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COVER: EPIDOTE from Knappenwand, Untersulzbachtal, Austria. (See the article in this issue, p. 167.) The specimen measures 5 by 7 cm. William Larson collection; photo © Harold and Erica Van Pelt.

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Mineral Specimen Trimming

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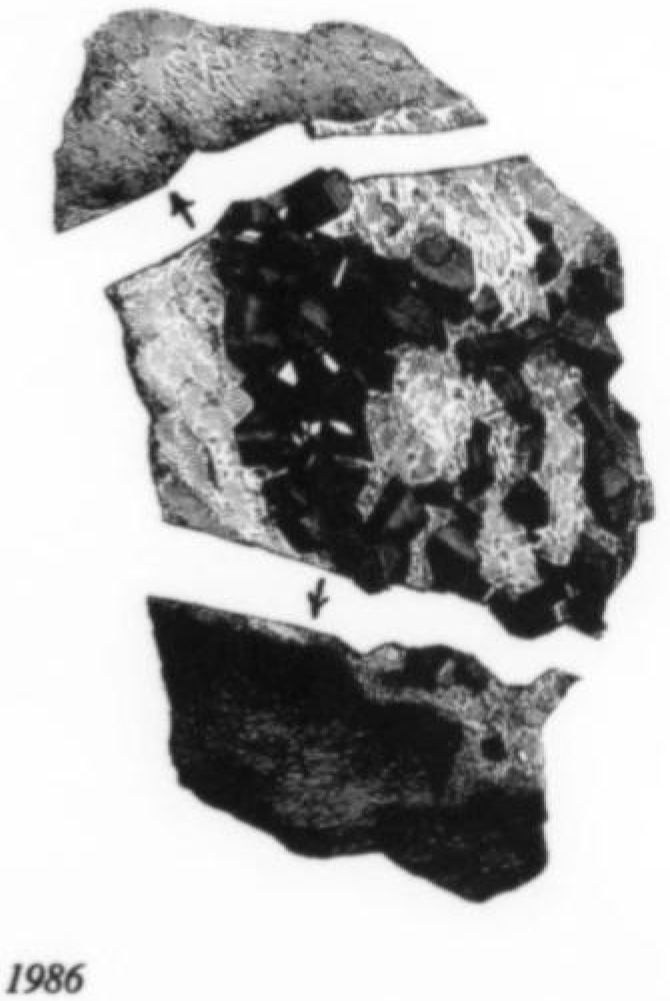
Specimen trimming poses a number of scientific, philosophical and esthetic questions. The implications should be kept in mind during specimen preparation.

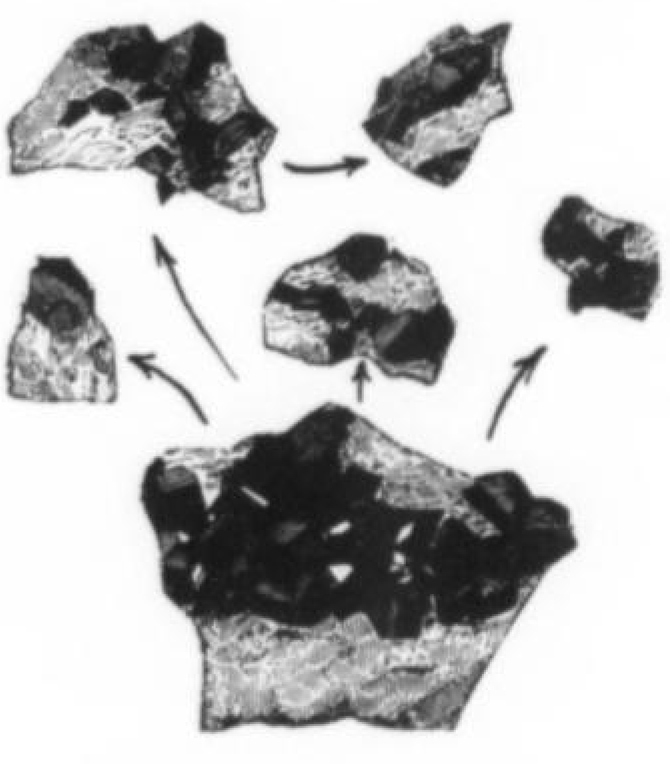
PRACTICALITY and ESTHETICS

Most people give relatively little thought to the implications involved in trimming specimens. However, the effects on future research and future collecting may be significant. Specimens can become whittled down in a long progression which can end in great loss overall.

The first trim which many specimens receive has been administered by Father Earth himself, through tectonic movements, explosive decompression of pockets, weathering, collapse of subsurface structures, and so on. In some cases the specimens are judged satisfactory as found, and are not further reduced. No problem there. In fact, restoration may even be attempted on some natural trims.

However, a trim is often made in the field, first of all, to reduce the specimen to a size which can conveniently be packed up and removed. When the collector has brought his treasure safely home, he may want to cut it down somewhat due to the size restrictions of his storage and display facilities. But once purely practical requirements have been met, he casts an altogether different eye on the specimen. He assesses its *esthetic* acceptability from a number of different viewpoints, and may decide to perform further surgery.





Here the collector enters into a peculiar realm which he may not be fully aware of: the *collector as sculptor.* He is working now to create what is essentially a work of subtle art very similar in concept to *bonsai* trees, but philosophically related to all sculpture. It's true that the specimen should *look* as if it has broken just that way naturally, but such is the case with much art which is heavily shaped by the artist. Features such as the size and orientation of the crystals, the acceptability of damaged crystals near undamaged ones, the size of matrix (if any) which seems esthetically "justified" by various crystals, the acceptability of saw-cuts, the presence of some mineral species which are judged to "detract" from others . . . all of these evaluations and more enter into the artistic equation.

It is generally supposed that in the long history of mineral collecting, the overall guiding concepts have remained much the same. And, the thought goes, we must be doing what collectors have always done, so why worry? But that premise is not true. The earliest mineral collections in Europe were formed for two reasons: to educate miners on the appearance of valuable minerals, and for display by the nobility as examples of the natural richness of the kingdom. With the Age of Enlightenment in the eighteenth century, scientists began to collect crystals with a view to fathoming their inner secrets of chemistry and crystallography. At the turn of the last century a wave of Natural History fever swept the general population, who connected nature study with "natural theology" and sought their "Sermons in Stones."

No doubt people have always appreciated the natural beauty of minerals, but it has only been in the last few decades that mineral specimens have risen in esteem to parallel artworks, and have been used interchangeably with art for interior decorating purposes. Minerals have found a place not just as filler for curio cabinets, but as free-standing sculpture and sizeable wall-hangings. Prices, for the first time in history, have reached the lower range of the Old Masters. Esthetics have never been remotely as important in monetary valuation of mineral specimens as they are today. Clearly, therefore, the collector feels financial pressure to render his specimens as acceptable to current taste as possible.

Esthetic pressure comes upon the collector from another direction as well. Even if he is relatively unconcerned with monetary value, he may wish to enter his collection into formal competition. The judges behave much as art critics, since they are forced to evaluate nebulous esthetic "quality" and "presentation." They do so, perhaps without realizing it, in the context of *modern* esthetic taste. Older collections, considered competitive or superior in their time, may be esthetically unimpressive today.

Because the phenomenon is rather new, one wonders if tastes will meander and change forever, as with clothing fashions, or will stabilize at gradually "higher" levels like the taste for the Old Masters. One might hope that *some* esthetic standards approach being universal and timeless, not subject to change or re-evaluation. In fact, encouragement toward the development of a refined and classic taste not subject to the whims of fashion will *help* to keep specimens safer from being trimmed into oblivion.

It is perhaps most difficult to build a positive case for trimming specimens down into arbitrary size classes for competition. As the late micromounter Neal Yedlin often remarked about his larger specimens: "I collect minerals, not sizes." To trim down perfectly satisfactory specimens for competition classification alone amounts to little more than capricious destruction.

