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photo by Harold and Erica Van Pelt, Los Angeles

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Articles

Columns

COVER: AMETHYST crystals to 2.5 cm across, from Ashaway Village, Hopkinton, Rhode Island. Smithsonian Institution specimen; photo by Victor E. Krantz.

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*Continued on p. 159

notes from the EDITOR

New Minerals

Included in this issue is the 1993 list of minerals approved by the International Mineralogical Association. Within the format for each species we have left an underlined blank space following the IMA number. This is to allow readers to write in the name and perhaps an abbreviated reference when the approved mineral is finally and formally published.

We will soon begin publishing abstracts of new mineral species as well, and in each case the IMA approval number will be given to facilitate cross-referencing with the annual lists of approved species. In this way collectors, curators and descriptive mineralogists will be able to keep fully informed on the work of the international community in describing new species.

It is true that abstracts of new species are already being published in the *American Mineralogist,* as they have been for many years. However, excluding libraries, the subscribers to that journal (at $60/year) number only about 2,100 people worldwide, and apparently a large percentage of those readers are uninterested in descriptive mineralogy. The work of many professional mineral scientists has taken them so far into the realms of mineral physics and petrological applications that they no longer feel much connection to what might be called "classical" descriptive mineralogy. There was even some talk for a while that *American Mineralogist* might dispense entirely with not only the abstracts but also the *articles* describing new species! In the end they decided to keep both for the time being, but limit the articles more or less to "significant" new species accompanied by full crystal structure determinations.

All things considered, the *Mineralogical Record* probably has more readers interested in information about new species than *American Mineralogist* has. So we have enlisted the services of Dr. Joseph Mandarino, co-author of the *Glossary of Mineral Species* and former chairman of the IMA's Commission on New Minerals and Mineral Names, to write the abstracts for us. He will begin with species published immediately following the closing date for the new edition of the *Glossary* which has just come out. Consequently, the abstracts will function as a continuous running update of the *Glossary,* for those users who need to keep their reference up to date at all times. In this way we hope to better serve the needs of the species-oriented contingent of our readership, allowing them to be less dependent on other journals and sources for their information.

The New Pasadena Show

For decades the Mineralogical Society of Southern California's annual show in Pasadena was known as one of the three or four best shows in the country for the serious mineral collector. This happy situation was no doubt the result of the many top-quality mineral dealers in and near southern California, the many top-quality mineral collections owned and regularly exhibited by Society members, and the prevalence of serious mineral people on the show committee making sure the focus did not drift off too far into the nether regions of crafts and lapidary. The commodious California climate in November didn't hurt either.

Despite all these advantages, the show has fallen on troubled times in recent years, with declining attendance and scheduling problems. (For the last two years it was held in Glendale, and could not even be referred to as the "Pasadena Show" any longer.)

In order to revive this important event, the MSSC has taken a bold move. Following the lead of the Munich Show, the MSSC has enlisted the services of a professional show manager to take over many of the functions, tasks and responsibilities of the Show Committee. The natural choice was Martin Zinn, already the promoter of successful, well-organized shows in Denver, Tucson, Springfield and Costa Mesa. Society members will still be responsible for displays, demonstrations, speakers and programs; Martin Zinn Expositions will handle the physical arrangements, dealers and advertising; and the two groups will collaborate in planning and production. It is hoped and expected that combining the resources and talents of a major mineralogical society and an experienced professional promoter will yield the best of both worlds.

The new show will bear the unwieldy title of the *California Mineral, Fossil, Gem, Jewelry and Lapidary Arts Show* (the C.M.F.G.J.&L.A. Show??). Well, since it will be held at the giant Los Angeles County Fairgrounds in Pomona, let's just call it the "Pomona Show" for now. It is scheduled for November 17–19, 1995. Despite all the flotsam in the Show title, Marty Zinn is a die-hard mineral collector, like many MSSC members, so I think we can trust them to produce a show with plenty to interest the mineral collector. If you haven't attended the MSSC show in some years, you might want to give it a try again. The new show will boast 100 (*predominantly mineral*) dealers and 40,000 parking spaces!

Foreign Correspondents Needed

An important feature of the *Mineralogical Record* has always been market news regarding new mineral discoveries and sales. The domestic scene, as represented by some of the major American shows, is covered under *What's New in Minerals?* by Tom Moore, Jeff Scovil, myself, and sometimes others. Foreign shows and news have been covered to some extent by Mick Cooper in England (he reviews the British scene, the Munich Show and a few other events for us) and Miguel Calvo (who covers the two major shows in Spain), under *Letter from Europe.* George Robinson and his colleagues generally provide an annual worldwide summary of finds. But this still leaves many areas as mineralogical *terra incognita,* especially regarding shows.

We would like to invite more people to cover shows and discoveries for us throughout the world. If you think you could write on specific shows or geographic areas please drop me a letter and we can discuss it further. If you or a friend can supply publishing-quality specimen photos to accompany the reports, so much the better; but it is not an absolute requirement. I would recommend, however, that reporters not also be mineral dealers, because of the unavoidable appearance of promoting one's own stock. Other than that, all you need is a reasonable amount of mineralogical knowledge and enthusiasm, and the ability to put pen to paper (or fingers to keyboard). In doing so you will not only be helping the *Mineralogical Record,* and your fellow collectors, but you will be taking a valuable part in the historical documentation of the products of our time. ⛏

AMETHYST ON MILKY QUARTZ FROM HOPKINTON, RHODE ISLAND

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The eastern United States is well-known for its many occurrences of exceptionally well-formed amethyst specimens. In the spring of 1981, an occurrence of amethyst scepter overgrowths on milky quartz was discovered in Ashaway Village, Hopkinton, Rhode Island. This deposit has produced some of the most beautiful amethyst specimens found in the Piedmont of the eastern United States.

INTRODUCTION

The recovery of sceptered amethyst on Diamond Hill, Ashaway Village, Hopkinton, Rhode Island has been described by Metropolis *et al.* (1986). These specimens were collected from subsurface quartz veins after removal of 1 to 3 meters of overburden. To date, a total area of approximately 6 x 9 meters has been excavated to a depth of 3 to 4 meters. In the latest excavation, August 1991, approximately 80% of the area so far uncovered was searched, yielding only eight noteworthy mineral specimens. Altogether approximately 500 to 600 single crystals (scepters) and 35 crystal groups with amethyst have been collected from the site since 1981. Some of the finest specimens recovered are in the collections of the National Museum of Natural History in Washington, the American Museum of Natural History in New York, and the Harvard Mineralogical Museum in Cambridge. The site is on private property and collecting is currently prohibited by the owners.

The formation of epitaxial amethyst overgrowths on euhedral milky quartz stems results from distinct changes in the physiochemistry of the fluids from which the quartz precipitated. Physiochemical data suggest a hiatus between the formation of the two quartz types. In this study, fluid inclusion and stable isotope geochemistry are used to constrain the mode of formation of the quartz.

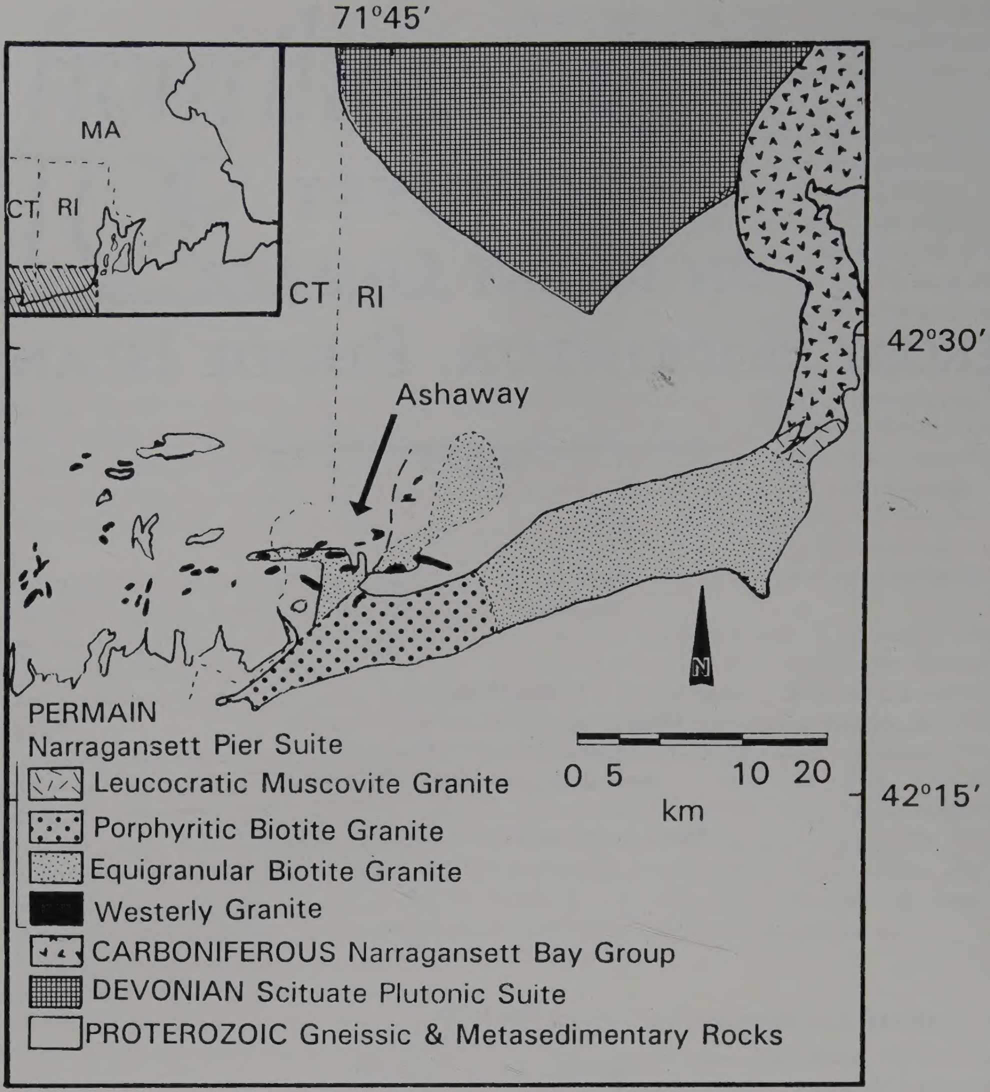

Figure 1. **Generalized geologic map of southern Connecticut and Rhode Island showing the location of Ashaway Village (modified after Hermes, 1987).**

GEOLOGY

Basement exposures in southwestern Rhode Island are dominated by multiply deformed late Proterozoic to late Paleozoic plutonic and metasedimentary rocks (Fig. 1). Many of the granite intrusions are of Permian Westerly and Narragansett Pier granites. Medium-grained phaneritic and pegmatitic granite dikes, most likely associated with the Permian granitic suite, are locally abundant. Diamond Hill is formed on the western limb of a north-south-trending syncline with displacement along a major fault that cuts across the southwestern corner of Rhode Island (Feininger, 1965). The quartz lies stratigraphically above a lithologically variable quartzite unit of the Proterozoic Plainfield Formation (Feininger, 1965) and is, in turn, overlain by 0.6 to 1.6 meters of glacial till.

The amethyst specimens occur in two quartz veins, each approximately 36 cm thick. No surface exposure of these quartz veins has been found, and they have only been accessible where small temporary pits have been dug during excavation. Consequently, little field data regarding the relationship of the veins to the regional geology is available. The veins are composed of a mosaic of partially displaced quartz blocks and are embedded in a clay sequence that is encountered 2.5 to 4.6 meters below the ground surface (Fig. 2). The clay is not related to the overlying till. The veins are almost entirely quartz. Some small mica crystals have been found intermixed with quartz blocks and clay; however, these may have been introduced during excavation. A contact between the deposit and the underlying bedrock has not been encountered, although a band of small displaced blocks of Plainfield quartzite has been found intermixed with the clay. Amethyst crystals are interspersed with the clay and vein blocks, and no open mineralized pockets or vugs were found. The clay unit is composed primarily of illite, kaolinite and quartz as determined by X-ray powder diffraction.

ANALYTICAL TECHNIQUES

Cathodoluminescence (CL), stable isotopes, fluid inclusions and trace elements have been utilized in this study to analyze the quartz and fluid chemistry. Standard techniques were used in the analysis of stable isotopes and fluid inclusions. (Complete experimental details can be obtained from the author or from the *Mineralogical Record* editorial office.) Trace element abundances were determined quantitatively by synchrotron X-ray fluorescence microanalysis (SXRFMA). For a detailed description of trace element analysis in minerals by SXRFMA see Rakovan and Reeder (1994).

CL analysis of amethyst and milky quartz was performed by D. K.

Figure 2. **The location of milky quartz blocks embedded in clay in one of the site excavations.**

Ramseyer (Universitat Bern, Switzerland) using the instrumentation and methods detailed by Ramseyer *et al.* (1988, 1989). The CL technique enables the identification of different generations of growth within a single crystal. CL analysis was conducted on two amethyst overgrowths with milky euhedral bases cut parallel to the *c*-axis and one milky stem cut perpendicular to the *c*-axis.

Primary, aqueous liquid-vapor (L-V) inclusions (criteria of Roedder, 1984) were examined in both the amethyst overgrowths and the milky quartz. The temperature range ($T_{h,l}$), and salinity of the fluids present when the quartz precipitated were determined from analysis of these aqueous (L-V) inclusions.

$T_{h,l}$ can be used to find the minimum possible temperatures of fluid inclusion entrapment, but a pressure correction may be required to equate $T_{h,l}$ to the true temperature of trapping (T_t).

Waters from fluid inclusions were analyzed for hydrogen isotopic ratios, and the quartz was tested for oxygen isotopic ratios. Stable isotopes are reported as delta (δ) values, defined as $\delta(X) = (R_v - R_{std} / R_{std}) \times 10^3$, where R_v is the isotopic ratio of the sample (e.g. D/H or $^{18}O/^{16}O$) and R_{std} is the isotopic ratio of a standard. $\delta^{18}O$ values were obtained from bulk samples of separated amethyst overgrowths and milky quartz stems.

RESULTS

Quartz Mineralization

Three varieties and several different habits of quartz crystals are present. Optically transparent quartz occurs as elongated, pencil-like euhedral crystals with a length-to-width ratio of 6:1 or greater. These commonly occur in tightly packed groups of crystals in parallel growth. The transparent quartz also occurs as short prismatic crystals that commonly are flattened perpendicular to $\{10\bar{1}0\}$. Frequently these crystals have one well-developed $(11\bar{2}1)$ face.

Euhedral milky quartz is the most abundant variety found. The crystals are typically uniform and prismatic with development of $\{10\bar{1}0\}$, $\{10\bar{1}1\}$ and $\{01\bar{1}1\}$ only. These crystals have a transparent core and a thinner concentric rim of alternating transparent and milky layers. The opaque, milky layers result from an increased concentration of microscopic fluid inclusions in the quartz. Rhombohedral faces are smooth whereas prismatic faces are covered by a layer of small crystals in parallel growth, leading to a macroscopically rough surface.

Amethyst is the third variety of quartz that occurs at this site. In almost all cases the amethyst occurs as "scepters" or epitaxial overgrowths on milky quartz crystals. These overgrowths are equant in habit, with the base of the amethyst overgrowth terminated and forming a re-entrant with the euhedral stem. This overgrowth produces a scepter with a mushroom-like appearance. The re-entrant always starts where the amethyst overgrowth comes in contact with the rough prism faces of the milky quartz. This suggests that the habit of the amethyst overgrowth is partially controlled by the surface topography of the milky quartz stems. Amethyst is found sparsely throughout the veins, and groups or plates of milky quartz crystals tend to have very few scepters. The largest group of scepters found contains 23 amethyst caps on a 25.4 x 30.5-cm plate of milky crystals. Several specimens exhibit amethyst that has grown in a random fashion on the fracture surfaces of brecciated blocks of vein quartz. These are all elongated in habit, rather than equant; this further indicates the role of the milky

WEW

Figure 3. Single amethyst scepter on a group of Hopkinton milky quartz crystals 8.9 cm across. Russell Behnke specimen.

Figure 4. Amethyst on milky quartz from Hopkinton. The specimen measures 12.7 x 15.2 cm. John Travasso specimen; photo by John Rakovan.

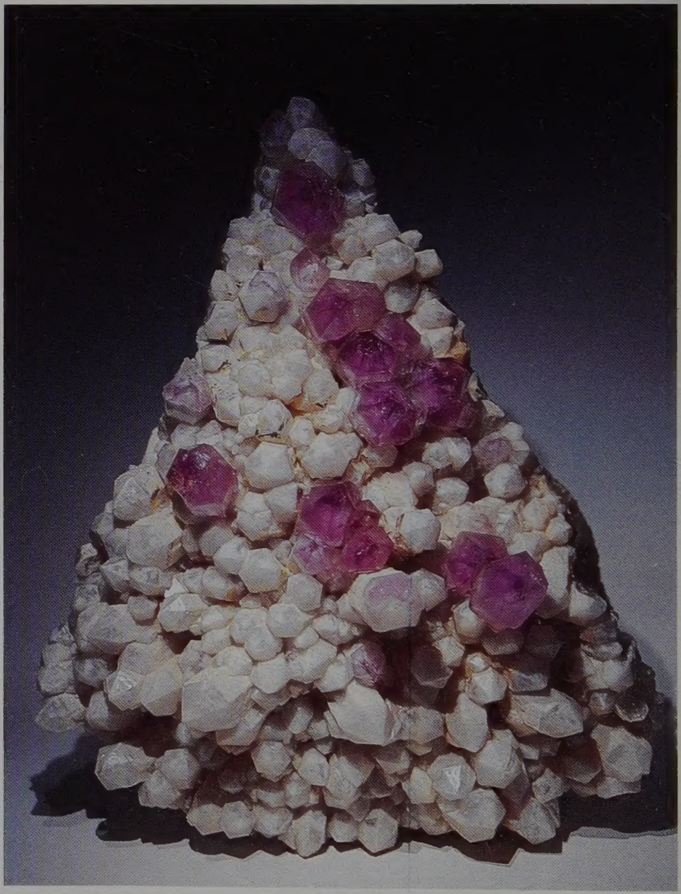

Figure 5. Amethyst on milky quartz from Hopkinton. The specimen measures 12.7 x 25.5 x 30.5 cm, and the largest scepter is 2.5 cm across. Sal Avella specimen; photo by John Rakovan.

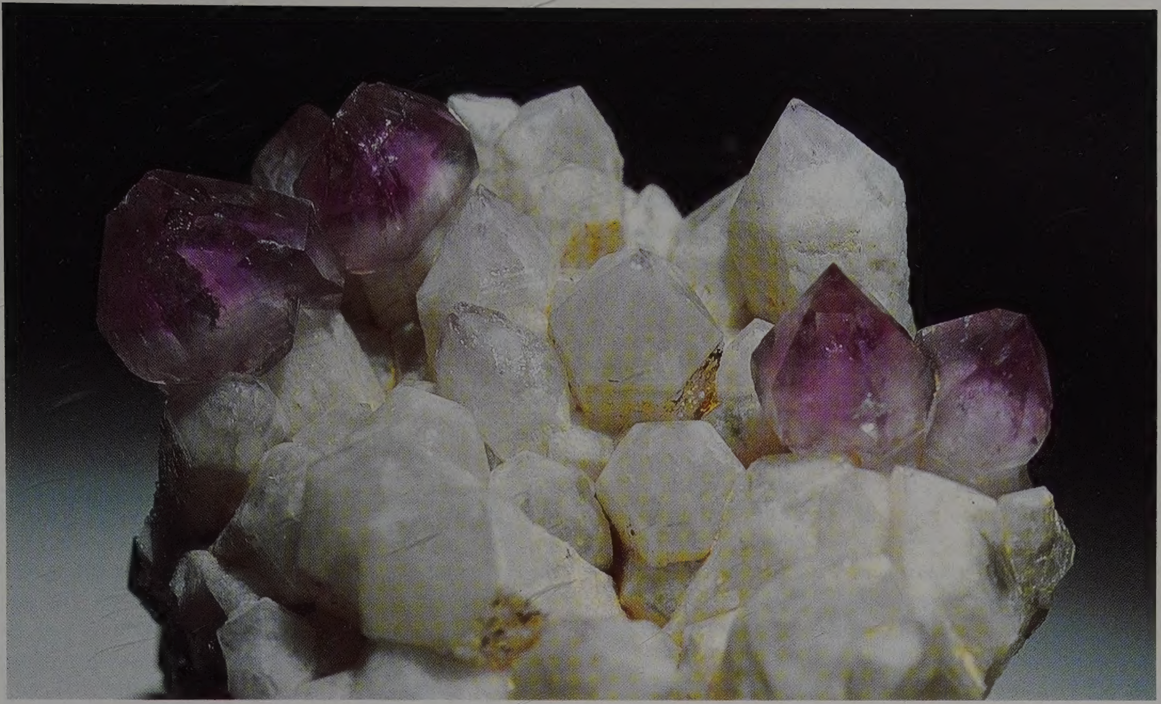

Figure 6. Amethyst on milky quartz from Hopkinton. Specimen measures 8 x 10 x 10 cm, and the largest scepter is 2.5 cm wide. John Rakovan specimen; John Jaszczak photo.

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Figure 7. Amethyst scepter from Hopkinton, 6.8 cm tall. Russell Behnke specimen.

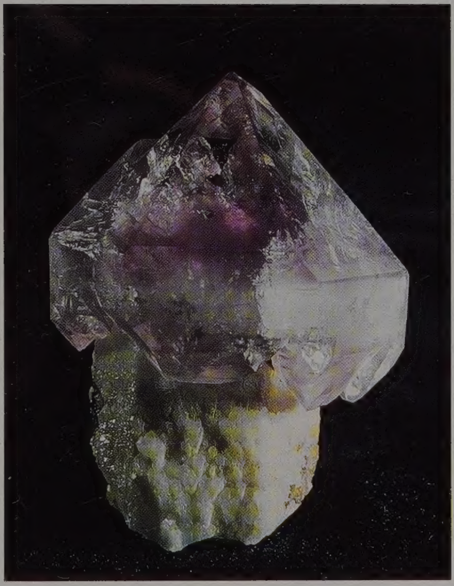

Figure 8. Amethyst on milky quartz from Hopkinton. The scepter measures 3.8 x 5.5 cm. John Rakovan specimen; photo by Laura Lakeway.

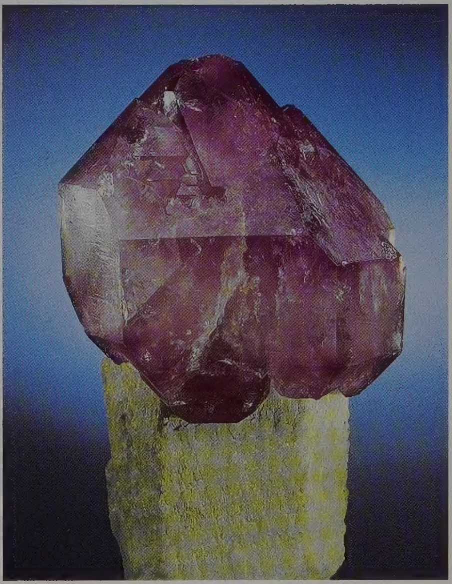

Figure 9. Amethyst scepter from Hopkinton. American Museum of Natural History specimen; photo by Harold and Erica Van Pelt.

quartz substrate in influencing the habit of the amethyst when epitaxially related.

Most of the scepters are 3 to 12 cm long in the *c* direction, but a single exceptional scepter measures 20.3 cm in length. Amethyst overgrowths range from about one-half to twice the width of the milky quartz stems. The amethyst is usually fairly transparent, with color ranging from faint violet to a deep purple. The amethyst is commonly sector-zoned with respect to color. Here, the color centers (causing the purple color) are concentrated in rhombohedral sectors and depleted in the prismatic sectors. Thus, a central band perpendicular to the *c*-axis is visible as clear to faint violet color in the overgrowths. Even though most of the amethyst is strongly color-zoned, a few dozen exceptional stones have been cut for gems. The largest cut stone weighs approximately 45 cts and currently resides in the collection of Rhode Island Senator Claiborne Pell.

Electron probe microanalysis indicates that the quartz is stoichiometric with no Fe or other trace elements detectable within instrumental resolution. SXRFMA was used to determine trace element chemistry. SXRFMA detected only very small amounts of Fe and Ga in the amethyst, 1 to 10 ppm range. No detectable Fe was found in the milky quartz.

Cathodoluminescence

CL reveals concentric zoning in the milky quartz. Several different generations of growth are distinguishable on the basis of variations in blue luminescence. There is a central zone of quartz that correlates with the previously discussed transparent core that lacks fluid inclusions. A second generation of quartz is delineated by large primary fluid inclusions. There is also a third generation of quartz with few fluid inclusions. A fourth generation of quartz growth also displays a high density of fluid inclusions. A highly zoned transitional phase of quartz concludes the growth of the milky stems. The amethyst overgrowths exhibit very dull luminescence. Limited areas of the basal terminations of the amethyst overgrowths show deep blue luminescence.

Fluid Inclusions

Microscopically, the contact between the amethyst overgrowth and the milky quartz is indistinguishable but for the presence of fluid inclusions. In the milky quartz the abundance of fluid inclusions is very high. Individual fluid inclusions are commonly over 100 µm in greatest dimension, but throughout the size range, the liquid/vapor ratio is consistent. This consistency of the liquid/vapor ratio may reflect uniform conditions of entrapment of the fluid in the milky quartz. Conversely, the amethyst overgrowths contain very few fluid inclusions. Those present have maximum dimensions between 5 and 10 µm.

The calculated salinities for the fluid inclusions in the amethyst are from 0.2 to 15.7 eq. wt. % NaCl (mean value 7.8), with these data displaying significant scatter. For the milky quartz they range from 7.7 to 15.8 eq. wt. % NaCl (mean value 14.7). No daughter crystals were observed in either type of quartz. Density ranges from 0.9227 to 1.0574 g/cm^3 (mean value 0.9972) for the amethyst and 0.9695 to 1.0427 g/cm^3 (mean value 1.0199) for the milky quartz.

$T_{h,l}$ ranges from 94.5 to 149.7 °C (mean value 124.6 °C) for the fluid inclusions in the amethyst overgrowths. For the fluid inclusions in the milky quartz, however, the $T_{h,l}$ is different, ranging from 125.5 to 186.9 °C (mean value 156.4 °C).

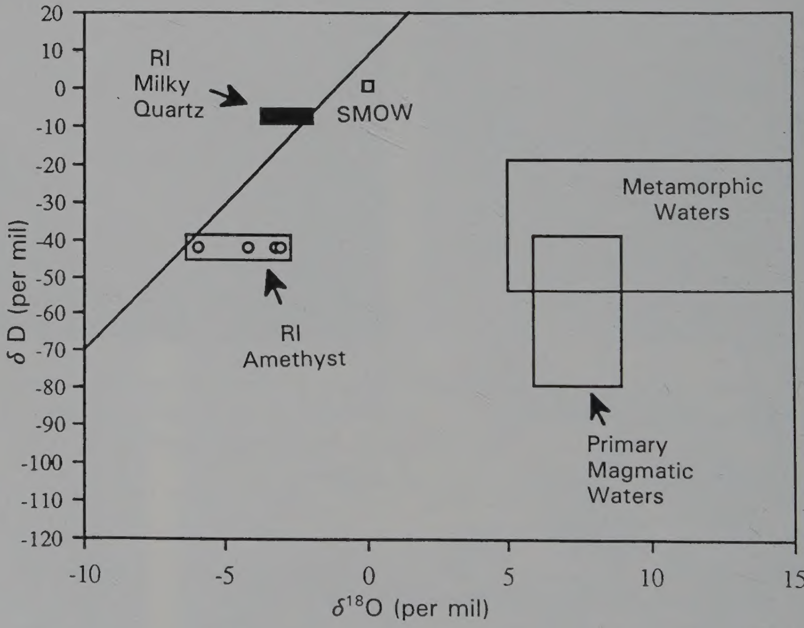

***Figure 10.* δD-δ^{18}O plot showing isotopic compositions and fields of Hopkinton quartz fluid inclusions, primary magmatic waters, metamorphic waters, and standard mean ocean water (SMOW). The line across the upper left part of the graph is the compositional line for meteoric waters.**

Stable Isotopes

Oxygen isotope ratios were determined for the milky quartz and amethyst overgrowhts. These values were calculated to represent δ^{18}O using the appropriate equation from Clayton *et al.* (1972). The values range from -3.5 to -2.2 ± 0.2 ‰ for the milky quartz and from -6.0 to -3.1 ± 0.2 ‰ for the amethyst overgrowths. The δD values for the inclusion waters from the milky quartz range from -8.7 to -6.3 ± 2.0 ‰ (SMOW). Because of the low abundance of fluid inclusions in the amethyst overgrowths, the amount of water obtained from the inclusions by thermal decrepitation was less than ideal. As a result, only one δD value of -42 ± 4.0 ‰ (SMOW) was obtained for the amethyst overgrowths.

DISCUSSION

The poor exposure of this deposit has made interpretation of its mode of formation difficult. Initially, Metropolis *et al.* (1986) postulated that the quartz veins and surrounding clay were the product of intense weathering of a preexisting granitic dike or sill. Quartz precipitated from a granitic source will have a geochemical signature indicating such a source. For example, primary fluid inclusions in the quartz represent the fluids from which the crystals formed. One tool in the determination of the origin of these waters is to use the variation in the isotopic ratios of oxygen and hydrogen. The δ^{18}O and δD values can help constrain both the source and history of a water (Valley *et al.*, 1986).

When the δD values are plotted verses the δ^{18}O$_{H_2O}$ values for the amethyst and the milky quartz, both boxes of data plot close to the meteoric water line (Fig. 10). The meteoric water line represents water that is derived from atmospheric precipitation. This implies a relatively shallow depth of quartz formation, such that the water had insufficient time to interact with waters from other sources. In Figure 10 the separation of the δD and δO for the amethyst and milky quartz along the meteoric water line suggests that a differently sourced meteoric water was present during formation of each quartz type. Such a shift could be the result of a temporal difference between the precipitation of the two quartz types and may also reflect a temperature difference during growth. An interesting feature in Figure 10 is the shift in δ^{18}O$_{H_2O}$ of the amethyst from the meteoric water line towards higher values. Such an oxygen-isotopic shift is a common feature in geothermal waters and has been interpreted to be from the interaction of meteoric waters with country rock at elevated temperatures (Hoefs, 1980).

Salinities of fluid inclusions in both the amethyst and milky quartz are comparatively low with respect to igneous or metamorphic waters. Fluids from the milky quartz are slightly more saline than those of the amethyst. Waters from igneous sources commonly become supersaturated with respect to NaCl, resulting in the formation of daughter crystals in inclusions.

The temperatures of homogeneization for the primary fluid inclusions in the two types if quartz are in the range of 90 to 180 °C; this is below the temperatures expected for igneous environments. These $T_{h,l}$ values represent the minimum possible temperatures of fluid inclusion entrapment. A correction for pressure is required to equate $T_{h,l}$ to the true temperature of trapping. No independent pressure data are available. However, based on the meteoric signature of the fluid inclusions, the low salinities of the fluid inclusions, and the low level of detectable trace elements in both the quartz and fluid inclusions, we postulate that the $T_{h,l}$'s are close to the true temperature of entrapment and that precipitation occurred close to the earth's surface. Furthermore, the almost complete lack of minerals other than quartz, kaolinite and illite suggests primary deposition as opposed to weathering of preexisting minerals. Based on all of the above data, the quartz shows few or no features of igneous formation. Rather, the data suggest that precipitation occurred from epithermal meteoric waters along conduits in the adjacent Plainfield quartzite.

CL variability is related to variations in luminescence-activating trace element concentration. Concentric zoning in the milky quartz is seen as differences in fluid inclusion density and in CL. The concentric zoning indicates fluctuations in physical and chemical parameters (e.g. temperature, pressure, composition of the fluid or pH) in the environment during growth.

Differences in color, CL, and fluid inclusion characteristics (salinity, $T_{h,l}$ and isotopic ratios) indicate either continuous growth accompanied by significant changes in the environment, or a hiatus between the precipitation of the milky quartz and amethyst. Several specimens contain amethyst that have not grown epitaxially on the terminations of milky quartz crystals but are attached to fracture surfaces of brecciated blocks of vein. This amethyst is identical to the amethyst caps in every manner other than habit. Such specimens suggest that there was a hiatus between the formation of the two types of quartz, during which time the milky quartz veins were brecciated.

For the well-formed euhedral crystals of milky quartz and amethyst to form they most likely grew into open spaces in the veins. No cavities have been found, suggesting collapse at some point of preexisting pockets. Excavation of the site revealed that the majority of amethyst occurs in a very localized area (approximately 1 x 2 meters). Of the 12 individual pits that have been dug only a few exposed more than a handful of specimens. The localization, absence of open pockets, brecciation of the quartz veins, and the presence of displaced blocks of the Plainfield quartzite intermixed with the clay suggest that the deposit has moved, possibly by the action of surface slumping or glaciation.

Contrary to initial speculations, the geochemical evidence demonstrates that the quartz is not related to an igneous source, but rather has precipitated from meteoric waters during several stages of precipitation.

The sceptered amethyst specimens from Hopkinton are undoubtedly some of the finest examples found in the eastern United States (see White and Cook, 1990), and are arguably some of the finest mineral specimens to be recovered in the state of Rhode Island. Recent excavations have resulted in very few additional specimens, however, and the future potential of the site is uncertain.

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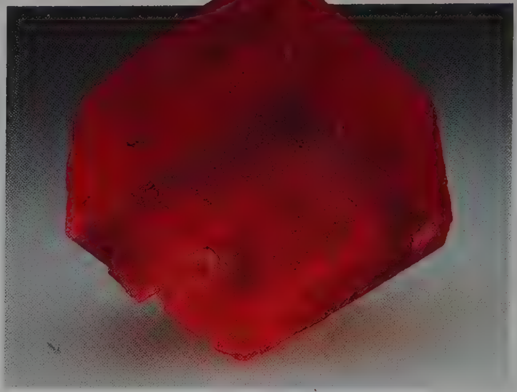
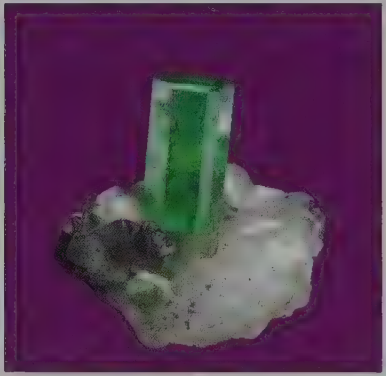
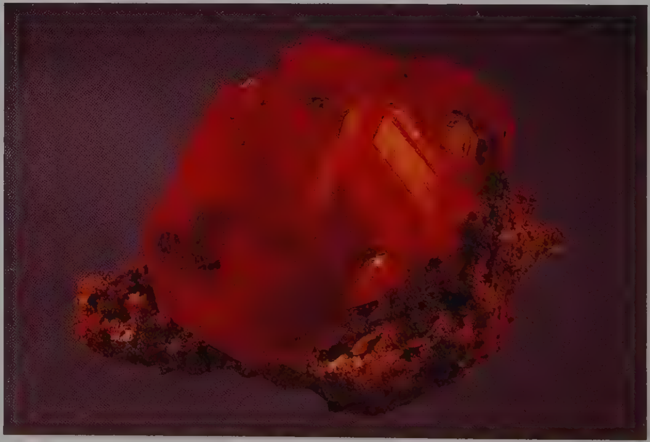
VIVIANITE
J. SCOVIL







EUHEDRAL SINHALITE CRYSTALS FROM SRI LANKA

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Euhedral sinhalite crystals, reported here from Sri Lanka for the first time, have yielded morphological data in agreement with that previously published for a crystal from Burma. Thirty-two faces were observed, representing 13 forms for one crystal, and 31 faces and 9 forms for the other. The pale brown color and weak pleochroism are attributed to ferric iron.

INTRODUCTION

Sinhalite, $MgAlBO_4$, is among the rarest of the 30 or so gem minerals found in the alluvial gem deposits of Sri Lanka. It was first recognized and described as a new mineral species based on faceted gemstones which were long thought to be brown forsterite (Claringbull and Hey, 1952). Gübelin (1961) noted sinhalite from Eheliyagoda in Sabaragamuwa Province. Gunawardene and Rupasinghe (1986) included a brief description of sinhalite in their report on the gem minerals from the Elahera gem field in Central Province. Henn (1985) characterized a distinctive olive-green sinhalite found at Elahera in 1981. In a systematic of Sri Lanka's gem deposits, Dissanayake and Rupasinghe (1993) reported finding sinhalite in the Ambalantota, Avissawella, Elahera, and Ratnapura quadrangles.

Four additional occurrences of this species have been reported in the literature. It was observed in thin section with serendibite near Johnsburg, Warren County, New York (Schaller and Hildebrand, 1955; Grew *et al.*, 1991a). The first morphological data for the species were determined on a water-worn crystal from Mogok, Burma (Payne, 1958). A pale pink to brownish pink, chromian variety of sinhalite has been reported in millimeter-size grains from a skarn occurrence in the Kwakonje area of the Handeni district in northeast Tanzania (von Knorring, 1967; Bowden *et al.*, 1969). It has also been found in drill cores as a mantle about ludwigite grains from the Aldan Shield in eastern Siberia (Grew *et al.*, 1991b).

Although commonly represented in collections of rare gems in sizes up to 240 carats (Arem, 1977; Koivula *et al.*, 1993), sinhalite is not often seen in mineral collections. Recently George Crevoshay, a dealer in Far Eastern gemstones, supplied the Harvard Mineralogical Museum with three sinhalite specimens from Sri Lanka suitable for display. A transparent, pale yellow pebble (#131010) measuring 2.6 x 1.6 x 1.2 cm and weighing 36 carats from Nivitigala, about 25 km southeast of Ratnapura, is intended for a "rough and cut" gem exhibit. The others are transparent, pale brown, rounded crystals from Balangoda, about 25 km east of Ratnapura, intended for the systematic mineral collection. Crystal #1 (#133407) measures 7 x 6 x 5 mm and weighs 0.673 g. It has a damaged region from which a small fragment was removed for optical, chemical, and X-ray study. Crystal #2 (#133408) measures 11 x 7 x 5 mm, weighs 0.717 g and is completely euhedral. As these are the only euhedral crystals of sinhalite known to us, save the one from Burma, a description and comparison with the British Museum crystal seem appropriate. The results are reported below.

