is very small.

**Grossular** [$Ca_3Al_2(SiO_4)_3$]—Contact metamorphic deposits are the most common host rock for grossular garnets. The most favorable protolith consists of argillaceous limestones or limy siltstones or marls. The best specimens of this garnet are most often found at the marble/garnet interface of contact metasomatic deposits. Grossular is one of the most common garnets of New Mexico, found in many skarn deposits of the southern part of the state. The mineral displays a range of colors from light **yellow to** brown. Near-gem-quality stones of *essonite* occur at Orogrande in Otero County and in the Hanover-Fierro district of Grant County. Grossular forms a complete solid solution with andradite. Accordingly large masses of mixed "grandite" occur in place and in tailing piles in many mining districts of the state. These large masses of garnet represent a potential resource, as yet untapped.

**Andradite** [$Ca_3Fe_2^{+2}(SiO_4)_3$—Andradite is a contact metasomatic mineral common in large skarn deposits where it often overgrows earlier-formed grossular. It is the most abundant type of garnet in the state. It is usually found in massive layers, and crystal face development is limited. Green *demantoid-like* andradite is known from the Continental open pit at Fierro although it is badly fractured and often contains inclusions. Most andradite is red brown, massive, and fractured. Large masses of this variety of garnet, in place and on dumps, represent the largest garnet resource in the state. Unfortunately, andradite is often fractured, has overgrowths, and contains foreign mineral inclusions that affect its physical properties. Feasibility studies of individual deposits or dumps will be required to utilize this type of garnet.

**Uvarovite** [$Ca_3Cr_2(SiO_4)_3$]—Uvarovite is a bright-green variety of garnet that is only found in very small grains. A single report of uvarovite is known in the state. The locality is in the South Canyon district in Doria Ana County on the White Sands Missile Range. The uvarovite is reported to be in a limestone xenolith. The district is off limits to the public.

In the past, garnet was of interest only to the gem and mineral collector. Mining companies considered the mineral to be part of the gangue assemblage. Today, interest is being shown in using garnet in industrial applications. Garnet has been used as an abrasive, a common use for the mineral for years, and is finding application in newer hydroblasting technologies. A more recent use of the mineral is for granular filter media. Large-scale filter beds are used for sewage and water purification. The angular particles of garnet do not settle upon repeated episodes of filter backwashing. Thus the filter bed does not need to be replenished as often as more common sand filter beds. A large quantity of premilled garnet exists in many tailings piles, especially in the skarn deposits of the southwest part of the state. These tailing piles represent a potential resource, and their use could help defray the cost of cleanup in some mine dumps. Royalstar Industries is currently awaiting approval to mine garnet at San Pedro in Santa Fe County for abrasive grit and sand-blasting material.

## A re-examination of bixbyite from the Thomas Range, Juab County, Utah and the Black Range tin district, Sierra and Catron Counties, New Mexico

(Location 6 on index map)


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Bixbyite, $(Fe,Mn)^{3+}{}_20_3$, occurs in Tertiary lithophysal rhyolite at a number of localities in the Thomas Range, Juab County, Utah and in the Black Range, Sierra and Catron Counties, New Mexico. Associated minerals may include hematite, quartz, sanidine, beryl, topaz, pseudobrookite, and rare amounts of other minerals.

Bixbyite is an example of an ion-deficient fluorite structure, with one-fourth of the anion sites vacant: pure a-$Mn_20_3$ (`partridgeite') is orthorhombic, but all natural bixbyite is cubic because of the stabilizing effects of even a small amount of ferric iron (approximately >0.75 mol% Fe).