DANGERS

The dangers inherent in trimming are real. A collector may trim off damaged crystals first of all, to achieve higher overall perfection. Then he may remove matrix or crystals in order to achieve a certain sculptural fashion. Through the course of this, the specimen may well be reduced from large cabinet to small cabinet size. Years later, the sculptural fashion may have changed, and the only way to restore some of the lost value will be to cut the specimen down further, perhaps to miniature size. Today, fine thumbnail size specimens can command a price as high as some fine miniatures. The collector may "see" a high-fashion thumbnail waiting to be liberated from a now-mediocre miniature. In every case a change in fashion encourages further reduction of specimens . . . there is no other direction to go, since previously trimmed away material can rarely be found and restored. Furthermore, collectors at any given time do not all have the same taste, and a simple transfer of ownership may well bring a specimen under instant esthetic disapproval, "requiring" a trim.

And what of the danger that future fashions in taste will call for *larger* matrix bases! The end of the line will be reached sooner or later if trimming continues. The fortunate pieces may wind up as a handful of (temporarily) fashionable micromounts. But in any case, once a specimen has lost too much of its esthetic potential, it is in danger of becoming worthless, or discarded, or cut up for gem material, or manufactured into a fake. These are sad ways for mineral specimens to end.

The most important and critical drawback of trimming is the *removal of information* about the specimen and its natural history. Although not often considered in the mineral marketplace, druses, coatings and stains, no matter how unsightly, convey information which may be useful. This information includes, but is not limited to, the conditions of crystallization; the post-formation geochemical conditions that existed; and their effects, or absence thereof, on the various minerals. Additionally, such coatings, druses and the like may convey information about natural transport of the specimen, and provide observations which permit other kinds of interpretation.

A no less important consideration is the loss of crystallization

history through selective trimming. Such data, perhaps manifested in varying sizes of crystals, or multigenerational crystal formation, can easily be obliterated or rendered misleading by selective removal of certain crystals.

Coatings and crystals are of principal interest to mineral collectors, but they represent only the most visible portions of a complete specimen. This concept of a "complete" specimen includes rock matrix, contact phases, subsequently formed phases, alterations, and coatings: in short, everything present, including the country rock. Interpretation of these specimens requires the "whole picture" for consideration. If part of the assemblage has been trimmed off, then part of the knowledge is lost, and with it, part of the long-term significance of the specimen, and its value to science.

Although false information about a paragenesis might be discovered and corrected, lost information might never be reclaimed. Such removal also implies, albeit indirectly, a certain overconfidence, for few who trim really know the precise nature and chemical composition of what is removed, let alone its mineralogic significance, or bother to record this information. Indeed, there may be new mineral species, residing hidden in calcite or other phases, which have been dissolved or trimmed away and are gone forever.

Because we are but temporary guardians of these materials, it is important that we preserve at least some untrimmed specimens, preferably in large, public, institutional collections, so that they will be available for future study. Indeed, it is *imperative* that this be done as a responsible adjunct to mineral collecting. Scientists who will study collectors' samples in the future might not know of the selective trimming, especially if it was carried out on a broad scale affecting hundreds of specimens, and might easily make incorrect assumptions concerning the assemblages and their formation.

ADVANTAGES

In fairness it must be admitted that there are some few *potential* advantages in trimming. One might optimistically hope that trimming disposes of portions which are not essential to science because they are well preserved on other samples, thereby making the storage and display of the specimen more efficient. Efficiency has some value. So too does the development of trimming skill, making less likely those trimming accidents which can destroy specimens.

Removal of certain minerals available in abundance has been known to reveal much more interesting species for study. A good example would be joaquinite and the other associated microminerals revealed by the chemical removal of natrolite from California benitoite specimens. And there have probably been cases of good luck (unfortunately unpredictable) where a trim intersected a small pocket in the matrix to reveal hidden treasures.

Regarding rare minerals, it has been argued that they should be subdivided extensively so that specimens may be available to as many different collectors and researchers as possible. But this represents an unusual case of trimming since nothing is discarded, and the concept is often taken to undesirable extremes resulting in the destruction of whatever scientific value the specimens may have had.

CONCLUSION

No one of healthy mind can advocate the useless destruction of specimen material. There can certainly be scientific, esthetic, financial and practical value in the careful trimming of specimens. But the potential disadvantages are great and irreversible. Collectors, dealers and curators should weigh all considerations carefully before reducing specimens in any way. ◆

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famous mineral localities:

Knappenwand

Untersulzbachtal, Austria

Robert Seemann *
Department of Mineralogy-Petrology
Natural History Museum of Vienna
Burgring 7, A-1014 Vienna, Austria

Knappenwand, in the Untersulzbach Valley, is among the most well-known mineral occurrences in Europe. It has been famous for over 120 years as a source of superb epidote crystals, apatite and other associated species. Fine specimens continue to be found there even today, continuing the rich history of mining, collecting and scientific inquiry which has always attended the locality.

INTRODUCTION

The Alps pass in a huge crescent across northern Italy and adjoining countries, from the Ligurian Sea on the west to almost as far as the Adriatic Sea on the east. Italy shares these beautiful mountains with France, Switzerland and Austria. In Austria, in the southern part of the province of Salzburg, a range of the Alps known as the Hohe ("high") Tauern dominates the landscape. Here Pleistocene glaciers shed torrents of meltwater which cut many steep-sided parallel valleys in the north front.

One of these remarkable valleys is the Untersulzbachtal (*-tal* = "valley"). Its confluence with the Salzach River is near the village of Neukirchen. Many famous mountains and peaks surround the Untersulzbachtal, the best known of which are the Grossvenediger and Kleinvenediger. Only a few scattered meadows are found where valleys widen a bit. The shepherds' huts stand mostly as abandoned ruins now, but since the formation of the Hohe Tauern National park, a few have been restored.

Equally well-known among Austrian collectors are the neighboring valleys to the west (Obersulzbachtal, Krimmler-Achental) and east (Habachtal, Hollersbachtal, Felbertal). Despite general similarities, each of these valleys has a special character and history all its own.

The head of the Untersulzbachtal, dominated by the Grossvenediger and Kleinvenediger, has long been a favorite area among sportsmen, hikers and adventurous climbers. In the foreground of this panorama is the mighty Untersulzbachkees, a well-developed tongue glacier which is among the most impressive in the Alps. Together with many small waterfalls along the steep valley flanks, it feeds the Untersulzbach (*bach* = "stream") which culminates in an 80-meter waterfall near the valley mouth. Were it not for the much larger Krimmler Falls in a neighboring valley, the Untersulzbach Falls would no doubt be much better known.

A second aspect of the Untersulzbachtal is its wealth of minerals, a feature common to many of the valleys in the region. Some of the mineralized clefts and caverns are reminiscent of the old folk tales about crystal palaces and treasure chambers hidden in the deep mountains, where "the walls and ceilings are covered with crystals and gems as well as bizarre rock formations, and everything glitters in fairylike charm."

The most important collector species in the Untersulzbachtal are quartz crystals, titanite, apatite, aquamarine beryl, adularia and, of course, epidote. The epidote from this valley has become world-famous because of its great variety of forms, and because of the size, luster and beauty of its crystals. Many people consider Unter-

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* This article was originally published in German as a booklet entitled *Epidotfundstelle Knappenwand, Geschichte, Geologie, Mineralien* (1985); published by Doris Bode Verlag and reproduced here in English with permission, in slightly shortened form and with some changes in the illustrations.