GEOLOGY

The gemstones of Sri Lanka are found in ancient alluvial deposits eroded from Precambrian rocks of the Highland and Southwest groups. These rocks underlie the topographic central highland of Sri

Lanka and represent an orogenic belt that runs from northeast to southwest across the island between the eastern and western blocks of the Visayan complex. The Highland group consists of a wide variety of rock types which were metamorphosed to pyroxene granulite grade during the Precambrian. The Southwest group was metamorphosed to the lower pressure cordierite granulite grade. Because the gem minerals are not found *in situ*, it is difficult to be specific about their mode of formation. Numerous authors have investigated these deposits and have offered various interpretations of the source lithologies. The review by Katz (1971) provides an overview of the relevant geology and sorts out the unfamiliar petrologic terminology. Wadia and Fernando (1945) suggest that the gem minerals were derived from pegmatites. Katz (1972) emphasizes the cordierite gneisses and associated rocks, along with some contributions from marbles and pegmatites, as the source of Ratnapura-type deposits. Dahanayake *et al.* (1980) attribute the gem minerals to garnetiferous gneisses and skarns. Dahanayake (1980) determined the sources to be garnetiferous gneisses, cordierite gneisses, marbles and pegmatites. Specific study of the Weddagala area near Ratnapura led Dahanayake and Ranasinghe (1981) to identify garnetiferous gneisses and granulites as the source lithologies. Munasinghe and Dissanayake (1981) and Rupasinghe and Dissanayake (1985) point to the intrusion of charnockites as forming the source rocks by contact metamorphism (desilication) of aluminous sediments and the intrusion of pegmatites derived from a charnockitic parent. A geologic map showing the distribution of charnockites, garnetiferous gneisses, undifferentiated metasediments, and zircon granite in the Ratnapura-Balangoda area is given in Rupasinghe *et al.* (1984).

Synthetic sinhalite (Werding *et al.*, 1981) is orthorhombic and shows {100} and {011} as dominant forms with {101} and {102} present less frequently. Twins and trillings on {103} also occur often. Of these forms only {102} was not observed in this study. A quantitative analysis of sinhalite morphology using computed surface energies for an ionic point charge model was made by 't Hart (1979). The computed equilibrium forms are {100}, {101}, {110}, {010}, {112}, and {021}. All of these forms were observed in this study.

MORPHOLOGY

The faces of the sinhalite crystals are finely pitted, which we attribute to etching rather than abrasion. This roughness precluded generation of usable signals during initial trials on a Goldschmidt two-circle goniometer. The crystals were then treated by spraying twice with a clear high-gloss acrylic resin solution, with drying between coats. Similar treatment of a microscope cover glass allowed determination of the coating thickness as approximately 3 µm. Goniometer signals sufficiently sharp to allow measurements with a repeatability of better than 22 minutes of arc were then attained. The crystals were measured in two settings: with (001) polar and with (00$\bar{1}$) polar. A total of 32 faces representing 13 forms were observed on crystal #1. The forms are given in Table 1, with observed and calculated angles. Three forms ({011} {140}, and {121}) not observed in the earlier morphological study (Payne, 1958) were found in this work, while the form {132}, observed earlier, was not seen here. The assignment of letters to forms follows that of Payne (1958), except for forms not observed by him. In these cases, the assignments of Dana (1892) for forsterite ("chrysolite") are used. A scanning electron microscope photograph with indexed faces is provided in Figure 1. The idealized crystal drawing, Figure 2, shows 28 faces out of a possible total of 58. The crystallographic orientation used here, *a* < *c* < *b*, is that used by both Claringbull and Hey (1952) and Payne (1958), and also follows the generally accepted orientation for minerals with the olivine structure. This convention differs from current practice for orthorhombic crystals, which is *c* < *a* < *b*, and from that used in the structural study of sinhalite by Fang and Newnham (1965) where *c* < *b* < *a* was employed. Crystal #2 was measured in the same way, with 31 faces representing 9 forms being observed. No new forms were seen on this crystal.

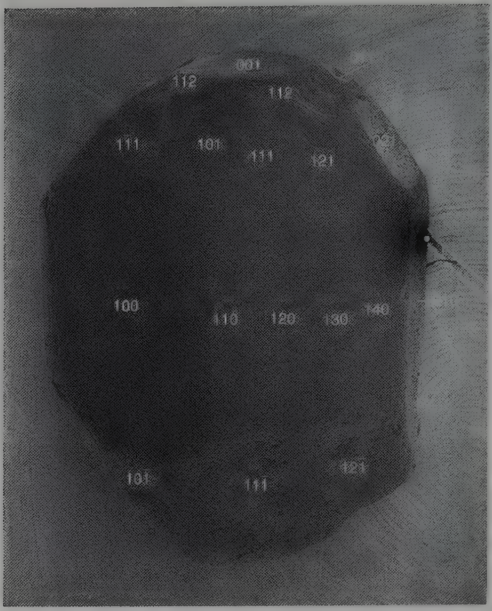

Figure 1. **Scanning electron micrograph of sinhalite crystal-1, with indexed faces.**

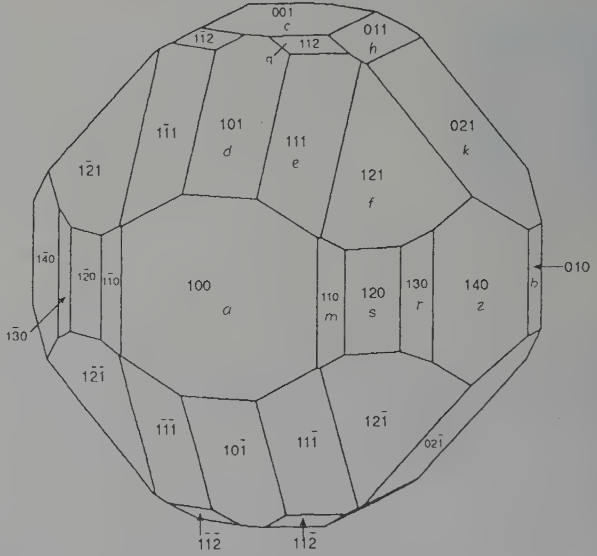

Figure 2. **Sinhalite crystal drawing.**

OPTICAL and PHYSICAL PROPERTIES

A small fragment, measuring 45 x 58 x 178 µm, was removed from the damaged region of sinhalite crystal #1. An optical study of this fragment conducted on a spindle stage showed it to be biaxial negative, with $2V = 55.6(8)°$ (calc.), and no dispersion of the optic axes. The indices of refraction are $\alpha = 1.669(2)$, $\beta = 1.698(2)$, and $\gamma = 1.706(2)$, in close accord with those of Claringbull and Hey (1952) and Bank (1977). The optical orientation, identical to that of olivine, is *a* = Z, *b* = X, and *c* = Y, which agrees with Payne's observation that the optic plane parallels the base and that the acute bisectrix is parallel to *b*. Weak pleochroism was observed, with X = pale yellow, Y = pale blue-gray, and Z = pale pink-gray.

The density of the entire crystal measured with a Berman balance is

Figure 3. **Euhedral sinhalite crystals (#133407 and #133408), about 1 cm each, from the Balangoda district, Sabaragamuwa, Sri Lanka. Harvard Mineralogical Museum.**

WEW

WEW

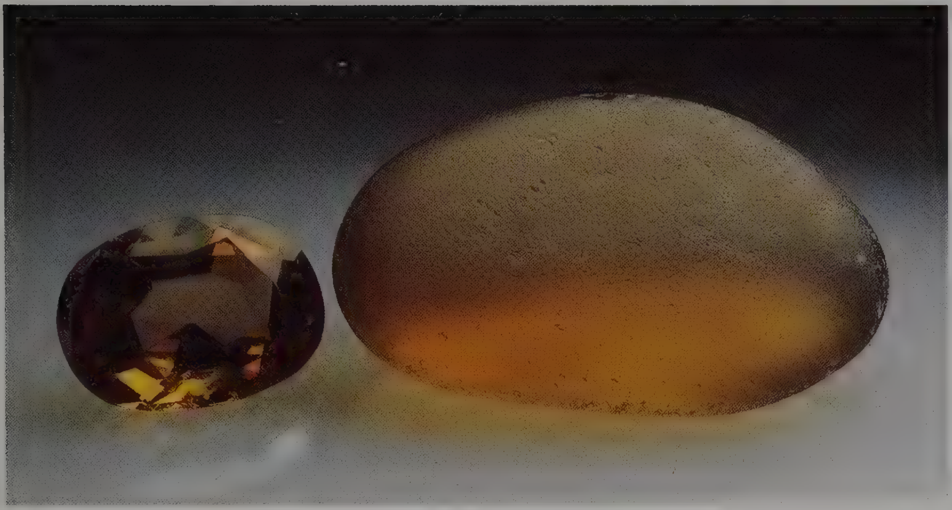

Figure 4. **Faceted sinhalite crystal (1.2 cm) and waterworn sinhalite stream pebble (2.6 cm) (#131010), from Nivitigala, Sagaragamu district, Sabaragamuwa, Sri Lanka. Harvard Mineralogical Museum.**

3.47(2) g/cm^3. This result compares favorably with 3.47 to 3.50 g/cm^3 measured by Claringbull and Hey (1952), and 3.49 g/cm^3 calculated by Fang and Newnham (1965). Crystal #2 yielded an identical result.

Fluid inclusions were observed in both crystals. A daughter crystal was noted in one fluid inclusion in crystal #1. In addition, solid inclusions were seen in crystal #2.

ABSORPTION SPECTRUM

Optical absorption spectra in the range 420 to 1,000 nm were obtained from both crystals utilizing a Sequoia-Turner Model 340 spectrophotometer with an 8 nm bandwidth. The measurements were made with the crystals immersed in symtetrabromoethane and with the light beam parallel to [010]. Both crystals exhibited a smooth decrease in absorption from 1,000 nm downwards. This behavior contrasts with the results of Henn (1985) on olive-green crystals containing 1.9 wt. % FeO. Henn observed a strong absorption band at 870 nm which, on the basis of the more detailed study by Farrell and Newnham (1965), he attributed to divalent iron. The lack of this band in the present spectra suggests the iron present in the crystals used in this study is trivalent.

X-RAY CRYSTALLOGRAPHY

The same fragment used for the optical study was mounted in a 114.6-mm Gandolfi camera and exposed to Cu $K\alpha$ radiation through an Ni filter. The pattern obtained contained 19 measurable reflections which are consistent with literature values for natural and synthetic

Table 1. **Sinhalite Angle Table**

Crystal-1

a : b : c = 0.4418 : 1 : 0.5725

Form	*φ (obs) (deg)*	*φ (calc) (deg)*	*ρ (obs) (deg)*	*ρ (calc)(deg)*
c 001	90	90	0	0
b 010	0.39	0	90	90
a 100	90.83	90	90	90
z 140	29.84	29.50	90	90
r 130	36.89	37.03	90	90
s 120	48.92	48.53	90	90
m 110	66.26	66.16	90	90
h 011	-0.86	0	30.72	29.79
k 021	-0.34	0	47.99	48.87
d 101	90.29	90	52.63	52.34
q 112	64.91	66.16	35.24	35.31
e 111	66.36	66.16	55.6	54.78
F 121	49.24	48.53	59.93	59.96
		Crystal-2 *a : b : c = 0.4371 : 1 : 0.5767*		
c 001	90	90	0	0
b 010	-0.75	0	89.39	90
r 130	36.97	37.33	89.39	90
s 120	49.04	48.84	89.39	90
m 110	66.38	66.39	89.39	90
h 011	-0.83	0	28.82	29.97
d 101	91.05	90	52.78	52.84
e 111	66.03	66.39	55.70	55.22
f 121	49.51	48.84	60.97	60.29

sinhalite (Claringbull and Hey, 1952; Schaller and Hildebrand, 1955; and Capponi *et al.* 1973). Least squares refinement gave $a = 4.327(2)$, $b = 9.887(10)$, $c = 5.678(3)$ Å^3, with a Smith-Snyder figure of merit of 6(0.033,101). These values are very close to those observed by Fang and Newnham (1965) in their refinement of the crystal structure.

CHEMICAL COMPOSITION

The same fragment used for the optical and X-ray studies was mounted, polished, and analyzed with a Cameca MBX electron microprobe. The standards used were Marjalahti olivine for Mg, kyanite for Al, synthetic fayalite for Fe, and synthetic tephroite for Mn. The results were $Al_2O_3 = 41.41$, $MgO = 28.83$, $Fe_2O_3 = 1.61$, and $MnO = 0.03$ for a total of 71.88 wt. %. Boron, an essential element in sinhalite, is beyond the range of conventional electron microprobes, but should theoretically be represented by 27.62% B_2O_3, bringing the total to 99.5 wt. %. As anticipated from the optical absorption study, qualitative wet chemical analysis showed that all the iron was in the ferric state, thus accounting for the pale color and the weak pleochroism.

A redetermination of sinhalite structure and a crystal chemical study have been made by Hayward *et al.* (1994). Their results, in contrast to ours, suggest that the iron in sinhalite is divalent, at least in the presence of excess aluminum. The microprobe analysis presented here, however, shows no excess of aluminum.

ACKNOWLEDGMENTS

The authors thank George Crevoshay for supplying the Museum with the sinhalite specimens. The electron microprobe analysis was done by D. E. Lange of the Department of Earth and Planetary Sciences, and the SEM photograph was graciously provided by Yuan Lu of the Division of Applied Sciences. Several obscure references were brought to our attention by Dr. Pete J. Dunn. The manuscript benefited from reviews by Richard C. Erd and Dr. Anthony R. Kampf.

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A MINERAL EXHIBITION IN ATHENS

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***Figure 1.* The National Museum of Archeology in Athens, site of the exhibition.**

Say that it is summer 1994, the year in which Greece will take its turn in assuming the presidency of the European Union. What are you to do, if you are the Greek Ministry of Industry, Energy and Technology, to celebrate the event, while also more generally to emphasize the claim of Greece to a place of special honor in modern Europe's fast-integrating cultural system? Well, what you do, it seems, is coordinate your efforts with those of a live-wire amateurs' organization, the *Greek Association of Mineral and Fossil Collectors,* and arrange a pan-European mineral exhibition, called "Environment and Culture," in the National Archaeological Museum in Athens. While you're at it you make a beautiful 71-page color catalog of the exhibition; you sponsor a concurrent two-day symposium, with distinguished speakers, called "Earth—Space—Man" at the French Institute in Athens; and you dedicate the whole to the late, beloved Greek actress and environmentalist Melina Mercouri. *That* is what you do!

The Greek Association of Mineral and Fossil Collectors (hereafter G.A.M.G.C.) is a most dedicated group, founded in 1986 and currently including about 200 members, most of whom worked hard as volunteers on this project under the high-adrenalin leadership of their president, Mrs. Maria Renieri-Yannopoulos (an Athens lawyer by trade). This was the second such exhibition; the first was held in October 1992, and, although it too was billed as "international," its only non-Greek participants were a couple of French institutions, the Paris School of Mines and the French National Museum of Natural History. This time, while G.A.M.F.C. members themselves and several academic Greek institutions provided the exhibition with its proper Greek core, there were also two 2-meter cases available to *each* member of an impressive guest list of foreign entities. These were (in no particular order) the Royal Institute of Natural Science, Brussels, Belgium; the Mineralogical Museum of the School of Mines, Paris, France; the University of Rome, Italy Mineralogical Museum ("La Sapienza"); the Manchester Museum, United Kingdom; the German Mining Museum, Bochum, Germany; the Idar-Oberstein Museum, Germany; the Geological Museum of Barcelona, Spain; the Spanish Institute of Geology and Mining, Madrid, Spain; the Vernadsky State Geological Museum of Moscow, Russia; the Nedra Ural Mineralogical Center, Ekaterinburg, Russia (with pieces from the Vladimir Pelepenko collection); and, for its first coming-out beyond its country's borders, the Geological Museum of China, Beijing. But I do regret to report that even with all this enterprise the G.A.M.F.C. people could not secure the attendance of either of the two American institutions that they invited.

So they had to settle instead for me: token American, pseudo-journalist, camp follower after all this curatorial clout, and with nary a rock on my own person to show to anyone. I'd been to Athens just once before, many years ago, and that very briefly. I had known

Figure 2. **At the Athens exhibition, showing the big show poster depicting Chinese orpiment; Mrs. Renieri-Yannopoulous at center.**

Figure 3. **A superb 10-cm creedite specimen from Akchatau, Kazakhstan; Vladimir Pelepenko collection, Nedra Ural Mineralogical Center, displayed at the Athens exhibition.**

Figure 4. **Display cases of minerals at the Athens exhibition.**

Figure 5. **Large, 15-cm Sicilian sulfur specimen from the "La Sapienza" collection, Rome University. (Thomas Moore photo.)**

nothing then of Greek minerals, and knew hardly more now. But Mrs. Renieri-Yannopoulos had flashed me a gracious welcome from across the sea, and was now smoothly handling my logistical needs (e.g. the lady who was to meet me at the airport was still there, handheld sign on high, even when my plane landed three hours late). There was the fine promise, too, of a guided excursion, with all the curatorial parties, to the Laurium mines. Naturally I was excited: so much so, as the plane approached Athens, as not to be put off even by the sight of the yellowish sickly haze that hung over the city.

But so bad is this air pollution that a municipal regulation permits only cars with odd- or even-numbered plates to drive into the city's center on alternate days. My ride fought the shrewish traffic: from up close my first impression was that Athens comes across as a densely packed, hard-baked and hard-angled city, especially in the high heat that day: it was more than 90° F, most unseasonable for late May.

However, even while fighting your way through these mean-spirited streets, you sometimes gaze out and up towards one of the many hills spiked with olive trees that ring Athens and push into it from all sides. You might get a flash, on a hilltop, of pure otherworldly white, of marble columns, porticos, or facades, either modern or ancient (from such a distance you can't tell), rising dreamlike against a uniformly deep blue sky. You might glimpse the Acropolis high on its limestone plateau, wheeling into and out of vision like a hallucination, or a remembrance—for this, after all, is where Europe as we know it began: kicked off for better or worse from amidst these temples and Dionysian theaters and gods' gazebos, the birthplace of democracy. It felt, in an oddly impersonal way, like a privilege to be here.

None of which musings helped with the heat. At the hotel I attended to my shower, my beer libation in the rooftop cafe, and token unpacking, then took my first walk downtown to the Museum of Archaeology. When I got there I had 45 minutes to meet people and to look around the exhibition; having done so, I went expectantly to a statuary-lined hall where the opening ceremony was scheduled to begin. It did not begin for another 45 minutes, and none of the 200-odd people, most of them in formal dress, milling multilingually in the heat, seemed surprised or even impatient. My fault: I'd forgotten a thing or two about schedulings and time operations in Mediterranean countries. The statues, at least, looked comfortable, in an *in situ* sort of way.

Just a word more about this unusual setting, to quote from the official announcement:

> The greatest Mineralogical and Paleontological Museums will be present in this unique cultural, scientific and educational event. For the first time art objects made by Man (Mycenaean and other collections of the Athens Archaeological Museum) and the raw materials (minerals) made by Nature, will be exhibited together.

If this last strikes you as a somewhat forced rationale for holding a mineral event in a museum of archaeology, well, there's a good reason. As yet there is no Greek national mineral collection, or natural history museum in which to house it or in which to hold an event like this. In any case, the Museum of Archaeology, with its august, high-ceilinged rooms washed in marble-clear light from windows and skylights, *did* make a good context for minerals. Outside and all around the mineral rooms reposed some of the most wondrous surviving artifacts of Greek history and prehistory: archaic smiling stone *kouroi*, urns and grave steles, the lovely/ghastly gold death masks that Schliemann dug up at Mycenae, the twice-lifesize bronze of spearthrowing Poseidon, among countless others. To wander between the two kinds of exhibits made a mysterious effect of beauty-juxtaposition having little to do with any pedantry about "art objects" and "raw materials."

One of the speakers at the opening ceremony—Mr. George Thomas, Secretary General of the Greek Ministry of Culture—did in fact express regret for the lack of a Greek national mineral collection and of a facility for its display. Could it be, he wondered, that the G.A.M.F.C. exhibition, with its proof of the country's great mineralogical interest, might point the way to a change? The politics of the matter are of course none of my business, but I can testify here that Greece *does* have at least one world-class mineral specimen locality, not well enough known as such in western Europe or the U.S. Certainly a good "national" display centered on the minerals of this one locality would, assuming reasonable tourist traffic, do much to correct the under appreciation. I'm talking, of course, about Laurium (Greek "Lavrion"), in Attika, barely 60 kilometers south of the museum chamber where my own education on Laurium minerals had already begun by opening-ceremony time. So now I'll usher you into the exhibition at last, lens cap removed.

Foreign guests first, however. Probably the two most impressive display cases from outside Greece, in terms of average specimen quality, were those of the *Nedra Ural Mineralogical Center,* with items from the Vladimir Pelepenko collection. My candidate for the most astonishing of these specimens, is an 8-cm spray of bright, glassy, purple creedite, with gemmy razor-edged crystals to 2 cm, sitting up on a 10 x 10-cm matrix, from the Akchatau mine, Kazakhstan; not even a large bash in the center of the spray mars too seriously the aesthetic quality of this piece. From Dal'negorsk, Primorskiy Kraj, Russia, there were also some very dramatic, very large specimens of fluorite, galena, sphalerite, pyrrhotite and others, and a colorless, flawless, English-like calcite twin almost 20 cm long. From Dzhezkazgan, Kazakhstan there was a highly aesthetic, flattened, arborescent native copper specimen measuring 22 cm; and from Bazhenovskoyed, Urals, Russia a brilliantly handsome 12-cm group of striated pyrite cubes. Finally (there were more, surely, but here my notes on these two cases breathlessly end), from the Pouyva mine near Saranpaul in the Polar Urals, Russia, there were the two best ferroaxinite specimens I've yet seen from this or any other place: the larger is a single brown 17-cm bladed crystal, which is gemmy well in from all its edges, with smaller crystals, on matrix. On this occasion, by the way, I met Mr. Pelepenko for the first time, he speaking in Russian to a companion who spoke in Greek to Mrs. Renieri-Yannopoulos who spoke in English to me. I've had snappier conversations, but found myself truly liking this amazing collector, who'd *driven* all the way to Athens from Russia for this exhibition.

The other Russian presence was also impressive: the *Vernadsky State Geological Museum* of the Russian Academy of Science had many good to excellent specimens of Ural and Transbaikalia gem pegmatite minerals. It also had a 4-cm euhedral eudialyte from the Kola Peninsula; some fine, sharp spinels, vesuvianites and green grossulars from the Vilui River, Siberia; and, a real oddity, five loose, very sharp *andesine* crystals, ranging from 2.5 to 4 cm, found in 1975 in a volcanic occurrence in Kamchatka. They are a dark, dull black from lava encrustations.

The *"La Sapienza" Museum* of Rome University shone with some fine old Italian classics. Admirers of Elba elbaite could choose between an incredible matrix boulder with five sharp "moor's head" elbaite crystals averaging 6 cm long rising straight up out of a pegmatite pocket, and an exquisite miniature with one gemmy, pink, terminated prism on a small bit of quartz. There were several beautifully iridescent clusters of thick, midnight-black hematite from Elba, with sharp-faced individuals reaching 5 cm; and there were a couple of 5-cm pieces consisting entirely of gemmy orange-brown grossular in 2-cm, complexly modified dodecahedrons, from the Ala Valley, Italian Piedmont. There was also a terrific 15-cm matrix plate with transparent crystals of sulfur to 2.5 cm long, from Sicily. But my favorite of this Italian gathering was an inconspicuous miniature consisting of gray granular galena matrix on which rested perfectly horizontally a doubly terminated transparent brown phosgenite crystal 4 cm long. The locality, of course, is Monteponi, Iglesias, Sardinia.

The *Spanish Institute of Geology and Mining* exhibited an extraordinary cinnabar from the Almaden mine, Ciudad Real, with fine, deep red, 1-cm crystals lining a cavity with quartz crystals in a 12-cm black matrix (for a close-up photo of this one see p. 259 of Burchard and Bode's *Mineral Museums of Europe*). An equally interesting, seldom-seen from a classic Spanish locality was the dense 25-cm cluster of good glassy cerussite crystals, with individuals to 3 cm, from Cartagena, Murcia. The *Geological Museum of Barcelona*—like the Chinese museum, here making its debut appearance outside its homeland—countered the Madrid folks with, among other fine things, a very beautiful, bright yellow-green cluster of long-prismatic tapered pyromorphite crystals, the whole 20 cm wide, from Horcajo, Ciudad Real.

From England there was a single "classics" case from the *Manchester Museum,* whose most winning denizen in my opinion was a twinkling calcite miniature from the famous Stank mine, Cumbria. From Brussels there was a case filled entirely with (would you believe) pretty minerals from Belgium, including some quite fine, orange, single scalenohedrons and groups of calcite to 18 cm long from Mont-sur-Marcienne; a second Brussels case featured the minerals of Zaire. The Chinese cases were filled with a miscellany of items from fossil dinosaur eggs to large shaggy stibnites to gorgeous azurite roses, to the "poster" specimen for this exhibition: a 17-cm group of white calcite dogteeth thoroughly infiltrated by immense, glowing orange, well-terminated orpiment crystals, from the Shimen mine, Hunan Province.

Other exhibitors chose to go chiefly non-mineral-specimen routes. The Germans were represented both by a casefull of polished Idar-Oberstein agates from that fine old town's museum, and by two cases full of highly detailed invertebrate fossils of Lower Devonian age from the Schiefengebirge shales, put in by the *Deutsches Bergbau Museum,* Bochum. The great *Paris School of Mines* had (besides a few specimens of general provenance and interest) a dignified case on René Just Haüy, with a set of his original (wooden, tiny) crystal models, an ancient microscope, manuscripts, and a matrix of Vesuvian lava showing a sharp, pale, opaque, greenish blue, 1-cm haüynite crystal in a shallow vug. Finally, *"La Sapienza"* of Rome displayed part of a lushly baroque old collection of 388 "ringstones"—cabochon-cut colorful rocks and semi-precious stones, and a few faceted gems—which, carved in Idar-Oberstein in the late 18th century, were given to the Rome collection in 1824 by Pope Leo XII.

But it was, inevitably and justly, Greek minerals which were the stars of the occasion, as shown in the fifteen or so G.A.M.F.C. and other "local" cases. Surprisingly, there was very little on hand from the recently productive green quartz/hedenbergite/andradite skarn on the island of Seriphos (see vol. 22, no. 4, p. 303), and only a few very large but not very interesting pyrite, sphalerite and galena crystal plates from the mining area around Chalcidiki, in the north. It was Laurium minerals that predominated, their quality, diversity and beauty winning my respect in preparation for the excursion to the Laurium mines on the following day.

This locality is perhaps best known in the U.S., and is revered by micromounters, for its microcrystals of extremely rare species which formed in the ancient lead slags after their centuries of immersion in seawater. Also, the ore horizons breached during the 19th–20th century period of mining have yielded many other rare species in attractive specimens. Thirteen such species were just recently described in vol. 25, no. 4, by Athanassios Katerinopoulos and Eftichia Zissimopoulou, whose *Minerals of the Laurium Mines* (1994) gives the full, systematic story (excluding the slags). Further, see Kohlberger (1976) for an earlier descriptive listing, with some discussion of ore geochemistry and paragenetic suites at various mines in the district.

But this event was a public exhibition requiring dramatic "museum"-size pieces. Happily, there were more than enough major specimens of major mineral species from Laurium on hand to answer the call. The visitor's entering glance was grabbed at once by the best one of these Laurium cases, with about 25 enormous pieces from the collection of a single G.A.M.F.C. member. I still have whiplash from the "flos ferri" aragonite that sat alone on the topmost pedestal of this case: a great labyrinthine wormy group of sparkling, perfectly clean, purest white 1-cm-thick squiggles (for want of a better term here) filling two cubic feet or so of space. Below, in this same case, was a 40-cm sword-spray of colorless, translucent to transparent, terminated gypsum crystals to 3 cm thick, with bright, isolated druse-patches of malachite and azurite adhering in all the right aesthetic places all over the specimen. And in the top-center position in another case was a tremendous Bisbee-like boulder of solid azurite/malachite and iron oxides, with dozens of brilliant little groups and sprays (to 2 cm) of azurite crystals peeking from vugs throughout.

Have you ever counted Laurium as among world-class fluorite or barite localities? There was a stout 20-cm group of pale grayish green, translucent fluorite cubes to 3 cm on edge. And the barite, of a Cumbria-reminiscent medium smoky blue with red hematite dustings, expressed itself best in a 30-cm plate of aggregated rosettes, quite stunning in total effect, with individual crystals to 1 cm. Somewhat better known are bright apple-green annabergite and cuprian adamite from Laurium, both occurring in glassy crusts of small crystals on matrix; spectacular specimens of these were here too. There were also those of another more familiar Laurium item: solid masses of clean, pale green or pale blue mammillary smithsonite. And the aragonite, besides the pure white flos-ferri type, could be seen in very pale green twisted branchings of what might be called a sub-flos ferri habit, as well as in etherially pale blue and green mammillary formations resembling the smithsonite. Remarkable too were the giant goethite casts after gypsum swords, with dense shining black to earthy brown shells over sharp solution cavities, the iron oxides mottled complexly in turn with the yellows, blues and greens of further secondary mineralization. Overall, I'd say the best of these Laurium pieces would hold up in any "general" public display in any Mineral Hall in any of the world's great museums . . . have I emphasized fully enough how revelatory they were for the mineralogical tourist to see?

Very well then—let's board the charter bus (it's the next morning now, in the Hotel Zafolia's busy lobby) for:

An Excursion to the Laurium mines

The 20 or so excursionists (other than me) were wide-awake, cheerful curatorial personnel from cities scattered from Spain to China. The day was hot, bright and clear; the tour's *lingua francae* were French and English; the tour leader was Dr. Athanassios Katerinopoulos, Assistant Professor of Geology at the University of Athens and co-author of *Minerals of the Laurium Mines* (1994).

The road out of Athens took us through Attika countryside placidly scrabbled with white villages, small farms and orchards on reddish soil, and small industries (light machinery, cement, building stuffs), in an environment of olive trees and flat, combed fields, with medium-sized brown hills ever ahead to the south. Enroute, Dr. Katerinopoulos briefed us on Laurium history—a long and proud story which I will now summarize, taking much information from the excellent summary in the Prologue of his book.

Some say that mining at Laurium began in Mycenaean times, or even earlier, or whenever it was that seafaring Pheonicians may have taught prehistoric Greeks to exploit the ore veins—say around 1000 B.C. There are, at any rate, references to the mines in the writings of several Greeks of the Periclean, "classical" age (5th–4th century B.C.). One of these is the early drama *The Persians,* by Aeschylus. In this story the playwright, himself a veteran of the Persian War of 490 B.C., boasts of the extraordinary defeat, in 480, of the Persian Emperor Xerxes by a modest league of tiny Greek political units in uneasy alliance. Proud modern Greeks may plausibly argue that it was Laurium mining which made possible the astonishing cultural flowering of 5th-century Athens. The great naval victory of Salamis (at a time when Persian troops occupied nearly all of mainland Attika, including Athens itself) was secured by the Athenian fleet, whose ships had been built with funds from Laurium silver. What mineral locality anywhere can match *that* for historical-cultural significance?

Throughout the classical period, Laurium produced silver in great abundance, and with noteworthy results, including: the famous Athenian silver tetradrachmae coins, stamped with the owl of the goddess Athena; the rebuilding of the Acropolis after the Persian devastation; and the maintenance of the fleet to sustain the "Athenian Empire." It was this empire which served as the cover and context for that civilization of genius in which philosophy, science, literature, the writing of history, and something like democracy all tried fledgling wings.

The decline of Laurium set in with Sparta's defeat of Athens at the end of the Peloponnesian War (404 B.C.). Sporadic mining activity continued through Hellenistic and into Roman times, but final closure of the ancient mines came sometime during the 2nd century A.D.

In their heyday the mines were leased piecemeal by the Athenian state to Athenian citizens, and occasionally to privileged foreigners. Each leaseholder paid the central government 5% of his profits, so that general prosperity, and some very large private fortunes, were created. According to Katerinopoulos and Zissimopoulou:

> The work done by the ancients proves that they had understood the primary rule of Laurium deposits, i.e. that the [hydrothermally emplaced] minerals are concentrated almost exclusively in . . . marble, but positioned where the marble was in contact with schists, near veins of granite.

I learned that in modern times these granite stocks came to be called "Eurekas," because they were such reliable indicators to the miners

Figure 6. **Mine entrances in the Karameza region, Laurium district. (Thomas Moore photo)**

Figure 7. **Red hematite coloring a 30-cm plate of barite crystals from Laurium, displayed at the Athens exhibition.**

Figure 8. **Copper-stained aragonite, 20-cm, from Laurium, displayed at the Athens exhibition.**

that rich ore lay along schist-marble contacts nearby. Ancient digging was done, of course, by hand, with pickaxes and hammers, with some use also of the fire-setting method for major gallery workings. Miners in narrow stopes lay on their backs and crawled, digging upward, along the orebodies, leaving columns of rock as support pillars along their way.

Now the unpleasant fact for us moderns is that this brutal underground work was carried out under the whip by slaves who'd been bought, and were cared for (or not), by the rich mining capitalists of classical Athens. Even such a worshipfully Grecophile scholar as H. D. F. Kitto (1951) complained that:

> The treatment of the [10,000 or so slaves usually at work underground in the district] was callous in the extreme, the only serious blot on the general humanity of the Athenians . . . though an Athenian apologist might point out that . . . only the most loutish slaves were sent there.

It seems indeed that those slaves condemned to underground work were in some sense criminal types, or belonged otherwise to a sort of lowest slave caste; "better" slaves worked above ground, in the less murderous process of ore refinement and smelting (of which more later). But those below, bound by iron rings around their ankles, lived more or less exclusively by the dim dirty light of oil lamps in the galleries. Poignantly, in one of those galleries "a cubic fluorite crystal was found, on the facets of which the slaves had cut marks, i.e. they were dice, with which these wretched creatures had tried to while away their leisure hours" (Katerinopoulos and Zissimopoulou, 1994). Each year, it is thought, about 25% of this workforce died or became useless for further work, and so had to be replaced. But so much for ancient times.

The story of modern Laurium begins in 1860, when the Italian mining engineer Giambattista Serpieri (for whom the sulfate mineral serpierite and its type locality, the Serpieri shaft, Laurium, were named) noticed that an Attica ship washed up on a beach in Sardinia had come with a ballast load of pure smithsonite. In 1864 the Italian-French company Serpieri-Roux de Fraissinet began operations, not at once underground, but by resmelting the ancient slags, extracting amazing metallic values from them—one typical slagheap proved to contain 18–21% lead, with 446–555 grams of silver per ton of lead. (The present-day scavenger learns to his disappointment that all land-lying piles of these ancient residues had been reprocessed by about 1900; all accessible slagheaps today date from the modern period.)

After a brief but intense phase of legal/political controversy in the 1860's and early 1870's between the Greek government and western European interests, the victory of the latter in 1873 resulted in the "French Lavrion Mines Company" to exploit the ore reserves still in the ground. Thus until their final closure in the 1970's the mines were a French enterprise; occasional signs and some lingering use of the spoken language in Laurium today testify to this long period of French colonization. And it was during this time, of course, that all specimens presently to be seen in collections were dug, with the exception of those in the ancient slags dredged up from the sea, those dug on dumps and in dormant workings since 1970 by eager G.A.M.F.C. members, and those scavenged by tourists like those in our party.

Figure 9. **The Lavrion Mineralogical Museum at Laurium.**

We first debarked from our air-conditioned bus and into the naked heat at the Mineralogical Museum of Laurium, near some blackish ruins of old mine structures. The Museum, formerly the on-site chemical lab of the French company, is a tiny, one-room one-story stone building that houses about 1,600 mineral specimens crowded into display cases on every wall and down the middle. I remember especially three wonderful azurite thumbnails, rosettes of brilliant 5-mm crystals; and there is a case with samples of ancient slags and photomicrographs showing what rarities lurk in their vugs; and there are immense gypsum, fluorite, aragonite and smithsonite specimens rivaling all but the greatest princes of the Athens exhibition. On the floor along the wall are old mining implements, and some dull black samples of raw argentiferous galena ore. By the desk is a custodian/collector selling off small specimens and postcards—and I will here pass on Hanke's (1992) report, although unfortunately I had no chance to verify it firsthand, that the region harbors dozens of former miners and/or present collectors willing to sell from their specimen hoards, usually at very low, "country" prices. This is generous of them, considering how hazardous collecting conditions can be; we heard of one German who, foolishly working alone, had been lost for some 30 hours in the pitch-black tunnels before Dr. Katerinopoulos, spotting his saucer-sized eyes all aglow, effected his rescue. There are, in all, about 160 kilometers of these underground workings, ancient and modern, accessed from about 1,000 old gallery entrances scattered throughout the district, but scattered especially thickly in the Plaka (north-central) and Karameza (south-central) regions.

Our next stop was a cluster of four mine entrances in Karameza: cool, 4-meter-high voids opening into hillsides from a limestone gully with sparse, spiky brush and piles of mine rock. The trail to them passed a vaguely comical little dwarf-colony of wooden blue-and-white beekeepers' boxes, alive with bees, sitting flat on the ground (for this is also, we were informed, the place which produces "the world's best honey"). From a bit of high ground just past the bee houses we could see for miles out over the rough karst terrain, and in one direction could catch a glint of the sea far off in the distance. All was vibrantly calm; the sun raged; the great blue sky vaunted; cicadas (or something like them) bickered and thrummed. Chatting and laughing and changing film, our dauntless little party scrambled happily on down the slopes of loose brown gossany rock to where the gallery entrances were. We did not penetrate more than a few meters in from those shady mouths; the tunnels reached back into the blackness and narrowed quickly. With an outlandish reflex optimism we scan-searched along the gallery walls for crystallized areas, although really the main point of these moments was to enjoy the cool breeze flowing out of the earth.

The wash outside proved more mineralogically tantalizing. Collectors clearly had been here of late, as there were little piles of freshly cracked rocks and discarded shards, specimen-wannabes, on many flat surfaces. Some of us found, even in our limited time and with no collecting equipment, some microcrystal seams. I took away, for example, a sparkling bright brown druse of jarosite crystals on massive goethite. One left the place with the feeling that a long weekend here would be a rewarding experience for a patient collector.

Next, we visited some extremely well-preserved ruins of ancient ore-separation facilities, or "washeries": relict stone mazes of vats, channels, mini-aqueducts and water-storage cisterns, in a dry gulch where once the chronically sparse rainwater and springwater had been gathered and put to work. Slaves with mallets once pounded the raw ore here into 1-mm particles; then the water would be led out from its big cisterns (whose ancient watertight linings remain largely intact today) into this engineering brainstorm of descending watery levels, for purposes of ore flotation. The heaviest particles concentrated thereby were argentiferous galena. This product would then be carried to nearby hillsides, or seaside cliffs (both good for catching the winds to further fan the ovens) for roasting, and separation of metallic silver by cupellation. An estimated 3,000 tons of silver were produced in this way throughout the classical period, and perhaps 1.5 million tons of lead—a byproduct used in building projects (there are ancient lead sheets remaining between some stones of the Parthenon), or in making ceramics. Hundreds of these furnaces once stood in Laurium's windy places, and hundreds of washeries like the one we visited stood in valleys . . . a complex thing, this ancient industry, and cutting-edge high-tech for its time.