Bixbyite from two localities in the north end of the Thomas Range (Cubic Claim and Pismire Knolls) and from five localities in the Black Range (Alexander, 'the clearing' near Boiler Peak, Easter Canyon, Inman South, and Paramount Canyon) were examined in this study. Bixbyite from the Thomas Range (TR) is Fe-dominant and shows only minor compositional variation with a small but distinct Mn-enrichment at the cessation of crystallization. Substitution of other elements is relatively minor (Table 1). Bixbyite crystals from the Black Range tin district **(BRTD),** however, generally are Mn-dominant and often are intergrown with braunite, $Mn^{2+}Mn^{3+}{}_6Si0_{12}$. A crystal of bixbyite from `the clearing' contains <0.1 wt % $SiO_2$ except for the presence of a few small growth zones with up to 2.1 wt% $SiO_2$. The crystal shows no Mn-enrichment trend. A crystal from Easter Canyon contains small amounts of braunite and also shows no Mn-enrichment. Three crystals from Alexander Cienega show discrete and major amounts of intergrown braunite (to 9.9 wt% $SiO_2$). Three crystals from Inman South show variable amounts of intergrown Fe-dominant bixbyite and braunite. Five crystals of bixbyite from Paramount Canyon show discrete and well-resolved alternating growth zones of bixbyite and braunite. Zoning patterns are intricate and show periods of rapid alteration as well as areas of single-phase braunite or bixbyite. Compositions of bixbyites from the literature as well as from this study are shown in Fig. 1.

Braunite previously had not been reported from the **BRTD.** The presence of braunite in most of the **BRTD** samples and its absence in the TR samples is interpreted to indicate significant differences in the degree of oxidation during crystallization and also in the activity of $SiO_2$. It should be noted that some minor elements such as Cu, Zn, and REEs have not previously been reported from bixbyite. The bixbyite from the TR contains more Al (average of 1.9 wt % $Al_20_3$) than that from the **BRTD** (average of 0.4 wt% $Al_20_3$). $TiO_2$ contents in bixbyite are comparable between the two areas. According to the published phase-equilibria diagrams of the system $Fe_20_3$-$Mn_20_3$, bixbyite from the TR is stable below about 970°C whereas that of the BRTD is stable at a slightly lower temperature (960°C). Both are stable above 650°C.