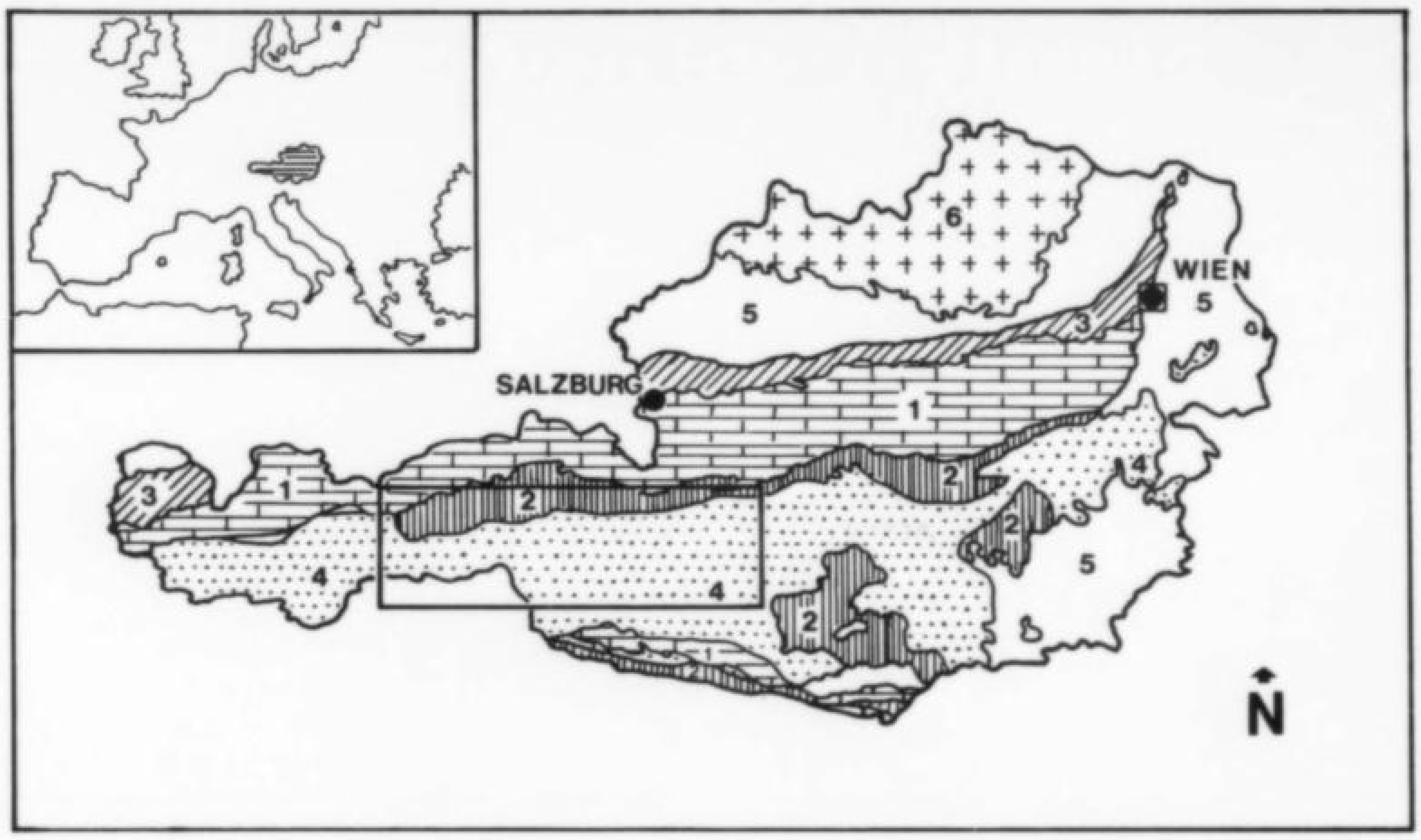


Figure 1. **General geology of Austria.**

1. **Northern and southern Mesozoic limestone.**
2. **Early Paleozoic metamorphic series (graywackes, limestone, phyllites).**
3. **Tertiary elveticum and flysch (limestone, sandstones, conglomerates).**
4. **Metamorphic rocks of the Central Alpine body containing the Tauernfenster (rectangle) (schists, amphibolites, gneiss). (See Fig. 11.)**
5. **Neogene sedimentary rocks.**
6. **The Early Paleozoic-Proterozoic Bohemian Massif (granites, gneisses, schists, amphibolites, granulites).**

sulzbachtal epidote superior to that from any other locality in the world, and specimens are so distinctive in appearance that they are easily recognized as to source.

The Untersulzbachtal is also the site of a centuries-old copper mining district, more or less dormant since the middle 1800s. According to old reports, the mines exploited a rich deposit containing perhaps some gold and silver as well. All of these factors have combined to produce a long and interesting history in the valley which is, in some ways, reminiscent of the old fairy tales.

HISTORY

Since prehistoric times there has been a close relationship between local inhabitants and the local rocks, minerals and ores (Lahnsteiner, 1965). Scanty archeological finds from the early Stone Age have turned up around Bischofshofen, St. Georgen and Saalfelden. Quartz crystals (most probably from the Hohe Tauern) have been found among the remains of ancient settlements around the Alps, and a number of localities existed in the region where copper ores could be found. Many settlements date back to the early Bronze Age, about 4000 years ago. Permanent settlements dating to about 3000 years ago have been excavated in the Salzach Valley between Zell am See and Krimml; Untersulzbachtal is in the center of this area and has yielded much evidence of Bronze-age copper mining. About 2500 years ago, Celtic people moved into the Salzach Valley, bringing the skills of animal husbandry, agriculture and mining with them.

Around 2000 years ago, the Romans conquered the province and named it Norikum, an area including Salzburg and the Pinzgau. They occupied the territory for nearly five centuries, during which time they were very active in mining. Generally, they were most interested in gold and silver, but copper was not ignored; and even some emerald might have been produced in the Habachtal.

Following the fall of the Roman Empire, there were several waves of settlement from Bavaria to the northwest. The cultural heritage now discernible in the region stems from this Germanic influence of the Middle Ages, and virtually nothing survives from Roman and Celtic times.

Following the departure of the Romans, large-scale mining ceased and was forgotten. Not until around 1200 did mining slowly resume, reaching its peak in the fifteenth and sixteenth centuries. Principally, gold and silver were mined, and later also copper.

The Untersulzbachtal Copper Mines

The earliest records of mining in the Untersulzbachtal mention the existence of an operation called the Hochfeld mine in 1537, and reference is also made to copper mines near Mühlbach and Habachtal. But as early as 1520, the records from the smelter at Mühlbach refer to serious competition from mines and smelters along the Salzach. One mine in the Untersulzbachtal, called the Phillip and Jakob mine, produced a small amount of high-quality ore in the late 1500s and is mentioned again in 1603.

From writings dated 1625, it is learned that several old adits were then being worked, referred to as the Weitmoser, Rosenberger and Brenntaler works. There were crushers, smelters and sleeping quarters for the miners. The hard rock was broken up by the fire-setting technique, but the resulting smoke deposited so much soot on the walls of the workings that the location of the ore zone was obscured and lost. The Brenntal mine was abandoned and forgotten until 1710, when it was rediscovered by Georg Perger. Despite the input of significant funds, Perger was unable to turn a profit at the mine and died penniless in 1725. His son maintained ownership of numerous local claims but preferred farming as a financially safer occupation.

Interest in the Brenntal mine would not die, however, and when some shares in the property were offered for sale in 1748, mining experts were called in to run things properly. The annual production by 34 miners totalled 560 metric tons containing about 3 kg of copper and 8 grams of silver per "Kübel" (56 kg) . . . relatively rich ore by today's standards. Based on this output and the advice of experts, the Archbishop of Salzburg purchased the mine in 1758. Later, in 1805, all of the Mühlbach and Untersulzbach operations were acquired by the Austrian state.

In 1818 the Imperial Cabinet in Vienna decided to dispose of the Untersulzbach operations and offered them for sale to the public at the ridiculously low price of 600 Gulden. Nevertheless, there were no takers, and so the Imperial Mining Board carried on mining there until 1864. During the last four years, a force of 30 men produced 450 tons of ore annually, averaging 7.5% copper.

The properties in the Untersulzbachtal were investigated shortly after the turn of the century by Goetting (1909) and von Isser (1909). Their reports are surprisingly positive, referring to "ore veins up to 2 meters thick." A connection was suspected between the orebodies of the Brenntal and Gamskogel mines over an intervening distance of about 10 km. Remaining ore reserves were "conservatively" estimated at 175,000 to 350,000 cubic meters, with local gold and silver contents emphasized. The meager results of past centuries were ascribed to poor management and primitive equipment. Despite these glowing recommendations, no one felt like risking the substantial sums of money that would be required to reopen the Untersulzbachtal copper mines. Plans were briefly entertained to resume operations in 1916, but were upset by World War I. A Hanover firm considered mining in the period between

Figure 2. **Lithograph after a watercolor painting by Friedrich Simony (1860) depicting the "Sulzbachtäler" (Sulzbach Valleys, Untersulzbachtal on the left).**

the wars, but nothing came from it. during the period of the Third Reich, a small amount of copper was mined; and several reports expressed cautious optimism, but serious exploitation was never again undertaken in the valley.