Then we strolled out along an old road lined on both sides with steep embankments of tailings from the late mines, brown goethite

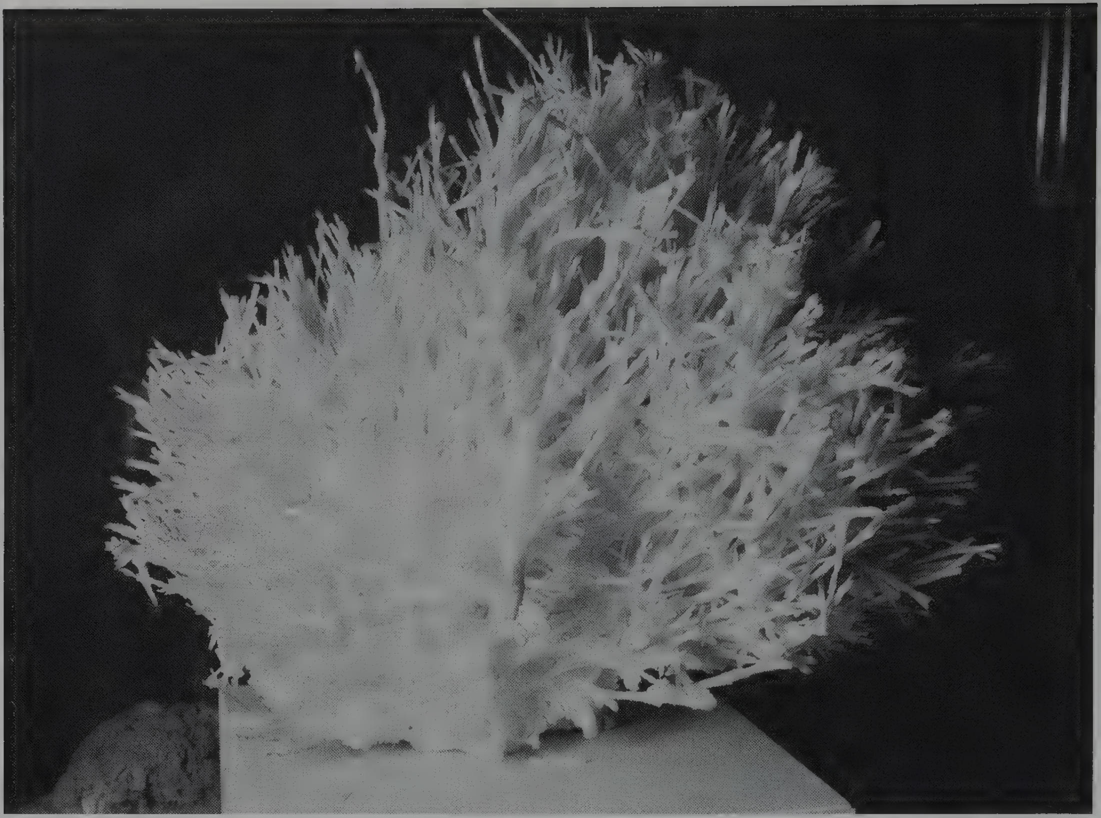

Figure 10. **A large, 45-cm *flos ferri* aragonite from Laurium, displayed at the Athens exhibition.**

basically, quite vuggy and liberally shot through with enticingly bright secondary colors. Although not one among our busfull of mineralogical pros had brought a rock hammer, we did manage to bring back to the bus enough samples to afford us with hours of microscope viewing back home and (who knows?) discovery pleasure. Dr. Katerinopoulos said that he brings his students out here each year, and each year, for quite a few years running now, one of them has found a brand-new Laurium species in this very place.

From the road, once again, the sea could be glimpsed far away, and the benign disuse of the place hummed and throbbed with insect voices. Meanwhile, upfront, rocks were busily cracked against one another, and everyone socialized, joked, compared sight-identifications, and passed around water bottles. The bus driver made his U-turn, and, all aboard again, we headed back into Laurium town.

There, our last instructional stop was at an old French mine building, a vast warehouse-like structure, now largely empty but clean inside, midway through its refurbishing as a little museum of mining technology. The mayor of Laurium met us here and made a speech, expressing the hope that this building would host in the future a permanent exhibition of Laurium minerals, and, each year, a small mineral show as well.

The tour's serious business had come to an end; the denoument of the outing featured a major seafood spread at a Laurium harborside restaurant. There was a good breeze off the water, and more pleasant talk, the amazing varieties of sea phyla grilled or baked or cold-marinated in oil (you want an octopus tentacle fixed in some way? you order it, and watch as one of the waitstaff plucks down the raw pinkish-purplish thing from a hanging row of them over the terrace), all washed down with much cold beer. Then came one final stop, for a look at the huge, solemn ruin of the Temple of Poseidon on Cape Sounion, the southernmost point of Attika. Here, from its promontory, the noble white structure had acted in ancient days as a kind of welcoming beacon for sailors coming home from the sea. And from this height we could see why it's so often said that no other water anywhere in the world has quite the colors of the Aegean. Lots of terms from the painter's lexicon have been proposed for these colors, in their gradation out from the beaches to the far depths, but our crew's consensus was something like "aquamarine to aurichalcite to chalcanthite to azurite." And with misty islands and white sail-flecks all the way to the southern horizon.

As I am finishing this report I receive happy news from Athens that the exhibition at the Museum of Archaeology has been extended another month, until July 27. The museum's entrance control service reports that as of July 23, 212,000 visitors, 75% of them foreign tourists, have attended. Bear in mind that the next G.A.M.F.C. exhibition in Athens is scheduled tentatively for the summer of 1996; and don't forget the first mineral show in Laurium, perhaps as early as summer 1995. Meanwhile, to my hosts and trip-expeditors for this terrific Greek Spring, well, if I knew the Greek words for some fanciness like "Hail and farewell," I would be shameless and say it, but as it is I will just say thanks, many thanks, again.

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A NEW OCCURRENCE OF MRAZEKITE FROM BENAMBRA, VICTORIA, AUSTRALIA

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A newly identified occurrence for the rare bismuth-copper phosphate mrazekite *has proven to contain other rare bismuth minerals as well, including namibite and schumacherite.*

INTRODUCTION

The bismuth-copper phosphate mineral mrazekite, $Bi_2Cu_3(OH)_2O_2(PO_4)_2 \cdot 2H_2O$, was first described from an historic copper mine near Lubietova (formerly Libethen) in Slovakia (formerly part of Czechoslovakia) by Ridkosil *et al.* (1992). Its crystal structure was revised by Effenberger *et al.* (1994) on material collected from Reichenbach and Gadernheim, Germany. Recently a new occurrence of well-crystallized mrazekite was discovered near the small settlement of Benambra, in northeastern Victoria, Australia. It is associated with other rare bismuth-bearing minerals, including namibite, schumacherite, pucherite and several unknown species.

OCCURRENCE

Mrazekite occurs in a vesuvianite-grossular skarn which has been invaded by secondary copper, bismuth and vanadium mineralization. The skarn outcrops on the western side of a gorge on Morass Creek, 15 km north of Benambra (Figs. 1 and 2) and within the boundaries of the Alpine National Park. The deposit was first investigated in the late 1970's and early 1980's by the Essex Minerals mining company and was named the Wombat Hole prospect. However, the findings were inconclusive and have not been followed up. Short exploration trenches cut in the mineralized skarn by the mining company were sampled by two of the authors (WDB and DAH) during visits in February and May of 1994. The specimens collected on these visits yielded the mrazekite.

No mining lease is currently in effect on the site, but collecting at the deposit still requires a State Government permit for research in National Parks.

GEOLOGY

Limestone deposits containing mixed sulfides have been known from the Mitta Mitta and Gibbo River area, north of Benambra, since the 19th century, when some of them were mined on a small scale for silver and copper. The deposits occur in the Wombat Creek Graben, a sequence of Silurian sedimentary rocks overlain by volcanic rocks (the Mitta Mitta Volcanics; Bolger, 1982). The gorge of Morass Creek has exposed the sequence in the southern part of the graben. On the western side of the gorge, steeply west-dipping sandstones, quartzites, cherty siltstones and conglomerates are exposed. Lenses of recrystallized dolomitic limestone occur toward the base of the sequence. A flow of basalt, dated at 2.3 million years, filled the former valley, and Morass Creek is now a lateral stream to this ancient flow. The

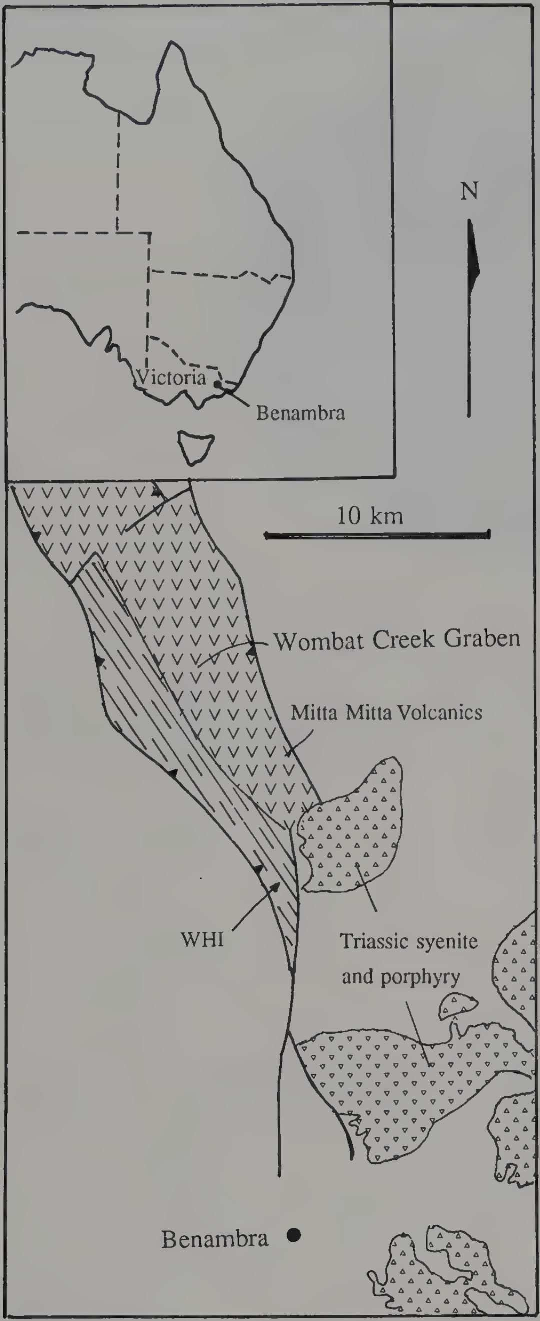

Figure 1. **Locality map of Benambra region.**

mrazekite-bearing skarn occurs at the top of one of the limestone lenses and beneath a cherty siltstone band. It has been exposed as a "window" only a few meters across, below an outlier and scree slope of the basalt filling the gorge.

The origin of the skarn is uncertain, but may have resulted from the intrusion of a quartz porphyry mass to the east, possibly during the Triassic. Drill core recovered during the original investigation of the deposit did not intersect either primary sulfides or the secondary mineralization. The core log and the drill hole orientation suggest it transected weathered skarn cropping out on the side of the former, now basalt-filled, valley (Fig. 3).

MINERALOGY

The skarn

The mineralized skarn exposed in the trenches is conspicuous for its bright blue and green veining. The body of the skarn is pale gray to pale brown and consists mainly of a dense granular aggregate of garnet (grossular-andradite) with patches of fibrous vesuvianite. The rock has been extensively fractured. Broken, randomly oriented, transparent brown vesuvianite crystals up to 3 mm long and euhedral pale brown garnet crystals of similar size occur embedded within patches and veins of chrysocolla.

Secondary Copper Mineralization

Unaltered chrysocolla occurs both as transparent bluish green veinlets and as translucent to opaque sky-blue and greenish blue patches and veins up to several cm thick. When altered it becomes pale blue to white and reveals either concentric banding or fibrous textures. Azurite occurs as veinlets and irregular patches several cm across make up of intergrown platy crystals. Malachite forms compact fibrous masses and veins. There are also irregular patches and coatings of pale yellow and pale green material which is largely X-ray amorphous. Globular crusts of colorless hyaline opal and black manganiferous coatings and stains occur on the chrysocolla. A vitreous, dark brown, non-crystalline material forms irregular patches several cm across and may represent replaced sulfides.

Table 1. **Microprobe analyses of mrazekite, namibite and schumacherite from Benambra.**

wt%	*1*	*2*	*3*		*4*	*5*	*6*
Cu_2O	—	12.23	0.33	Cu^{1+}	—	1.06	0.04
CuO	26.22	—	—	Cu^{2+}	2.88	—	—
Bi_2O_3	50.74	73.10	79.96	Bi	1.89	1.94	3.19
V_2O_5	0.21	13.26	16.42	V	0.02	0.90	1.68
P_2O_5	15.40	1.35	2.24	P	1.88	0.12	0.29
As_2O_5	0.05	0.02	0.32	As	—	—	0.03
SiO_2	0.06	—	0.60	Si	0.01	—	0.09
F	0.24	—	—	F	0.11	—	—
H_2O_{diff}	7.18	—	—	H	6.9	—	—
-O≡F	0.10	—	—				
Total	100.00	99.93	99.87				

1. Mrazekite (average of 6 analyses)
2. Namibite (average of 2 analyses)
3. Schumacherite (average of 2 analyses)
4. Mrazekite formula, based on 14 oxygens
5. Namibite formula, based on 5 oxygens
6. Schumacherite formula, based on 10 oxygens

Mrazekite $Bi_2Cu_3(OH)_2O_2PO_4)_2 \cdot 2H_2O$

The mrazekite usually forms royal-blue spheres up to about 1 mm consisting of tightly packed radiating fibers. Mrazekite spheres are usually enclosed within chrysocolla, although some have been found in malachite. Rosette-like aggregates up to 1 mm across may also be found on fractures in the skarn. Singles and clusters of prismatic, transparent, royal-blue crystals up to about 0.5 mm long are less common. The prisms are flattened with a shallow wedge-shaped termination. The physical properties and various habits of the Benambra mrazekite closely resemble those reported for the mineral from Slovakia and Germany. The optical properties of the Benambra mineral were not determined.

Chemical analysis of the Benambra mrazekite was undertaken using a CAMECA SX50 microprobe operating at 15 kV. The resulting formula (Table 1) is in close agreement with that reported for the type material. Due to the scarcity of the Benambra mrazekite, the water content was not determined directly, but was calculated by difference.

Powder X-ray diffraction data were obtained using a Guinier camera with 100 mm diameter and CuKα_1 radiation (Table 2). The powder pattern agrees closely with that of type mrazekite. The data were indexed on the basis of a monoclinic unit cell refined from the

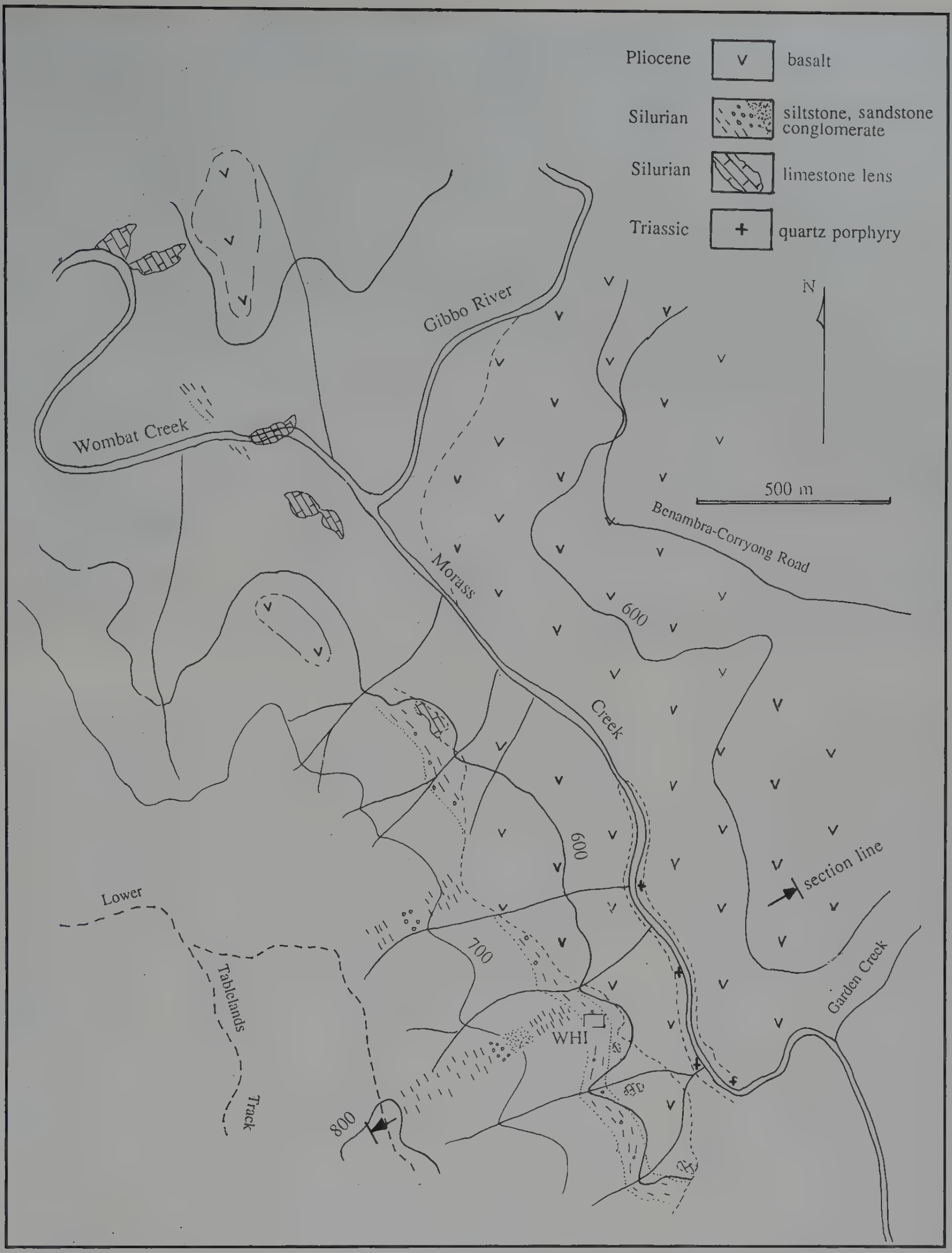

Figure 2. **Simplified geological map of the Morass Creek Gorge. Note section line for cross-section of Fig. 3.**

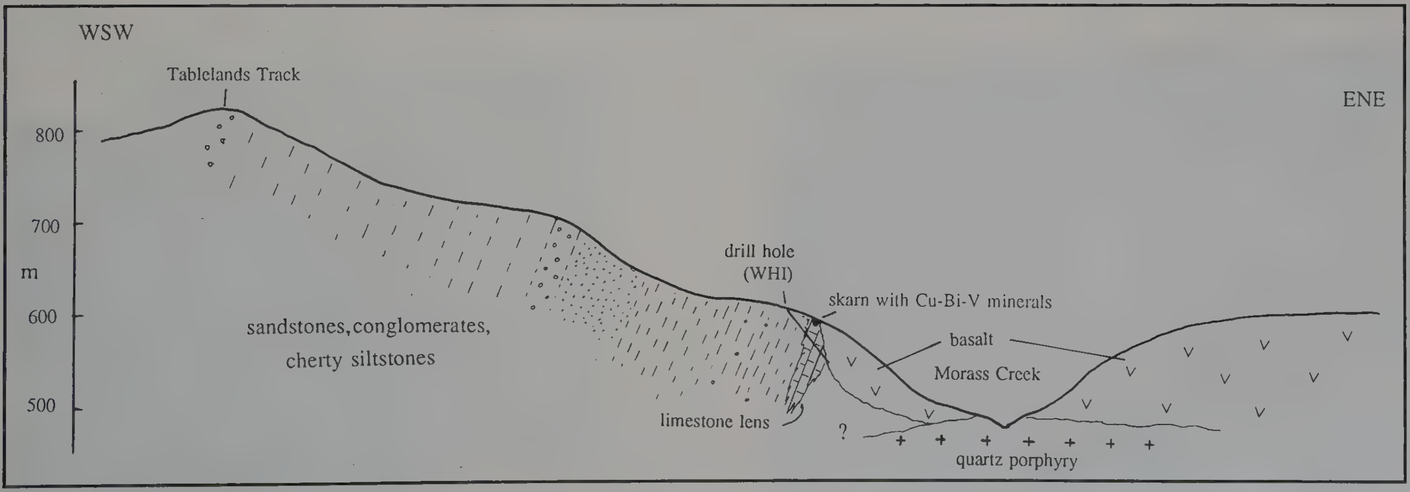

Figure 3. **Geological cross section through the skarn deposit (geology based on mapping by Essex Minerals).**

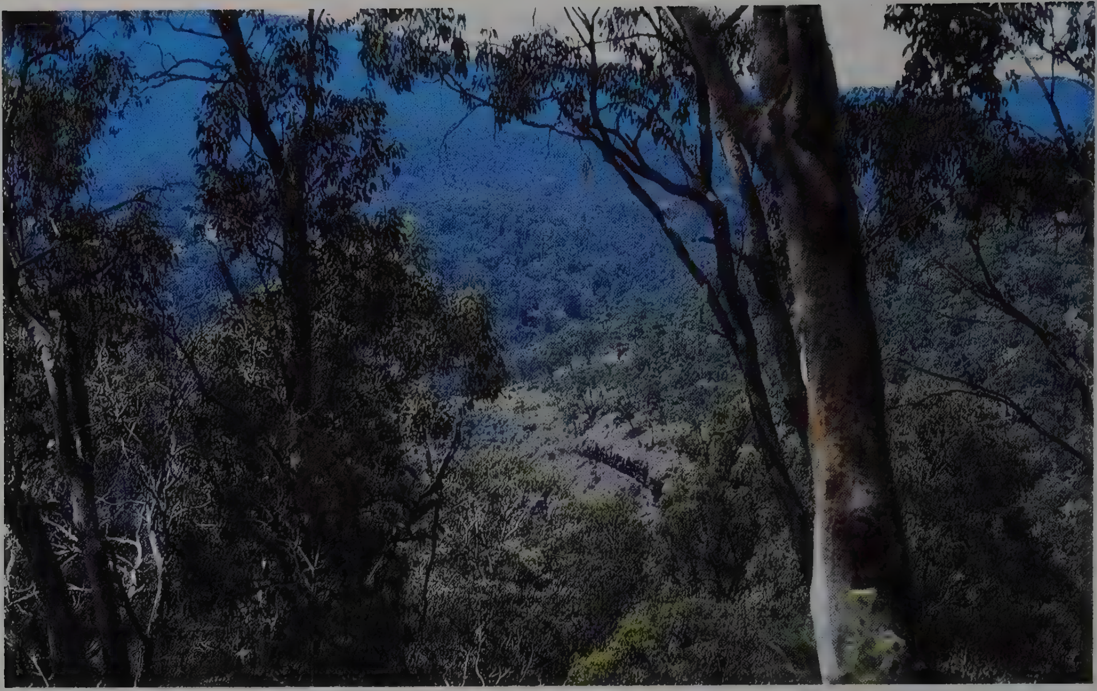

Figure 4. Morass Creek Gorge.

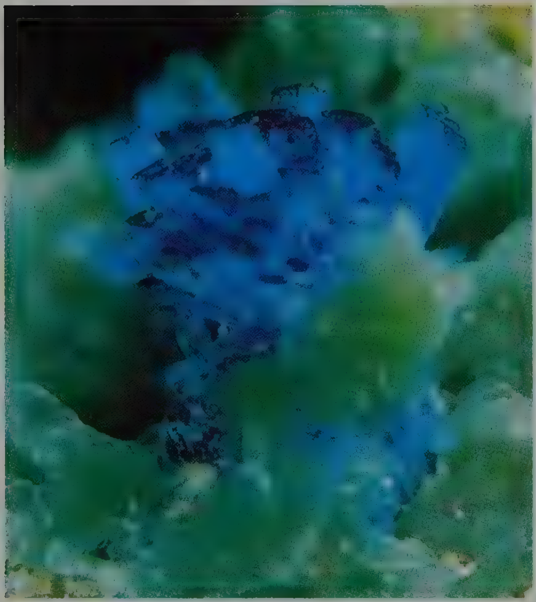

Figure 5. Mrazekite crystal group 1 mm across (photo by Bill Birch).

Figure 6. Mrazekite group, with crystals to 0.3 mm, in chrysocolla (photo by Frank Coffa).

Figure 7. Mrazekite spheres up to 0.2 mm (photo by Frank Coffa).

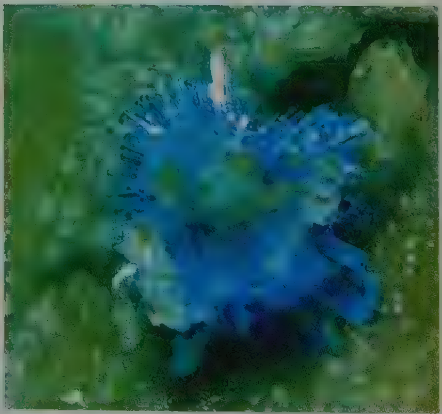

Figure 8. Mrazekite rosette 0.9 mm across (photo by Bill Birch).

Figure 9. Vesuvianite crystals (up to 1 mm) embedded in chrysocolla (photo by Frank Coffa).

Figure 10. Pucherite crystals (brown) up to 0.2 mm, with pale green globular schumacherite on chrysocolla (photo by Frank Coffa).

Figure 11. Namibite (green) with schumacherite (brown) in chrysocolla. The largest hemisphere is 0.8 mm (photo by Frank Coffa).

Figure 12. Wulfenite crystal (0.5 mm) in chrysocolla (photo by Frank Coffa).

Figure 13. Unknown yellow sphere, 0.2 mm across, in malachite (photo by Bill Birch).

powder data, and based on the cell determined by Effenberger *et al.* (1994); their cell is slightly larger than that of the Benambra mrazekite (see Table 2).

Other minerals

Other rare species occur within small cavities and on fractures in the chrysocolla.

Namibite, $Cu^{1+}Bi_2VO_6$, occurs sparingly as pistachio-green to nearly black hemispheres and coatings which consist of very thin tabular crystals. The largest namibite hemisphere is about 5 mm in diameter. This is the fourth known occurrence of namibite, the others being Khorixas, Namibia (Knorring and Sahama, 1981), Iron Monarch, South Australia (Pring *et al.,* 1992), and Cumbria, England (Neall *et al.*, 1993).

Schumacherite, ideally $Bi_3O(VO_4,AsO_4,PO_4)_2(OH)$, forms yellow-brown to pale green spheres, hemispheres and globular coatings with

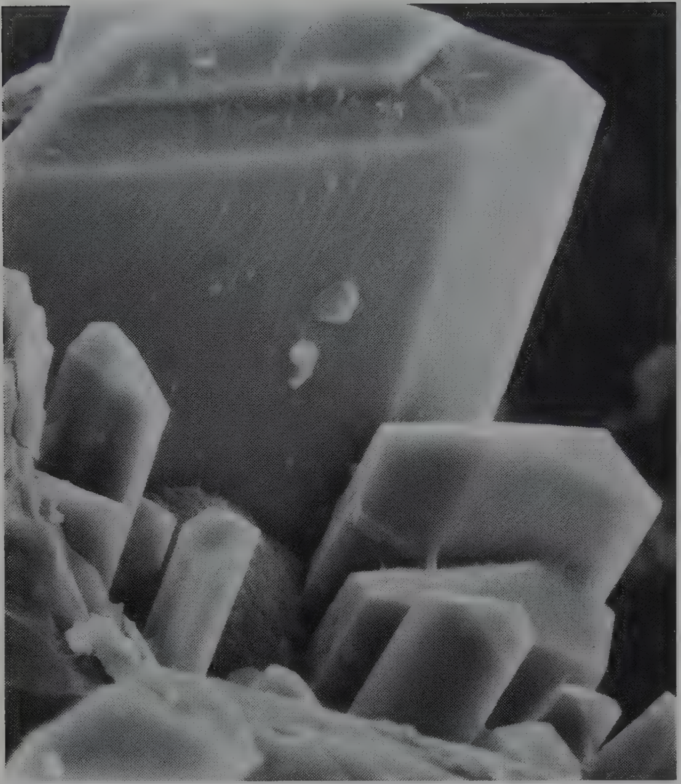

Figure 14. **Scanning electron micrograph of Benambra mrazekite crystals to about 0.03 mm.**

a waxy appearance. Identification was confirmed by X-ray diffraction and microprobe analysis, which showed that the mineral contains only small amounts of As and P (Table 1). This is only the second world occurrence of schumacherite (Walenta *et al.*, 1983).

Eulytite (?): A mineral occurring as botryoidal coatings and as minute spheres enclosed by schumacherite was encountered during microprobe analysis. It has a chemical formula close to $Bi_4(SiO_4)_3$ and is probably eulytite.

Pucherite (?): Honey-brown to orange-brown microcrystals up to about 0.2 mm long occur rarely with schumacherite and namibite. They have an elongated, rounded "dog-tooth" habit and an adamantine luster. Microprobe analysis indicates that they are a polymorph of $BiVO_4$, most likely pucherite on the basis of color and the curved crystal faces (Qurashi and Barnes, 1952).

Wulfenite, $PbMoO_4$, in tabular yellow crystals up to 1 mm across, occurs rarely, enclosed in chrysocolla. Microcrystals (to 0.5 mm) with a stumpy tetragonal bipyramidal habit have been found in cavities. This is the first record of wulfenite in Victoria.

Gold (Au): A few irregular grains of very pale gold have been discovered in the altered skarn. The gold is probably silver-bearing.

Unidentified minerals: Several so-far unidentified minerals have also been noted. The most common of these forms very small, yellow-brown, finely fibrous spherical aggregates up to about 0.3 mm across, suspended in chrysocolla or malachite. A smooth-textured, pale lime-green clay-like material forming rounded cores and patches in chrysocolla is a poorly crystalline bismuth oxide.

FORMATION OF THE MRAZEKITE

In the absence of primary sulfides, either exposed at the surface or in drill core, the timing and source of the secondary copper-bismuth-vanadium mineralization is conjectural. It may have been mobilized from elsewhere in the skarn, or possibly introduced by magmatic fluids from the nearly quartz porphyry intrusion. The formation of the skarn and the secondary copper-bismuth mineralization appear to have been separate events. One possibility is that the skarn, containing primary copper and bismuth sulfides, formed as temperature increased, followed by an influx of oxidizing solutions which caused dissolution of the sulfides and precipitation of the secondary minerals during cooling. Alternatively, the secondary mineralization may have formed during a later period of oxidation and weathering.

The secondary copper mineralization appears to have exploited fractures and channelways lined with large vesuvianite and garnet crystals, which were broken off and incorporated in the chrysocolla and malachite. Alternatively, dissolution of veins and patches of calcite enclosing vesuvianite and grossular may have taken place during the secondary mineralization, followed by precipitation of chrysocolla in the resulting voids.

The mrazekite often appears as spherules suspended in chrysocolla and malachite, suggesting nucleation in copper-rich gels prior to their solidification. Its nucleation may possibly be explained in terms of low-temperature insolubility of Bi and P in the gel phase. Free-standing crystals of mrazekite on open fractures also imply some transport of Cu, Bi and P-rich solutions over short distances.

The vanadium-bearing minerals are the last to crystallize in the secondary assemblage. The change in oxidation state of Cu from

Table 2. **X-ray powder diffraction data for mrazekite.**

Benambra				*Lubietova*		*Gadernheim*	
I/I_o	d_{obs}	d_{cal}	*hkl*	I/I_o	d_{obs}	I/I_o	d_{obs}
90	7.63	7.64	101	78	7.62	100	7.630
30	6.06	6.08	$\bar{1}03$	23	6.10	42	6.089
40	5.40	5.41	012	43	5.41	56	5.407
40	5.19	5.20	004	52	5.20	46	5.198
35	5.14	5.14	$\bar{1}11$	45	5.15	49	5.146
20	4.41	4.41	202	27	4.42	29	4.417
15	3.83	3.82	202	23	3.81	21	3.817
30	3.64	3.63	210	31	3.63	35	3.637
20	3.43	3.43	$\bar{1}15$	31	3.44	28	3.440
15	3.17	3.16	020	37	3.17	35	3.170
10	3.122	3.125	021				
			116	11	3.047		
15	3.038	3.038	$\bar{2}06$	100	3.041	87	3.045
35	3.015	3.014	$\bar{3}01$	63	3.014	77	3.016
15	3.002	3.001	$\bar{1}07$	17	3.003		3.006
100	2.923	2.924	121	83	2.924	76	2.927
			123	1	2.809		
10	2.776	2.776	214	17	2.771	19	2.773
5	2.675	2.674	$\bar{3}05$	14	2.680	13	2.681
10	2.598	2.600	311	13	2.598	18	2.601
10	2.571	2.569	$\bar{2}22$	27	2.573	20	2.574
			206	14	2.497	20	2.500
2	2.485	2.490	321				
5	2.455	2.454	117	16	2.452	16	2.454
10	2.346	2.350	125	35	2.349	22	2.351
5	2.297	2.297	$\bar{2}18$	18	2.303	16	2.301
5	2.220	2.220	400	12	2.218	12	2.220
10	2.182	2.182	$\bar{3}21$	7	2.183	24	2.184
5	2.131	2.131	$\bar{4}12$	7	2.133	11	2.134
				plus 30 lines to d = 1.397Å		plus 54 lines to d = 1.478Å	

Unit cell

Benambra

$a = 9.057(4)$, $b = 6.323(4)$, $c = 21.21(1)$Å, $\beta = 101.34(4)°$,
$V = 1191.0(8)$Å^3

Gadernheim

$a = 9.065(1)$, $b = 6.340(1)$, $c = 21.239(3)$Å, $\beta = 101.57(1)°$,
$V = 1195.8(2)$Å^3

divalent in mrazekite and chrysocolla to monovalent in namibite requires the presence of a strong reducing agent. This was probably a hydrolyzed V^{4+} ion, which was subsequently oxidized to V^{5+} to form VO_4^{3-}. This suggests that the solutions precipitating the secondary minerals changed from strongly acidic initially to basic in the final stages.

ACKNOWLEDGMENTS

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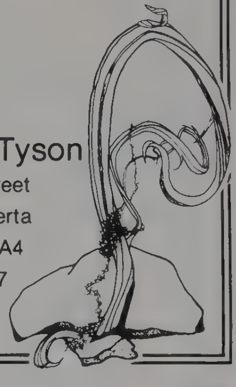

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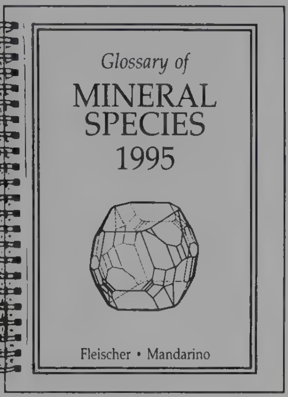

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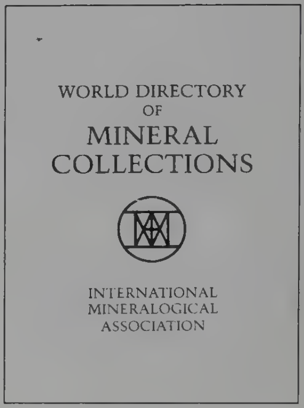

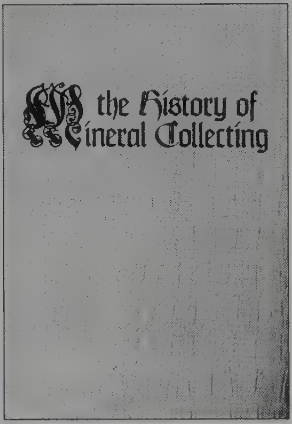

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Each mineral is described in the following format:

Chemical Formula
IMA No. (any relationship to other minerals) ________
Crystal system, space group
unit cell parameters
Color; luster; diaphaneity.
Optical properties.
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1993 PROPOSALS

$Na_3(Ca,REE,Sr)_3(CO_3)_5$

IMA No. 93-001 ________
The calcium-analogue of burbankite and khanneshite.
Hexagonal: $P6_3mc$, $P\bar{6}2c$ or $P6_3/mmc$
a 10.447 c 6.318 Å
Deep orange; vitreous; translucent.
Uniaxial (-), ω 1.636, ε 1.631.
5.20 (4), 3.68 (3), 3.01 (5), 2.601 (10), 2.130 (6), 1.649 (3).

$NiMn_3O_7 \cdot 3H_2O$

IMA No. 93-002 ________
The nickel-analogue of chalcophanite.
Hexagonal (trigonal): $R\bar{3}$ or $R3$
a 7.514 c 20.52 Å
Very dark brown to almost black; submetallic to vitreous; opaque, but translucent in thin plates.
Uniaxial (-), $\omega > 2.00$, ε 1.97.
6.84 (10), 4.01 (2), 2.219 (3), 1.884 (2), 1.575 (2).

$AlAsO_4$

IMA No. 93-003 ________
The arsenate-analogue of berlinite.
Hexagonal (trigonal): $P3_121$ or $P3_221$
a 5.031 c 11.226 Å
Colorless, white, cream; vitreous; transparent.
Uniaxial (+), ω 1.596, ε 1.608.
4.36 (20), 4.06 (31), 3.442 (100), 2.359 (15), 1.873 (16), 1.4202 (11).

$K_3Cu_3AlO_2(SO_4)_4$

IMA No. 93-004 ________
The aluminum-analogue of klyuchevskite.
Monoclinic: I2
a 18.423 b 5.139 c 18.690 Å β 101.72°
Dark green; vitreous; transparent.
Biaxial (+), α 1.542, β 1.548, γ 1.641, 2V(meas.) unknown, 2V(calc.) 30°.
9.15 (84), 9.04 (100), 7.20 (52), 3.781 (37), 3.757 (33), 2.786 (21).

$NaBa_3(Mn^{2+},Mn^{3+})_4[Si_4O_{10}(OH)_2][Si_2O_7]O_2F \cdot H_2O$

IMA No. 93-005 ________
Orthorhombic: Pnma
a 23.42 b 12.266 c 7.181 Å
Black with a green shade; vitreous to greasy; translucent.
Biaxial (+), α 1.767, β 1.793, γ 1.871, 2V(meas.) 60-65°, 2V(calc.) 62°.
4.580 (5), 3.303 (9), 2.999 (10), 2.715 (5), 2.655 (10), 2.156 (4), 1.648 (5).

$BiAsO_4$

IMA No. 93-006

A tetragonal polymorph of rooseveltite.

Tetragonal: $I4_1/a$

a 5.085 c 11.69 Å

White to yellowish white; earthy; opaque.

Uniaxial (+), mean n > 2.0.