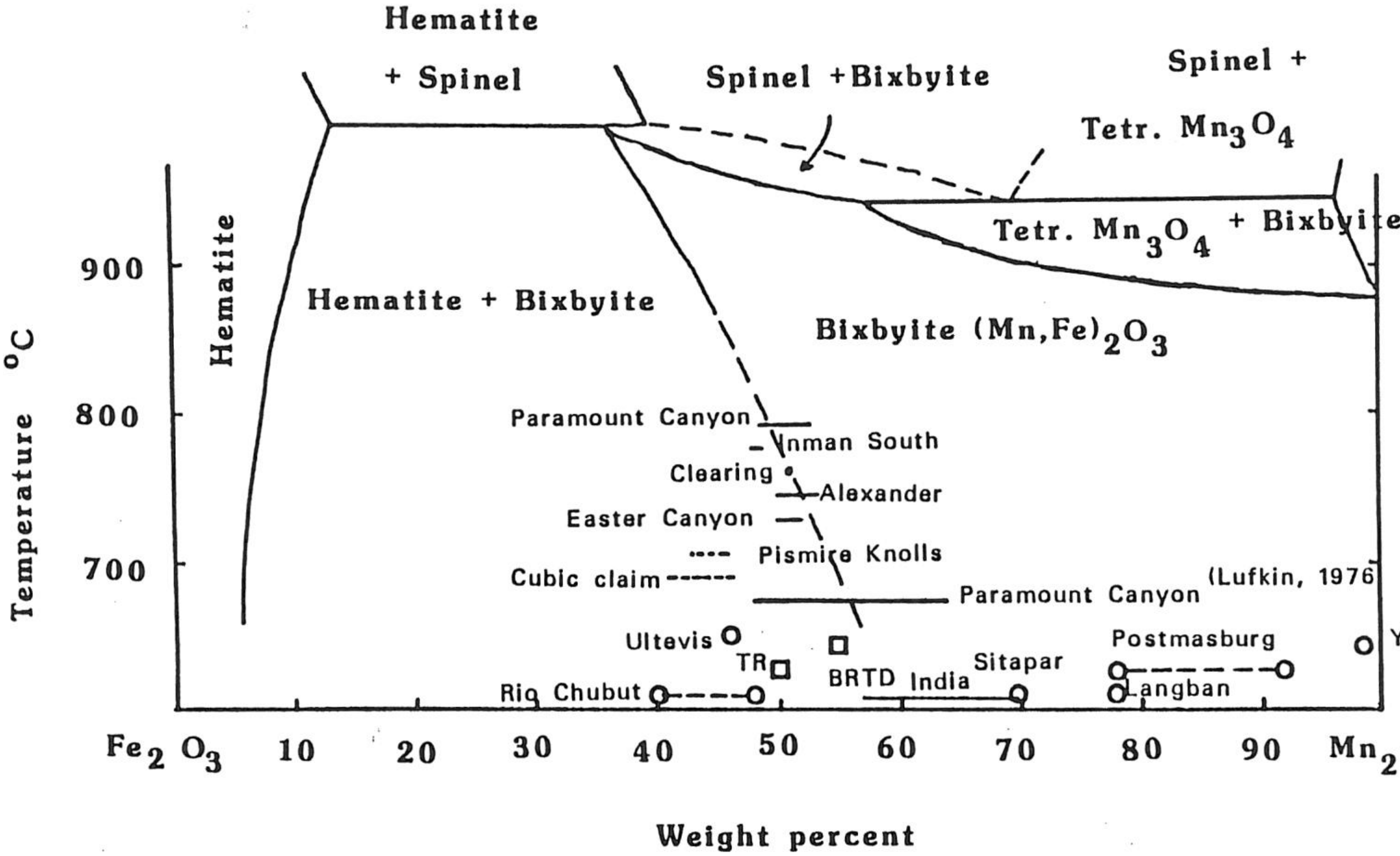
The nomenclature of bixbyite needs to be addressed by the CNNMMN IMA. Type material from Utah is Fe-dominant whereas most of that from New Mexico is Mn-dominant. Extremely Mn-rich bixbyite occurs in manganese deposits elsewhere in the world, and the name partridgeite has been used unofficially for the orthorhombic end-member $Mn_20_3$.

Table 1—Electron-microprobe analyses of bixbyite from Utah and New Mexico. Data is reported in wt%.