Following World War II, a Polish mining engineer by the name of Ludwig Hubicki obtained mining rights to the Untersulzbachtal copper deposits and, in 1947 and 1948, he explored the old workings and cleared the Hieronymus tunnel. Finances proved inadequate for a sustained operation. Sporadic re-examinations and studies have continued through the 1970s. At present, the tunnel entrance is blocked by rubble, and only a few of the shafts are still clear. The lower levels of the mine (which in total is estimated to consist of several kilometers of workings) are flooded.

Mineralization at the copper mines consists of chalcopyrite with some pyrite and marcasite, and minor amounts of galena, sphalerite, tetrahedrite and bornite. Recent evidence for gold and silver (mentioned in early reports) is entirely lacking. These are emplaced in schists and gneisses of the Habach formation.

Discovery of Knappenwand

Alois Wurnitsch was born in Prägraten in 1834. Later, he lived and worked as a shoemaker in Wald. One afternoon in 1865, while resting at the foot of a rock wall or face (= *wand*), he found some exceptionally large and beautifully formed crystals of epidote in a shallow pool. At the time, he did not know they were epidote but, being an experienced mountain guide and mineral collector, he knew the value of Alpine crystals. Digging further into the waterhole, he found a number of elongated crystals to 6 or 7 cm each, and finally a pocket filled with intergrown epidotes.

Wurnitsch took several of the crystals to his friend, Andreas Bergmann, an Innsbruck tailor and part-time mineral dealer. Bergmann purchased them and, in order to obtain an identification, passed them along to Professor Victor von Zepharovich at the University of Prague, who was a correspondent of the Imperial Geological Survey in Vienna. The specimens had at last fallen into knowledgeable hands; Zepharovich was an excellent mineralogist who also happened to be already involved in a study of Tauern minerals including epidote (Zepharovich, 1859). The new crystals were eventually described in a small communication entitled "Neuere Mineralfundorte in Salzburg" ("New mineral discoveries in [the province of] Salzburg") (Zepharovich, 1869). Unfortunately, he was unable to give the precise locality because it was still being held secret by Wurnitsch and his associates, as was customary.

Even these first-found crystals were immediately seen as being among the finest known for the species . . . "equally outstanding for their habit, columnar crystals with plane reflecting faces in various combinations, and their dimensions." Zepharovich made particular note of doubly terminated crystals up to 2 x 6 cm. He mentioned associated species including calcite, apatite, feldspar and acicular actinolite (*byssolite*) which he called "asbestos."

The small epidote crystals rich in well-developed crystal forms proved ideally suited to precise goniometric measurement. At the time, goniometry was one of the few methods available for positive mineral identification, and was increasingly reliable where the number of different forms was large. Before the discovery of the Knappenwand locality, only 44 different habits (i.e., combinations

Figure 3. **A portion of the Untersulzbachtal in 1785, showing extensive workings: the old copper mining area (across the bottom), and also the Blauwandel and Blauwandstollen (upper right) near the subsequently discovered Knappenwand.**

Figure 4. **Victor Ritter von Zepharovich, mineralogist and Professor at the University of Prague. In 1869 he published the first description of Knappenwand epidote.**

of crystal forms) were known for epidote. By 1878, Bücking had increased that number to 183, largely through study of Knappenwand crystals.

While mineralogists were reveling in the scientific aspects of the find, Andreas Bergmann obtained a lease on the locality from the Imperial Austrian Forest Service in 1867 and began mining for specimens. He and a few hired workers labored for three months without success. The rock, an epidote amphibolite, is extremely hard and tough, and work with hand tools progressed very slowly. But at last a crystal cavity was broken into, and the surrounding rock was removed with great care. The specimens recovered far surpassed the initial discovery.

The first suite of superb epidote crystals went to the Museum in Vienna in that same year, 1867.

As there was much conflicting information about the locality circulating in Vienna, Aristides Březina, associated with the Imperial Mineral Cabinet in Vienna, made the trip to Untersulzbachtal in 1869. Bergmann showed him the locality, which had been named Knappenwand (Knappen = "miner"), and together they collected some small epidote crystals and associated species. From these, Březina subsequently described apatite, titanite and adularia in a brief article on his visit, and added some physical and crystallographic data gleaned from them and other crystals in the Vienna Museum (Březina, 1871). An epidote crystal measuring 2.5 x 13 cm is mentioned in particular. At the same time, he mentioned a study collection of more than 1000 crystals reserved for goniometric measurement and chemical and physical examination. He announced plans for a forthcoming comprehensive work on the Knappenwand epidotes which, sad to say, never appeared.

The early literature on Knappenwand contains references to many "mystery" specimens, the whereabouts of which (if they ever existed at all) are unknown today. Rumors arose that thousands of wonderful epidote crystals were being secretly hoarded at the Vienna Museum (Bücking, 1878; Fugger, 1878). Although many fine specimens are indeed still in the museum, and many more were sacrificed early on to destructive analyses or traded to other institutions, the rumors were greatly exaggerated. Other rumors involved giant crystals supposedly in storage at the museum. Zepharovich himself (1873) and Fugger (1878) referred to crystals as thick as your arm, one measuring 40 cm and another 47 cm (18.5 inches!). Weinschenk (1896), Gasser (1913) and Fruth (1975) have written of individual crystals 70 to 80 cm long. Brendler (1954) reported hearing of a crystal almost a meter long which had supposedly been sold to a London museum for 1000 Gulden. Unfortunately, none of these huge crystals are currently known to exist.

Bergmann and his miners, particularly Sebastian Trojer from

Figure 5. **Aristides Březina, curator of the Imperial Mineral Cabinet in Vienna, visited the Knappenwand locality in 1869.**

Neukirchen, exercised extreme caution and great collecting skill in their removal of many large and undamaged crystals and crystal groups. Bergmann also excelled as a promoter. He carried thousands of dollars worth of specimens with him across Europe, selling to large museums and universities and prominent mineral dealers. Thus, the locality quickly became famous, and collectors became ever more eager to obtain the beautiful specimens. Today one can see Knappenwand epidote in all major museums and important private collections.

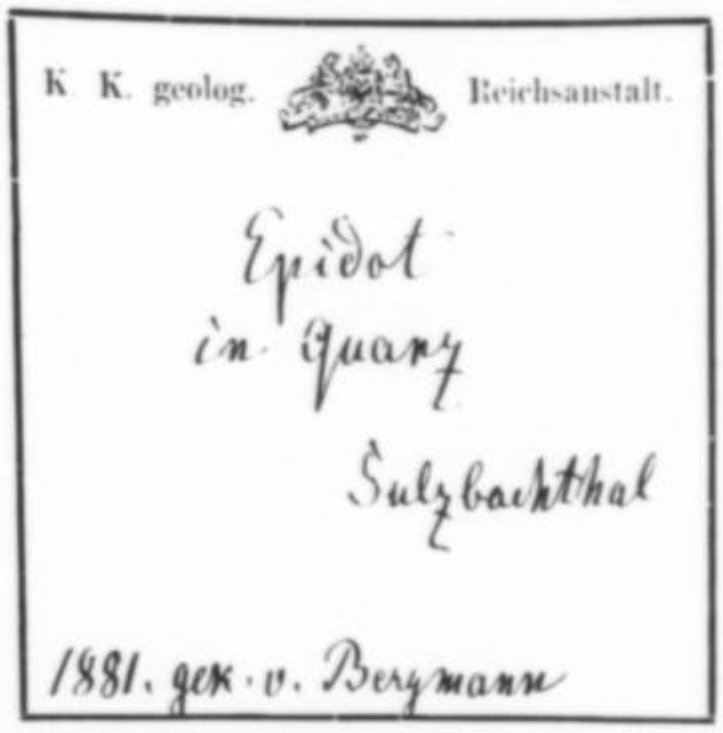
The Knappenwand occurrence was, after a few years, depleted to the point where the specimens cost more to find and remove than they could be sold for, and Bergmann was forced to shut down the operation. It was at this time, with a market clamoring for specimens and none being mined, that the practice of "assembling" epidote specimens began. Single, loose crystals were glued onto chunks of matrix and the join hidden by tufts of byssolite. A great many of these fakes are known in museums.