4.660 (11), 3.066 (100), 2.546 (12), 1.797 (11), 1.581 (10), 1.551 (17).

NH_4BF_4

IMA No. 93-008

Orthorhombic: Pnma

a 9.0615 b 5.6727 c 7.2672 Å

Colorless to white and yellowish; vitreous; transparent to translucent.

Biaxial, mean n calculated from Gladstone-Dale is 1.308.

4.472 (75), 3.540 (90), 3.183 (100), 2.8982 (80), 2.5362 (65), 2.2822 (65), 2.1631 (70).

Bi_2O_3

IMA No. 93-009

A tetragonal polymorph of bismite.

Tetragonal: $P4_2/n$ or $P4_22_12$

a 8.08 c 6.46 Å

Green, yellowish; adamantine; translucent.

Uniaxial (+), ω 2.13, ε 2.18.

5.73 (7), 3.44 (5), 3.16 (10), 3.01 (4), 2.56 (4dif.), 2.02 (5), 1.902 (6).

$Na_2CaMg_7(PO_4)_6$

IMA No. 93-010

The magnesium analogue of fillowite and johnsomervilleite.

Hexagonal (trigonal): $R\bar{3}$

a 14.967 c 42.595 Å

Colorless; vitreous; transparent.

Uniaxial, indices of refraction calculated from reflectance values: n_1 1.60, n_2 1.62.

3.694 (S), 3.558 (M), 2.960 (S), 2.753 (S), 2.500 (M), 2.126 (M), 1.851 (M).

$Cu_3MoO_4(OH)_4$

IMA No. 93-011

Orthorhombic: Pnnm

a 8.499 b 12.527 c 6.067 Å

Dark green; adamantine; transparent.

Biaxial (+), α slightly < 1.89, β unknown, γ slightly < 1.91, 2V(meas.) 74°.

5.471 (S), 3.754 (S), 3.043 (S), 2.591 (VS), 1.519 (S).

$CaSrAl(F,OH)_7$

IMA No. 93-013

Monoclinic: $P2_1/c$

a 8.215 b 11.989 c 6.076 Å β 96.22°

Colorless; vitreous; transparent.

Biaxial (+), α 1.4240, β 1.4320, γ 1.4415, 2V(meas.) 85.5°, 2V(calc.) 85.6°.

6.758 (7), 4.250 (9), 3.643 (8), 3.148 (7), 3.063 (8), 3.030 (7), 2.840 (7), 2.125 (8).

$IrBiTe$

IMA No. 93-016

Cubic: Pa3

a 6.502 Å

Steel black; metallic; opaque.

In reflected light: bright white with a yellowish tint, moderate anisotropism, no bireflectance, nonpleochroic. R: (51.0%) 470nm, (52.6%) 546nm, (52.9%) 589nm, (49.2%) 650nm.

2.89 (70), 1.955 (100), 1.735 (80), 1.250 (80), 1.207 (70), 1.148 (70), 1.054 (70).

$Ir_{1-x}Te_2$ x = 0.24

IMA No. 93-017

Cubic: Pa3

a 6.413 Å

Steel black; metallic; opaque.

In reflected light: bright white with bluish tint, no anisotropism, no bireflectance, nonpleochroic. R: (44.3%) 470nm, (46.0%) 546nm, (46.9%) 589nm, (45.5%) 650nm.

2.86 (70), 1.93 (100), 1.235 (80), 1.132 (90), 1.040 (80), 0.9780 (80).

$IrTe_2$

IMA No. 93-018

Hexagonal: $P\bar{3}m1$

a 3.933 c 5.390 Å

Steel black; metallic; opaque.

In reflected light: bright yellowish white with bluish tint, moderate anisotropism with bluish or yellowish tint, no bireflectance, nonpleochroic. R_O & R_E: (41.4, 49.0%) 470nm, (40.2, 48.2%) 546nm, (41.1, 49.0%) 589nm, (45.2, 51.2%) 650nm.

2.85 (100), 2.10 (80), 1.95 (60), 1.580 (70), 1.160 (60), 1.110 (70).

$Bi_6Te_2O_{13}$

IMA No. 93-019

Orthorhombic: space group unknown

a 5.689 b 10.791 c 5.308 Å

Yellow green to light green; adamantine; transparent.

Biaxial n's > 2. In reflected light, R: (14.8%) 470nm, (13.0%) 546nm, (13.2%) 589nm, (13.6%) 650nm.

3.146 (100), 2.841 (80), 2.694 (20), 1.956 (10), 1.695 (20), 1.631 (10).

$K_6(Na,K)_4Na_6Mg_{10}(IO_3)_{12}(SeO_4,SO_4,CrO_4)_{12}\cdot 12H_2O$

IMA No. 93-020

The selenate-dominant analogue of 93-021

Hexagonal: $P\bar{3}c1$

a 9.590 c 27.60 Å

Pale yellow; vitreous; transparent.

Uniaxial (-), ω 1.655, ε 1.642.

13.75 (30), 7.10 (20), 3.974 (16), 3.561 (100), 3.082 (32), 3.058 (39), 2.715 (39).

$K_6(Na,K)_4Na_6Mg_{10}(IO_3)_{12}(SO_4)_{12}\cdot 12H_2O$

IMA No. 93-021

The sulfate-dominant analogue of 93-020

Hexagonal: $P\bar{3}c1$

a 9.4643 c 27.336 Å
Pale yellow; vitreous; transparent.
Uniaxial (-), ω 1.622, ε 1.615.
13.67 (50), 7.05 (40), 3.927 (100), 3.515 (24), 3.023 (41), 2.681 (33), 2.3273 (21).

$CaNaB_5O_8(OH)_2\cdot 3H_2O$

IMA No. 93-022
Monoclinic: $P2_1/c$
a 6.506 b 13.280 c 11.462 Å β 92.97°
White; silky to pearly; translucent.
Biaxial (-), α 1.540, β 1.554, γ 1.558, 2V(meas.) 60°, 2V(calc.) 56°.
8.64 (100), 6.62 (30), 4.18 (17), 2.868 (26), 2.845 (16), 2.795 (17), 2.587 (15).

$AlCa_2(SO_4)_2F_2Cl\cdot 4H_2O$

IMA No. 93-023
Tetragonal: I4/m
a 6.859 c 13.310 Å
White; vitreous; transparent.
Uniaxial (+), ω 1.509, ε 1.526.
6.67 (60), 3.922 (50), 3.729 (40), 3.431 (100), 3.335 (80), 3.052 (40), 2.483 (40).

$NaAlZr(PO_4)_2(OH)_2\cdot H_2O$

IMA No. 93-024
Monoclinic: space group unknown
a 20.840 b 9.871 c 11.195 Å β 104.41°
Pale pinkish orange; vitreous; translucent.
Biaxial, n's vary from 1.62 (parallel to fibres) to 1.64 (normal to fibres)
8.865 (40), 4.128 (80), 3.711 (65), 3.465 (60), 3.243 (35), 2.603 (100).

$TlPb(As,Sb)_3S_6$

IMA No. 93-025
Monoclinic: $P2_1/a$
a 8.444 b 23.97 c 5.844 Å β 113.58°
Brilliant black, but dark red in thin fragments; metallic to submetallic; opaque, but translucent in thin fragments.
In reflected light: greyish white, clearly visible anisotropism from bluish to very weak reddish, visible bireflectance, nonpleochroic. $R_{min.}$ & $R_{max.}$: (29.7, 35.4%) 470nm, (28.8, 33.1%) 546nm, (26.7, 30.3%) 589nm, (26.6, 29.9%) 650nm.
5.346 (32), 3.998 (74), 3.816 (54), 3.587 (86), 2.823 (100), 2.778 (84), 2.670 (58).

$NaNa_2[(Fe^{2+},Mn^{2+},Mg)_2Fe^{3+}_2Li]Si_8O_{22}F_2$

IMA No. 93-026
A member of the amphibole group
Monoclinic: C2/m
a 9.792 b 17.938 c 5.3133 Å β 103.87°
Bluish black to black; vitreous; opaque.
Biaxial (+), α 1.675, β 1.683, γ 1.694, 2V(meas.) 87°, 2V(calc.) 81°.
8.426 (45), 4.481 (54), 3.404 (57), 2.985 (38), 2.710 (100), 2.585 (38), 2.536 (92).

AuSn

IMA No. 93-028
Hexagonal: $P6_3/mmc$
a 4.316 c 5.510 Å
White, greyish-black to black (when oxidized); metallic; opaque.
In reflected light: white with light yellow tint, clear anisotropism light yellow with a brown tint, faint bireflectance, nonpleochroic. R_O & R_E: (65.4, 65.2 %) 470nm, (76.7, 74.8 %) 546nm, (80.5, 77.9 %) 589nm, (82.8, 79.5 %) 650nm.
3.726 (34), 3.087 (38), 2.218 (100), 2.159 (57), 1.546 (31), 1.258 (25), 1.256 (26).

$Na_3Sr(PO_4)(CO_3)$

IMA No. 93-030
Monoclinic: $P2_1$
a 9.187 b 6.707 c 5.279 Å β 89.98°
Colorless to white; vitreous; transparent.
Biaxial (-), α 1.520, β 1.564, γ 1.565, 2V(meas.) 20°, 2V(calc.) 17°.
3.35 (50), 2.708 (100), 2.648 (90), 2.172 (100), 2.080 (50), 1.891 (80), 1.676 (50), 1.415 (70).

$PbAl(F,OH)_5$

IMA No. 93-031
Triclinic: P1 or $P\bar{1}$
a 6.259 b 6.791 c 5.053 Å α 90.92° β 107.45° γ 104.45°
White to colorless; vitreous; transparent.
Biaxial (-), α 1.629, β 1.682, γ 1.691, 2V(meas.) 41°, 2V(calc.) 44°.
4.42 (100), 4.05 (35), 3.221 (40), 2.595 (70), 2.190 (65), 2.030 (50), 2.015 (40).

$CaVOSiO_4$

IMA No. 93-032
Monoclinic: C2/c
a 6.526 b 8.691 c 7.032 Å β 113.88°
Deep red; adamantine; transparent.
Biaxial (sign unknown), α ~ 1.95, β unknown, γ 2.105, 2V(meas.) unknown.
4.90 (W), 3.22 (VS), 2.97 (M), 2.59 (S), 2.271 (W), 1.641 (W).

$(Y,Ca,Na,REE)_4Si_5O_{15}\cdot nH_2O$ n ~ 4

IMA No. 93-034
Triclinic: P1 or $P\bar{1}$
a 9.245 b 9.684 c 5.510 Å α 97.44° β 100.40° γ 116.70°
White; vitreous; translucent.
Biaxial (-), α 1.602, β 1.607, γ 1.611, 2V(meas.) 73°, 2V(calc.) 83°.
8.44 (80), 8.01 (50), 4.51 (50), 3.76 (70), 2.973 (100), 2.930 (60).

$(Cr,V)_2Ti_3O_9$

IMA No. 93-035
The chromium-dominant analogue of schreyerite
Monoclinic: C2/c, Cc, $P2_1/c$, P2/c or Pc
a 7.03 b 5.02 c 18.83 Å β 119.60°
Black; metallic; opaque.
In reflected light: white, faint anisotropism, faint bireflectance, faint pleochroism pale brown.
$R_{min.}$ & $R_{max.}$: (18.1, 20.1 %) 470nm, (18.5, 19.9 %) 546nm, (18.4, 19.8 %) 589nm, (18.6, 20.9 %) 650nm.
2.88 (2), 2.75 (3), 2.43 (2), 1.635 (3), 1.386 (2).

$BaCuSi_4O_{10}$

IMA No. 93-036
Tetragonal: P4/ncc
a 7.441 c 16.133 Å
Blue; vitreous; transparent.
Uniaxial (-), ω 1.633, ε 1.593.
8.055 (100), 4.031 (35), 3.544 (15), 3.200 (21), 2.688 (18), 2.395 (19), 2.016 (26).

$NaKZr_2(Be,Al,Ca,Mn)(PO_4)_4\cdot 2H_2O$

IMA No. 93-037
The K-dominant analogue of gainesite
Tetragonal: $I4_1/amd$
a 6.570 c 17.142 Å
Intense bluish purple or pale lilac; vitreous; transparent.
Uniaxial (+), ω 1.624, ε 1.636.
6.161 (100), 4.291 (25), 3.286 (50), 3.039 (30), 2.895 (20).

$Na(REE,Ca)_2F_6$

IMA No. 93-038
Hexagonal: $P\bar{3}$
a 6.099 c 11.066 Å
Pale pink to colorless; vitreous; transparent.
Uniaxial (+), ω 1.483, ε 1.503.
5.29 (70), 3.036 (100), 2.146 (70), 1.757 (80), 1.152 (40), 0.9189 (40).

$Bi_2O(OH)(PO_4)$

IMA No. 93-040
The PO_4-analogue of atelestite and a monoclinic polymorph of petitjeanite
Monoclinic: $P2_1/c$
a 6.954 b 7.494 c 10.869 Å β 107.00°
White to yellow; adamantine; translucent.
Biaxial (+), α 2.05, β 2.06, γ 2.09, 2V(meas.) 45°, 2V(calc.) 61°.
4.268 (17), 3.271 (51), 3.254 (100), 3.145 (34), 2.727 (29), 1.885 (16).

$Hg_3^{1+}(CO_3)(OH)\cdot 2H_2O$

IMA No. 93-041
Orthorhombic: Pcab
a 11.130 b 11.139 c 10.725 Å
Black to very dark red-brown; sub-metallic to adamantine; opaque.
In reflected light: grey with slight bluish tinge, weak anisotropism (dull and dark greys and browns), weak to moderate bireflectance, nonpleochroic. $R_{min.}$ & $R_{max.}$: (11.4, 12.15 %) 470nm, (10.95, 11.6 %) 546nm, (10.85, 11.5 %) 589nm, (10.7, 11.2 %) 650nm.
4.84 (50), 2.969 (70), 2.786 (70), 2.648 (100), 2.419 (60), 1.580 (50).

$(Mg,Al,Fe^{2+})_9(Si,Al)_6O_{15}(OH)_{12}$

IMA No. 93-042
A regular interstratification of amesite and clinochlore
Monoclinic: Cm
a 5.323 b 9.214 c 21.45 Å β 94.43°
Colorless to very pale green; nacreous; translucent.
Biaxial (+), α 1.575, β 1.575, γ 1.581, 2V(meas.) 0°, 2V(calc.) 0°.
7.1 (100), 4.61 (60), 3.560 (80), 2.557 (40), 2.427 (60), 1.536 (70).

$NaSbO_3$

IMA No. 93-044
Isostructural wuth ilmenite and geikielite
Hexagonal: $R\bar{3}$
a 5.301 c 15.932 Å
Colorless; pearly; transparent.
Uniaxial (-), ω 1.1.84, ε 1.631.
5.30 (53), 3.00 (55), 2.650 (67), 2.365 (69), 1.874 (100), 1.471 (69).

$K_2Fe(SO_4)_2\cdot 4H_2O$

IMA No. 93-045
The Fe-analogue of leonite
Monoclinic: C2/m
a 11.843 b 9.552 c 9.945 Å β 94.89°
Colorless to light yellow; vitreous; transparent.
Biaxial (+), α 1.497, β 1.501, γ 1.509, 2V(meas.) 73°, 2V(calc.) 71°.
4.776 (30), 3.504 (52), 3.439 (100), 3.330 (48), 3.051 (29), 2.405 (30), 2.389 (49).

$(Rh,Ir,Pt)_3S_4$

IMA No. 93-046
Monoclinic: F2/m
a 13.44 b 10.749 c 10.448 Å β 118.32°
Megascopic color not observed; metallic; opaque.
In reflected light: pale slightly brownish grey, weak anisotropism in greys and browns, weak bireflectance, pleochroism weak. R_1 & R_2: (47.2, 48.9 %) 470nm, (48.4, 50.3 %) 546nm, (49.1, 50.7 %) 589nm, (49.8, 51.0 %) 650nm.
3.156 (100), 3.081 (100), 2.957 (90), 2.234 (60), 1.871 (80), 1.791 (90), 1.532 (70).

$Cu_2Te^{6+}O_4(OH)_2$

IMA No. 93-047
Monoclinic: $P2_1/n$
a 9.095 b 5.206 c 4.604 Å β 98.69°
Medium leaf green; adamantine; transparent.
In reflected light: pale grey, weak anisotropism with brown rotation tints, weak bireflectance, nonpleochroic. The mean index of refraction calculated from the reflectances at 589nm is 2.00.
4.506 (40), 4.337 (60), 3.838 (50), 2.891 (70), 2.598 (100), 1.834 (40), 1.713 (40), 1.500 (40).

$Bi_2(Fe^{3+},Cu)_2O(OH)_3(AsO_4)_2$

IMA No. 93-048
Triclinic: P1 or $P\bar{1}$
a 4.569 b 6.162 c 8.993 Å α 94.56° β 99.68° γ 94.31°
Brown-yellow; adamantine; transparent to translucent.
Biaxial (-), α 2.04, β 2.10 (calc.), γ 2.11, 2V(meas.) 45°.
8.822 (62), 3.749 (100), 3.596 (77), 3.468 (58), 2.903 (69), 2.810 (51), 2.685 (48).

$Ca_3B_2O_6$

IMA No. 93-049
Hexagonal: $R\bar{3}c$ or R3c
a 8.638 c 11.850 Å
Greyish white; vitreous; transparent.
Uniaxial (-), ω 1.726, ε 1.630.
2.915 (100), 2.756 (61), 2.493 (44), 2.160 (19), 2.044 (21), 1.976 (18), 1.895 (75).

$Tl_5Sb_9(As,Sb)_4S_{22}$

IMA No. 93-050

Triclinic: $P\bar{1}$

a 7.393 b 8.707 c 17.58 Å α 103.81° β 91.79° γ 109.50°

Black; metallic; opaque.

In reflected light: white, distinct to strong anisotropism with blue or blue-green colors, weak to medium bireflectance, pleochroism white to white with grey-blue tints. $R_{min.}$ & $R_{max.}$: (34.0, 36.7 %) 470nm, (32.0, 34.9 %) 546nm, (30.5, 33.0 %) 589nm, (28.1, 29.7 %) 650nm.

3.459 (100), 3.388 (64), 3.177 (54), 3.076 (65), 2.802 (44), 2.287 (57), 1.736 (38).

Fe_4S_8O

IMA No. 93-051

Monoclinic: space group unknown

a 9.717 b 7.280 c 6.559 Å β 95.00°

Yellow; metallic; opaque.

In reflected light: yellow, strong anisotropism with orange, yellow-orange and greenish grey colors, distinct bireflectance, pleochroism greyish brown, orange, yellow orange. $R_{min.}$ & $R_{max.}$: (19.5, 32.1 %) 470nm, (23.8, 36.8 %) 546nm, (24.6, 37.4 %) 589nm, (25.1, 37.3 %) 650nm.

2.709 (10), 2.419 (8), 2.323 (7), 1.92 (6), 1.758 (8), 0.9605 (6), 0.9576 (7).

$CaAl_4O_7$

IMA No. 93-052

Monoclinic: C2/c

a 12.94 b 8.910 c 5.446 Å β 107.0°

Colorless to white; vitreous; transparent.

Biaxial (+), α 1.6178, β 1.6184, γ 1.6516, 2V(meas.) 12°, 2V(calc.) 15.5° (synthetic material).

4.460 (43), 3.609 (13), 3.515 (100), 2.882 (13), 2.605 (36), 2.440 (21), 1.764 (20).

Pb_2OCO_3

IMA No. 93-053

Orthorhombic: $P2_122_1$ or $P2_12_12_1$

a 9.294 b 9.000 c 5.133 Å

White; waxy; transparent to opaque.

The mean index of refraction calculated from the reflectance value at 589nm is 2.09.

6.49 (30), 4.02 (40), 3.215 (100), 3.181 (90), 2.858 (40), 2.564 (35).

$FeSe_2$

IMA No. 93-054

The Se-analogue of pyrite

Cubic: Pa3

a 5.783 Å

Black; metallic; opaque.

In reflected light: pink-yellow, no anisotropism, no bireflectance, nonpleochroic. R: (42.4 %) 470nm, (42.7 %) 546nm, (45.7 %) 589nm, (49.8 %) 650nm.

2.888 (50), 2.588 (100), 2.364 (80), 2.045 (40), 1.743 (50), 1.546 (60), 1.1131 (40).

$Na_3K_6Ti_2Al_2Si_8O_{26}Cl_3$

IMA No. 93-055

Monoclinic: C2/m

a 10.37 b 16.32 c 9.16 Å β 105.6°

Colorless; vitreous; transparent.

Biaxial (+), α 1.601, β 1.625, γ 1.654, 2V(meas.) 85°, 2V(calc.) 86°.

8.22 (71), 3.50 (42), 3.157 (35), 3.049 (100), 2.900 (71), 2.835 (84).

$Pb_{18}Ba_2Ca_5Mn_2Fe_2^{3+}Si_{30}(O,OH)_{96}Cl$

IMA No. 93-056

Hexagonal: R

a 9.863 c 79.45 Å

Colorless; adamantine; transparent.

Uniaxial (-), ω 1.845, ε 1.815.

13.4 (50), 4.43 (30), 3.98 (30), 3.32 (100), 3.11 (40), 2.969 (40), 2.671 (80).

$Pd_3Ni_2As_3$

IMA No. 93-057

Hexagonal: $P6_3/m$, $P6_3$ or $P6_322$

a 8.406 c 6.740 Å

Megascopic color not observed; metallic; opaque.

In reflected light: rose, distinct anisotropism from light grey to greyish-brown, no bireflectance, nonpleochroic. $R_{min.}$ & $R_{max.}$: (48.4, 50.2 %) 470nm, (51.2, 53.2 %) 546nm, (53.2, 55.3 %) 589nm, (56.6, 58.7 %) 650nm.

2.626 (10), 2.477 (10), 2.429 (8), 2.283 (7), 1.978 (7), 1.818 (7), 1.781 (7).

$Na_{10}(Mn,Ca,Sr)Ti_3Nb_3(Si_2O_7)_6(OH)_2F\cdot 12H_2O$

IMA No. 93-058

Monoclinic: Pm, P2 or P2/m

a 5.468 b 7.18 c 31.1 Å β 94.0°

Colorless, white, silvery, pale pink or cream; greasy to pearly; transparent to translucent.

Biaxial (+), α 1.608, β 1.630, γ 1.660, 2V(meas.) 82°, 2V(calc.) 83°.

15.56 (9), 5.16 (6), 3.11 (10), 2.850 (7), 2.665 (7), 2.627 (7), 2.217 (6), 1.795 (6).

$Sb_2O_3\cdot WO_3$ or Sb_2WO_6

IMA No. 93-059

Orthorhombic: probably $P22_12_1$

a 8.59 b 9.58 c 6.12 Å

Green to dark green; pearly to dull; translucent to opaque.

Biaxial (+), α 2.285, β 2.40, γ 2.58, 2V(meas.) large, 2V(calc.) 82°.

3.32 (10), 3.06 (10), 2.98 (4), 2.73 (6), 2.46 (5), 1.919 (4).

$Cu_2(OH)_3Cl$

IMA No. 93-060

A monoclinic polymorph of atacamite, botallackite and paratacamite

Monoclinic: $P2_1/n$

a 6.157 b 6.814 c 9.104 Å β 99.65°

Green to dark greenish black; adamantine; translucent to transparent.

Biaxial (-), indices of refraction could not be measured because mineral reacts with immersion liquids, 2V(meas.) 75°.

5.44 (100), 2.887 (40), 2.767 (60), 2.742 (70), 2.266 (60), 2.243 (50), 1.704 (50).

$(Ba,Pb)_6(Cu,Fe,Ni)_{25}S_{27}$

IMA No. 93-061

Cubic: Pm3m
a 10.373 Å

Megascopic color unknown; metallic; opaque.

In reflected light: pale brownish grey, no anisotropism, no bireflectance, nonpleochroic. R: (22.0 %) 470nm, (24.85 %) 546nm, (26.2 %) 589nm, (27.55 %) 650nm.

3.460 (40), 3.281 (40), 2.996 (90), 2.378 (90), 1.835 (100), 1.779 (40).

$(Pd,Ag)_2Te$

IMA No. 93-062

Tetragonal: P$4_2$22, P4_2/m or P4_2
a 8.913 c 6.098 Å

Megascopic color unknown; metallic; opaque.

In reflected light: brownish-rose, distinct to strong anisotropism from white to rose-brown, distinct bireflectance, pleochroic from brownish-grey to violet-rose. $R_{min.}$ & $R_{max.}$: (38.7, 48.7%) 470nm, (44.0, 55.5 %) 546nm, (47.3, 58.2 %) 589nm, (50.7, 60.7 %) 650nm.

3.051 (6), 2.825 (10), 2.553 (4), 2.231 (6), 2.042 (5), 1.326 (3).

A NEW U-TI-CA-HREE HYDRATED OXIDE AND ASSOCIATED NIOBIAN RUTILE FROM TOPAZ VALLEY, UTAH

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INTRODUCTION

In October of 1988, specimens of yellow and/or white acicular needles growing out of equant to platy hematite were collected from the east side of Topaz Valley by one of us (WC). For the past five years, attempts have been made by all of the authors to completely characterize what we believe to be a new mineral species. Because of several major factors (paucity of material—less than 4 mg total, extreme compositional zonation, extreme degree of hydration and the resulting poor response to X-ray diffraction because of its high water content) the space group, exact formula, and structure are still unknown. The potentially new mineral and some associated minerals are described here with the hope that elsewhere in the world better and more material exists that will allow complete characterization.

GEOLOGY and MINERALOGY

Figure 1 is a map of the Topaz Valley area showing the location of the potential new mineral. The occurrence of this new oxide at the discovery location (Fig. 2) is restricted to lithophysae within rhyolite along two intersecting, steeply dipping fracture zones, one trending north-northeast and the other north-northwest. The two zones are approximately 30–50 cm (NNE) and 1 cm (NNW) wide respectively. The wider zone is severely weathered near the surface and filled with detritus between slabs of rhyolite. The new oxide was not found in the upper 50 cm below the original ground surface, but is more abundant with increasing depth. Single and multiply intergrown hexagonal crystals are restricted to a substrate of blocky rhombohedral or thick black plates of niobian rutile (cores) and/or hematite (rims) crystals. They do not occur on thin hexagonal plates of specular hematite which also are abundant in the lithophysal cavities. There is no apparent crystallographic control, as the angle between *c* of the mineral and the substrate is variable. Excavation to obtain specimens was concentrated on the NNE-trending fracture, and excavation extended 4 meters along the fracture. The NNW-trending fracture was not examined deeper than 30 cm in solid rock because the fracture is tight, voids (up to 1 cm) having been filled by calcite and uraniferous opal. The size of the needles decreases with distance from the NNW-trending fracture. The new oxide was also found along this fracture, 30 meters NNW of the intersection, in the area where oriented bixbyite on topaz have been found (first described by Pabst, 1938).

Recently, the new oxide has been found to occur at two additional localities: (1) Starvation Canyon (Searle Canyon), approximately 2 miles northwest of Topaz Valley, and (2) approximately 0.5 mile southwest of Pismire Knolls. The occurrence in Starvation Canyon was first found by Mr. John Holfert and Mr. Steve Allred (Robinson, 1993; Robinson and King, 1993). At Starvation Canyon, yellow needles of the new oxide occur as jackstraw-like inclusions in tabular crystals of red beryl. The needles are up to several mm in length. Yellow needles of the oxide to about 1 mm long also occur in lithophysae associated with hematite at a location southwest of Pismire Knolls.

Minerals associated with the new oxide are sanidine, quartz, calcite, topaz, and beryl (red). Needles may be all white, a combination of white and yellow, or all yellow (Figs. 3–5). Growth zonation indicates a progressive enrichment in uranium and corresponding depletion of titanium with time. Early-formed needles are entirely white, and may grade to yellow. Late-formed crystals are entirely yellow. The needles appear to nucleate on niobian rutile and coexist with hematite. Yellow needles coexist only with hematite. Clearly, there was a progressive enrichment of uranium and depletion in titanium in the system with time. The needles are extremely late in the paragenesis and are of low-temperature hydrothermal origin (100–200°C) or possibly crystallized at near-ambient conditions. Figures 6a and 6b show a surface of hematite to which is attached the broken off remnant of a crystal (color-zoned white to yellow) of the potential new mineral. The oxide initially grew out of niobian rutile, and when the U/Ti ratio increased (fairly abruptly), hematite became stable and crystallized along with uranium-rich material. Because the oxide is so highly hydrated and the

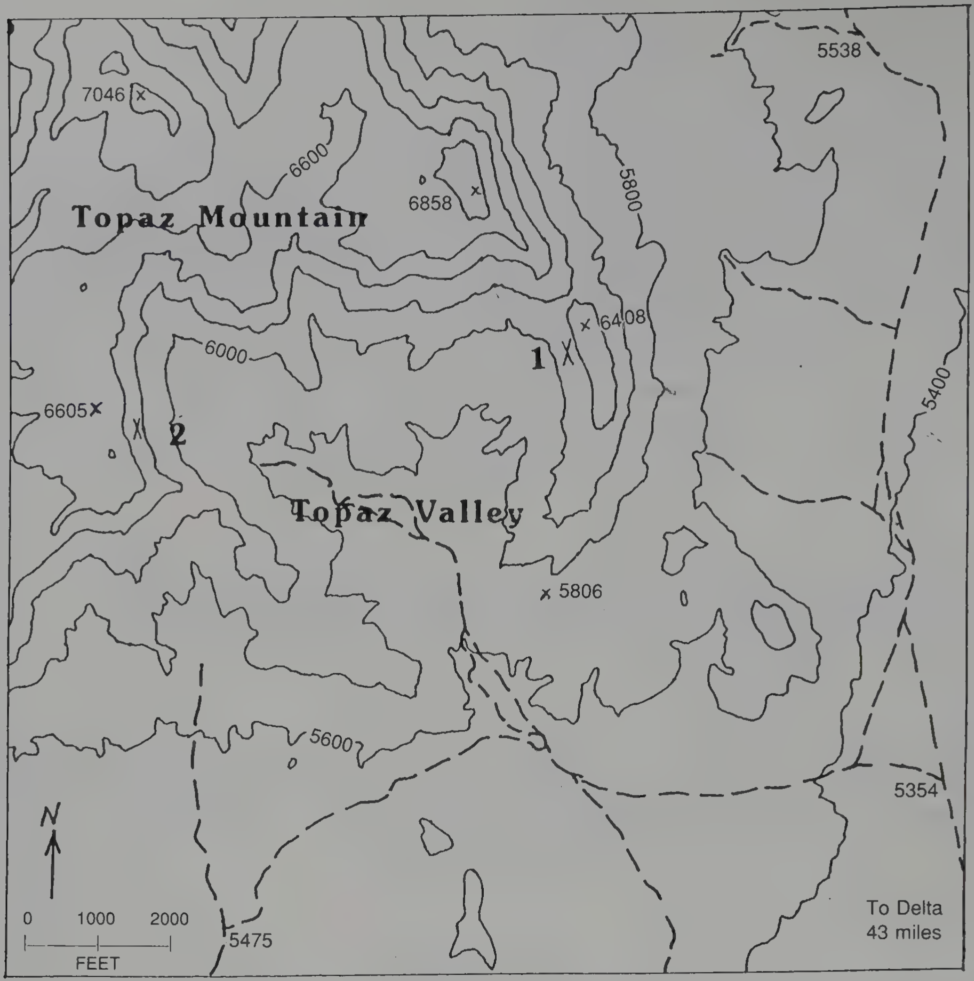


Figure 1. **Map of Topaz Valley showing occurrences of the new Ti-U-Ca-HREE hydrated oxide. 1. type locality of potential new mineral, 2. red beryl pit.**

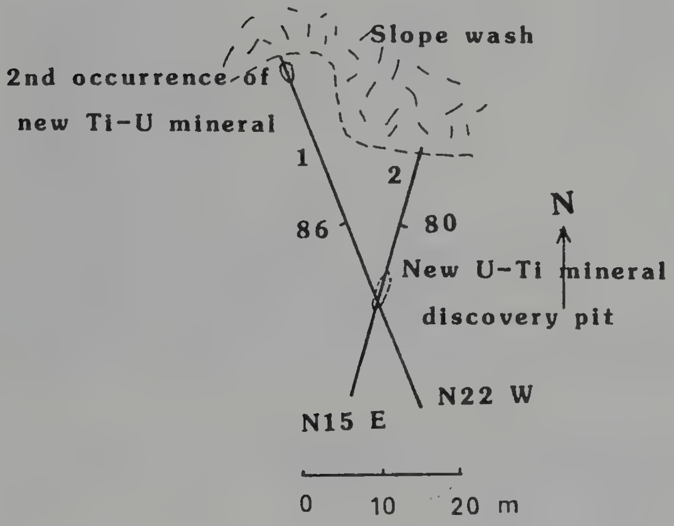


Figure 2. **Sketch of intersecting fracture systems (1 and 2) in the discovery area of the potential new U-Ti-mineral. 1. Fracture tight to 1 cm wide, filled with calcite and uraniferous opal, 2. 30–50 cm wide fracture zone.**

water is present as molecular water (H_2O) rather than structural water (i.e. OH), indicating a low-temperature hydrous environment, the niobian rutile and hematite also must have grown from a low-temperature aqueous solution. Hematite and rutile are conventionally thought of as being only of high-temperature origin in rhyolites, but in some cases, such as this, growth of these minerals must have taken place at low temperatures.

New U-Ti-Ca-HREE hydrated oxide

The new hydrated oxide is hexagonal, showing first-order prism $\{10\bar{1}0\}$ and simple pedion, $\{0001\}$ forms. The total amount of the new mineral recovered from five collecting trips by Chirnside is only about 4 milligrams! However, the mineral is very noticeable against the black or red background of hematite and rutile. The largest overall single crystal recovered is about 300 microns long by 20 microns wide. Some crystals may be as much as 1 cm or more in length, and span an entire lithophysal cavity, however, they are only several microns thick. Specimens of rhyolite containing lithophysae that have the mineral present must be handled gently because the needles have a tendency to break off if the host specimen is sharply jostled or struck. Loose needles are often found in lithophysae when they are opened, having broken off of the hematite-rutile substrate while being collected. About 50 matrix specimens of the mineral currently exist in the possession of the authors. Figures 3–7 show the varied color of the crystals, morphology, varied habits and nature of the substrate hematite-rutile, as well as other features. The crystals are opaque to subtranslucent, and vary from white to distinct lemon-yellow. Many yellow crystals are hollow and this may be due to rapid growth, poisoning of the $\{0001\}$ surface preventing additional growth on the Ti-rich substrate, or other unknown factors.

Precession camera studies indicate that the potential new mineral is

Table 1. **Indexed X-ray powder diffraction data for new yellow hydrated Ti-U-Ca-HREE oxide mineral from Topaz Valley.**

hkl	d_{obs}	d_{calc}	I/I_o
100	9.40	9.31	strong
200	4.70	4.66	strong
002	3.74	3.75	weak
210	3.52	3.52	very weak
112	3.05	3.08	weak
202	2.92	2.92	strong
400	2.34	2.33	medium
320	2.15	2.14	very weak
410	2.03	2.03	very weak
004	1.87	1.87	moderate to strong
204	1.74	1.74	weak
602	1.435	1.434	weak
006	1.225	1.250	very weak

Table 2. **Composite chemical analysis of the yellow zone of a new hexagonal hydrated Ti-U-Ca-HREE oxide from Topaz Valley. Analysts: A. M. Davis, F. E. Lichte, and E. E. Foord.**

Na_2O	0.1	MgO	0.1
CaO	3.25	TiO_2	45.5
Y_2O_3	3.1	La_2O_3	0.45
Ce_2O_3	0.09	Pr_2O_3	0.36
Nd_2O_3	1.4	Sm_2O_3	0.29
Eu_2O_3	0.003	Gd_2O_3	0.36
Tb_2O_3	0.11	Dy_2O_3	0.90
Ho_2O_3	0.24	Er_2O_3	0.99
Tm_2O_3	0.16	Yb_2O_3	1.42
Lu_2O_3	0.16	UO_2	18.5
H_2O (by difference)	22.0	BaO	0.55
Ta_2O_5	0.01	Total	100.0

Elements looked for and not detected or less than 0.1 wt. %: Li, Be, B, P, K, Sc, V, Cr, Mn, Rb, Sr, Zr, Cs, and Th.

hexagonal. Upper-level photographs were not possible because of the small crystal size and degree of hydration. Thus, the space group of the mineral remains unknown. However, from zero-level photographs, there are no extinctions for *h*00 reflections, and *l* = 2*n* for 00*l* reflections. Unit-cell parameters of approximately *a* - 10.7Å and *c* - 7.52Å were determined. Because of the extreme degree of hydration by molecular water (approx. 35 wt. %), incoherent scattering of X-rays becomes a major problem at increasing 2θ angles. The isotropic thermal parameters (B_{isos}) are extremely large. This is particularly noticeable on films taken along the *c* axis.

Powder diffraction data were obtained using a Gandolfi 114.6-mm camera and a Siemens D-500 automated diffractometer. Table 1 lists indexed powder diffraction data for the mineral on the basis of Gandolfi and single-crystal precession film data. In excess of 100 unground yellow and white crystals or crystal aggregates were run on the Siemens D-500 using a zero background quartz plate. Four reflections: (100) sharp and intense, (200) moderate and broad, (210) weak and broad, and (004) very weak and sharp, were observed. The same lot of crystals was then used for TGA (thermogravimetric analysis) to determine the amount of water present. No IR-spectra of the mineral were made because of a paucity of material. Unit-cell refinement of 114.6-mm Gandolfi film data for yellow crystals, utilizing all thirteen observed reflections, yielded *a* 10.756Å, *c* 7.496Å, and V 749.67Å^3. Powder diffraction data for the white, uranium-poor crystals are substantially different, both in d-spacing and intensity, from those of yellow, uranium-rich crystals, as would be expected from the major compositional change that occurs between the white and yellow portions of crystals. The diffraction data for the white crystals is of lesser quality than that from the yellow crystals. This difference in quality is primarily a function of the composition.

Heating to 1000°C in air results in recrystallization of the oxide. Recrystallized material is black and yields a sharp X-ray diffraction pattern with the following *d*-spacings and intensities: 9.0 m-, 5.8 s, 5.1 w, 4.7 w, 3.72 w+, 3.50 w+, 3.40 w+, 3.17 m, 3.00 w, 2.90 vs, 2.675 m-, 2.50 w, 2.45 w, 2.25 w, 2.17 w+, 2.01 w, 1.96 w+, 1.90 w, 1.86 w, 1.78 m+, 1.68 m+, 1.62 w+, 1.56 w+, and 1.52 m- (vs very strong, s strong, m+ moderate plus, m moderate, m- weak moderate, w+ weak plus, w weak, w- very weak).