| Locality | MgO | $Al_2O_3$ | $SiO_2$ | $TiO_2$ | $Mn_2O_3$ | $Fe_2O_3$ | ZnO | $SnO_2$ | $Ce_2O_3$ | Total |
|---|---|---|---|---|---|---|---|---|---|---|
| Cubic Claim 1+ rim | 0.13 | 2.10 | 0.2 | 1.3 | 46.5 | 50.0 | -- | -- | -- | 100.40 |
| Cubic Claim 1 core | 0.12 | 2.10 | 0.3 | 1.9 | 42.0 | 54.0 | -- | -- | -- | 100.42 |
| Cubic Claim 2 rim | 0.10 | 1.8 | 0.1 | 1.6 | 43.0 | 53.5 | -- | -- | -- | 100.1 |
| Cubic Claim 2 core | 0.13 | 2.0 | 0.1 | 1.9 | 41.0 | 55.5 | -- | -- | -- | 100.63 |
| Pismire Knolls 1 rim | 0.17 | 1.85 | 0.35 | 1.40 | 45.8 | 51.5 | -- | -- | -- | 101.07 |
| Pismire Knolls 1 core | 0.15 | 1.80 | 0.10 | 2.00 | 43.0 | 53.5 | -- | -- | -- | 100.55 |
| Pismire Knolls 2 rim | 0.14 | 1.85 | 0.3 | 1.4 | 46.0 | 50.6 | -- | -- | -- | 100.19 |
| Pismire Knolls 2 core | 0.14 | 1.65 | 0.1 | 2.0 | 43.0 | 53.5 | -- | -- | -- | 100.39 |
| Easter Canyon | 0.10 | 1.4 | 0.0 | 2.0 | 48.0 | 48.0 | 0.3 | 0.0 | 0.0 | 99.8 |
| Easter Canyon | 0.10 | 1.3 | 0.0 | 2.8 | 50.2 | 45.3 | 0.2 | 0.0 | 0.0 | 99.9 |
| Alexander 1 | 0.06 | 0.11 | 0.0 | 1.5 | 51.4 | 45.2 | 0.3 | 1.0 | 0.18 | 99.75 |
| Alexander 2 | 0.09 | 0.11 | 0.14 | 1.3 | 50.5 | 46.6 | 0.32 | 0.95 | 0.18 | 100.19 |
| Alexander 3 | 0.08 | 0.12 | 0.0 | 1.8 | 48.8 | 47.5 | 0.4 | 0.7 | 0.17 | 99.57 |
| "Clearing" | 0.10 | 1.1 | 0.0 | 2.4 | 49.5 | 46.4 | 0.2 | 0.0 | 0.14 | 99.84 |
| Inman South 1 | 0.07 | 0.61 | 0.06 | 0.37 | 48.1 | 50.3 | 0.0 | 1.4 | 0.07 | 100.98 |
| Inman South 2 | 0.09 | 0.52 | 0.0 | 1.2 | 46.1 | 52.0 | 0.0 | 1.2 | 0.10 | 101.21 |
| Paramount Canyon 1* | 0.12 | 0.15 | 0.05 | 1.5 | 51.8 | 45.8 | 0.3 | 0.5 | 0.16 | 100.53 |
| Paramount Canyon 2a | 0.2 | 0.2 | 0.2 | 1.8 | 50.2 | 46.5 | 0.3 | 0.45 | 0.19 | 100.04 |
| Paramount Canyon 2b | 0.23 | 0.16 | 0.1 | 2.2 | 48.5 | 48.0 | 0.3 | 0.65 | 0.18 | 100.32 |
| Paramount Canyon 2c | 0.25 | 0.16 | 0.0 | 2.2 | 48.4 | 48.1 | 0.3 | 0.6 | 0.16 | 100.17 |
| Paramount Canyon 3 | 0.2 | 0.24 | 0.05 | 2.1 | 52.5 | 45.0 | 0.3 | 0.45 | 0.17 | 101.01 |
| Paramount Canyon 4 | 0.3 | 0.17 | 0.05 | 2.4 | 47.5 | 49.2 | 0.25 | 0.70 | 0.16 | 100.73 |
| Paramount Canyon 5 | 0.06 | 0.14 | 0.0 | 2.0 | 50.0 | 47.0 | 0.3 | 0.5 | 0.18 | 100.18 |

+ Total includes 0.03 wt% $Ce_2O_3$, 0.04 wt% $Sc_2O_3$, 0.07 wt% $SnO_2$, and 0.03 wt% ZnO (ICP-AES analysis).
* Total includes 0.15 wt% CuO.

Figure 1. Compositions of bixbyite from various world-wide localities compiled from the literature and from this study.



**Fluorite mining**
**Castleton, Derbyshire, England**

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**History—**The Peak district of north central England includes some of the oldest mines in Europe with mining artifacts dating back to the Roman period (2nd Century A.D.). The Peak district is one of the richest mineral districts (debatable) in United Kingdom with more than 280 localized mines, soughs, rakes, and veins. (Soughs are adits or tunnels driven specifically to drain a mine and in which workable veins were found. Rakes are the main type of mineral vein in the Peak district. Veins are orebodies enclosed by the host rock.) The mines in the district were worked exclusively for lead. By 1750 new mining techniques had been introduced, particularly steam power, and mining activity had reached its peak. By 1940 most of the lead veins had been worked out, but the mines were worked for fluorite (fluorspar) so necessary in the war effort. Today lead is produced as a by-product in the mining of fluorspar.