Bergmann allowed his lease to lapse and, in later years, a number of other lessors tried their luck at the Knappenwand mine. In 1884 an official announcement appeared in the newspaper *Salzburger Volksblatt*; the Imperial Forest Service offered for sale a five-year lease on the locality for specimen mining. Records are fragmentary, but Albert Schett of Neukirchen probably purchased the lease, considering that he is known to have worked the deposit after Bergmann.

Alois Hollaus of Bramberg had the lease until 1905, and the good fortune of mining into a major pocket. The pocket was first broken into by a drill, and it is said that water flowed from the bore hole for a long time. The chamber was opened with great care, and the miners found a large, almost walk-in pocket lined with epidote crystals and associated minerals. Nine knapsacks were filled with selected epidote crystals and were carried carefully down the valley. A large portion of these were subsequently sold to a mineral dealer named Kohl in Munich. Despite the significance of this find, the specimens overall were not of comparable size or quality to the finds of Bergmann.

A review of the early reports from the days of Bergmann and Hollaus reveals certain similarities attending the discovery of major pockets (Brendler, 1954). In general, the lower section of the pocket would be found to be filled with water which issued from the bore hole under pressure. This was followed or accompanied by the release of an unbreathable, nauseating gas. It is conceivable that these pockets had retained their integrity since formation, and that the gas was carbon dioxide of hydrothermal origin. But this would be remarkable considering the near-surface location, vertical bedding, intense tectonism, and deep weathering characteristic of the area. Once blasting was employed on a significant scale, pressurized gas pockets were no longer encountered.

The water partially filling pockets seemed to help absorb the shock waves from the blasts. It was reported again and again that crystals situated below the water level were unharmed by blasting whereas those above the water suffered notable damage.



K. K. geolog. Reichsanstalt.

Epidot
in Quarz
Sulzbachthal

1881. gek. v. Bergmann

Figure 6. **A label from the collection of the Imperial Geological Survey in Vienna, indicating that the specimen was purchased from Andreas Bergmann, first leaseholder at Knappenwand.**

The last decades of the 1800s saw a flurry of scientific activity regarding Knappenwand epidote. Soon after its discovery, nearly all of the natural science institutions in Europe were producing publications on the material. Most of the work centered on goniometric studies of the various crystal forms and habits (Brezina, 1871; Schrauf, 1871; Klein, 1872; Zambonini, 1903). The most comprehensive studies are those of Bücking (1878) and Kokscharow (1880). Many physical and chemical studies were also carried out (Kenngott, 1871; Rammelsberg, 1872; Ludwig, 1882). Klein (1874) and Ramsay (1888) reported on the optical properties. In spite of the primitive apparatus then available, the old results on optics differ only minimally from modern data, and the chemical formula determined (Tschermak, 1864; Ludwig, 1882) coincides precisely with that now accepted.

In 1905 the Knappenwand mine was taken over by a man known only as "Herr Nicolusi" (or Nicolosi, or Nicolasi . . . perhaps only his first name, a form of Nikolaus).* He was an Italian railroad engineer who came originally to work on the Zell am See-to-Krimml railway. From documents, it is unclear whether he held the lease alone or was working in association with Wurnitsch, Hollaus and Karl Hanselmann of Neukirchen (Brendler, 1954; Lahnsteiner, 1965). Nicolussi's technique was one he had learned during the construction of railway tunnels: large-scale blasting. He bored up to 62 holes at a time, several meters deep, and enlarged each one so that it could hold more dynamite. Not surprisingly, the small mine soon took on the look of a railway tunnel, measuring 5 to 10 meters in height and width. Nicolussi mined in this fashion until 1922 and, although many fine epidote specimens were recovered, many more

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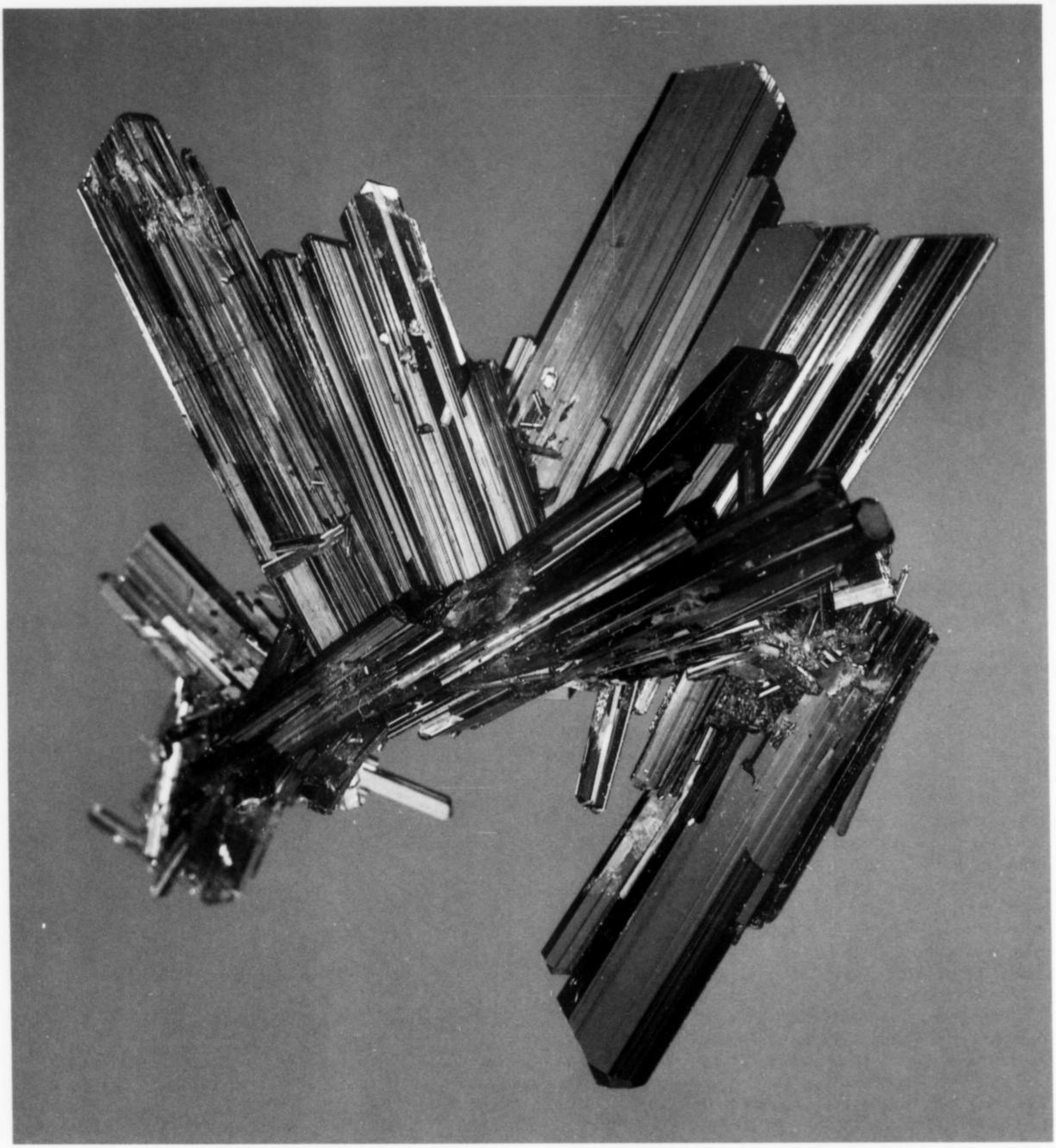
*According to Siefried Nicolussi of Innsbruck, the Nicolussi family originated in Luserna in the Southern Tyrol, Italy.



were blasted to splinters by the heavy explosives. In fact, many crystals deeper within the rock were damaged by the shocks, much to the chagrin of subsequent lessors who found them.

Following this unfortunate period, the locality passed through a succession of lessors, most of whom failed to obtain much from it. Most successful were Kajetan Stockmaier and Ehrenreich Schuchter, who worked the mine from 1948 to 1956. By very careful blasting, they managed to recover many fine specimens equal in quality to any found previously.