Only partial optical data could be obtained on the oxide because of its poor optical qualities. It shows parallel extinction; all refractive indices are less than 1.70 and the oxide is uniaxial negative.

It is somewhat flexible in very thin needles, but larger crystals are brittle.

The density was determined on both yellow and white crystals by sink-float techniques in bromoform-acetone mixtures. Densities of 2.64 and 2.62 were measured for yellow and white varieties respectively.

A TGA study of 0.92 mg of white and very pale yellow crystals showed a steady loss of water to 1000°C amounting to about 35 wt. %.

Chemical analyses were done by electron microprobe, ion-microprobe, and LA-ICP-MS methods, and a composite analysis is given in Table 2. No carbonate is believed to be present in the oxide because of lack of any evolution of CO_2 gas when immersed in hydrochloric acid. The mineral slowly dissolves in about 1–2 minutes, turning clear and gelatinous and finally disappearing altogether.

Electron microprobe analyses are not considered fully quantitative because of extensive beam damage during analysis. The beam could not be opened up sufficiently wide to minimize the damage because of the small crystal size (width). Totals were about 70–75 wt. % on the yellow rims and about 65 on white cores of crystals. Thus, the values given in Table 2 are normalized to 78 wt. %, using a value of 22 wt. % H_2O by difference. However, both EDS and WDS analysis by electron microprobe and SEM indicate that the amount of heavy rare-earth elements (HREE) present correlate directly with the titanium content. Thus, during growth from white to yellow crystals, Ti and HREE's were incorporated first and then increasing amounts of U and decreasing amounts of HREE's were incorporated into the structure. The substitution of U^{4+} for Ti^{4+} is 0.97, well outside the limits of which substitution normally occurs. The amount of calcium present dropped about 20%. The yellow color of the later crystallized mineral is due to the presence of U^{+6}. Analysis for the different valence states of uranium was not possible.

The REE distribution pattern (CNR plot) for the new mineral shows a strong negative Ce spike in addition to a strong Eu depletion spike. The negative Eu spike is due to preferential incorporation in earlier crystallized feldspars. The negative Ce anomaly indicates partitioning under extremely oxidizing conditions that stabilized Ce^{4+}. This same phenomenon was found for HREE-bearing titanite from the Black Range of New Mexico (Foord *et al.*, 1993).

The new mineral also occurs as white needles (i.e. no uranium present) on hematite rhombs at the red beryl pit (locality 2, Fig. 1). It should be looked for elsewhere in the Thomas Range.

Rutile (niobian)

Plates and tablets of cochineal-red to blood-red niobian rutile as much as 4 mm across and 1 mm thick occur in the lithophysae within and adjacent to the fracture zone. Rutile has not been reported previously from volcanic rocks in the Thomas Range. Reports of "ilmenite" are probably incorrect; no ilmenite was found by the authors. Identity of the niobian rutile was confirmed by X-ray

Figure 3. **Spray of acicular yellow crystals of the potential new Ti-U-Ca-HREE hydrated oxide mineral on hematite. Associated minerals are quartz and sanidine.**

Figure 4. **Spray of acicular composite white-yellow needles of the potential new Ti-U-Ca-HREE hydrated oxide mineral on hematite. Note presence of several bent white crystals. Associated minerals are quartz and sanidine.**

Figure 5. **Group of white and yellow needles of the potential new mineral showing both single crystals and intergrown crystals.**

diffraction studies and electron microprobe analyses. Figures 6–10 show the niobian rutile and its relationship to epitaxially overgrown hematite. Electron microprobe analyses of the niobian rutile and hematite are given in Table 3.

An empirical formula for the niobian rutile, on the basis of two oxygen atoms, is: $(Ti_{0.84}Nb_{0.08}Fe_{0.06}Mn_{0.02})_{\Sigma 1.00}O_2$. Charge balance is maintained by an equal amount of trivalent iron and manganese substituting along with niobium for titanium.

Niobian rutile also has been found in lithophysal cavities at Easter Canyon in the Black Range Tin District, New Mexico (personal communication, E. E. Foord and P. F. Hlava, 1991). There the niobian rutile occurs as lustrous, vertically striated prisms as much as 4 mm long and 0.5 mm wide. The niobium content and accompanying iron content are even higher than in the niobian rutile from Topaz Valley.

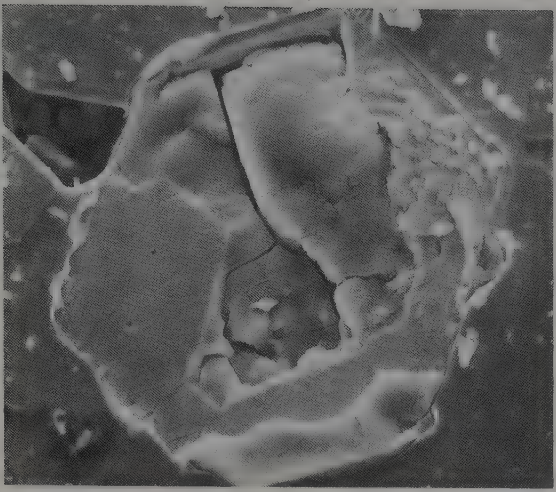
Hematite

Hematite occurs ubiquitously within lithophysal cavities in the rhyolite. Two main habits are present: rhombs, and (thick to thin) plates (Figs. 3–8). The white to yellow crystals of the new oxide are present only on rhombs and thick plates. Plates of hematite, epitaxially overgrown on niobian rutile, may be as much as 5 mm across and 1 mm thick. Rhombohedral crystals of hematite may be as much as 3 mm in mean dimension. Table 3 gives an analysis of the hematite coexisting with niobian rutile and the new oxide. An empirical formula, on the basis of three oxygen atoms, is $(Fe_{1.88}Mn_{0.09}Ti_{0.02}Al_{0.01})_{\Sigma 2.00}O_3$.

Bixbyite and Pseudobrookite

Samples of lithophysal bixbyite, $(Fe,Mn)_2O_3$ and pseudobrookite, $(Fe^{3+}, Fe^{2+})_2(Ti, Fe^{3+})O_5$, from the Cubic claim, in the northern end of the Thomas Range, about 2 miles west of Dugway Pass, and bixbyite from Pismire Knolls were collected by Chirnside for ICP-AES analysis. Results of these analyses are shown in Table 4. The pseudobrookite contains significant quantities of manganese (6.3 wt. % Mn_2O_3), and niobium (2.3 wt. % Nb_2O_5) in addition to iron and titanium. In addition to iron and manganese, the bixbyite contains 2.5 wt. % Al_2O_3, and 2.0 wt. % TiO_2.

An empirical formula, calculated on the basis of five oxygen atoms, for the pseudobrookite, subtracting the SiO_2 (included silicate minerals), and normalizing to 100%, is: $(Fe_{1.68}Mn_{0.20}Al_{0.12})_{\Sigma 2.00}(Ti_{0.93}Nb_{0.04}Sc_{0.004}Sn_{0.002}Ta_{0.002}Mg_{0.01}Fe_{0.01})_{\Sigma 1.00}O_5$. This formula is reasonable and



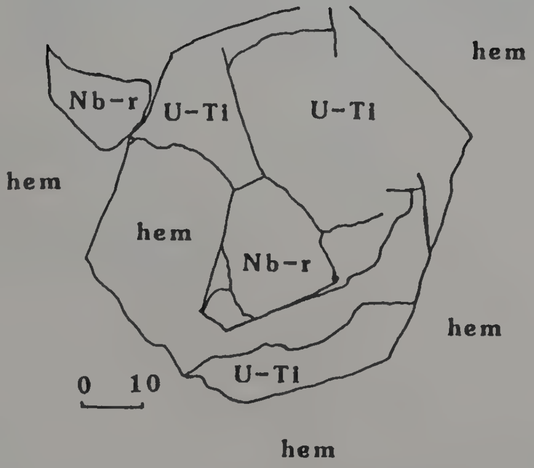


Figure 6a. **SEM photograph of niobian rutile crystal epitaxially overgrown with hematite showing hexagonal attachment point of a zoned white-yellow needle of the potential new mineral as in Figures 3 and 4. Note that growth of niobian rutile and the white portion of the needle were simultaneous and growth of the yellow portion and hematite were simultaneous.**

Figure 6b. **Tracing of Figure 6a showing the various minerals and contacts between them.**

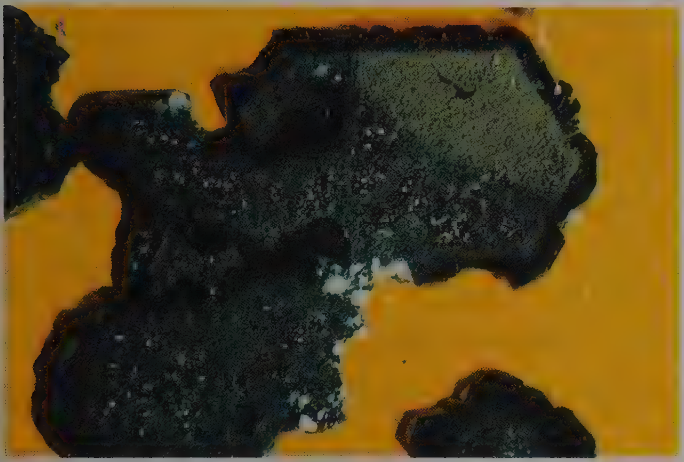


Figure 7. **Platy crystal of red-brown niobian rutile with overgrowth of black hematite. Group of acicular crystals (white to yellow) growing from niobian rutile substrate.**

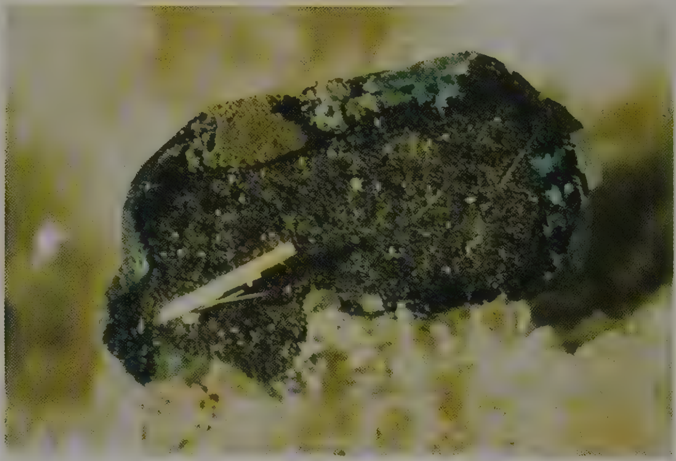


Figure 8. **Platy crystals of niobian rutile and hematite showing epitaxial rims of hematite and intergrowths of the two minerals.**

Figure 9. **SEM photograph of the edge of a composite niobian rutile-hematite crystal showing the perfection of growth of the hematite relative to the multiple nucleation growth of the niobian rutile.**

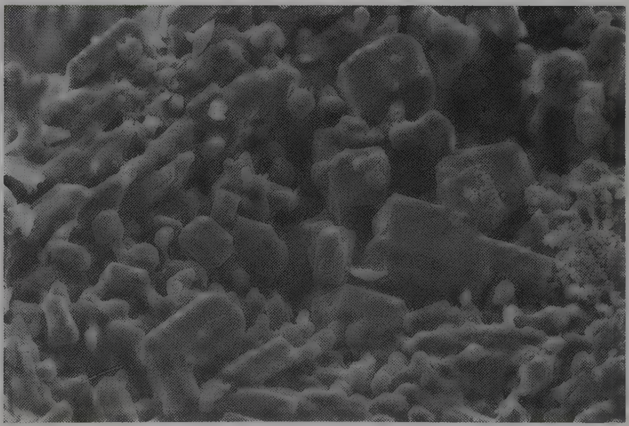


Figure 10. **Close-up view of niobian rutile crystals showing coating of alumnio-silicate minerals. Some crystals are uncoated.**

Table 3. **Electron-microprobe analyses of niobian-rutile and hematite intergrowths from Topaz Valley. Analyst–E. E. Foord. All iron expressed as Fe_2O_3.**

	Niobian rutile	*Hematite*
TiO_2	80.0	0.8
Al_2O_3	0.0	0.15
Mn_2O_3	2.0	4.6
Fe_2O_3	6.0	94.5
Nb_2O_5	12.5	0.0
Total	100.5	100.05

supports the contention made above that conditions were extremely oxidizing and that all of the iron was present as ferric rather than a combination of ferrous and ferric. An empirical formula, calculated on the basis of three oxygen atoms, for the bixbyite from the Cubic Claim on the basis of the electron microprobe analysis is: $(Fe_{1.06}Mn_{0.82}Al_{0.06}Ti_{0.04}Si_{0.01}Mg_{0.01})_{\Sigma 2.00}O_3$ and a similar formula for the bixbyite sample from Pismire Knolls is: $(Fe_{1.02}Mn_{0.86}Al_{0.05}Ti_{0.04}Si_{0.01}Mg_{0.01})_{\Sigma 1.99}O_3$. A detailed paper on the crystal chemistry of bixbyite from Utah and New Mexico is in preparation by P. F. Hlava and E. E. Foord.

ACKNOWLEDGMENTS

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Table 4. **ICP-AES and electron-microprobe analyses of pseudobrookite and bixbyite from the Cubic Claim and from Pismire Knolls, Thomas Range, Utah.**

	Pseudobrookite, Cubic claim	*Bixbyite, Cubic claim*	*Bixbyite Cubic claim*	*Bixbyite, Pismire Knolls*
Analyst	P. H. Briggs	P. H. Briggs	P. F. Hlava	P. F. Hlava
Al_2O_3	2.5	2.5	1.99	1.67
Fe_2O_3	54.3	50.0	54.5	52.7
MgO	0.13	0.10	0.12	0.15
TiO_2	30.0	2.0	1.88	1.80
Mn_2O_3	6.3	40.5	42.0	43.9
Ce_2O_3	0.0	0.03	0.09	0.14
Ga_2O_3	0.03	0.01	—	—
Cr_2O_3	0.0009	0.002	—	—
Nb_2O_5	2.3	0.09	—	—
Sc_2O_3	0.12	0.04	—	—
SnO_2	0.14	0.07	0.0	0.0
Ta_2O_5	0.13	<0.03	—	—
ZnO	0.02	0.05	—	—
SiO_2	2.1	3.4	0.28	0.37
Total	98.1	98.8	100.86	100.73

Other elements looked for by ICP-AES and not detected at respective limits of detection: K, Ca, P, Ag, As, Au, Ba, Bi, Cd, Cu, Eu, Mo, Nd, Ni, Sr, Th, U. All iron expressed as Fe_2O_3.

PYRITE AND MARCASITE INTERGROWTHS

FROM NORTHERN ILLINOIS

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Excellent microcrystals of pyrite and marcasite are found in vugs in Ordovician limestone at several quarries in northern Illinois. The crystals include pyrite "bars" and marcasite blades which are epitactic on early-formed marcasite whisker crystals.

INTRODUCTION

Three quarries in northern Illinois (Fig. 1) have produced very similar microcrystals of marcasite and pyrite from rocks of the middle Ordovician Galena Group. The Irene quarry of the Rockford Sand and Gravel Company has provided the majority of the specimens described in this paper; it is located 2 miles north of Irene, Boone County, Illinois in the NW ¼ of Section 9, T43N R4E (Cherry Valley 7.5′ Quadrangle Map). The Mulford quarry of the Rockford Sand and Gravel Company is the source of many other specimens; it is located southeast of Rockford in Winnebago County (E ½, SE ¼, Section 33, T44N, R34E, Rockford South 7.5′ Quadrangle). The Mount Carroll quarry, owned by Wendling Quarries, DeWitt, Iowa, is located 3 miles southwest of Mount Carroll, Carroll County (SW ¼, Section 10, T24N R4E, Wacker 7.5′ Quadrangle). Although it produces many collectible mineral specimens, the Mount Carroll quarry has produced only a single specimen relevant to the subject of this paper. This specimen consists of one vug with numerous chains of pyrite cubes. Access to all of these quarries is restricted, and collecting visits must be arranged in advance with the quarry management; access is prohibited during times when the quarries are not in operation.

Though these quarries are not noteworthy for large crystals or rare species, a number of common carbonates and sulfides occur as small crystals generally not exceeding several millimeters. The pyrite/marcasite associations which occur here are interesting examples of pyrite/marcasite epitaxy. These associations form the focus of this paper.

GEOLOGY

The three quarries exploit the same stratigraphic units. The follow-

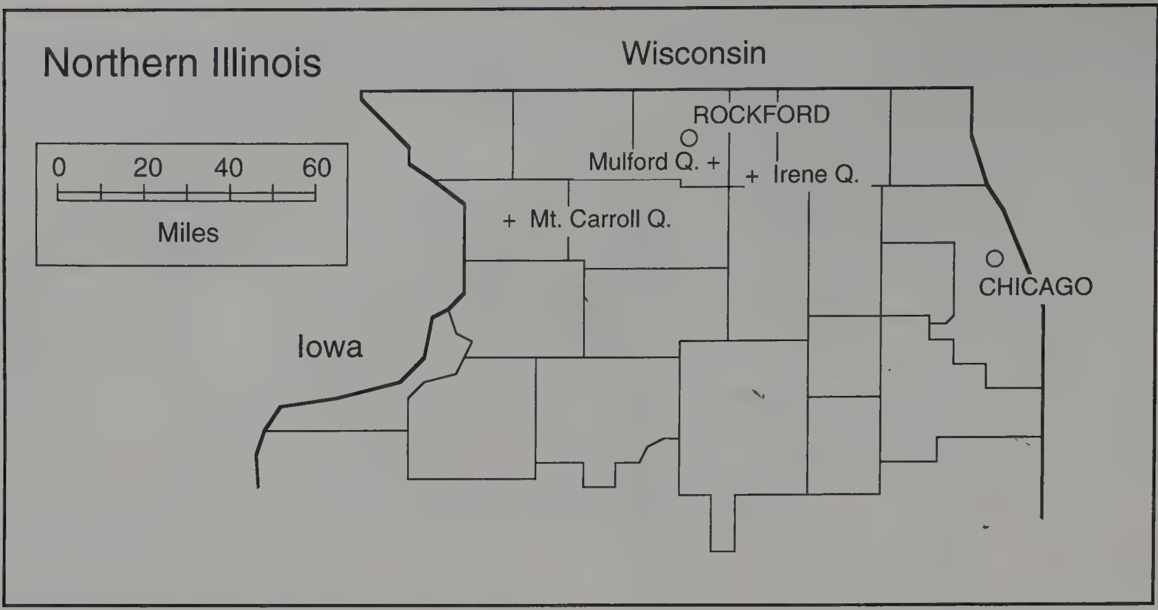


Figure 1. **Map of northern Illinois showing the location of the three quarries.**

ing description of the Irene quarry is applicable in general terms to all three. The strata are nearly flat-lying: Dips in the Rockford area generally are to the southeast and average 4 meters per kilometer (20 feet per mile).

The Irene quarry exposes the lowest 3.5 meters (12 feet) of the Dubuque Formation and about 17 meters (57 feet) of the underlying Wise Lake Formation, in which the minerals described in this paper are found. Both formations belong to the Galena Group of middle Ordovician age, which is approximately 450 million years old. The Galena Group is locally about 70 to 80 meters thick and consists primarily of dolostone (a rock composed mostly or entirely of the mineral dolomite) with occasional regions of limestone in the lower third, and with several thin, extensive beds of bentonite (altered volcanic ash) in the lower two thirds. In extreme northwest Illinois and southwest Wisconsin, the Galena Group and the underlying Platteville Group are host to the galena and sphalerite deposits of the Upper Mississippi Valley mining district, a leading lead and zinc-producing region for much of the 19th and early 20th centuries.

The Wise Lake Formation consists of about 22 meters of high-purity dolostone, formed by replacement of calcite by dolomite. The voids which usually host the minerals described below are of uncertain origin; some may result from the dissolution of massive fossils such as corals and stromatolites. The medium-grained pale gray to pale brown stone is very tough, and makes the collection and preparation of undamaged microminerals quite difficult.

Further information on the geology of this area can be found in Cote *et al.* (1969), Goodwin (1983), and Willman and Kolata (1978).

MINERALOGY

The mineral species attributed to the Wise Lake Formation in these quarries are described below, and are limited to simple carbonates and sulfides, and their alteration products. A somewhat larger species list characterizes the Dubuque Formation at the Mt. Carroll quarry, but is beyond the scope of this paper.

Calcite $CaCO_3$

Calcite occurs occasionally as small, waxy lustered, colorless rosettes of intergrown rhombohedral crystals to 1.5 mm on edge, deposited upon drusy dolomite in vugs. The intergrown nature of these crystals prevents goniometric study. However, the crystals appear to be composed of the common rhombohedron $\{10\bar{1}1\}$, as judged by their shape and the orientation of the cleavage.

Chalcopyrite Cu,FeS_2

Chalcopyrite occurs sparingly as sharp, striated, lustrous to lightly tarnished individual disphenoidal crystals to 2 mm, implanted on the drusy dolomite vug linings, usually without other sulfide minerals present in the same vug. In at least one vug from the Irene quarry, however, chalcopyrite occurs together with pyrite and marcasite. The disphenoid is {112}, which is the usually dominant form on chalcopyrite crystals (Palache *et al.,* 1944).

Dolomite $Ca,Mg(CO_3)_2$

Dolomite constitutes most of the rock in the quarries, and also occurs abundantly as tiny, sparkling rhombohedra of uniform size (0.4 mm on edge) densely lining irregularly shaped but well-defined vugs from 1 to 5 cm across. The dolomite is translucent, and sometimes has a colorless outer layer within which the translucent core is seen as a white phantom. Crystal faces are very flat and lustrous.

Goethite FeO(OH)

Goethite (or "limonite") replacements of chalcopyrite, marcasite and pyrite have been observed in vugs in locally weathered zones of yellowish dolostone.

Marcasite FeS_2

Marcasite occurs in crystals of many different habits. Intermediate forms blur the distinctions between many of these habits, however. Marcasite crystals in these rocks tend to be flattened perpendicular to the *b* axis. Crystal habits range from diamond-shaped or rhomb-shaped plates through broad or narrow blades (Fig. 2) to elongated and commonly irregular-sided whisker-like crystals, which may occur as parallel growths. The edges of the diamond-shaped crystals, and the points of the blades, are composed of the prism {101} or sometimes a bipyramid such as {111}, based on measurements of angles formed by the edges, made using a petrographic microscope and in a few cases using scanning electron microscope images. These edge faces are small and extremely narrow, and are usually too narrow to be seen clearly under a stereoscopic microscope. Whisker-like crystals may be elongated parallel to either the *a* or the *c* axis, but elongation parallel to *a* is more common, based on the configuration of pyrite crystals oriented on them, as discussed below. Most of these crystals are too small and narrow to permit measurements of their terminations, thus goniometric study is impossible in most cases. Crystals are commonly transversely striated, so that the {010} "face" is actually composed of

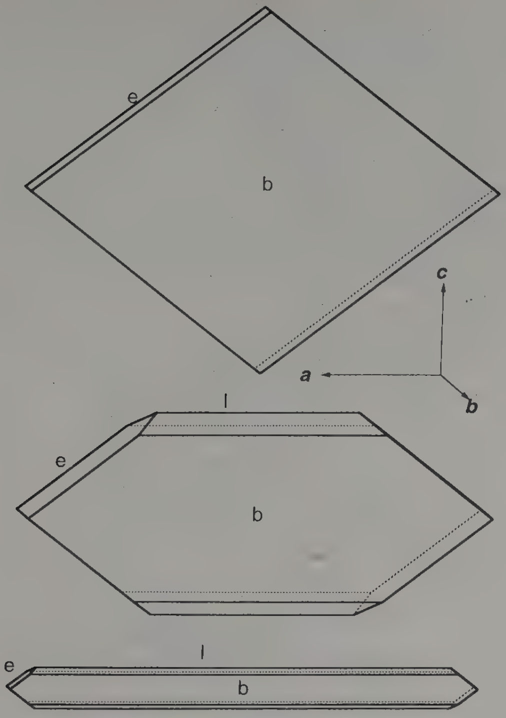


Figure 2. General habits of marcasite. Forms are *b*{010}, *e*{101}, and *l*{011}.

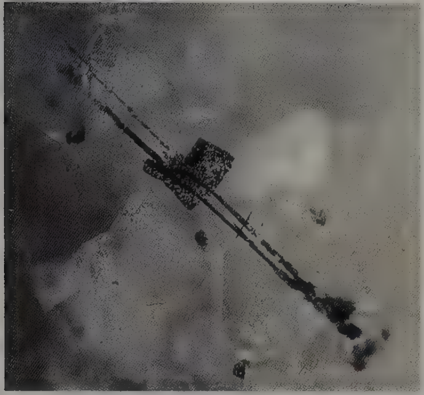
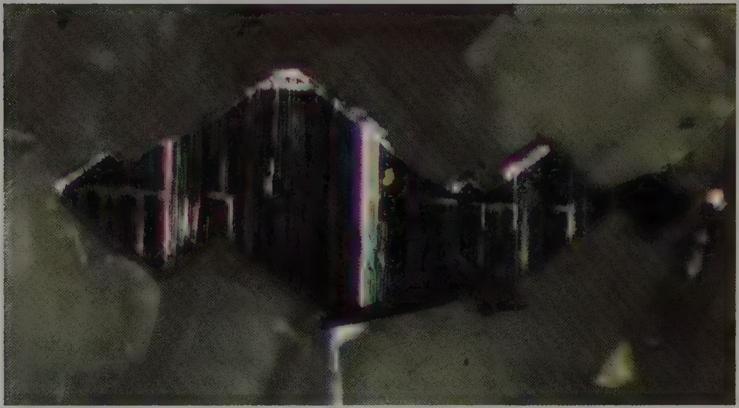


Figure 3. Hair-like acicular marcasite, a composite crystal composed of two nearly parallel branches which merge at one end. The crystal is 1.3 mm long. Irene quarry; Edwin L. Clopton specimen, Dan Behnke photograph.



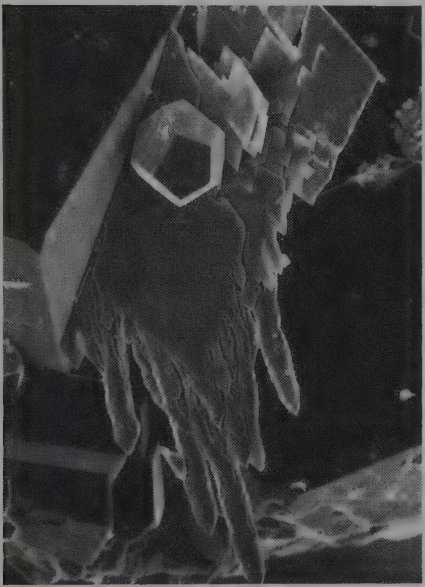


Figure 5. Marcasite crystal composed of rhombic elements overgrown with irregular dendritic extensions, attached to a dolomite crystal and with an attached pyrite crystal. Compare with Figure 14. The field of view is about 0.3 mm wide. Irene quarry; R. Peter Richards specimen and SEM image.

Figure 4. Rhombic marcasite crystal, heavily striated and with a horizontal "rib" which appears to represent an earlier, more acicular crystal, now partly overgrown. The crystal is 2 mm long. Irene quarry; R. Peter Richards specimen and photo.

Figure 7. Pyrite chains to 8.8 mm long. Irene quarry; Edwin L. Clopton specimen, Dan Behnke photograph.

Figure 6. A chain of pyrite crystals, overgrowing an acicular marcasite crystal. The top pyrite crystal is 0.8 mm tall. Irene quarry; Dan Behnke specimen and photo.

alternating, inclined faces which only approximate {010} in aggregate.

Two habits are of particular interest and are the main topic of this paper. Marcasite sometimes occurs as hair-like acicular crystals (Fig. 3), to several millimeters long, but less than 0.1 mm in cross-sectional dimension. These whisker-like crystals appear at first to be rare, but are often overlooked because of their small size. Also, they are the first generation of marcasite to form, and they are usually hidden by subsequent overgrowths of marcasite and/or pyrite.

Marcasite also occurs as thin diamond-shaped or rhomb-shaped plates attached to dolomite crystals. Some of these have a "rib" running down the middle (Fig. 4) between opposite corners of the plate, and with striations running perpendicular to it. This rib represents an earlier-generation, nearly overgrown crystal elongated parallel to the *a* axis.

Other diamond-shaped plates are of brilliant golden color and irregular outline, and many have one pyrite crystal (or rarely two) located in an interior position (Fig. 5), and usually projecting from both faces of the marcasite plate, as if penetrating the marcasite plate. Crystals with this morphology have been found only in one small boulder in the Irene quarry, and occur with lustrous chalcopyrite. The aggregates of platy marcasite and pyrite have a complex growth history, including epitactic growth of pyrite on marcasite, and several generations of both marcasite and pyrite growth. These interesting intergrowths will be discussed in more detail in the section below on "leaf epitaxy."

Pyrite FeS_2

Pyrite occurs in microcrystals usually 2 mm or smaller, and showing a range of habits which combine the cube, pyritohedron and octahedron. The cube is nearly always present and is usually the dominant form. Pyritohedra are dominant on some crystals; these lack the octahedron entirely. Pyrite is found attached to dolomite crystals in the pockets, and commonly attached to marcasite crystals, in random or systematic orientations. Octahedral crystals are more abundant at Mt. Carroll than at the other two quarries.

In some of the most spectacular material from these quarries, pyrite occurs as very interesting, elongated bar-shaped aggregates of crystals of two types. In one type, referred to hereafter as "chains," cubic crystals are joined into chains up to 9 mm long (Figs. 6 and 7). The crystals are typically strongly striated and somewhat distorted, and pyritohedral faces often are present along the edges of the cubes. The cubes are joined along mutual edges, and appear to overlap somewhat, due to continued growth after they came in contact with each other. Striations on successive cubes usually run in opposite directions. In the other type ("bars"), crystals are joined together nearly parallel to faces of the rhombic dodecahedron {110} into bars up to 5 mm long. The crystals show combinations of cube, octahedron and pyritohedron, but are distinctly flattened, and elongated parallel to the length of the bar. This distortion leads to the total disappearance of some faces, systematic differences in the size of remaining faces of the same form, and a final shape which appears monoclinic rather than cubic (Fig. 8). In most cases, striations running in different directions along the bar and slightly non-parallel crystal edges demonstrate that the bar is actually composed of a number of crystals (Fig. 9). Some bars are decorated with a second generation of sharp, cubic crystals, apparently in random orientation. Some specimens (Fig. 10) show mirror-faced overgrowths of a second generation of pyrite along the crystal edges of a pyrite bar.

Sphalerite ZnS

Sphalerite is occasionally encountered as crude black aggregates of crystals to 1 cm. These aggregates occur in fossil cavities and other dolostone openings which are not lined with drusy dolomite. More rarely, pinkish tan sphalerite has been found at Mulford quarry,

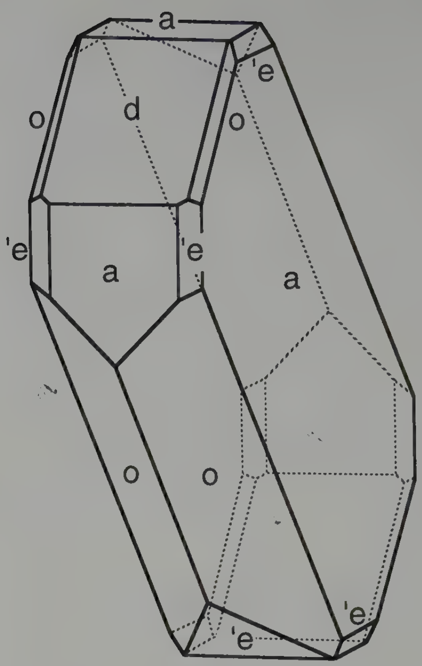


Figure 8. The pseudo-monoclinic symmetry displayed by crystals on pyrite bars. Faces shown belong to the isometric forms *a*{100}, "*d*{110}," '*e*{210}, and *o*{111}. The face labeled *d* (and its equivalent at bottom) is actually the contact surface with the adjacent crystal along the bar, and is not a true crystallographic face.

Figure 9. A pyrite bar, 4 mm tall, composed of four crystals. Irene quarry; R. Peter Richards specimen and photo.

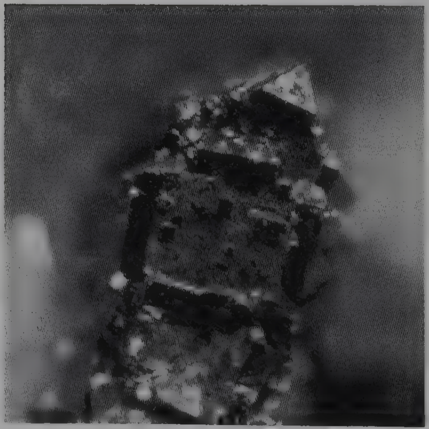


Figure 10. Mirror-smooth second-generation pyrite overgrowths along the edges of rough faces of first-generation pyrite. Second-generation growth occurs on both cube and octahedron faces. Visible length of the specimen is 1.5 mm. Irene quarry; Edwin L. Clopton specimen, Dan Behnke photograph.

implanted on drusy dolomite, sometimes as reasonably sharp euhedral crystals showing combinations of positive and negative tetrahedra and a trapezohedron.

PYRITE-MARCASITE INTERGROWTHS

Because of the unusual nature of several types of pyrite/marcasite intergrowths from these quarries, we have focused our efforts on an understanding of the development of these intergrowths, the presentation of which forms the rest of this paper. Our hypotheses were formed through:

(1) A study of the literature on pyrite and marcasite associations.

(2) Thorough study of numerous specimens with a stereoscopic microscope.

(3) Detailed study of representative specimens with a scanning electron microscope.

(4) Study of polished sections of selected specimens in reflected polarized light with a petrographic microscope.

(5) Goniometric measurement of selected pyrite crystals.

(6) Comparisons of the crystal structures of pyrite and marcasite, facilitated by development of oriented stereoscopic drawings of these structures using the program ATOMS.

(7) Morphological analysis and modeling using the program SHAPE.

(8) X-ray and electron diffraction study of selected specimens.

Bars and Chains

Pyrite bars are of mineralogical interest because they so obviously deviate from the equant habit expected of an isometric mineral. Pyrite bars have been reported from many localities. Most are microcrystals with extreme length/width ratios: lengths may reach several millimeters but widths are generally less than 0.1 mm. These crystals are often so small in cross section that they are nearly invisible, even under a microscope at 30x, unless the microscope light is reflecting from a line-like crystal face. These tiny acicular crystals, often called whiskers, are known from low-temperature hydrothermal deposits at a number of localities, and are highly elongated single crystals. The distorted habit has been attributed to screw dislocations (Henderson and Francis, 1985, 1989; Murowchick and Barnes, 1987; Richards, 1985).

Pyrite bars large enough to be easily seen with the naked eye are far less common, but are known from several localities (listed in Table 1) in addition to the quarries described in this paper. They are commonly more irregular than the "whisker" crystals, and many are not single crystals. They share several characteristics which separate them from other distorted pyrite crystals or crystal aggregates.

Where such crystals occur, the bar-shaped habit is common among crystals at the locality, at least in a particular vein or pocket. The bars are dramatically more elongate than "normal" crystals of the same species with which they may occur. While these elongated crystals are common, there are, conversely, no crystals which are shortened to create a platy habit. These characteristics indicate that a mechanism other than "accidents of chance" is at work, and separates bars from slightly elongated crystals which result from irregularities of growth, either accidental or imposed by a non-uniform supply of atoms to the growing crystal.

Bars are composed of one or only a few crystals, in a non-random arrangement, and are found in cavities in the host rock. Thus they are distinct from polycrystalline pyrite aggregates of linear form (for example, pyritized worm burrows or linear pyrite concretions), which contain thousands of randomly oriented pyrite crystals, generally forming an overall cylindrical shape. Many of these polycrystalline aggregates are found embedded within the host rock, whereas pyrite bars are typically found free-growing in cavities in the host rock.

While the bars from the northern Illinois quarries initially appear to be similar to those from the localities listed in Table 1, careful examination shows that they are distinctly different from crystals from all of the localities with the exception of some from Rensselaer, Indiana. In the other occurrences, the pyrite bars are elongate parallel to an *a* axis of the pyrite, and are either apparently single crystals or are composed of a few parallel or nearly parallel crystals. These crystals are typically nearly square in cross-section. By contrast, the bars from the Illinois localities are usually composed of a larger number of crystals. More importantly, the *a* axes of all crystals are aligned in one of two directions, both of which are inclined to the long axis of the bar (Figs. 6, 7 and 9). They sometimes deviate from square cross-section, being flattened parallel to the coplanar *a* faces of the component crystals.

Table 1. Previously known localities for macroscopic pyrite bars.

Location	*Size of crystals* *Length*	 *Cross-section*	*Comments*
Amex mines Boss, Missouri	to 32 cm	to 7.6 cm	Pitted but apparently single cuboctahedral crystals or parallel aggregates with elongated rectangular axial cavity parallel to the *a* axis. See White (1975).
Naica Chihuahua, Mexico	to 5 cm	2.1–2.4 mm	Morphologically complex single crystal overgrowths on pyrite whiskers elongated parallel to the *a* axis. See White (1973).
Rensselaer and Pleasant Ridge, Indiana	to 3 cm	to 1 cm	Combinations of cube, octahedron and pyritohedron. Single crystals or several sub-parallel crystals. A central tubular cavity is present in most specimens. Some are elongated along *a* and probably epitactic on pyrite; others may be epitactic on marcasite. See Brock (1986).
Stillwater, Arkansas	10–20 mm	1 mm	Cuboctahedral crystals of uncertain size and highly variable shape. Elongated parallel to the *a* axis. See Shannon (1923).
Rondout, New York	(?)	1 mm	Cubic crystals elongated parallel to the *a* axis, size uncertain. See Whitlock (1905).

The first impression given by these bars, after one realizes that the component crystals are not parallel to each other or to the bar axis, is that they are composed of alternating crystals twinned on {110}. However, this geometric configuration would result in crystals of the more complex habit having parallel edges, and striations on differently oriented crystals would be perpendicular. Neither configuration is observed; rather, the striations make angles of about 75° and 105° with each other, and the crystal edges which would be parallel under twinning instead make angles of about 15° with each other (see Figs. 6 and 14).