In the district is found one of the two world occurrences of a fibrous banded fluorite known as Blue John. The first source, locality unknown, is between Turkey and Syria. This was reported in the form of two goblets found in a grave. Although of fibrous material, the banding does not resemble that of Blue John. Similar material is now coming from China in association with pyrite. (As yet I have not seen it being used in lapidary items.) The second occurrence of fluorite known as Blue John is found in only one cavern, Treak Cliff, yet there are four caverns at Castleton! The first mention of Blue John is in 1743 when a local "carver" was commissioned to make a vase from a block of fluorite stalagmite! It is recorded by the King's Barmaster (the Crown agent for lead mining) that the source had 16 windlasses set over separate shafts.

Mining of Blue John from Treak Cliff Cavern continues to this day, although the cavern is open to visitors! It is mined during the off season. Average annual production is approximately half a ton, although during the last century up to 20 tons a year were reported! Blue John is used exclusively in lapidary items such as bowls, urns, goblets, inlay tile, and jewelry. The largest one-piece bowl was 20 inches in diameter and was made in 1835. A vase in the Geology Museum in London was made in 1840 and is 30 inches high.

**Mining—**The mining is done by hand. The veins are approached from the side by removing limestone blocks with hammer and wedges. In a unique mining method, holes are drilled by hand and packed with wooden wedges, and a steel wedge is driven down the middle. If the wooden wedges are **dry and are** then soaked with water and left overnight to swell, they will crack solid limestone.

**Geology—**The mineral veins of the Peak district are contained in the Carboniferous limestone and associated basalt lavas. Castleton lies at the northern extremity of the limestone massif. As a result of the action of water over time the area around Castleton is fissured by caverns. The district **was part of an Inland Sea** as evidenced by many marine fossils. In fact the district is known as the "Paleontologist's Treasure House". There are four caves that can be visited by the public. The great cave is Peak Cavern with an inner chamber 100 ft high and floor length almost a mile. This cavern is noted for its typical wet cave deposits of stalagtitic formations. The second cave, of definite interest to mining historians, is Speedwell Cavern/Mine. This was a working mine in the 1700s, and underground movement of waste rock and lead ore was by boat. Tours of this cavern are still by boat. Treak Cliff Cavern, which has the Blue John deposit, consists of a series of rooms that are appropriately named Witches Cave, Aladdin's Cave, Fairyland, Dream Cave, and the Dome of St. Paul. At the dome the visitor is some 160 ft below the surface. Veins of Blue John are seen throughout the progression of rooms. The vein does not reach the surface, hence mining is done on the inside.

**Mineralogy—**Minerals of the district include, galena, sphalerite, barite, calcite, and fluorite. The proportions of these in the various deposits vary considerably, and in Treak Cliff fluorspar is dominant. Blue John is "an unusual variety of fluorspar. When pure it is white or colorless, but varieties of all colors are known - red, pink, yellow, green, blue and purple. In all these one or more impurities included within the fluorspar either stain or influence their light-reflecting properties." In Blue John the impurity is oil. The rough surface of Blue John shows the typical cubic structure. When cut, its banding has shades of light and dark blue, purple, and almost black alternating with colorless, milky-white, yellow, or pale violet. The patterns vary across Treak Cliff and there are some 14 different banding patterns.

A mineralogist states, "it isn't the oil itself which causes the color. It appears to be radiation from minute quantities of uranium adsorbed onto the oil which has caused dislocations in the molecular structure and these in turn affect the way in which light passes through the crystals or is reflected from them."

Supplemental reading

Ford, Trevor D., 1979, Blue John—Derbyshire's Unique Gem: Gems, v. 11, no. 2 (84 High Street, Broadstairs, Kent).

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