In 1957 the Austrian Federal Forest Administration declined to grant further leases because of concern for conservation. Private collectors continued to work the locality without authorization, and there is no record of discoveries made by them.

Protracted negotiations between the Natural History Museum of Vienna and the Forest Service began in 1973 and culminated in 1977 with an agreement. This provides that the museum will lease the locality for ten years and will continue the mining of specimens from the tunnel and dump. The author was entrusted with the direction of this project.

A research program was initiated, not only to recover specimens, but to carry out a detailed geological study of the locality as a whole. Knappenwand is situated at a geologically important point in the Alps, giving more than local significance to the results.

A cabin was constructed at the site, along with an equipment

Figure 7. (Facing page) **Knappenwand epidote, 4 x 4 cm, from the collection of William Larson. Photo by Harold and Erica Van Pelt.**

Figure 8. (Upper left) **Apatite crystal, 1 cm across, with epidote and actinolite. Werner Lieber photo.**

Figure 9. (Upper right) **Epidote crystal, 6 mm, with albite and actinolite from cleft no. 15. Rainer Bode photo.**

Figure 10. (Right) **Large epidote crystals to 16.5 cm, collected by Andreas Bergmann. It was initially purchased by Norman Spang, a prominent Philadelphia collector, who sold it in 1883 to the even more prominent Clarence S. Bement. Bement's collection later became part of the American Museum of Natural History; the specimen was traded out in 1983. Russell Behnke specimen; photo by Joanne Schmaltz.**

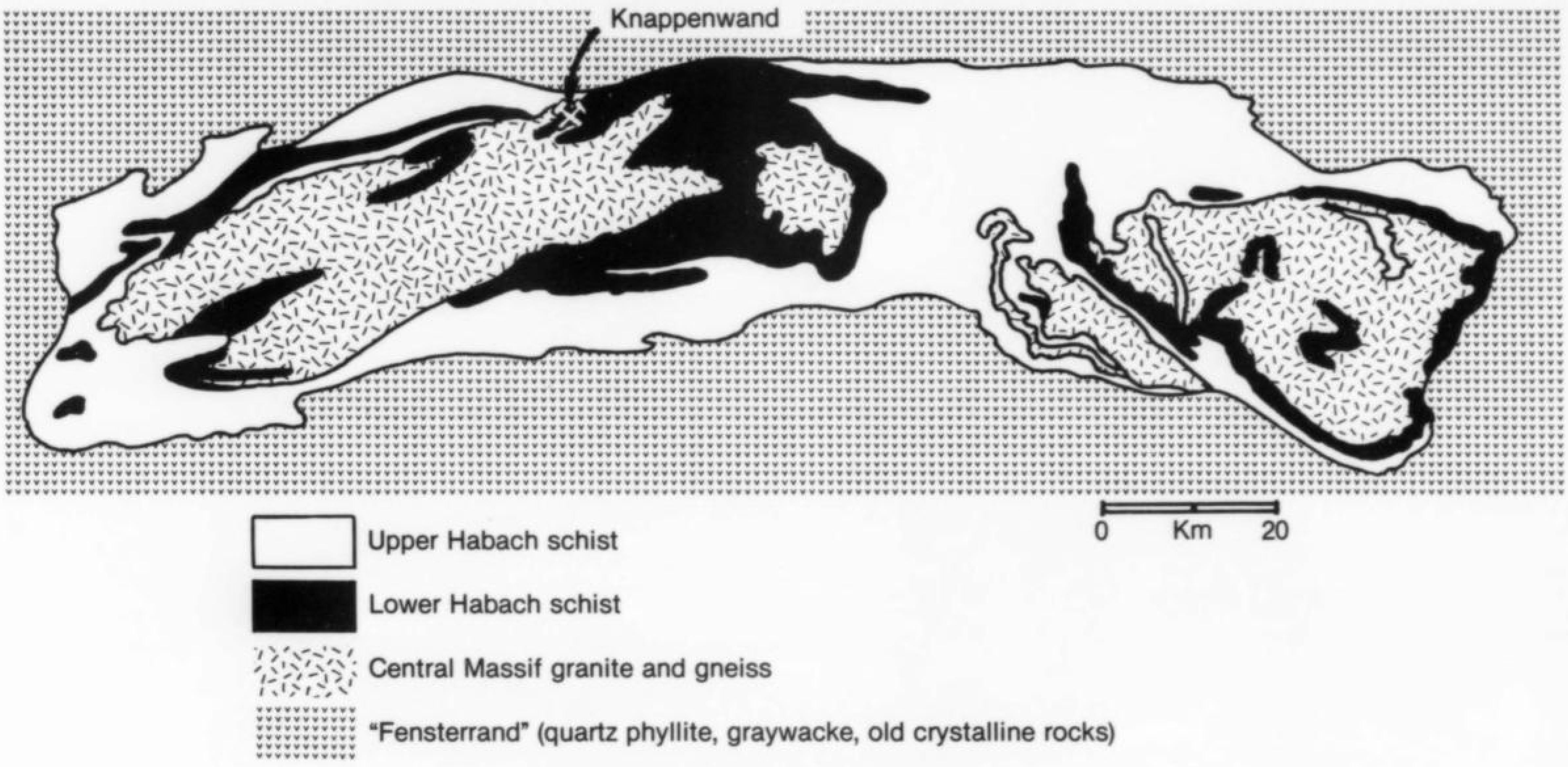


Figure 11. **Geology of the Tauernfenster.**

depot and aerial tramway. Carefully directed work (subject to environmental impact restrictions) has created a three-dimensional exposure of great value to petrologic, mineralogical and geochemical research.

When the museum first took over the property, the excavation measured about 25 meters deep, 8 to 10 meters wide and 10 to 15 meters high. Counting some minor workings outside the tunnel entrance, the total amount of rock removed up to that time was estimated at 7000 to 8000 tons. This material (minus specimens) forms a steep dump about 300 meters long. Up until a few years ago, epidote crystal fragments and associated species could still be collected on this dump. Since then, most of the waste rock has been thoroughly reworked by private collectors, and little of interest remains.

The workings are situated at an elevation of about 1250 meters, at the foot of an overhanging wall about 100 meters high called the Blauwandl. Near the main epidote workings are two old tunnels started in the 1500s for copper ore and said to have yielded a small amount of gold. The upper tunnel, called the Blauwandlstollen, is about 85 meters in extent, and the lower workings, known as the Blauwandl-Unterbau, penetrate for only about 10 meters.

Before our mining began, the tunnel and surrounding areas were carefully mapped in detail. Then, as mining and collecting progressed, the work was continuously documented, surveyed and sampled. Cavities exposed were assigned registration numbers, and their contents carefully weighed and cataloged. since these operations began about six years ago, 55 clefts have been discovered and examined in the area of the back wall. The working face measures about 7 x 8 meters, and has been worked by the museum staff to a depth of 3 to 4 meters (about 600 tons of rock removed).

Most of these 55 clefts were small and their mineral contents meager. However, five or six clefts of substantial size were discovered, measuring 1 to 3 meters long and 10 to 80 cm wide. The mineral content of these was generally rich, though varied. Cleft no. 39, for example (opened July, 1984), was almost devoid of epidote but contained over 200 kg of large calcite crystals and 40 kg of chlorite, plus minor amounts of albite, byssolite, titanite and apatite. Clefts no. 15 and no. 25, only 50 to 100 cm away, yielded many large epidote crystals.

Obviously, the rock is quite rich in clefts, and so it is necessary to proceed with caution and to use explosives only sparingly. As a result, many large and undamaged specimens have been recovered. On the last day of mining in 1985 an extraordinary specimen was found, the best so far recovered by the museum. The epidote crystal measures 20 cm, is of very good quality and has well developed faces. It was the only epidote crystal in a relatively small cavity, accompanied by a few crystals of actinolite, apatite, calcite, albite and chlorite.

GEOLOGY

The epidote locality is located in epidote amphibolites of the so-called Knappenwandmulde (Frasl, 1953), a part of the Habach series (Frasl and Frank, 1966). Slaty rocks in the area have a near vertical orientation and strike northeast-southwest. They separate the northern and southern Salzbach Tongues of the central gneiss massif (Zentralgneismasse).