A hypothesis which explains the geometric observations is that the pyrite is epitactic on an acicular marcasite crystal, which is completely overgrown by the pyrite. Under this hypothesis, a cube face of the pyrite would be parallel either to the (101) structure plane of marcasite, or to the crystallographically equivalent $(10\bar{1})$ plane. These two planes make an angle of 74°38′ with each other. In order to fully specify the epitactic relationship, a direction in each parallel face must also be specified. Two possibilities would explain the observed morphology; either [100] or [010] of pyrite is parallel to [010] of marcasite. These two epitactic models can be summarized in crystallographic shorthand as:

A: (001)[100] pyrite ∥ (101)[010] or $(10\bar{1})$[010] marcasite, or
B: (001)[010] pyrite ∥ (101)[010] or $(10\bar{1})$[010] marcasite.[1]

The two models are very similar. The only difference is a 90° rotation of the pyrite about the *b* axis of the marcasite. This difference, while subtle, is crystallographically significant. Recall that cube faces of pyrite have two-fold symmetry, not four-fold symmetry. Thus the [010] and [001] directions are not equivalent in pyrite. This fact is reflected in the orientation of striations on cube faces, and by the observation that the pyritohedron {210} is very common, while the pyritohedron {120}, which is morphologically identical but rotated by 90° relative to the structure, is extremely rare. Furthermore, the directions of striations and the positions of {210} faces of pyrite in epitactic associations formed according to model A will be different from those in associations formed according to model B.

When the interfacial angles between adjacent crystals on pyrite bars are measured, these two models predict the measured interfacial angles, within the measurement error. Thus either is a satisfactory description of the observed morphology. Only model A is recognized in the literature, however, and it is the more probable of the two when the crystal structures are considered (Brostigen and Kjekshus, 1970; Fleet, 1970; Brock and Slater, 1978). This can be understood by studying Figure 12, which presents stereopair drawings of slices of the marcasite and pyrite structures, superimposed according to each model. Model A causes entire sheets of the two structures to coincide almost perfectly. The misfit between the two structures in this orientation is minimal, and intergrowths with this orientation would be expected, according to the laws of crystal physics. Model B causes only alternating chains of the two structures to coincide. The misfit between the two structures is much larger, and intergrowths with this orientation would therefore be much less likely to occur.

Examination of a number of bars shows that all are consistent with respect to placement of the {210} faces. Thus only one of these two models is realized in this material. The question is, which one? If the direction of elongation of the marcasite were known, the correct model could be deduced from the placement of the {210} faces of the pyrite. Unfortunately, determining the direction of elongation of the marcasite is not a trivial matter. Most bars show no external evidence of a marcasite crystal. Studies of polished cross-sections of bars reveal that marcasite is present near the center of the bar, but the areas of marcasite are very small and the orientation of the marcasite cannot be deduced from these sections. The mass of the pyrite is much greater than the mass of marcasite, preventing X-ray examination of the marcasite in typical bars.

***Figure 11.* Pyrite bar with acicular marcasite crystal projecting from one end. The part of the aggregate shown is 3 mm long. Irene quarry, R. Peter Richards specimen and photo.**

A few specimens have been found with acicular marcasite projecting from one end (Fig. 11). Acicular marcasite crystals with isolated epitactically oriented pyrite have also been found, and these pyrite crystals show the same orientation as those which form the bars, as determined by the placement of the {210} faces. These associations are equivalent to more typical bars in the early stages of their development. X-ray study of the marcasite projecting from one bar showed that it was elongated parallel to the *a* axis. This result, in combination with the orientation of the pyrite {210} faces, indicates that the bars have developed according to model A.

Several remarkable specimens have also been located which have parallel marcasite crystals projecting *between* the pyrite crystals which form the bar (Fig. 13). These marcasite crystals are also overgrowths on the original acicular crystal, and apparently grew simultaneously with the pyrite, or nearly so. Their habit sometimes includes the bipyramid {111}, the orientation of which is also consistent with an original marcasite crystal elongate along the *a* axis and with epitactic model A.

Our ideas and observations are summarized in Figure 14. Initially, acicular marcasite crystals grew in vugs in the dolostone. These crystals were elongate parallel to their *a* axes. Thereafter, pyrite crystals nucleated epitactically on the marcasite whiskers, in one of two equivalent orientations. Further growth led to the partial or complete coalescence of adjacent like-oriented pyrite crystals, and contact between opposite-oriented crystals. Partial coalescence creates crystals with notches (see Fig. 14D, lower). Complete coalescence results from filling of the notches, and produces crystals such as those in Figure 14E and Figure 8. Coalescence can sometimes be recognized by irregularities in the surface texture or slight misfit of the coalesced crystals. Extensive coalescence seems to be associated with the habit involving larger octahedron and pyritohedron faces; aggregates with these properties form the pyrite bars. Pyrite chains typically have

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[1] The first of these epitactic relationships is geometrically equivalent to one listed, with several others, by Palache *et al.* (1944) in reference 11 to the section on marcasite: {001}[100] pyrite parallel to {010}[101] marcasite. While our statement of the relationship is geometrically identical to Palache's in terms of the external morphology, ours is preferable because marcasite (101), not marcasite (010), is the structural plane which is similar to pyrite (001) (Brostigen and Kjekshus, 1970; Brock and Slater, 1978). What may be the same relationship is listed by Palache *et al.* in the section on pyrite on page 284. However, on page 284 two relationships (including this one) are listed as involving {001}[001] of pyrite. We note that these are in error, because the direction [001] does not lie in the plane {001}. Possibly {001}[100] was intended instead.

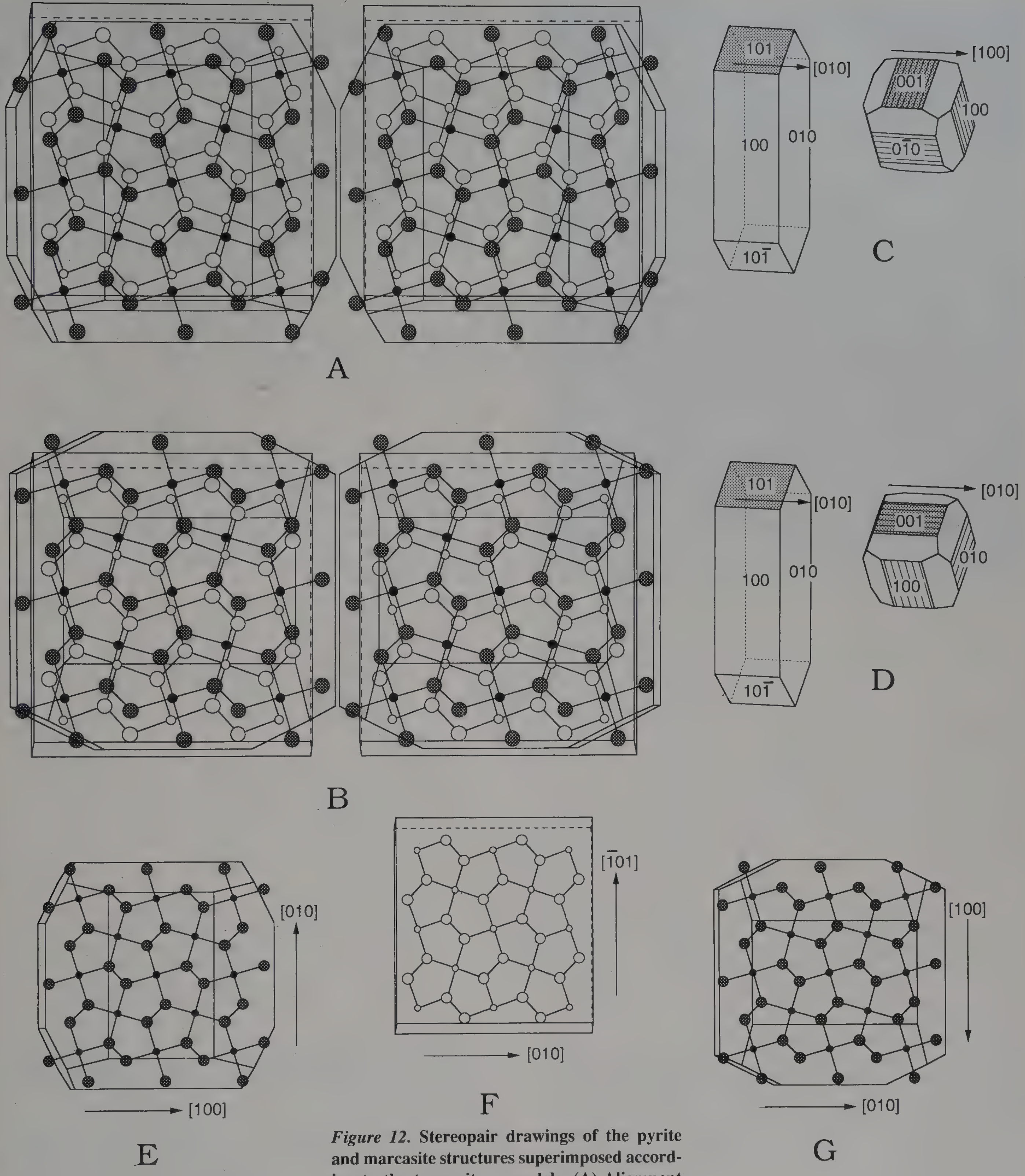


Figure 12. **Stereopair drawings of the pyrite and marcasite structures superimposed according to the two epitaxy models. (A) Alignment according to Model A causes entire planes of both structures to coincide. (B) Alignment according to Model B only causes alternating chains of the structures to coincide. (C) Hypothetical pyrite and marcasite crystals oriented according to Model A. (D) The same oriented according to model B. (E) The pyrite structure for Model A drawn separately. (F) The marcasite structure. (G) The pyrite structure for Model B.**

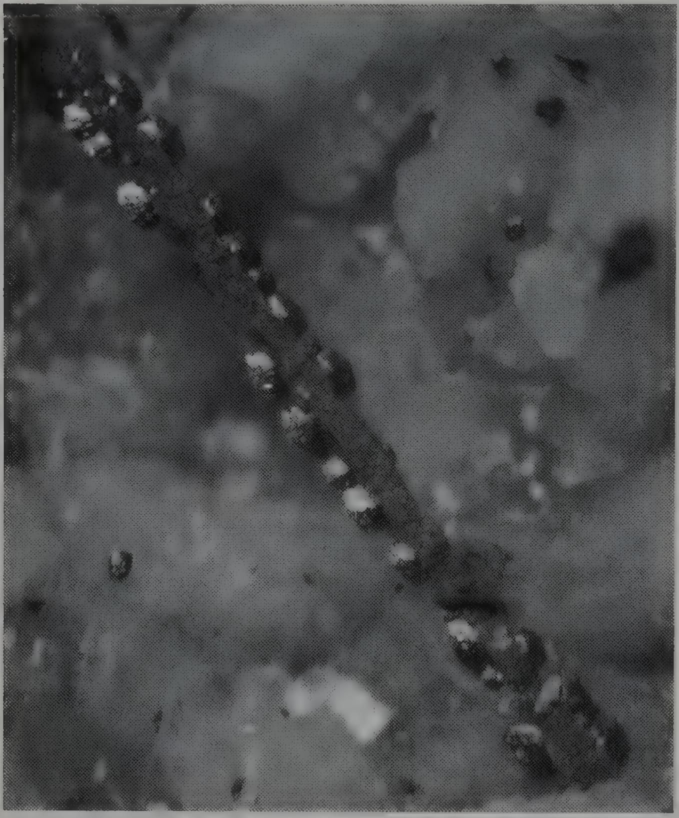
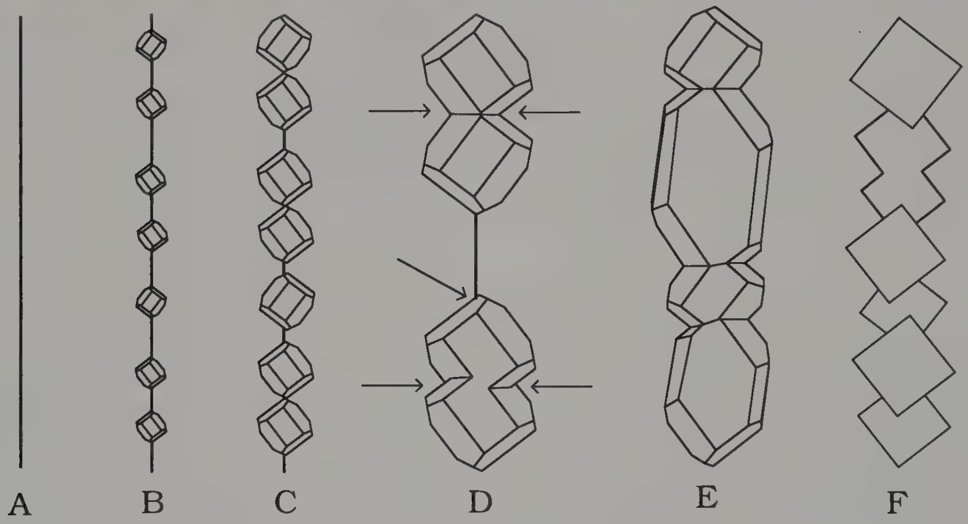


Figure 13. **Pyrite bar with marcasite crystals projecting between individual pyrite crystals. The portion of the bar shown is 5 mm long. Mulford quarry; R. Peter Richards specimen and photo.**

Figure 14. **Sequence of development for pyrite bars and chains. When individual epitactic pyrite crystals begin to contact each other, like-oriented adjacent crystals may merge by reentrant filling, leading to the bar form. If such crystals do not merge to any great extent, the chain form results.**



mineral, or a different direction of elongation for an acicular marcasite host. The bars (and other materials) from Rensselaer, Indiana offer an excellent opportunity for further study of pyrite-marcasite epitaxy, particularly if some bars are identified in which the mineral of the central cavity is still present.

Pyrite occurs in epitactic orientation on acicular marcasite from other localities as well, but in these occurrences the pyrite crystals do not merge to form bars. Instead, they form chain-like configurations or remain isolated from each other on the host marcasite. These localities include Pint's quarry, Raymond, Iowa; Hamilton, Illinois; Keokuk, Iowa; Milan, Ohio; and possibly Rockbridge County, Virginia (Dietrich, 1985; reported as a marcasite twin). In all these instances, the orientation of the pyrite to the marcasite host appears to be the same as described in this paper.

crystals of more cubic habit and with limited coalescence.

In crystals in which pyrite and marcasite were developing simultaneously (or nearly so), new marcasite growth occurred in parallel with the acicular marcasite. Geometric competition (Grigor'ev, 1965) between growing crystals favored continued growth of marcasite only in "notches" between the pyrite crystals (if at all), where pyrite growth was slowest.

Armed with an explanation for these pyrite bars, we return briefly to the pyrite bars from elsewhere. Some bars from Rensselaer and Pleasant Ridge, Indiana are clearly polycrystalline, with the individual pyrite axes inclined to the length of the bar. They also typically have an elongate cavity parallel to the length of the bar, which may represent a now-dissolved acicular marcasite crystal. In these characteristics they are comparable to the crystals from northern Illinois. However, the orientation of the pyrite relative to the bar axis is different in many specimens; this may indicate an overgrowth not involving epitaxy, a different epitactic relationship, a different host

What about occurrences of pyrite bars elongate parallel to an *a* axis, such as those listed in Table 1? Hansen (in White, 1975) reported that the bars from the Amex mine had a rectangular hole at the bar axis, and speculated that they represented second-generation pyrite overgrowths on pyrite or marcasite whiskers. While marcasite whiskers are unlikely to provide the right crystallographic orientation for these bars, pyrite whiskers are usually elongate parallel to an *a* axis, and would provide an appropriate substrate. White (1973) showed elegantly that the pyrite bars from Naica are overgrowths on pyrite whiskers of square cross-section and about 0.03 mm thick. Overgrowth on a pyrite whisker probably also explains the materials from the other two localities. The Amex crystals are truly remarkable, because the original whiskers must have been as much as a foot (30 cm) long, which is extremely long for naturally occurring whiskers.

Leaf Epitaxy

Careful study of numerous examples of the relationship shown in Figure 5 reveals a history of development similar to that of the bars and chains, and involving the same epitactic relationship, but one in which marcasite deposition dominated over pyrite deposition, and in which the initial marcasite crystal was elongate along the *c* axis (but not nearly so extremely as the marcasite within the bars). This growth history is diagrammed in Figure 15. Its development from an elongated marcasite crystal is supported by a faint textural difference in the final marcasite crystal, running along the middle of the crystal and passing though the pyrite; by the observation that one end of the midline of the marcasite is always in contact with the matrix, but the pyrite often is not (thus marcasite preceded pyrite); and by the fact that the pyrite is invariably located near the midline of the marcasite crystal, which suggests that was the only part of the crystal present when the pyrite began to grow.

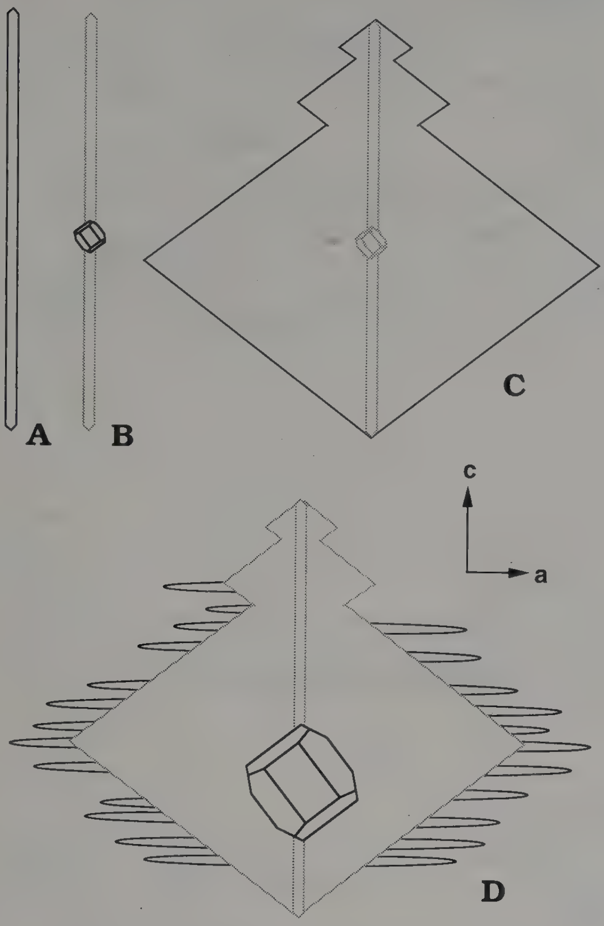


Figure 15. **Sequence of development for "leaf" epitaxy. Marcasite growth dominates over pyrite growth. The initial acicular marcasite crystal is elongated in the *c* direction.**

The conclusion that the first generation marcasite crystal is elongated parallel to the *c* axis is based on the orientation of the later-formed rhombic marcasite crystals. In these later crystals, the short dimension of the rhombic shape is parallel to the *c* axis (Fig. 2, top). This dimension is consistently oriented parallel to the long dimension of the first-generation crystal, which indicates that the long dimension of the first-generation crystal must also be parallel to the *c* axis. It is important to note that these crystals were found in a single pocket together with chalcopyrite, and do not occur together in the same vug with the bars discussed earlier. One would not expect to find marcasite elongated along *a* together with marcasite elongated along *c* in the same pocket (unless they were of two different generations); finding different directions of elongation in different pockets is less problematic.

The formation of one or a few small pyrite crystals as a second stage is supported by their location only along the midline of the marcasite crystal, and by the fact that many of these pyrite crystals are complete, with half on each side of the marcasite leaf. If the leaf were completely developed, there would be no reason for the pyrite to be confined to the middle, and no way for the pyrite to "penetrate" the marcasite.

The idea that the pyrite enlarged after the marcasite reached full or near-full size is supported by the observation that the pyrite breaks away from the marcasite very readily, leaving no hole in the marcasite and a flat surface on the pyrite where it had been in contact with the marcasite. Only a very tiny spot near the center of this surface appears broken. The pyrite did not bond strongly to the marcasite along much of this contact surface, perhaps because of a thin film of impurities on the marcasite, or perhaps simply because the contact surface is not the one involved in the epitactic relationship.

The development of the fringed edges is a late step, as indicated by the presence of a fine line where the fringes join to a much more regular diamond-shaped crystal edge. Often the fringes merge, forming an irregular margin. There is no evidence to indicate whether the pyrite enlarged before the fringes formed, or vise versa.

Study of thin edges of these fringes with transmission electron microscopy has produced selective area diffraction (SAD) images with a known orientation to the long direction of the fringe crystals, and hence a known orientation to the entire marcasite plate. Indexing these SAD images reveals that the flat faces are (010) and that the fringe crystals are elongate parallel to the *a* axis. This verifies the morphological interpretation of the orientation of these plates, and the *c*-axis elongation of the nucleus crystal.

In the leaf epitaxy, much more of the mass of the aggregate is composed of marcasite, and less of pyrite, than is true of the bars and chains. While these leaves have a more complex growth history, they are comparable to examples of pyrite epitactic on marcasite from many other localities, in which bladed marcasite crystals are decorated with one or a few pyrite crystals. We have personally seen such aggregates from Bellevue, Ohio and Rossie, New York; other localities are mentioned in the literature.

CONCLUSIONS

(1) Bar-like and chain-like polycrystalline aggregates of pyrite from northern Illinois formed by epitactic overgrowth on acicular marcasite crystals. Some bars also have marcasite crystals alternating with the pyrite crystals. Bar habits of these morphologies have not been described previously.

(2) The relationship we have described as "leaf epitaxy" also involves epitactic overgrowths of pyrite on marcasite, but with a more complex history of formation, and one which involved more marcasite deposition and less pyrite. Leaf epitaxy is morphologically related to pyrite epitactic on bladed marcasite from other localities.

(3) Pyrite bars described in the literature can be divided into (microscopic) pyrite whiskers; overgrowths on pyrite whiskers; overgrowths on acicular marcasite crystals, some with a different direction of elongation than reported here; and possibly overgrowths on acicular marcasite governed by different epitactic relationships than reported here.

ACKNOWLEDGMENTS

We thank Bill Cook of Cleveland Crystals for x-ray studies of selected marcasite crystals; the Department of Metallurgical and Materials Engineering at Michigan Technological University and Eric McCarty for help with transmission electron microscope studies of leaf epitaxy; the Oberlin College Biology Department for access to their scanning electron microscope; the Oberlin College Geology Department, Pete Munk, and Bruce Simonson for thin section preparation and use of their petrographic ore microscope; and the owners and operators of the quarries for access to the specimens which are the subject of this paper. RPR thanks the Seaman Mineralogical Museum at Michigan Tech for support during a research visit, during which the TEM work was done.

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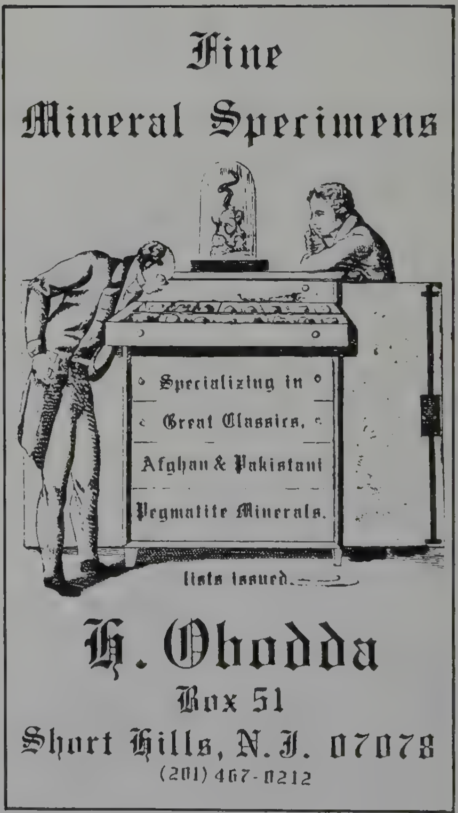

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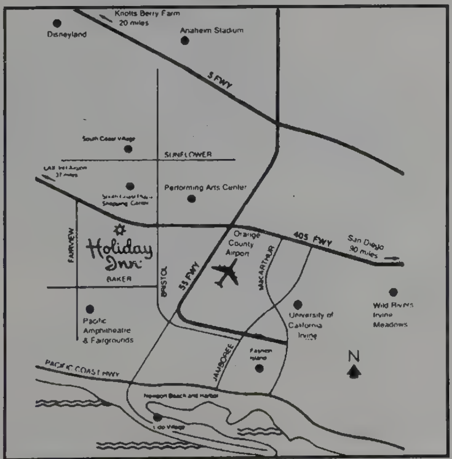

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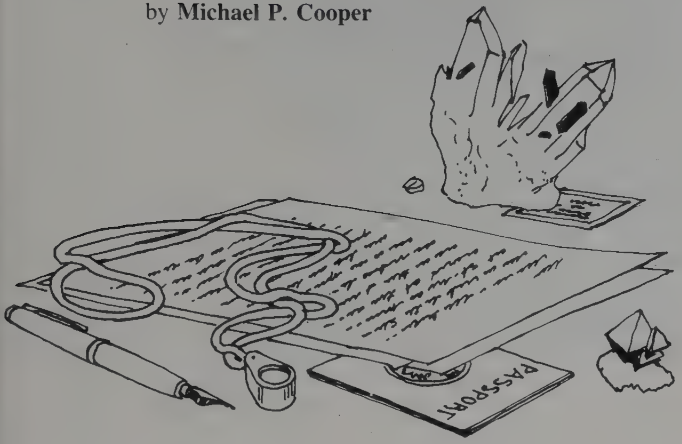


Munich Show 1994

by Michael P. Cooper

[October 14–16]

Grüss Gott from the *Mineralientage München*—"the Munich Mineral Days"—where I have been chasing specimens, gossip, collectors, dealers and mineral history for 5 very solid days. I missed the Ste-Marie-aux-Mines show this year, so this was my first big show in ages and I had a lot to catch up on. Despite being on the go constantly, and fighting a heavy cold, I had a good time at the show and managed to get a few nice pieces for my own collection in between seeing a lot of superb but unaffordable (or worse still, affordable but just bought by somebody else) specimens. We were all helped by the beautiful weather, so there was plenty of opportunity to sit outside with a drink and chew the fat (and the ridiculously over-sized German sausages) with friends old and new. This atmosphere compensated a little for missing Ste-Marie, where relaxing sunlit conversation is taken for granted, the more so since past Munich shows have been known to take place in appallingly cold weather (speaking as an island dweller and beneficiary of the Gulf Stream, unused to continental winters).

I came to Munich early this year, but still not early enough of course. For instance I missed the best of a new batch of Indian **cavansite**, but the remainder was quite good enough thank you: deepest blue balls of crystals in rich specimens. *Wilke Mineralien* had a fine display of this and other recently acquired basalt quarry finery from India. However, as someone said, it was just *more* superb cavansite. The same was to some extent true throughout the show: more excellent galena from Bulgaria, more beautiful stibnite from Romania, more world-class scheelite from China, more Bunker Hill pyromorphite. Well, it's a common "lament" and I won't belabor the point. Except to say that do you remember when there was so much *more* Los Lamentos wulfenite that it was as uninspiring as today's glut of blood-red Moroccan vanadinite? Well, you don't see much anymore, and the prices of good pieces reflect this. Using this argument I bought yet another blood-red Moroccan vanadinite. Well, it *is* beautiful isn't it? It heads up my small display of the mineralogical spectrum through descloizite, crocoite, wulfenite (orange and yellow), brochantite (the stuff from Copiapo, Chile, selling as "aurichalcite" a few years ago), malachite, azurite, fluorite and erythrite.

So, what were the principal delights of Munich this year? Honors for quantity and quality must go to China, Romania, Bulgaria, India and Morocco; honors for one-off or two-off killers go to Sweet Home mine rhodochrosite, San Francisco mine wulfenite which stood out on a couple of stands, and to China again for things shown to me under tables.

Some of the Central European suites were very impressive. **Galena** from Madan, Bulgaria, was available in quantity and in some superb specimens. *Geocommerce* (Samena Gora 10, Plowdiv, Bulgaria 4003) had a particularly interesting display of small to large specimens featuring tabular spinel-law twins to 3 or 4 cm at reasonable prices (45 to 450 DM for most pieces). (Perhaps someone could explain to me why spinel twins are so common in galena in some localities, such as those in central Europe or South America, and so rare in others, such as Tri-State or Northern England?) *Geocommerce*'s largest piece was a spectacular "museum specimen" some 30 cm square, covered in quartz and galena twins, the latter to about 5 cm. They also had some nice **chalcopyrite** and some globular **rhodochrosite** specimens. Other remarkable galenas—probably the best of their kind in the show—were also available from *Pierre and Martine Clavel* (4, Chemin vie Borgne, 38460 Crémieu, France). These show complex (untwinned) tabular rectangular crystals, with parallel overgrowths of small cubes, in perfect glittering condition, beautifully displayed on quartz matrix, or in parallel-growth masses of small, sharp cubes. The crystals reach several centimeters across and were priced at several hundred marks. Several excited collectors approached me with specimens from this lot, each saying they had acquired the best one. And they were all right. Very worthy specimens indeed.

Several stands had specimens of **stibnite** from Herja, Maramures, Romania. In this recently mined batch the lustrous black crystals vary from a centimeter to about 15 cm long, forming sprays and "hedgehogs" ("porcupines" might be more appropriate for the larger pieces) on and off matrix. The best have no damage and contrast well with the pale gray, rather vesicular quartz-rich matrix. Prices were generally very reasonable, although the best were priced accordingly high. A particularly attractive suite of specimens was available from *Top Minerals* (A-2700 Wr. Neustadt, Rudolf Hawel-Gasse 21, Austria), the owner of which—Rene Triebl—introduced me to an unusual dealer's expression: the "nail price." I'd heard of "keystone prices," "best"

Figure 1. **Stibnite spray, 7.5 cm, from Herja, Maramures, Romania. Rene Triebl specimen, now in the author's collection.**

prices and so forth but never a nail price. It's the price you put on a specimen label if you like the specimen so much that you want it to grace your stand as long as possible: it's so high you might just as well have nailed the piece down. Also available from Herja were some fine specimens of **semseyite** in fans of small blades to 1 cm or so, the best again on a contrasting matrix of white quartz prisms; but the more typical pieces show the mineral—itself often tarnished black—on a dark sulfide matrix. Herja is also producing **freibergite** and **fizelyite** in reasonable specimens, some with a few rather dull **bournonite** crystals. These were mostly available from the smaller central European dealers dotted around Hall 5.

Some excellent sulfide minerals were also available from China. **Chalcopyrite, galenobismuthite, galena, sphalerite** and **bournonite** from "near Chenzou, Hunan" were seen at several stands. The chalcopyrite probably constituted the finest specimen material, and some excellent bisphenoids to 4 cm and complex (etched?) masses to 6 cm were being offered by *Peter Bosse* (Wilhelmhöher Alee 321, Kassel, Germany 34131). The latter are attractively associated with white lenticular calcite crystals on a reddish matrix. The bournonite (again Bosse had the best) forms bright, striated crystals, but specimens are small. Some of the sphalerite forms attractive blood-red crystals to 5 or 6 mm on matrix; other specimens show the more common black crystals but in sizes to 1.5 cm. According to Gabriel Risse, on the stand of *Budil & Budil* (Herzog Albrecht Strasse 36, Zomeding, Germany 85604), the mine is near the town of Yiou Guam Xiang, but I also saw a specimen of this characteristic chalcopyrite at another stand, labeled Leyang, Hunan. My knowledge of Chinese geography is not good enough to say whether these are all in the same area, or whether there is some disinformation at work again, as there has been with the scheelite/beryl combinations recently available. I talked to several people about this problem, but it is an intractable one, compounded by the transliteration of Chinese names into several European languages, using different transliteration regimes, and the fact that one rarely sees an actual mine name, so that the nearest town, village or city is given instead, with or without the addition of the word "mine." Thus, specimens of this sulfide suite may be seen labeled "Chenzou mine," although Chenzou is a good 200 km from the mine I'm told, and "Chenzhou" is the spelling on my maps of this south Hunan city near the border with Guangdong province.

A new Chinese mine, opened during the last year, is showing great potential for **fluorite**. This is the "Tao Ling mine, Yue Yang City, Hunan." (I feel fairly happy with this locality name because several people gave me exactly the same one, although I suppose this could mean merely that they all got their specimens from the same person. And a Yueyang city does exist in northwest Hunan on the Hubei province border!) This is a lead-zinc mine, but few sulfide specimens were to be seen at Munich. Several dealers had promising fluorite either as groups and singles of relatively small, delicately green, transparent cuboctahedra on matrix, as larger purple octahedra or as white drusy quartz pseudomorphs after the latter. The octahedra reach 4 cm on edge. Associations include transparent green sphalerite to 1 cm or so, tabular white barite, and small chalcopyrite crystals. Good specimens were available from Budil & Budil and from *Christian Gobin*, but both felt that the best was yet to come. Budil & Budil's stand also boasted a large lump of native **bismuth** showing the impressions of quartz crystal terminations. This was labeled from Yizhang, Hunan (also on my map in south Hunan on the Guangdong province border) and was purportedly an old piece. It is very similar to the better known and equally excellent material from Australia. Among other Chinese things I was told about, but didn't get to see, were **stibiconite after stibnite** and some bipyramidal **vesuvianite**—unfortunately I don't know any more than that (no sizes, or localities), but my informant was obviously impressed by them, and they might be worth asking your nearest China specialist about.

Excellent Chinese **scheelite** is still relatively plentiful. There seem to be two current sources, one yielding deep orange, sometimes gemmy, crystals with colorless beryl, and rarely with colorless fluorite or pink beryl, on mica. The other source produces gray, sharp, highly lustrous bipyramids to 3 cm on edge with **arsenopyrite** (very lustrous to 3 cm), quartz and **cassiterite.** The source of the orange scheelite has been in dispute for a while now; at first cited as from Hunan, it seems that Sichuan is now the more widely accepted province. I saw it labeled more precisely as both the "Leng Bao Dings Hill" or as "Ping Wu Town, Miang Yang City"—Mianyang city is northwest of the provincial capital Chengdu. *Frédérick Escaut* (Ostrea Location, Route des Huitres, 17550 Dolus, France) still has the finest of this variety in crystals, to 8 cm or so on edge. Christian Gobin (*Ourika,* Chemin des Terres Longues, Venelles, France 13770) had the best of the gray crystals and said the material was from Jiao Kan Tchièn, Hunan, a name remarkably like the Yiou Guam Xiang (given the change of language from German to French) cited as the source of the chalcopyrite mentioned above. I will not pretend to know which site is which here, and will hazard no suggestions as to whether geography or language decides the difference. Some wonderful **cassiterite** is coming from the same mine (or another close by) that produces the orange scheelite. It occurs as huge, complex twins to 10 cm and more across, some on matrix and some crowned with tabular colorless beryl several centimeters across. Other crystals are prismatic to lengths you would not believe. I saw only a limited number of these specimens and I look forward to seeing more; they set a new standard for the species.

In my last Munich report I also complained about problems with locality names, especially problems encountered with Russian sites. This resulted in a couple of interesting and informative letters from Russian mineralogist and mineralogical author Boris Kantor in Moscow. Explaining that he had had to devise standard Western spellings for Russian names himself for use in translated mineral articles, Boris listed several of his preferred versions: Nikolai mine (Dalnegorsk) should preferably be the Nikolayevsky mine; "Rudnui, Kusteni" should be Rudnyi, Kustanai; "Kerch, Keren Peninsula" should be Kerch Peninsula (and there is no "Kerch mine" as such, but a series of individually named open pits). He pointed out that "Oblast," as in "Kustenai Oblast," means "region" and that a "krai" (sometimes, wrongly, rendered "kraij") is a big oblast. He also says that the recently mined Russian crocoites currently on the market are probably from Beriozovsky (near Ekaterinburg), not Berezov (or Beriosova) which are different places, though all in the Urals. His last point was that the "galena after wire silver" recently pictured in the *Mineralogical Record,* and also from Beriozovsky, has been known for decades and is usually interpreted as a product of plastic deformation of galena squeezed through fissures by tectonic forces rather than as a pseudomorph. [Ed. note: Galena in an open cavity is *not* ductile! The pseudomorphic explanation is more credible.]

Back in Munich, and back with further locality confusion, lime-green **olivine** glowed on several stands. The locality was given as Sappat (or Sopat), Kohistan province, Pakistan. This is nice material. Crystals are generally rather rounded and etched, but are limpid and of very good color within. Individuals are all loose and generally show only one termination. An exceptional 3-cm *doubly terminated* crystal was held by *Martin Rosser and Maria Grundner* (Orthstrasse 14, 81245 München, Germany). According to Martin the locality is at 13,000 feet and is a two-day walk or 9 hours on horseback from Dasso (between Gilgit and Islamabad). Either way you arrive with sore bits you didn't have when you started out. I was also told that the site had been attacked in force by specimen and gem miners and is likely to become rapidly depleted.

From the other side of the world (from where I'm sitting at the moment) there was little new to report. Australian **opal** was in evidence, especially in the show's colorful special exhibit of that mineral, but no new finds were represented. I was disappointed not to have been able to take up an offer of an escorted trip around this

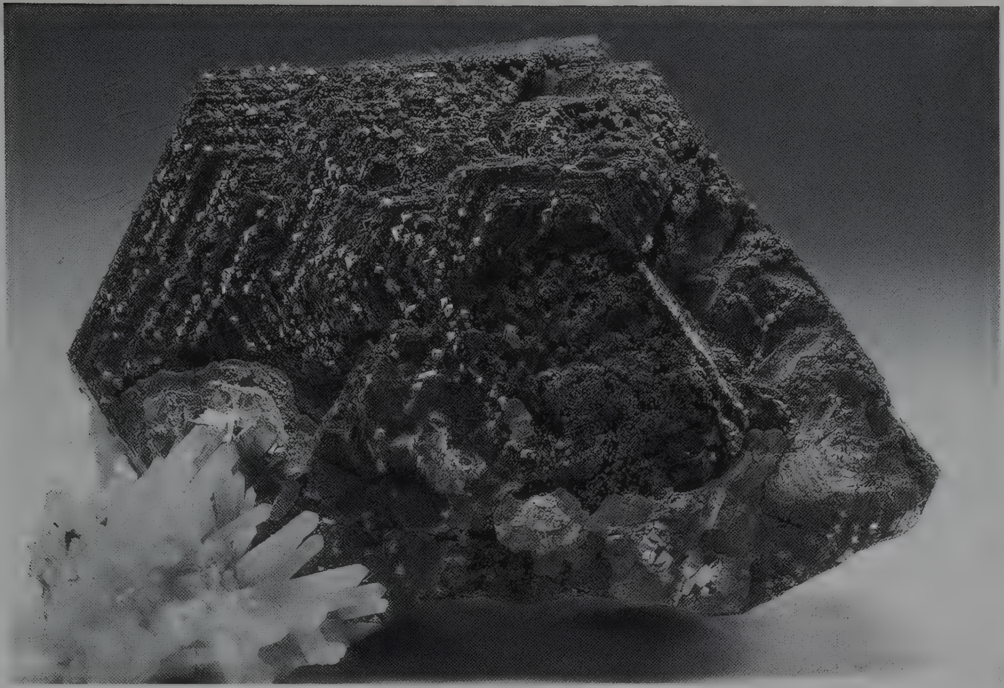


Figure 2. **Pyrrhotite crystal decorated by rows of minute epitaxial galena octahedra, 8 cm across, from Dalnegorsk, Primorsky Krai, Russia.** ***MinGeo*** **specimen, now in the author's collection.**

exhibit by an Australian dealer, as I'd have liked to learn more of the occurrences of this mineral. Among the many beautiful stones on view here I was most taken by one rather less colorful than most: a large opal "pineapple" pseudomorph after glauberite, from White Cliffs, New South Wales, surely one of the top ten pseudomorphs of all time. Otherwise the only antipodean item in quantity was **crocoite** from the Adelaide mine, Dundas, Tasmania, which was available on several specialist stands. Most of these pieces appear to have been etched from enclosing minerals and look it, being dull and milky. Nonetheless, they often show very large crystals for the species and can be very attractive if grouped in a sculptural arrangement of prisms. Specimens were reasonably priced and sold well.

From South America there was a lot of fine Argentinean **rhodochrosite** in evidence, another repeat performance, but at much more reasonable prices than heretofore. Superb, thick, polished slabs taken from intergrown or individual stalactites, some showing a fair degree of transparency, could be had for 50 to 500 DM. A special opportunity for European collectors was the chance to see fine specimens of the new mineral **szenicsite** at the stand of *Aurora Minerals*. Good specimens of this Chilean species were to be had from $400, and the best, featuring large (3 cm) crystals with powellite needles, for $12,000.

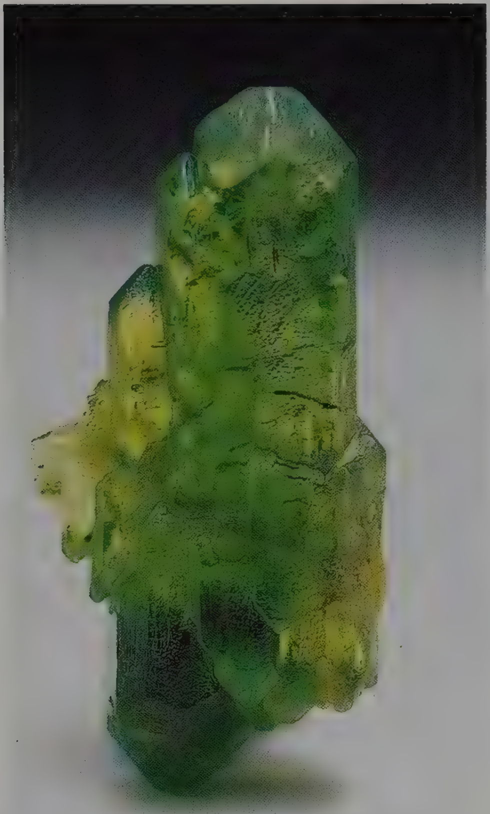
Russian minerals were popular, though quantities of many are still dwindling and prices still escalating. Dalnegorsk **sulfides** and **fluorites** are still available in fine specimens, and I bought yet another nice **pyrrhotite** (from *MinGeo*, Pardubická 734, 500 02 Hradec Králové, Czech Republic) unusual for its lines of minute octahedral galena crystals epitaxially arranged on the prominent, 8-cm pinacoid face. *Top Minerals* had a killer **ilvaite** from Dalnegorsk, a superb spray of large, lustrous black prisms sprouting from a matrix of quartz pyramids and spiky hedenbergite. This was regarded by several collectors as one of the best pieces in the show, and it was certainly one of the finest of all Russian ilvaites. It was sold before the show opened.

In Hall 5, certain canny Russian dealers, long steeped in the barter mentality and a regime of shortages, held court at tables brimming with unlabeled, unpriced specimens. It paid the collector to revisit these tables several times, as new batches of material were constantly being added. A four-deep throng of collectors was a periodic sign that something had been brought out. In this way scores of specimens of the honey-yellow blocky **calcite** from Sokolovskoye, Rudnyi, Kazakhstan, were moved on to collector's cabinets. A nice display of this material, which has been around in reasonable quantity for a year or so now, was also mounted by *Wilke Mineralien*. Russian and CIS rarities were dotted about the show in rather smaller quantities (I guess that's the way of it with rarities): from the Kola Peninsula *Top Minerals* had an unusual pale blue **kovdorskite** crystal from the type locality, Kovdor, and *Fabre Minerals* had an excellent **plumbomicrolite** octahedron, 3 cm on edge, from Mt. Ploskaya, Keivi. Jordi also had a good **betekhtinite** from Dzezkazghan, Kazakhstan, a rich mass of darkly iridescent, deeply striated crystals 1 to 2 cm long from the romantically titled Mine 55. As for other (generally smaller) rarities I turn once again for assistance to collector Simon Howell, whose dedication to obscure minerals far exceeds my own. Simon kindly provided me with the following eight paragraphs on some of the more interesting rarities available at Munich.

It's hard work being a systematic collector at the Munich show, where there is such a pronounced contrast between the small specks of material representing some fascinating chemical combination and the large and magnificent aesthetic specimens of more common species which appear to surround you at every moment. Nevertheless, the Munich show is well known for the excellent representation by dealers and collectors specializing in systematic minerals, and 1994 was certainly no exception!

Dr. Marek Kotrly (Severozapadni V/11, 141 00 Prague 4, Czech Republic) had a number of interesting species available from eastern European localities, including: **tounkite** and **bystrite**, from the type locality of Malaya Bystraya in Siberia; and several specimens of the rare copper-lead-bismuth sulfide-selenide **soucekite**, from Oldrichov, near Tachov, western Bohemia in Czechoslovakia. Specimens of another rare selenium mineral, **poubaite** (with **clausthalite**) were also available from the same locality.

As usual, *Falko Baatz* (Dorfstr. 21, Gerdshagen, Germany 18276) had a staggering array of systematic species available, the majority from their type localities, including **belyankinite, betpakdalite, mushistonite, perlialite, rasvumite, shortite, shcherbakovite, srebrodolskite, strontiopyrochlore, tadzhikite-(Ce), vauquelinite,**



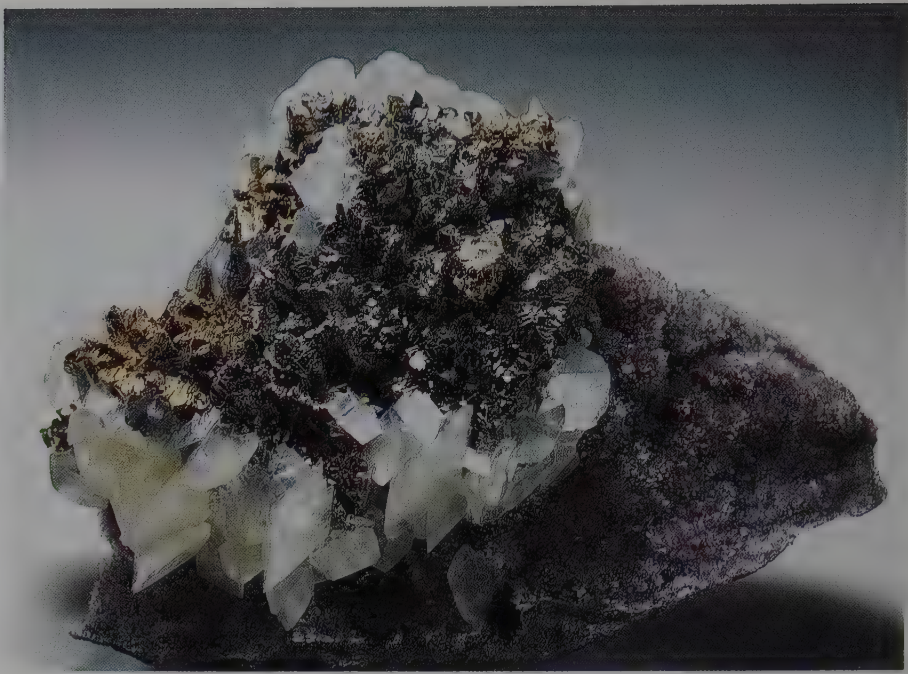
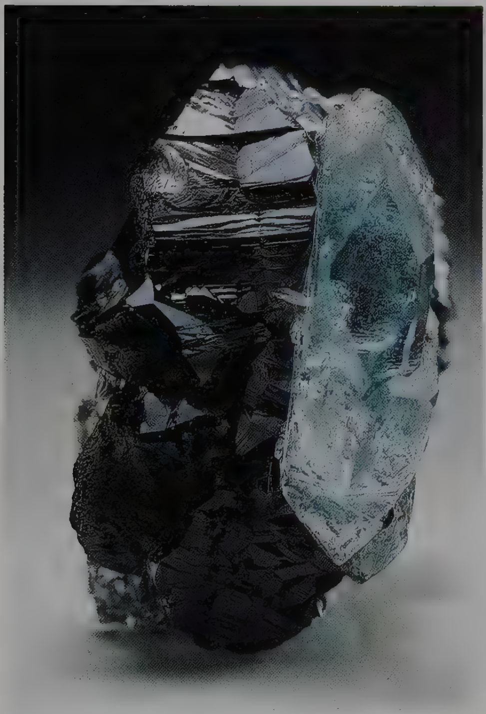


Figure 3. (above) **Chalcopyrite with white calcite, 12 cm, from Chenzhou, Hunan, China. Peter Bosse specimen.**

Figure 4. (above left) **Olivine crystal, 3 cm, from a new find at Sopat, Dusso, Kohistan, Pakistan. Martin Rosser specimen.**

Figure 5. (left) **Cassiterite crystals (black) with beryl, 3.5 cm. Frédéric Escaut specimen.**

Figure 6. (right) **Kovdorskite crystal with an attractive pale blue color, 2 cm, from Kovdor, Kola Peninsula, Russia. Rene Triebl specimen, now in the Keith Hammond collection.**



vitusite-(Ce), and **yuksporite.**

It was interesting to see some rare species available from Japanese localities at the stand of *Hori Mineralogy* (P.O. Box 50, Nerima, Tokyo 176, Japan), including specimens of **minamiite** and **shigaite** from their respective type localities of Okumanza Hot Spring, Gunma and the Ioi mine, Shiga, Honshu, and the hydrated manganese sulfate, **jokokuite,** from the type locality of Jokoku, Hiyama, Hokkaido.

One enormous specimen that caught my eye was a single crystal of **sperrylite** 2.2 cm (nearly an inch!) across, embedded in a sulfide matrix, from the well-known locality at Talnach, Siberia. This specimen had been placed directly below a large halogen spot light, and was almost dropped when I picked it up to examine the crystal because the sulfide matrix had reached such a high temperature!

Claudio and Marisa Albertini (via A Grandi, 22 Frax, Verta 28026 Omegna (Novara), Italy) had several specimens of the newly reported (1994) sodium antimonate **brizziite,** together with a large selection of both rare and more common alpine minerals from localities in Italy, which included good crystals of **vigezzite.** In addition, several specimens of **aschamalmite** (a lead-bismuth sulfide) were available from the first recorded occurrence in Italy, at Val Basso in the Valle Vigezzo, Novara.

A few small specimens of the rare palladium-tin mineral **paolovite** were offered from the type locality by *Dr. Jarosmir Tvrdy* (Vodarenska 10, 360 10 Karlovy Vary, Czech Republic), together with the platinum-antimony species, **geversite,** both from the Oktjabrs'koe deposit, Talnach, near Norilsk in northern Siberia, Russia; and *Manfred*

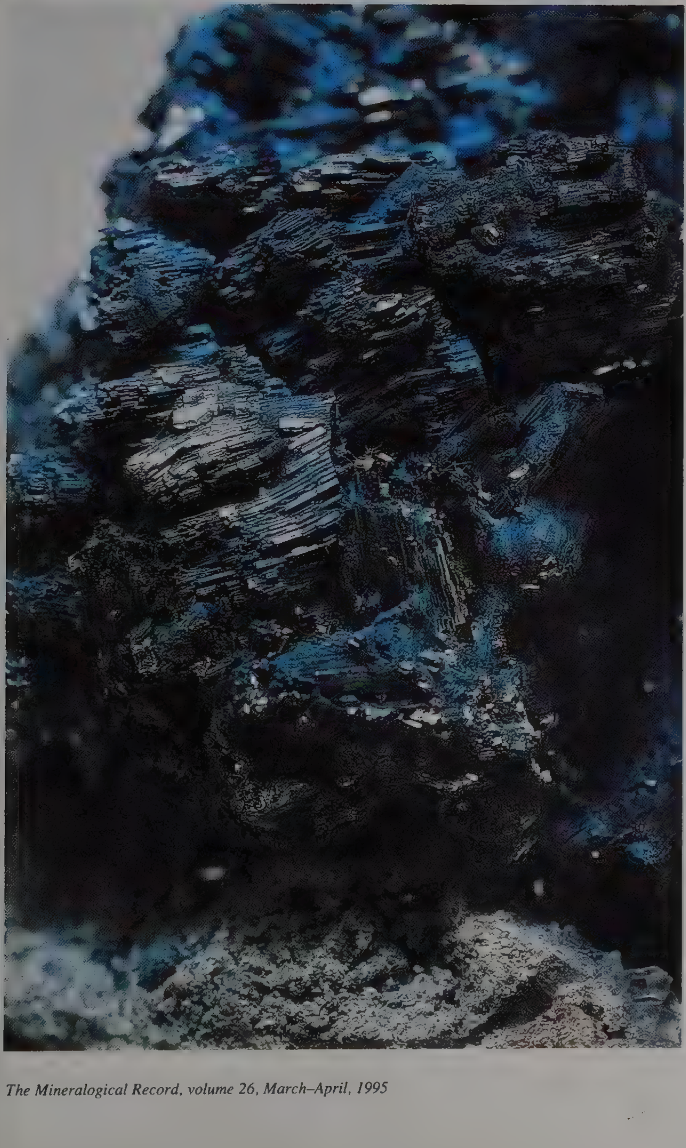


Figure 7. **Large cabinet specimen of fluorite from La Collada, Berbes, Asturias, Spain. Jordi Fabre specimen.**

Figure 8. **Aggregate of semi-parallel betekhtinite crystals, on copper sulfides, 8 cm, from Dzezkazghan, Kazakhstan. Jordi Fabre specimen.**

Schaefer (Rosenstr. 5, Detmold, Germany 32756) had a wide selection of rare elements, sulfides and sulfosalts, including a large number of specimens of the rare iron-nickel-antimony-arsenic mineral, **seinäjokite,** accompanied by native **antimony, westerveldite** and **breithauptite,** from the type locality at Seinäjoki, Vaasa, Finland.

Helga and Horst Geuer (Am Sonnenhang 39, 53639 Königswinter, Germany) had their usual excellent selection of specimens from Eifel and Lengenbach, the former including **brenkite, calciobetafite, cuspidine, jacobsite, jasmundite, nickenichite, perrierite** and **srebrodolskite**, and Lengenbach being represented by some early material from the Novacki Institute, which was also the source of some excellent specimens of **marrite, rathite, seligmannite, trechmannite** and **imhofite**, together with a small number of lengenbachite specimens of typical bladed form.

Back in the world of the more mundane species, there was also yet another new find of Spanish **fluorite,** this time from La Collada, Asturias, from a find known as the *Geoda del Reguerín*. These pale bluish crystals, which had made their debut at Ste-Marie-aux-Mines, reach 3–4 cm and were available in Munich in specimens up to a meter long at the stand of *Fabre Minerals*. Jordi is also the sole supplier of a new batch of **pyrite,** as sharp floater crystals and groups, the individuals to about 3 cm or so, from the Ambasaguas 1 mine, Ambasaguas, Logroño, Spain. Forms include both pyritohedrons (some rather elongated) and cube/pyritohedron combinations. These make excellent single-crystal pieces.

The institutional and private-collection displays at Munich presented the expected fine selection of goodies. Being a sucker for mineral collecting history, I was especially taken with that of London dealer Brian Lloyd (of *Gregory, Bottley & Lloyd*) featuring specimens sold at auction in 1829 by leading European dealer Henry (heulandite) Heuland. Alongside the auction catalog, marked with the names of famous buyers such as Henry Brooke, Countess Aylsford, Isaac Walker and Sir George Tuthill (whose fine collection was later to form the core of the more famous accumulation made by sculptor Francis Chantrey), were the actual specimens described in the lots! A nice historical snapshot. The Houston Museum displayed the usual suite of incredible specimens—phosphophyllite, cerussite on dioptase, etc.; it was nice to see them again, but as someone said to me: "Don't they have anything else?" The Royal Museum in Stockholm displayed their cobaltites (still the world's best as far as I know), including a plaster cast of the big dodecahedron with its customized carrying case. There were Alpine minerals in abundance too in the collector's cases, but not so many of them for sale around the show.

Munich is also a good show for books and magazines new and old. Standing out among the new ones worthy of mention was *Meisterwerke sachsicher Minerale,* a beautifully produced volume of 60 exquisite paintings of Saxon minerals by Eberhard Equit, originals of which made such a big impact in a special exhibit in the 1992 Munich show. Copies (which cost 179DM) are available from Equit Verlag (Fehrbellinerstr. 49, 10119 Berlin, Germany) and Christian Weise Verlag, publishers of leading German collector mineral magazine *Lapis.* And Falko Baatz had a copy of a relative rarity, a book on Russian gem minerals, *Gemstones of Russia and Adjoining States,* by J. P. Samsonov, published by the Agricultural Bank of Moscow in 1993. Fifty percent of the print run had been reserved by the bank for promotional purposes, but copies are available in the West for about 100DM. Also on Russian minerals, *World of Stones* magazine is still going strong and a further 2 issues were available at Munich.

By Sunday I was wiped out. Munich keeps me on my feet almost all day, and socializing late each night. It's a thoroughly enjoyable and generally good-humored event (collector jealousies aside!), and Munich itself is rumored to be a beautiful place, though I get to see little of it apart from the underground stations. Next year's show is later in the month: October 27–29, and the show theme will be ***"Fluorite, the collector's favorite."*** Should make for good special exhibits!

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Bilbao and Barcelona Shows 1994

by Miguel Calvo

As is customary, the two largest mineral shows in Spain, Bilbao and Barcelona, were held in the fall. (It is surprising that Madrid, the capital of Spain, does not have a major mineral show.) As in other years, some new specimens could be seen, mainly from discoveries in Spain.

The Horcajo lead mine is a classical mineralogical locality in Spain (see the article about this locality in the *Mineralogical Record,* **25**, 21–27). This year two interesting minerals surfaced from Horcajo. First, in the Bilbao show, *Javier Garcia* from Madrid had about two dozen **cacoxenite** specimens, some associated with **beraunite,** found on the dumps in the summer of 1994. The specimens are richly covered by rosettes and botryoidal crust of both minerals. From the same locality, *Jordi Fabre* had in the Barcelona Show about 20 **pyromorphite** specimens, the remains of more than 100, most sold at the Munich Show two weeks before. The specimens are very fine for the species and locality, and very reasonably priced. Two types of specimens are included: grass-green acicular crystals, and yellow, relatively blocky crystals. All specimens are crystal groups without matrix, and miniature size or smaller. Fabre stated that these specimens are from an old find, mined at least 30 years ago.

A large basalt quarry producing crushed stone for road construction is located between Albatera and Hondón de los Frailes, in Alicante province; it has been the source of some relatively modest **epidote** specimens in the past, with sheaf-like groups of millimeter-size crystals covering the surface. This year, *Francisco Piñol* from Alicante had specimens (from this quarry) with the epidote associated with **titanite** crystals or black **garnet** crystals, both up to 1 cm, and/or transparent **quartz** crystals up to 3 cm. Many specimens, obtained by dissolving the calcite to expose the enclosed epidote, are very nice.

Jose Javier Saura from Cartagena had in Bilbao and Barcelona newly mined **barite** from Teresita mine, La Unión, Murcia. Specimens from this new find are groups of thin, tabular blue crystals up to 2 cm. These are found as floaters up to 15 cm. Larger specimens are very fragile and tend to get broken in the extraction process. In total, more than 1,000 specimens have been found. It is interesting to point out that this barite is found with blue color in the mine. Many "blue" barites from Asturias, also in Spain, are found colorless, but exposure to sunlight changes the color to a more or less intense blue. This process is natural in the dumps, but, of course, is also well known, and used, by many dealers.

Javier Saura also had blue **barite** from an unnamed mine near Gorguel, Murcia. The specimens from this locality are composed of crystals up to 5 cm, with their edges slightly rounded and faces slightly curved, probably due to some dissolution.

Among the specimens from localities outside of Spain, the most outstanding at the Bilbao Show was a **malachite** specimen from the Mashamba mine, Zaire, with curved leaves up to 5 cm. This specimen was sold by *Luis Miguel Fernandez,* a dealer from Zaragoza, to the Museo Mollfulleda, in Arenys de Mar, Barcelona. *Martin Oliete,* from Madrid, had in Bilbao five **willemite** specimens from Sterling Hill. These have relatively sharp, pink crystals up to 4 cm in a marble matrix. These, obtained about 15 years ago from *Jim's Gems,* Wayne, New Jersey, are probably the finest specimens of this mineral seen in Spain in many years.

At the Barcelona Show, *Jordi Fabre* had a fine old specimen of **wurzite,** a mineral rarely seen as good crystals. The small miniature specimen from Llallagua has two 1-cm hexagonal, very bright crystals in a matrix of **siderite** microcrystals pseudomorphous after some tabular mineral. The label is from the Harvard Mineralogical Museum.

Many interesting minerals of reference value for Spanish occurrences were to be found in *Juan Viñals'* booth in the Barcelona Show. This year, the most prominent mineral is **planerite,** found by Viñals near the prehistoric variscite and turquoise mines in Bruguers, Barcelona province. These mines, from the Neolitic age, are now classified as a site with historical interest, and collecting minerals inside is, of course, forbidden. However, specimens can be obtained at the surface in nearby areas. Planerite is found filling large fractures in quartz. Viñals had also two specimens of a Spanish classic: large (more than 10 cm) **brannerite** crystals from Sierra Albarrana. The specimens from Viñals are crude and somewhat damaged loose crystals, but of jumbo size for this mineral.

Also in the Barcelona show, *Periz Minerales,* from Granada, had some **wulfenite** specimens found in May 1994 in an old, small prospect, named Minillas del Hambre, near Quentar, Granada. The specimens, consisting of limestone matrix covered by yellow, tabular crystals up to 5 mm, are not very impressive by American standards, but are nice and rank among the finest found in Spain.

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What's New in Minerals?

Denver Show 1994

by Thomas Moore

[September 13–18, 1994]

I suppose there's nothing favorable that one can say about the Denver Shows that's not also predictable: The "Main Show" at the Merchandise Mart is one of the Great Ones, and Marty Zinn reliably does a great job (with minimal administrative friction) packing all of his merchants into the Holiday Inn North, and even sometimes diverting them a bit while they're here. This year the diversion happened by the poolside on Wednesday evening, when dealer-donated specimens, books, lapidary items, hotel reservations-for-two, and other desiderata were auctioned off for the greater good of the Denver Museum of Natural History. And to help the donors enjoy the afterglow of their philanthropy there was a nice spread of dips and vegetable dipsticks, cheese cubes, nachos and salsa, etc., all graced by free beer and wine.

Again it was reliable fun to enjoy the commerce and sociability, business and busyness, that trafficked through all rooms and passageways on three floors of the Holiday Inn. If there were actually any non-Earth-materials people among the paying guests during those four days, one wonders what they made of things overheard along the hallways—"double termination" . . . "pseudomorph" . . . "ding" . . . "eurypterid" . . . "*killer.*"

Following are some descriptions of some of this year's noteworthier subjects for mineral people, both at the hotel show and at the Denver Merchandise Mart, here considered together.

Quite aside from the intrinsic merits of the **vanadinite** specimens which new dealers Dan and Susan Whitcomb had, what reviewer could neglect to mention a new dealership that calls itself *Gangues Khan Minerals* (P.O. Box 663, Manchester, MO 63011)? Almost as special is the new name of the mine at which this strike was made: the Pure Potential mine, La Paz County, Arizona—formerly the North Geronimo mine. A single, vuggy zone yielded (in May 1994) this fine batch of vanadinite; and in future collecting seasons, the Whitcombs say, more may well be uncovered. The very bright orange-red crystals are seldom larger than 5 mm, but they lavishly blanket the open seams and peek brightly into crannies. These are somewhat like the old Apache mine specimens, but the crystals are lighter-colored while being fully as lustrous as their older blood-brothers. The matrix is a dense, massive gray calcite, with no other species visibly present. About 100 pieces in all were available, in all sizes; an excellent thumbnail was going for about $20.

Ed Coogan of *Coogan Gold Company* (P.O. Box 1631, Turlock, CA 95381-1631), working with Auburn University's Dr. Bob Cook, prospected hard for hardrock **gold** in June of 1994, in the Excelsior Mountains, Mineral County, Nevada. About 125 fine thumbnails and miniatures, shown by Ed in the big room just off the lobby, spoke eloquently of their success. The gold habit is dendritic, with bright, delicate, medium-yellow tracings lying flat on or wispily rising from quartz matrixes (some overlying quartz having been etched away). A couple of hundred dollars could buy a very impressive thumbnail. Miniatures were more expensive, including (for $2900) a 4 x 5-cm matrix with energetically shining gold dendrites all over the front.

A champion pocket of **elbaite** was mined in early March of 1994 from the famous, undying Himalaya mine, in San Diego County, California. Kent Bricker of *Pala International* (912 S. Live Oak Park Rd., Fallbrook, CA 92028) showed me a magnificent 12-cm matrix piece, with four great prisms, the biggest one 8 cm long. It was pictured in vol. 25, no. 5, p. 382. Certainly this is one of the very best large matrix pieces taken from this mine in recent times. The pocket also contained about a dozen outstanding large loose crystals of the same type (i.e. "watermelon," with thin, precise, gemmy dark green top zones over translucent pink middles), and there were at least eight flats of smaller crystals.

Dave Bunk (9240 W. 49th Ave. #317, Wheat Ridge, CO 80033) was handling about 20 new specimens of **Japan-law quartz twins** from the PC mine, Jefferson County, Montana. Typically a single prominent twin rises from a matrix plate full of "normal" colorless quartz crystals; the twins tend to have shallow re-entrant angles, or none at all, and are clean and clear, although occasionally there's a fetching inner accent of included green elbaite needles. These are mostly miniatures, but one stately piece is an isolated twin 9 cm across the wingtips.

Talk about "new" . . . just one week before the show a hotel-room-filling find was made at the Hidden Treasure mine, Tooele County, Utah: pale bluish green to apple-green **smithsonite** in reniform crusts all sparkly with smithsonite microcrystal faces. These come in all sizes, and there were several hundred with Jim McGlasson of *The Collector's Stope* (7387 South Flower St., Littleton, CO 80123). Associations for these lovely green waves of smithsonite cavity linings are small grayish white calcite crystals and dark green rosasite spots; the matrix is a silicified shale, which thus is also sparkly, with its myriad quartz micropoints. A handsome 20-cm cabinet piece ran about $50.

Two dealers at the Main Show shared honors for having some recently mined and good-as-it-gets specimens of the charismatic **red beryl** from the Wah Wah Mountains, Beaver County, Utah. *Harvey Gordon Minerals* (1002 S. Wells Ave., Reno, NV 89502) had matrix pieces in greater numbers (about 25), while David Lewis of *Diversified Minerals* (1955 North Redwood Rd., Salt Lake City, UT 84116) had six larger ones (to 6 cm). The beryl crystals are vibrant, part-gemmy deep red, with textbook-sharp simple hexagonal prisms reaching 3 cm; also appealing is the way that many of them stick straight up, or nearly so, from the brown rhyolite matrix. Dave's four gemmiest specimens average around $1700.

Diversified Minerals weighed in as well with a good lot of **epidote** specimens from the Calumet mine, Salida, Chaffee County, Colorado—about 50 in all. The blocky, striated crystals can reach 2.8 cm, are well-placed and well-individualized on their massive epidote matrixes, and wink at the viewer with pistachio-green internal highlights, as epidote should. The most aesthetically successful pieces are miniatures to small cabinet-sized specimens of this description, but there are a few matrixes up to 17 cm across, with solid crusts of smaller, intergrown crystals.

For the best of Canadian exotica, one learns to go most expectantly to Rod and Helen Tyson of *Tyson's Minerals*. At the Main Show, their booth offered excellent Northern material, particularly from Mont Saint-Hilaire, Quebec, and from the Big Fish/Rapid Creek, Yukon phosphate locality. From Saint-Hilaire there were perfect, opaque white trapezohedrons of **analcime** to 3.5 cm, in beautiful matrix miniatures; a dozen bright orange-pink **serandite** miniatures with crystals of the blocky type; and "competition" thumbnails of **leifite** and **sodalite**. From the Yukon there were good **lazulite**, **wardite** and **whiteite** specimens, and also **collinsite** in pale yellow sprays of bladed 1-cm crystals, and rarities like **gormanite**, **kulanite** and (rare for here) **vivianite** in fine small specimens. Finally, the Tysons had some

Figure 1. Vanadinite from the Pure Potential mine, La Paz County, Arizona; 5.2 cm across. Gangues Khan Minerals specimen; Jeff Scovil photo.

Figure 2. Galena crystal group, 3.4 cm, from the Polaris mine, Little Cornwallis Island, Northwest Territories, Canada. Tyson Minerals specimen; Jeff Scovil collection and photo.

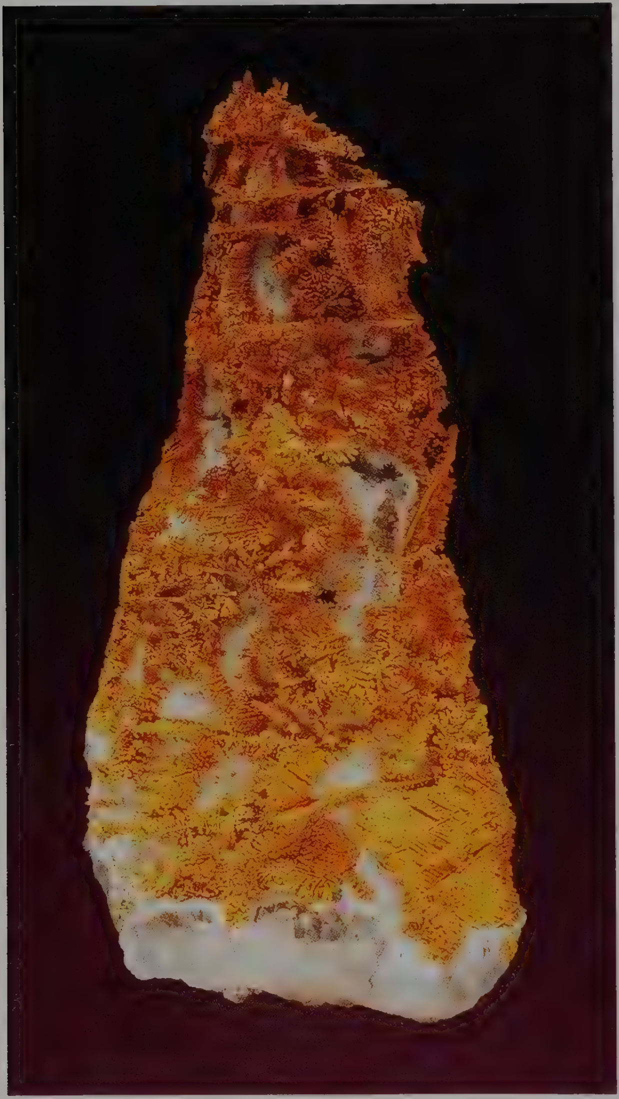

Figure 3. Vein gold on matrix, 4.4 cm, from the Excelsior Mountains, Mineral County, Nevada. Coogan specimen.

Figure 4. Beryl (emerald) crystals with calcite, to 4 cm, from the Coscuez mine, Boyacá, Colombia. Steven Smale collection; Jeff Scovil photo.

brilliantly lustrous, sharp, cubic **galena** in miniature clusters from the Polaris mine, Little Cornwallis Island, Northwest Territories.

Several dealerships, but most abundantly *Treasures of Nature* (12215 Coit Rd., Suite 161A, Dallas, TX 75251) had selections of an unusual new "moonstone" **feldspar** in good crystals (!) from Mina de la Pili, Chihuahua, Mexico. This locality was first noticed in the 1970's but it was not until a couple of years ago that, thanks to the efforts of Benny and Elva Fenn and Bill Panczner, limited quantities of specimens were brought onto the U.S. mineral market (though this was the first time I'd seen or even heard of them). A gemstone lover could have no complaint about the lovely blue sheen on the surfaces of the crystals, but mineralogists probably will be more impressed by the crystals themselves: sharp triclinic forms that can reach several centimeters across. This seems to be predominantly an alkali feldspar, being labeled "oligoclase" by most dealers, but perhaps it is a very finely layered orthoclase/albite intergrowth. More work is needed. Anyway, Beau Gordon had a large cabinet cluster with a 5.5-cm "moonstone" crystal on top, but the most winsome pieces were the thumbnails and small miniatures: translucent to transparent, gray-white (though sometimes lightly Fe-stained), with a fine lunar iridescence and good overall composition in groups with (sometimes) euhedral black augite crystals. Certainly these are a major breakthrough specimen-wise for the lowly feldspars . . . and some fine faceted "moonstone" gems up to about 8 carats have been cut.

I spent a rather awed but enjoyable half-hour with Don Bachner, Jose Vesca and their wonderful new **emeralds** in the Holiday Inn room of *Delta Bravo Gemstone* (P.O. Box 1858, Boulder, CO 80306). In July of 1994, an exciting period of work at the Coscuez-Los Gavilanes ("sparrow hawk") mine, Boyaca, Colombia, yielded superb matrix emerald specimens—including the one pictured on the cover of vol 25, no. 4. The Coscuez workings are approximately 12 nearly impassable (except by helicopter) miles from the Muzo mine, and, like Muzo, date back to Conquistador times—in fact to times earlier still, for the Spaniards found native people already digging green stones here. The crystals, like their red siblings in Utah, are all simple, sharp hexagonal prisms; some grew free in pockets and some have been etched from enclosing calcite; all of the matrix pieces I saw are clean and bright, and the gemmy transparency and deepest green color meet the highest of gemstone standards. The matrixes are black shale, white calcite and an odd black calcite (with yet-unidentified inclusions), this last in glassy crystals to 1 cm. The most amazing pieces are cabinet-sized white-and-black specimens with fine emerald prisms to 2 x 2 x 3 cm lying around on them, or sticking straight up; topnotch thumbnails and miniatures, of course, exist too. This particular strike, in an underground working, seems exhausted, but digging proceeds as always.

Huanuni, Bolivia, is now bestowing on our markets **vivianite**, **ludlamite** and vivianite/ludlamite specimens of the type and caliber seen in the cover photo on vol. 25, no. 5; but I was less prepared for the first-rate **stibnite** specimens from the Eterovich mine, Oruro. The Zweibels of *Mineral Kingdom* (20660 NW 27th Ave., Boca Raton, FL 33434) had only six pieces, but one was an almost unbelievably bright 10 x 15-cm cluster, and the others too (miniature and small cabinet-sized) were extremely high-lustered, clean, irregular aggregations of metallic black needles, innocent of any associations. Reportedly these were mined about 10 years ago.

Much more modest, yet more surprising, were the thumbnail specimens of **bismuthinite** from the Garbiel vein of the Farellon Viejo mine, Tafna, Bolivia. Brian Bond collected these in August of 1994, and a couple of dozen were being offered by Dave Shannon. The specimens are dense packings of thin, splintery crystals to 1 cm on massive bismuthinite, and, granted, are not much to look at—but where and when else save Cornwall, England, in ancient days has the species been seen in such good metallic-gray acicular forms at all? And where else can you get such a thing, as you could here, for around $5?

Scattered sparsely about the show were some excellent new single crystals and small crystal groups of **euclase** from Equador, Rio Grande do Norte, Brazil. Similar specimens were produced 22 years ago, and it's nice to see them back. They are satisfyingly thick, well terminated (some doubly so) prisms, transparent to translucent and colorless but with a distinctive blue zone or stripe down the middle of each crystal: pretty indeed. Thumbnails are the most common, but clusters up to 6 cm across, as well as matrix pieces with euclase perched on milky quartz faces, also occur. Over in the Travelodge I found the man who'd brought them to the light of day: longtime Brazilian-gem prospector Jerry Call (P.O. Box 296, Little Switzerland, NC 28749), who, unlike the strictly-specimen dealers, was selling these euclase eudehrons by the gram; a first-rate thumbnail ran around $300.

The Djebel Hamimat antimony mine near Constantine, Algeria, has been closed for 70 years, but this didn't stop Jochen Hintze of the *Marianne Jentsch Company* (Im Busche 1, 4923 Extertal-Lassbruch, Germany) from going there to see what **senarmontite** he could see. After two trips, three and two years ago, he stopped going, not because the locality is worked out but because it is "politically inaccessible" i.e. strangers tend to get murdered by armed bands of undemocrats. However, the sharp, translucent, gray-white senarmontite octahedrons may be dug from their enclosing clay as loose single crystals to 1.5 cm and as tightly packed groups on massive senarmontite; the gray color comes, by the way, from included stibnite (as pure Sb_2O_3 is white). Of the 30 or so specimens Jochen had at the Main Show, about half are smallish thumbnail loose crystals at around $10 each; the rest are groups reaching 10 x 10 cm.

Back in the *Pala International* room were the first mineral specimens of any kind I'd ever seen from the Saharan country of Mali. We're talking about very sharp, sometimes very large, loose dodecahedrons of "garnet"—probably **andradite**—ranging in size from thumbnails up to a 12-cm brute. The interior color is an almost-gemmy medium green, but the surfaces are a dull mottled green and brown, more attractive however than they may sound. According to Bill Dameron, the American Ambassador to Mali, the occurrence is in western Mali in the Nioro region, 15–20 km south of Sandaré near a small village called Diakon on the Mauritanian border. Because of the bright green color of the crystal interiors a brief "emerald rush" to the remote area resulted. Traders are now bringing out sacks of loose 1 to 8-cm garnets, most of which get cobbed down to isolate the near-gemmy green cores. From the same region have come nicely formed **epidote** crystals to 3 cm, some deep black garnets to 4 cm (probably also andradite), well-formed dark green **vesuvianite** crystals to 3 cm, and gemmy, doubly terminated **quartz** crystals. As the market develops we may see more of these; watch all passing camels.

Visiting a room occupied by François Lietard's *"Minerive"* (Au Bourg, 42800 Tartaras, France) is always a gem-studded, heady, breathless (what with those Himalayan altitudes) show experience. This time the visitor saw what was probably the star discovery at this show (see under peridot later), but also and meanwhile saw, from Morogoro, Tanzania, some outstanding loose gem **scapolite** crystals, about 10 of them, thumbnail-sized. One has seen these around for some years, but François' new ones are gemmy all the way through, and of a lovely winey orange color, and with very good pyramidal terminations (albeit still without matrix). Average price for a 2.5-cm crystal: $125. Oh yes, and François had the authoritative mumble on the name of the locality: the *Mpwampwe mine.* (Got that?)