The Habach series (early Paleozoic, about 400–500 million years old) makes up the schist cover or roof of a late Paleozoic intrusion associated with the Variscan orogeny (300 million years). These rocks, mostly granitic, granodioritic and tonalitic, were metamorphosed by the older (100 million years) and younger (30 million years) Alpine orogenies. They now form the central gneiss mass. Both the Habach series and the central gneiss belong to the "Tauern Window," the lowest geological unit exposed in the Eastern Alps. The work of Frasl (1958), Frasl and Frank (1966), Höll (1970, 1975), Steyrer (1982) and Pestal (1983) suggests that the Habach formation is a relic of an old Paleozoic island arc probably originally consisting of interbedded marine sediments and andesitic to siliceous volcanic material characteristic of continental margins. The younger Alpine metamorphism of these rocks is thought to be responsible for the formation of the cleft minerals.

The thin-bedded rocks of the Knappenwand itself are called "prasinites" (actually epidote amphibolites). Embedded in the series are small to very large beds particularly rich in epidote which are thought to have been mobilized. Local enrichments of biotite, titanite, albite and quartz are known; and rare, very localized beds rich in garnet, scheelite, molybdenite, magnetite, pyrite and chalcopyrite have been noted. The rock mass as a whole is traversed by numerous shear zones. The epidote crystal occurrences are

Figure 12. **A view of the Knappenwand workings in the late 1940s.**

Figure 13. **Diamond drilling on a steel scaffold at the back of the Knappenwand mine in 1983.**

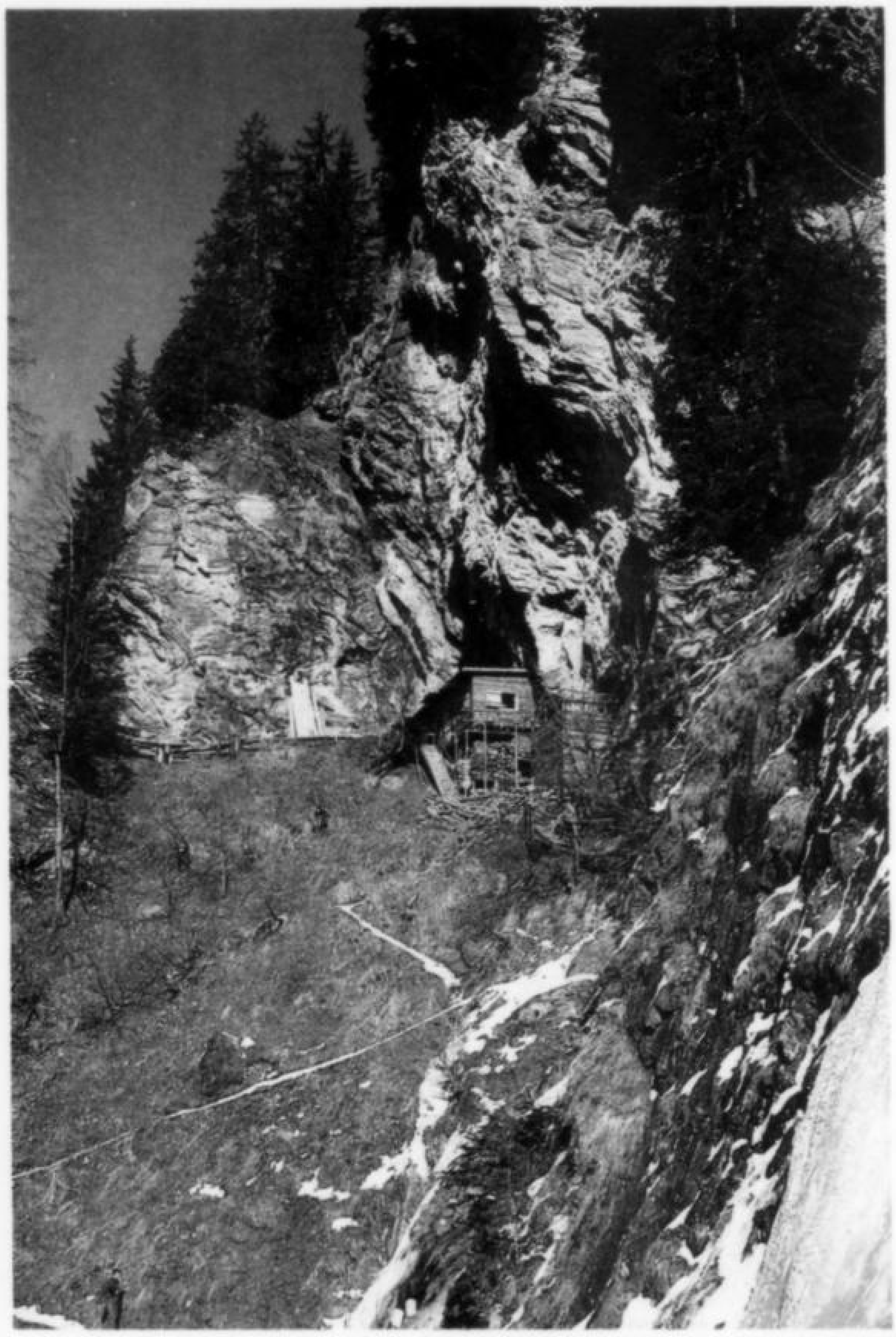


Figure 14. **Cabin built at the Knappenwand workings by members of the Natural History Museum of Vienna staff.**

located mostly in or near the shear zones, and also along bedding planes in epidote-rich layers and lenses.

Mineral Clefts

Tectonism associated with the younger Alpine folding phase gave rise to dilatation, that is, to the formation of open shear zones. Because this occurred under a considerable superincumbent load, the same pressures and temperatures prevailed inside the clefts as in the surrounding rock. These openings became filled with superheated water containing chemicals leached from the rocks. Gradual elevation and erosion as well as cooling of the intrusion caused a gradual decrease in temperature and pressure and, therefore, a diminished metamorphic intensity. Over a period of perhaps 15 million years (beginning 30–35 m.y. ago), the cleft temperatures dropped from 440–560° C to about 300° C, and cleft minerals precipitated in sequence. The composition of solutions varied somewhat from cleft to cleft, and so the resulting mineral contents now vary correspondingly.

In the Knappenwand, four different types of cleft have been recognized:

1. The oldest clefts, typically only a few millimeters in size, are found in narrow, vein-like, strongly sheared portions of garnet-rich rocks surrounded by epidote amphibolite containing the amphiboles hastingsite and actinolite, plus titanite, chlorite and epidote pseudomorphs after diopside. The cleft minerals are generally the same as the minerals comprising the surrounding rock.

2. Large, high-temperature clefts formed in rock undergoing plastic deformation. These may reach sizes of several meters and are the source of the largest and best epidote crystals. The clefts are typically oriented normal to bedding along the borders of thick epidote amphibolite beds. Bent and broken epidote crystals, rehealed to varying degrees, give evidence of the continuance of tectonic deformation during crystallization of the pocket minerals.

3. Small to medium-size cavities developed normal to bedding in the epidote amphibolite where plastic deformation was less and the rock was greatly broken and sheared. High-temperature minerals such as epidote and byssolite are scarce in these pockets, but low-temperature minerals such as calcite, albite, adularia, titanite and chlorite are common.

4. Small to medium-size cavities developed at a late stage in rocks rich in albite, quartz and chlorite. These are usually found near epidote amphibolite contacts and they parallel the bedding. Byssolite and epidote are scarce, whereas calcite, quartz, titanite and chlorite are common. The surrounding rock shows plastic deformation.