Still deeper in Africa, the Mt. Malosa, Zomba, Malawi locality (see vol. 25, no. 1) continues to turn out the world's best **aegirine** specimens, in spiky sprays and occasional giant loose prisms and parallel groups, brilliant black, with raggedy compound terminations. Many specimens also feature some highly respectable blocky gray-white **orthoclase** crystals, and there are microcrystals of rare species too. Mining rights belong now to Rudi Cullmann of *Die Rohsteinquelle*

Figure 5. Crocoite crystals on quartz matrix, 4 cm, from Berezov (or perhaps Beriozovsky), Ural Mountains, Russia. KARP specimen.

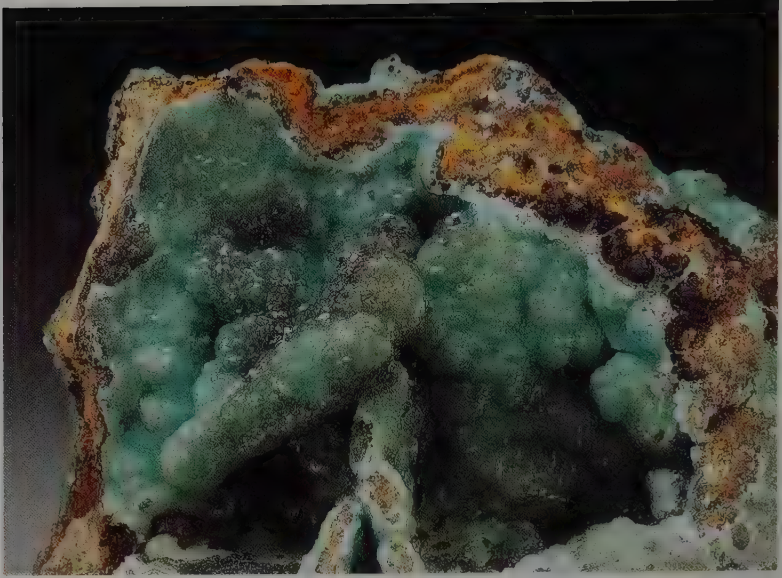

Figure 6. (above) Smithsonian, 6.1 cm, from the Hidden Treasure mine, Tooele County, Utah. Collector's Stope specimen; Jeff Scovil photo.

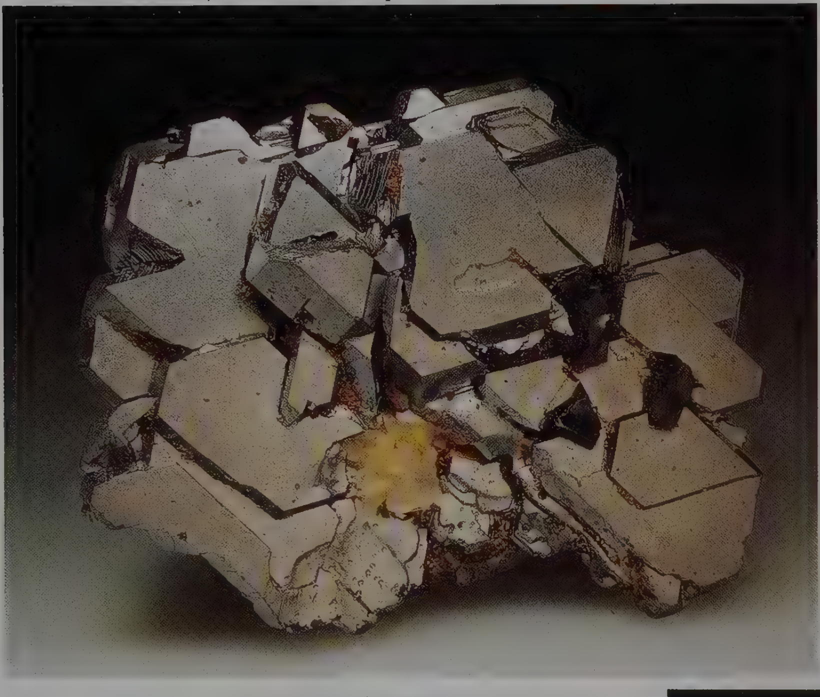

Figure 7. Galena plate of spinel-law twins, 14 cm across, from the Nikolai mine, Dalnegorsk, Primorskiy Krai, Russia. Heliodor Minerals specimen; Jeff Scovil photo.

Figure 8. Golden yellow pyromorphite group, 10.3 cm, from the Bunker Hill mine, Kellogg, Idaho. Wayne Thompson specimen; Jeff Scovil photo.

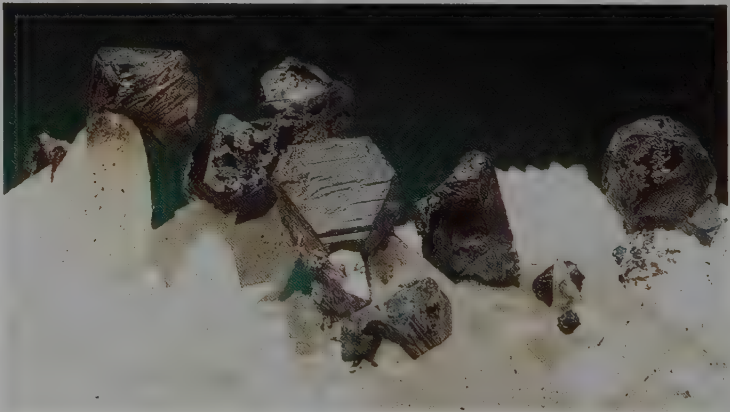

Figure 9. Bornite crystals on calcite, Mine 57, 180-meter level, Dzezkazghan, Kazakhstan. The large crystal is 8 mm. Heliodor Minerals specimen; Jeff Scovil photos.

Figure 10. Olivine crystals to 4.9 cm showing extreme "chisel" habit, from northern Pakistan. François Lietard specimen; Jeff Scovil photo.

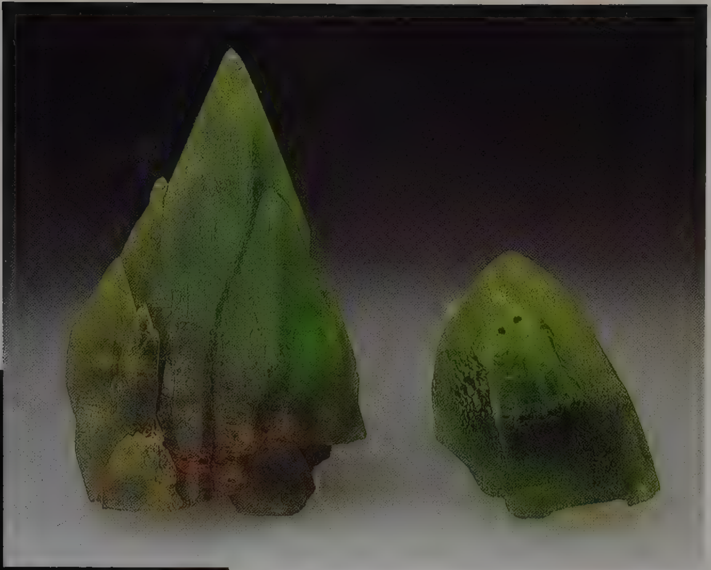

Figure 11. Wulfenite and mimetite group, 9 cm across, from the San Francisco mine, Sonora, Mexico. Wayne Thompson specimen; Jeff Scovil photo.

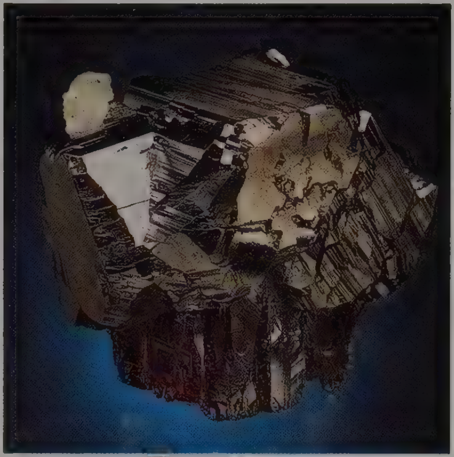

Figure 12. Stephanite and pyrargyrite, 1.8 cm, from the San Luis mine, Fresnillo, Zacatecas, Mexico. Irish Rovers specimen; Jeff Scovil photo.

Figure 13. White bertrandite crystals on smoky quartz, 3.6 cm, from Mt. Antero, Chaffee County, Colorado. Dave Bunk specimen; Jeff Scovil photo.

Figure 14. Calcite with pyrite, 18.8 cm, from the Brushy Creek mine, Reynolds County, Missouri. Mike New specimen; Jeff Scovil photo.

(Diamant- und Edelsteinbörse 8.14–8.15, Mainzer Str. 34, 55743 Idar-Oberstein, Germany): he had the only significant Malawi aegirine stock in Denver, in all sizes up to a 34-cm columnar group ($3200).

Wright's Rock Shop (3612 Albert Pike, Hot Springs National Park, AR 71913) was fairly well-stocked with the new specimens of **barite** on malachite from the Shagulowe mine, Katanga, Zaire—an old copper mine recently reopened to dig for specimens only. The yellowish gray barite comes in parallel groups of crystals, narrower side faces lying together; they are transparent except for attractive zones of foggy greenness from malachite (?) inclusions. However, the overall greenish-glowing aspect of these pretty pieces is owing chiefly to the shiny, bloated-looking reniform malachite on which the barite has the good taste to grow. Specimens around 10 cm across are most commonly seen, at Wright's and elsewhere.

It must be admitted that the great flood of surprising new things from the former Soviet Union is ebbing (pausing a bit, only temporarily, we hope), but certainly there are still plenty of beautiful minerals to fill the usual fat-as-Asia space in this report. Let's get on our camels and lope off, first, to Kazakhstan. The Dzhezkazgan copper mine continues strongly productive of amazing crystallized **bornite**: typically, very sharp, iridescent black crystals to 3 cm showing multiple isometric forms, sitting up either alone or as small branching groups on white quartz or barite matrixes. The Van Scriver-Pljaskov dealership (new name, *"Heliodor"*; continuing best address, P.O. Box 10, 19900 Praha-9, Czech Republic) again had a handful of bornite specimens of this type. Also from Dzhezkazgan, and lurking in a big bureau drawer at "Heliodor," came a monstrous 15 x 30-cm flat matrix plate entirely covered with flat-lying bundles of silky metallic black acicular **betekhtinite** crystals, the whole topped with a single 5-cm white calcite crystal. This, surely the world's best betekhtinite specimen, has already gone to a major museum.

Recently, and more than ever just now, there has been a plenitude of handsome **calcite** in translucent to transparent pale orange blocky twinned rhombohedrons, sometimes on matrix but usually not, from the Sokolovskaya mine, near Rudniy (village), Kusteni Oblast, North Kazakhstan. These "Rudniys" are quite beautiful and like no other calcites; in the fall of 1993 some 5,000 new specimens were dug, all of medium-miniature to large-cabinet size. At this show the biggest hoard belonged to the Czech dealers' association called *KARP* (P.O. Box 54, 272 80 Kladno, Czech Republic).

In the KARP room also could be found what was arguably the show's best small buy: almost any piece out of three flats of **crocoite** from the old Berezov area, Urals, Russia (though some say the real locality may be Beriozovsky near Ekaterinburg). They are modest enough, to be sure, all thumbnails and miniatures, but the crocoite crystals are not mere cuneiform traces on matrix, as in most of the old "classic" pieces; rather, they're fairly thick 5-mm prisms, very bright orange, on brownish white matrix, making for very attractive purchases in the $12–$35 range. KARP, finally, was selling, besides the usual swarms of loose yellow **heliodor** crystals from Volodarsk, Ukraine, a couple of dozen loose gemmy **blue beryl** crystals from the same locality, and likewise deeply etched; these blue crystals result from heat-treatment of the deep yellow-green crystals.

Back in the Van Scriver-Pljaskov *"Heliodor"* room, some very rare species from the Kola Peninsula of Russia were on hand, two of these in truly aesthetic representations. Particularly appealing were two thumbnails, each showing one very sharp tetragonal tabular (wulfenite-style) crystal of **fersmite** nicely perched on massive gray-green nepheline; the (precise!) locality is Mt. Eveslogcharr, Vuannemyok River Valley, Central Khibiny Massif, 50 km ENE of Apatity, Murmansk Oblast, Russia. And from Mt. Nyorkpakhy, Khibiny Massif, also in the Kola Peninsula, comes the best **eudialyte** from anywhere I've yet seen: a sharp, lustrous, 2-cm wide, part-gemmy raspberry-red crystal on a 3 x 4 cm black aegirine matrix.

The Nikolai mine at Dalnegorsk, Primorskiy Kraj, Russia, continued to prove itself, at dozens of dealerships throughout this show, as one of the world's very best localities for, among others, **galena**, **sphalerite**, **pyrrhotite**, **ilvaite**, **fluorite** and **calcite**. I saw at *Heliodor,* too, one 25 x 25-cm **chalcopyrite** specimen with beautifully brassy, slightly pitted but sharp, intergrown 4-cm crystals covering most of the front of a massive sulfide matrix.

In this connection, some up-and-coming sources for fine Russian minerals—especially those from Dalnegorsk—should be mentioned. Young Danny Trinchillo of *De Trin Minerals* (145-62 7th Ave., Whitestone, NY 11357) goes to Russia a lot and comes back with abundant topnotch examples of the already classic ice-clear Dalnegorsk **fluorite** cubes and of the beautiful, colorless, transparent **calcite** dogtooth specimens from the same place, to mention just a couple of highlights of this glittering room. And *Min-Geo* (Pardubicka 734, 500 02 Hradec Kralove 4, Czech Republic) excelled as well in Dalnegorsk things, and had a new one on me: a 15 x 18-cm group of dark green **hedenbergite** crystals, with flattish individuals to 3.5 cm standing up edgewise from a solid green mass, with small garnet crystals—is there a Seriphos, Greece-type skarn at Dalnegorsk *too*?

At the Main Show stand of Gilbert Gauthier (7 avenue Alexandre III, 78600 Maisons-Laffitte, Belgium) was a small upright case full of **diamonds** from Russia, Zaire, South Africa and Australia. All crystals are of very good specimen grade, but the Russian ones, from the Aikhal mine, Yakutia, impressed me most: they are simple sharp octahedrons all about 1 cm on edge. Because they are brownish to grayish with included matter they cost just $60/carat—and go up to 9.65 carats.

Long ago I wrote from the Munich Show what I believe was the first notice in this publication of the pale brown, gemmy, striated prisms of **diaspore** from "the Aydin-Mugla region" of western Turkey. These have remained very scarce, and in crystals showing good terminal faces exceedingly so, but recent rumors of V-twinned specimens of some distinction were proven true at the Main Show by Victor Yount (Rt. 3, Box 250, Warrenton, VA 22186). These are simply loose thumbnail-sized matrixless V's, the two crystals at about a 45° angle. Terminations are raggedy/rudimentary, but prism faces are clean and reasonably bright; prices were $150–$200. Out in Vic's front display case, though, was the one you may have been waiting for: a miniature with 2.5 cm-thick wings measuring 5 and 3 cm long, medium brown, and almost 100% gemmy inside.

Don Olson (P.O. Box 858, Bonsall, CA 92003) had a few large specimens each of two playful cast-overgrowth behaviors of **prehnite**, both from India. From Malad, Maharashtra, there come huge jackstraw groups of very pale green prehnite casts after laumontite prisms, with transparent white apophyllite pseudocubes for decoration: these specimens, to be sure, are familiar, but don't get jaded, as some of them can be very dramatic (here there was one 15 x 22-cm girderwork). Don's other prehnite-replacement type, however, was new to me: from Ahmadnagan, Maharashtra, great shining palest green crystal plates (to 35 cm) showing solid, thick prehnite coatings over hexagonal-tabular calcite individuals averaging 3 cm across. Some of these may be complete pseudomorphs, but broken edges on others do show a remnant white calcite core.

Dudley Blauwet of *Mountain Minerals International* (P.O. Box 302, Louisville, CO 80027-0302) came into some good **vesuvianite** in Pakistan in August 1994: the locality so far is simply "Nuristan," somewhere along the Afghan border. The spread consisted of about 30 specimens of all sizes, with stout prismatic vesuvianite crystals of the Bellecombe, Italy type, highly lustrous, to about 2 cm. The nicest thing is the color: a very rich reddish brown with rootbeerish internal highlights. Best as a whole are the small cabinet specimens, whose earthy brown matrixes come alive with scatterings of the bright crystals, which often show flat basal terminations on both ends as they lie lightly embedded.

Now for that François Lietard coup/surprise that I hinted about some while back. In my Tucson '94 report I noted a few specimens, in François' care, of rough-faced but inwardly gemmy green **forsterite** peridot crystals from "China." Over the summer, a new find has appeared from "near Chilas, Province of Kohistan, Pakistan"; and the good news is that they have also grown dramatically larger and better. Still richly gemmy in typical peridot-green, the best individuals are *sharp*, thick 4.5-cm single crystals with chisel-shaped terminations; also there are some thumbnails which, oddly, are much rougher than their very big brothers. Active, reportedly, for about 5 years now, this is obviously a locality to watch closely—as soon as we figure out exactly where it is.

Among the photos shown here you'll see some things I've noted earlier, and a few items that photographer Jeff Scovil made note of but I did not: golden yellow **pyromorphite** from the Bunker Hill mine in Idaho [Ed. note: a recent batch of green Bunker Hill pyromorphite rivals anything ever found there!], Kazakhstan **bornite,** San Francisco mine **wulfenite,** Fresnillo **stephanite** and **pyrargyrite,** Mt. Antero **bertrandite,** and one of Mike New's big lot of Brushy Creek **calcites.**

As a capper to this report—out of my rough geographical sequence but so what—I will offer a sketchy update on Bryan Lees' fabled **rhodochrosite**-mining project at the Sweet Home mine, Alma, Colorado. The last *great* pocket to date, the "Good Luck," was hit in September 1992. Since then Bryan had been getting increasingly worried about finances, but (more due to very hard work than to any good luck) two more quite substantial pockets were recently entered. One, called the "Tight Pocket," breached in early August 1994, yielded all sizes of needle-quartz-covered plates with pale pink, mostly opaque, frosty (silica-coated) rhodochrosite rhombs to 3 cm. At the end of August came the second and probably still better strike, the "Corner Pocket," which is not even yet fully cleaned out; but its specimens, with deep red, often gemmy rhombs over quartz (there are no other associated minerals here) were among the big stars of this show. So it seems after all that another collecting season at the Sweet Home this coming summer is in the cards.

Regrettably I lack space and time to dilate on the Main Show exhibits, except to observe that pyrite was the theme mineral—so you can just imagine what great shining beasts were everywhere to be seen. But a single Sweet Home rhodochrosite specimen, all by itself in a case put in by Bryan Lees, *demanded* notice. One of the "Good Luck" pocket pieces of late '92, it has been held out of public view until now, and is already sold to a Japanese collector. It is, believe it or not, a credible rival to the renowned "Alma King" and "Rose" specimens for best-of-species, best-rock-in-the-world, etc., etc. honors . . . about 35 cm long and about 18 cm high and deep, it consists of a matrix of solid bright black tetrahedrite with, along the top, lustrous tetrahedrite crystals to 1.5 cm. Covering almost all of the front face is a pocket lining of interlocking (but not too tightly so), richest rose-red, gemmy/transparent rhodochrosite rhombs to 4 cm on edge. Gasping crowds and clattering camera shutters testified to the unbelievable impact of this piece of utterly great Good Luck.

Wendell Wilson's 1994 Denver Show poster (for Marty Zinn's show) featured also a burst of rhodochrosite red. It's a wittily beautiful thing, with a colored drawing of an imaginary super-pocket at the Sweet Home, the red rhombs actually being *larger* than the busy miners who stand next to them on the ground or climb over them, like mountaineers, up the vug. It was the talk of the show among many appreciative rhodochrosite fanciers.

It is now 2:00 A.M. as I finish this report in my motel room, and fatigue pseudomorphoses my form and being entirely; so, so long, and a very good night, from Denver.

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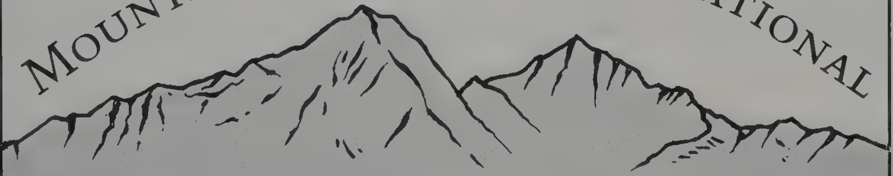

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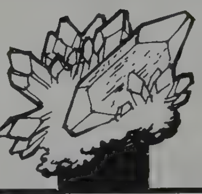

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Letters

POSTAGE STAMP BROOKITE

On page 446 of vol. 23, no. 5 (1992), you posed a question regarding the provenance of the brookite crystals on a stamp from Monaco. Information provided to me by Pierre Gatel, an internationally known collector, and author of the book *Les Micromontures (Micromounts)* (1983), indicates that these crystals came from the area of La Tinée, Parc national du Mercantour, France; that they were collected by Mr. Gatel, and that they were illustrated by Mme. Odette Baillais as part of a series of stamps showing the flora, fauna, and minerals of the area.

The National Park of Mercantour is a narrow, winding area of 70,000 hectares (270 square miles) stretching along the Maritime Alps, close to the border with Italy, north of the city of Nice. It is bordered to the west by the valley of the river Var, and stops just short of highway N204 in the east. The park itself straddles mountaintops, but can be seen best by beginning at Saint Martin-Vesubie, 40 km due north of Nice, then following highways D2565 and D2205 through Saint Sauveur sur Tinée and the Valabres Gorges, northwest along the valley of the river Tinée to Saint Etienne-de-Tinée.

There are several old mines and mineral localities in and near the park. The specimens illustrated were found at a small locality just outside the north border of the park on the left bank of the Guerche, a small river which enters the valley of the Tinée at the village of Isola (visit the Romanesque tower), roughly midway between Saint Etienne and Saint Sauveur. The Guerche flows south from the Italian border towards Isola, following the Chastillon valley for a short period, then cutting its own valley until it reaches the Tinée. The locality was rediscovered serendipitously, after the artist came across a specimen of anatase in a micromount collection at the School of Mines in Paris. Mme. Baillais proposed that minerals from the park region be obtained for inclusion in the stamp series, whereupon some members of l'Association Française de Micromineralogie (A.F.M.) made a prospecting trip to the locality and obtained the specimens shown. The interesting feature of the occurrence is that all three TiO_2 polymorphs, brookite, anatase and rutile, can be found together on the same specimen.

The minerals associated with the brookite are those of the classic Alpine cleft occurrences: albite, chlorite and quartz. All are illustrated in the series of six stamps which Mme. Baillais produced for the set. Descriptions of the stamps and of the locality were published as an article in a supplement to the bulletin *La Philatélie Thématique* (No. 38, 1991) done by the Geology and Prehistory

Group of l'Association Française de Philatélie Thématique (L'A.F.P.T.). The article, written by Mr. Gatel, outlines the history of the discovery, and gives a brief description of the minerals illustrated. For example, on one piece of matrix, 10 x 15 mm in size, there is an elliptical fissure about 2 x 3 mm which contains a brookite of square cross-section, 0.4 mm on a side, a group of rutile crystals of 0.3 to 0.8 mm, several albite crystals from 0.1 to 0.6 mm, a group of twinned anatase crystals 0.5 x 0.2 mm, and a multitude of chlorite plates ≤0.1 mm. The quartz crystals, taken from another piece, are veritable giants, at 2–3 mm.

The brookite crystals illustrated are described as flattened prisms, to the point of being lamellar, with parallel striations. Often translucent, the crystals are particularly well done in the drawing, with their yellow-brown color, swarming with darker zones verging on black. Most work on the minerals was performed under the microscope at 80x. Photographs of the specimens were taken by R. Vernet. As Pierre Gatel writes in his article: "The talent and the minute attention to detail by Madame Baillais did the rest."

The specimens used for the stamps remain in the collection of Pierre Gatel in Paris.

I hope that this clears up any confusion with the Prenteg material. The "Brookite Mystery" is a mystery no longer!

Quintin Wight
Ottawa, Ontario

EARTHQUAKES & MINERALS

Just received my copy of the July/August issue of the *Mineralogical Record* (vol. 25, no. 4), and I can't help but comment on Tony Kampf's fine article. I enjoyed reading the first article ever to combine my vocation and avocation. It is clear from the negligible losses during the Northridge earthquake at the Natural History Museum of Los Angeles County that Tony has developed effective procedures to deal with the shaking hazards. However, I must take some minor exceptions with his "earthquake statistics."

Regarding the statement "the magnitude of an earthquake increases about 30-fold with each whole number increment on the Richter Scale": Back in the early 1930's Charles Richter was about to issue Caltech's first listing of California earthquakes. In an attempt to quantify the differences in **size** of the earthquakes in the catalog, Richter developed the concept of *earthquake magnitude*. Richter chose to pattern earthquake magnitude after scales used in astronomy to describe the brightness of stars. Earthquake magnitude is proportional to the *logarithm* (to the base 10) of the amplitude of ground shaking. Thus, one unit increase in magnitude results in a **10-fold** increase in ground shaking at a particular frequency. It is true that the *energy* in shaking increases by a factor of about 30 for a unit magnitude increase—however, energy is not the most important factor in the damaging motions of earthquakes.

Tony also noted the irregular damage caused by the Northridge earthquake. We are just beginning to understand why this particular earthquake was so damaging (30 billion dollars loss). There is a consensus that this was *NOT* a very unusual earthquake—just one that occurred in the wrong place. I suspect that a magnitude 8 earthquake on the San Andreas (75 km north of the Natural History Museum) would not cause extensive damage at the Natural History Museum, but the next Northridge type event, if located closer to downtown Los Angeles, could. Seismologists are struggling to understand the decade-long increase in Southern California seismicity, and the probability for events similar to Northridge in the future. I strongly urge private collectors in California to protect their collections—in particular, I recommend the extremely fragile specimens, such as a San Francisco mine wulfenite, not be left indefinitely on display shelves. Collectors need to balance the desire to display their spectacular specimens with the need to preserve them for future generations. Putting away a nice specimen in a protective box in the bottom of a closet is a pain, but it really is the most effect earthquake protection.

Tony's article outlines some very effective measures to reduce risk from ground shaking. These precautions should be taken by *all* museums. The measures are not particularly expensive; furthermore, earthquake damage has been experienced in *33* states of the Union. Although damaging earthquakes occur relatively infrequently, why take chances?

Terry C. Wallace
Professor of Geosciences
Tucson, Arizona

BURMESE VANADIAN UVITE

Regarding the letter from Mark Feinglos (vol. 25, no. 4) concerning the vanadium-bearing tourmalines from Burma: Last fall I received several crystals of bright green Burmese "chrome-uvite" from Bill Larson of Pala International. Analysis by SEM with EDS confirms that these tourmalines are vanadium-bearing, and that no chromium is present within the sensitivity of the analysis. Minor amounts of iron, titanium, potassium and chlorine were detected as well, giving credence to the notion that tourmaline chemistry resembles "a medieval doctor's prescription more than the making of a respectable mineral." (The origin of that quote escapes me, otherwise I would give proper credit.)

While EDS is only a semi-quantative analysis, it appears that calcium is present greatly in excess of sodium, thus the proper species should be uvite, and not dravite. Though I have not encountered even a hint of matrix on any of the crystals examined I would suspect that they come from a marble or similar calcium-rich metamorphic rock. If anyone has matrix specimens of this material I would be interested knowing it's composition.

Jesse Fisher
San Francisco, CA

The quote is from John Ruskin's The Ethics of Dust *(1891). Ed.*

FRENCH CREEK

Regarding the French Creek mines article (vol. 25, no. 2), readers might be interested in looking up the seven-page report of an early field trip there by several persons, including Sam Gordon. It appeared in the very first volume of *American Mineralogist* (1916), on pages 93–99, and was written in amusing, conversational style by Harry Trudell.

Dana M. Morong
Madbury, NH

CUSTOMER PROFILES

Despite the dangers of generalization, I frequently find myself musing about the characteristics of customers—and especially non-customers—as I sit around show booths or motel rooms. For example, I seldom sell a mineral to someone with spouse in tow. It seems neither half of a marriage wants the other to know how frivolous they are when it comes to expanding their collection—until later. We might add those with lapidary dealer badges, I suppose, but that is too easy a call. One of my Brazilian dealer friends gave me a list of all sorts of people who seldom buy anything, concluding with "anyone with a toothpick will never buy a mineral." On upper floors, I see folks doggedly going about the business of seeing everything with glazed eyes, tired feet and either hunger or thirst (or both) which prevent them from seeing much. They rapidly scan a sea of minerals hoping that something wonderful will leap into focus. Alas for me, it seldom does. However, it is the incessant chatterer I choose to single out here. I have recently had two experiences which started with an apparent potential customer starting up a conversation which they then continued into further unrelated subjects without pause. I confess that in each case my switch turned off and, as the individual moved down the table, I avoided further conversation, and indeed eye contact, for fear of unleashing another torrent. In each case I was relieved of expensive specimens without the need for writing sales tickets or accepting payment!

Carter Rich
Aldie, VA

VIVIANITE/LUDLAMITE

I draw your attention to the fact that the (Sept.–Oct.) front cover, vivianite-ludlamite, is almost certainly from *Huanuni* rather than Morococala. I have seen several similar specimens from Huanuni and none from Morococala. Also, the long prismatic vivianite is typical of Huanuni, and quite different from the blocky habit at Morococala.

Alfredo Petrov
Cochabamba, Bolivia

Right you are. Jeff Scovil, the photographer, admits to a glitch in photo recordkeeping, and did not discover the error until we had already gone to press. Ed.

LAURIUM

I was very pleased to see the article (in vol. 25, no. 4) on "New mineral occurrences from the Laurium mines, Greece," by Katerinopoulos and Zissimopoulou. Considering that information in this article was actually extracted by the authors from the recent book, *Minerals of the Lavrion mines* (1994), published by the Greek Association of Mineral and Fossil Collectors, I thought perhaps your readers might be interested in learning they can order the complete book from:

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Fossil Collectors
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Maria Renieri-Yannopoulos
Athens, Greece

COPPER ROSES

I read with interest the recent article (vol. 25, no. 3) on the Rose mine in Grant County, New Mexico, and congratulate Mr. Hanson on an excellent review of the site's colorful history. Readers may be interested to know that this study was at one time a collaborative effort, and that some of the initial results, as reported, are contradicted by subsequent data. Revised and expanded data are presented with alternative interpretations in my article which is currently in press and scheduled for publication in the November issue of the *Annals of the Carnegie Museum*. Reprints may be purchased from: The Office of Scientific Publications, The Carnegie Museum of Natural History, 4400 Forbes Avenue, Pittsburgh, Pennsylvania 15213.

Marc L. Wilson
Head, Section of Minerals
Carnegie Museum of Natural History

POSTAL PROBLEMS

On the occasion of my first anniversary as a subscriber to the *Mineralogical Record*, I would like to pass on a few observations about your magazine:

(1) It is by far the best magazine for the mineral collector, regardless of specialty. The articles are highly interesting, and cover a wide variety of topics supported by brilliant photos and a marvelous layout.

(2) I am particularly pleased that all of your papers are reviewed in advance by expert mineralogists, helping to assure the constant high level of the publication.

(3) Unfortunately a problem exists with regard to delivery of copies to your Austrian and Australian subscribers. Some officials at the post office apparently cannot distinguish between the two country names; one of my issues arrived very late, postmarked from Sydney where it had gone first. Other Austrian subscribers have had the same problem. Please address all future Austrian copies to "AUSTRIA/EUROPE." That should solve the problem.

(4) The second sore point is that a comprehensive index is not available to the complete run of the *Mineralogical Record*.

All in all I must say that I regret not having started my subscription years ago.

Branko Rieck
Vienna, Austria/Europe

We have corrected all Austrian mailing labels as you suggest. And a comprehensive 25-year index will be published very shortly. Ed.

FIRST CHOICE MINERALS

I don't know whose idea that ad was [*First Choice Minerals*, vol. 25, no. 4, p. 280], but it sure was fine! Good to see a bit of humor here and there; I've always thought that collecting and studying were supposed to be fun as well as serious. Keep up the good work!

Michael Tarachow
Minneapolis, MN

Okay, who did it? At first I was going to accuse Rock Currier—Maybe I still will.

Dona Leicht
Laguna Beach, CA

Rock didn't do it. But you can go ahead and accuse him anyway, just to keep him alert. Ed.

EHRMANN

I just finished reading the article on Martin Ehrmann in vol. 25, no. 5, and I wanted to congratulate you on running this feature. It has instantly made this one of my top ten favorite issues the *Mineralogical Record*. It's an incredible story with great writing, research and human insight. Prior to reading it I had only known this man as a name on a mineral label; now he is a person. You've brought his life to all of us who could never have known him.

Minerals are wonderful but often times the people behind them, like Martin Ehrmann, give them a history and a life. Specimens without a history are much like paintings without a signature. Beautiful to look at but have a bit less personality. Stories like this give a human dimension to our love of minerals. I congratulate the authors, Bill and Carol Smith, on an important article well done. I look forward to their next biography.

Stuart Wilensky
Wurtsboro, NY

I found the article concerning Martin Ehrmann very interesting and entertaining. With regard to specimens that he handled, however, I must point out that the aquamarine shown in Figure 10 is in the National Museum of Natural History (#115228), and was obtained through A. G. Parser in 1961. Ehrmann's only involvement in the transaction was as an appraiser for Parser. Also, the specimen measures 22 cm, not 14 cm. Perhaps the caption refers to a similar crystal in the Los Angeles County Museum?

Regarding the speculation that Harvard failed to acquire any of the "Famous Twenty-five" in 1967–1968 because Clifford Frondel was "swamped by the efforts required to complete the third volume of *Dana's System*" and preoccupied by his duties as a Principal Investigator of the Apollo moon rocks: Volume three had already been published five years earlier, in 1962, and the first moon rocks did not reach earth until July 1969. Something else had to be happening that possibly only Dr. Frondell now knows.

Paul W. Pohwat
National Museum of Natural History
Washington, D.C.

Mr. Pohwat provides a cogent analysis of our "speculation" on why Harvard got none of the "Famous Twenty-five." We hope that his remarks will spur others to provide more plausible reasons for this curious abstention.

Bill and Carol Smith

Regarding the aquamarine, curator Tony Kampf at the Los Angeles County Museum of Natural History (who supplied the photo) double-checked, at my request, by holding the published photo up next to the actual specimen on public display. They match precisely, right down to the fractures and surface irregularities. The specimen pictured is indeed the correct one, and not the Smithsonian specimen. The two crystals must have come from the same pocket, to look so similar. In fact, I once photographed Keith Proctor's aquamarine (13.8 cm) from the Teofilo Otoni area, and it too is terminated in identical fashion. Ed.

It was a great pleasure to read the recent article on Martin Ehrmann. I wish to make one correction to the Smith's well-researched and written article. The picture on page 367 taken at the Stewart mine in Pala, California, was taken in 1969, not 1971 as indicated. More than likely it was taken some time during the months of August to October, at a time when gem-quality pink tourmaline was literally pouring from the mine.

(continued on p. 159)

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Letters

continued from p. 157

I remember well the moment the picture was taken. Though the viewer can't tell, Ed Swoboda's face was masked in pain; he had just come from the dentist's office, but as usual with his intense interest in minerals and people, he put suffering aside to entertain Martin Ehrmann and Dr. Strunz at the Stewart mine that day, where I was acting as mine foreman and operator. More than likely the photographer was Mr. Carl Larson of Fallbrook, now deceased.

In the picture we were leaning against a khaki-green Volkswagen Variant squareback. I can recall making the long drive in that car many times from Pala to Swoboda's jewelry manufacturing company office at 672 North LaPeer Drive in West Hollywood, hauling sacks and sacks of gem-quality and carving-grade pink tourmaline, along with boxes and boxes of fine gem-specimen tourmaline crystals, the best of which are now in museums. Incidentally at that same famous address Martin Ehrmann occupied the upstairs offices where I was one of the fortunate ones who got to know him in those years. I can say Martin Ehrmann had a tremendous influence on my life (as he did with many others), toward eventually going into the international mineral specimen and gem business, which for me continues up to this very day here in Chile.

That Charlie Key had referred to himself as "the new Martin Ehrmann" is true. I have heard this before. Charlie simply recognized that Martin Ehrmann was the very best, and wanted to emulate him. What is wrong with that? In fact, in those years, we all, repeat, *we all* wanted to imitate Martin Ehrmann. He was a benchmark for all of us, not only as a successful gem and mineral dealer, but as a person as well.

And I want to congratulate the *Mineralogical Record* on "coming of age": You finally used the word "shit" in a recent article (vol. 25, no. 4, p. 309)! It cracked me up, the story by Larry Conklin about the insurance underwriter's low opinion of the quality of his specimens. (The word was indeed essential to the story.) In fact, I knew Larry in those early years, having met him in 1960 at his first New York office on 47th Street when I was a ripe 14 years old. He had anything but excrement in his office! I remember lots of pink crystallized smithsonite, a fine North Carolina emerald, alexandrite crystals in matrix from Russia, and many more. I remember in particular a richly colored, apple-green pyromorphite from Broken Hill, Zambia, which I could have bought for only $300, but back then I didn't have any money. The famous Spanish collector Joaquin Folch-Girona ended up buying it.

Terry Szenics
Santiago, Chile

VERZEIHUNG!

We must apologize to Matthias Rheinländer of *Mikon Mineralien Kontor,* German supplier of fine minerals, gemstones, rare species, micromounts and microscopes. Our November–December issue carried his half-page ad (p. 246), which we had typeset and layed out according to the wording he supplied. The problem is, our graphics artist selected a nice little design from a book of artists' "clip art" and used it to dress up the ad. Unfortunately the design is an "iron cross," which apparently still symbolizes fascism and anti-semitism in Germany! We just want to assure readers that Mr. Rheinländer is not a fascist, and had no knowledge that the design would appear in his ad. Ed.

MINERALS OF SOUTH AFRICA

In the ad announcing this new publication (vol. 26, no. 1, p. 74), the price of the special leather-bound limited edition was incorrectly given as $200; the correct amount is $300. We regret any inconvenience caused by this error. Ed.

ERRATUM

In the article on the Orford nickel mine (vol. 25, no. 5, p. 343), the millerite crystal in Figure 32 is 1.2 *centimeters* long, not "1.2 mm."

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Photo by Earl Lewis,
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Dr. Wendell Wilson in his video review in *M.R.*, Nov/Dec 1992, p. 504, says "The collector of aesthetic mineral specimens will find much to savor in Keith Proctor's video catalog of his collection. . . . It really delivers in terms of extraordinary mineral images and specimen information and will stand for many years to come as a historically valuable documentation of one of the great private collections of our time."

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