Studies of the 55 clefts uncovered by the museum staff suggest the following sequence of crystallization:

Diopside (earliest)
Actinolite
Epidote
Garnet
Chalcopyrite
Cyanotrichite
Galena
Scheelite
Molybdenite
Apatite
Quartz
Albite
Calcite
Adularia
Titanite
Chlorite
Fe and Mn oxides and hydroxides (latest)

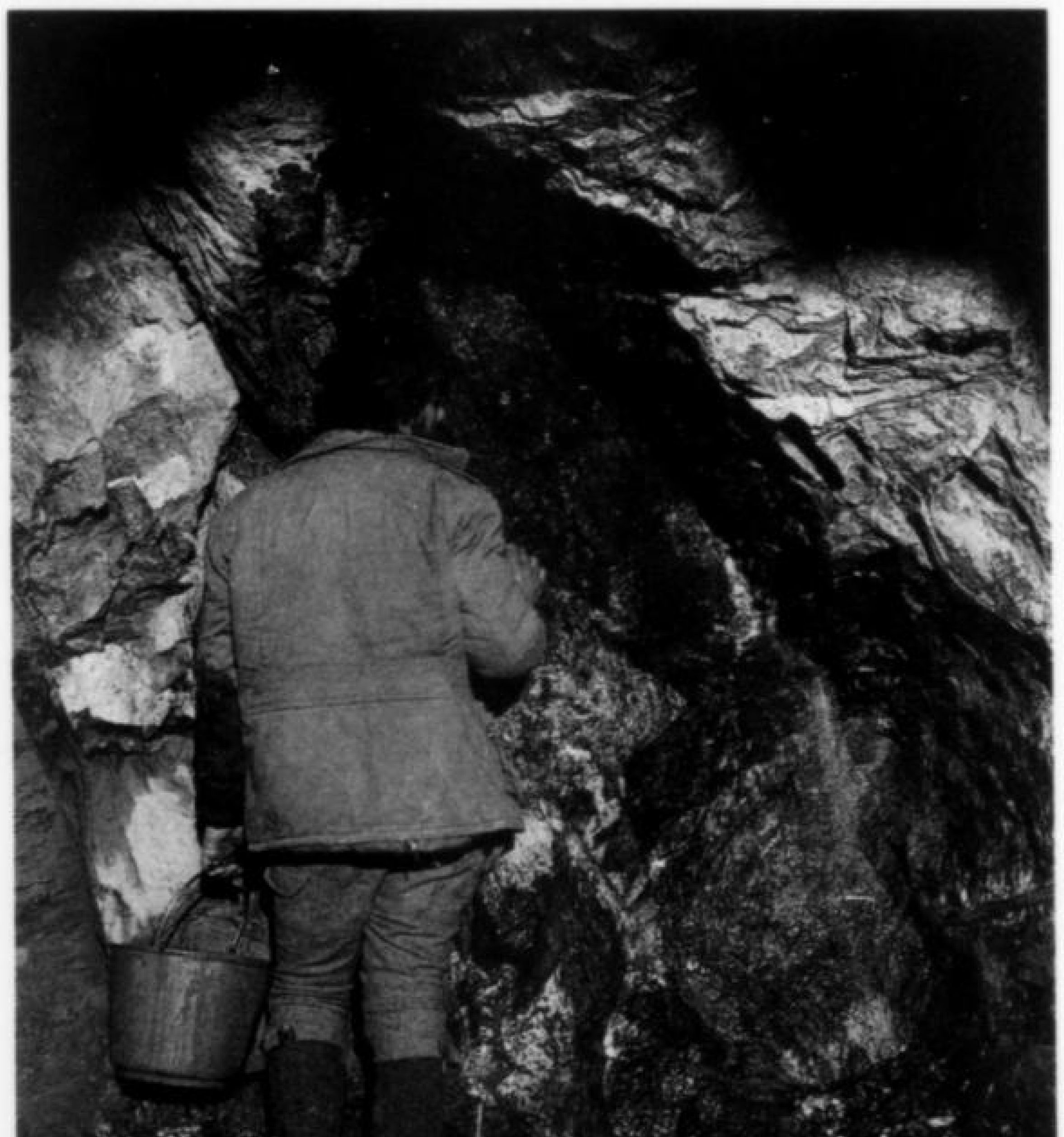


Figure 15. **George Sverak, Natural History Museum of Vienna, examining cleft no. 25.**

The actual situation, of course, was much more complex than this simple list would indicate, and includes several generations of some minerals formed in response to tectonic disturbance. And, as mentioned, mineral content varies from cleft to cleft so that some species are omitted or suppressed.

MINERALS

Described below are the habits and occurrences of cleft minerals having greatest collector significance at Knappenwand (see also Seemann, 1978 and 1984).

Actinolite $Ca_2(Mg,Fe^{+2})_5Si_8O_{22}(OH)_2$

Amphiboles at Knappenwand vary in composition from actinolite to hornblende. They are brittle, gray-green and capillary in habit. The hair-like crystals vary from 0.001 to 0.3 mm in thickness and occur in two generations: darker green (older) and lighter green (younger). Actinolite, also called byssolite or amianthus, is one of the earliest cleft minerals to form and is therefore commonly found as inclusions in later minerals.

Figure 16. **Actinolite ("byssolite") needles with tiny white albite crystals. The view is 1 cm tall. Werner Lieber photo.**

Albite $NaAlSi_3O_8$

Small, white crystals of albite to 5 mm in size and intergrowths to 2 cm have been collected. They generally occur on actinolite and epidote crystals. Albite, though not in large quantity, is present in almost every cleft. Polysynthetic twins of alternating albite and orthoclase reported by Tschermak (1872) on material from Knappenwand have not been confirmed.

Figure 17. **Calcite crystal on epidote matrix measuring 13 cm. Natural History Museum of Vienna collection.**

Figure 18. **Calcite rhombohedrons, 6 cm, with chlorite from cleft no. 39. Natural History Museum of Vienna collection.**

Andradite $Ca_3Fe_2^{+3}(SiO_4)_3$

Pale brown garnet, mostly as microcrystals, is found in small cavities in garnet-rich rocks, associated with calcite and epidote. Zoned garnets analyzed have proven to be andradite. Very rare.

Calcite $CaCO_3$

Calcite is found as white to gray or yellowish crystals and crystal aggregates, some partially transparent. The faces are generally dull and deeply corroded. Forms most common are various rhombohedrons; scalenohedrons are rare. Rhombohedral crystals to 35 cm on an edge have been reported. Some crystals carry a brownish black crust of Fe and Mn oxides and hydroxides.

Cerussite $PbCO_3$

A little cerussite as microcrystals on galena has been found.

Chalcopyrite $CuFeS_2$

Chalcopyrite is rather rare at Knappenwand, occurring as heavily oxidized crystal aggregates to a few millimeters in size. It is often associated with pyrite.

Clinochlore $(Mg,Fe^{+2})_5Al(Si_3Al)O_{10}(OH)_8$

Ripidolite, an iron-rich variety of the chlorite-group mineral clinochlore, occurs in large amounts as fine-grained, dark grayish green pocket fillings. Crystal size is below 0.2 mm.

Diopside $CaMgSi_2O_6$

According to Weinschenk (1896), diopside was encountered only rarely during the early days of mining at Knappenwand. He described the crystals as black and dull (unlike the lustrous epidote), forming in blunt habits and step-like parallel growths.

In recent times, diopside has again been found, but only as poorly formed, millimeter-size crystals altering to epidote and chlorite.

Epidote $Ca_2(Al,Fe^{+3})_3(SiO_4)_3(OH)$

Epidote is among the earliest formed pocket minerals, and has been identified in at least four generations of growth. Crystals to enormous size (40 to 100 cm) are mentioned in the early literature, but today crystals 10 to 20 cm in length are considered outstandingly large. Crystal size ranges down to the microscopic, and crystal quality is excellent. Faces are generally sharp and lustrous. A wide variety of habits is known, the most common being greatly elongated in one direction and somewhat flattened on another. Crystals commonly show a high degree of transparency when held up to a strong light source.

Parallel and semiparallel growths are common, making for some striking cabinet specimens, particularly the "herringbone" aggregates (see cover). Fluorapatite and actinolite are typically associated.

Fluorapatite $Ca_5(PO_4)_3(F,OH)$

Lustrous, water-clear apatite crystals of simple habit are among the later formed pocket minerals. Most crystals are tabular in habit and measure only a few millimeters in size, but a few are known as large as 8 cm. Apatite crystals commonly enclose actinolite needles.

Figure 19. **Epidote group, with actinolite, apatite and albite, collected in 1870. Natural History Museum of Vienna collection.**

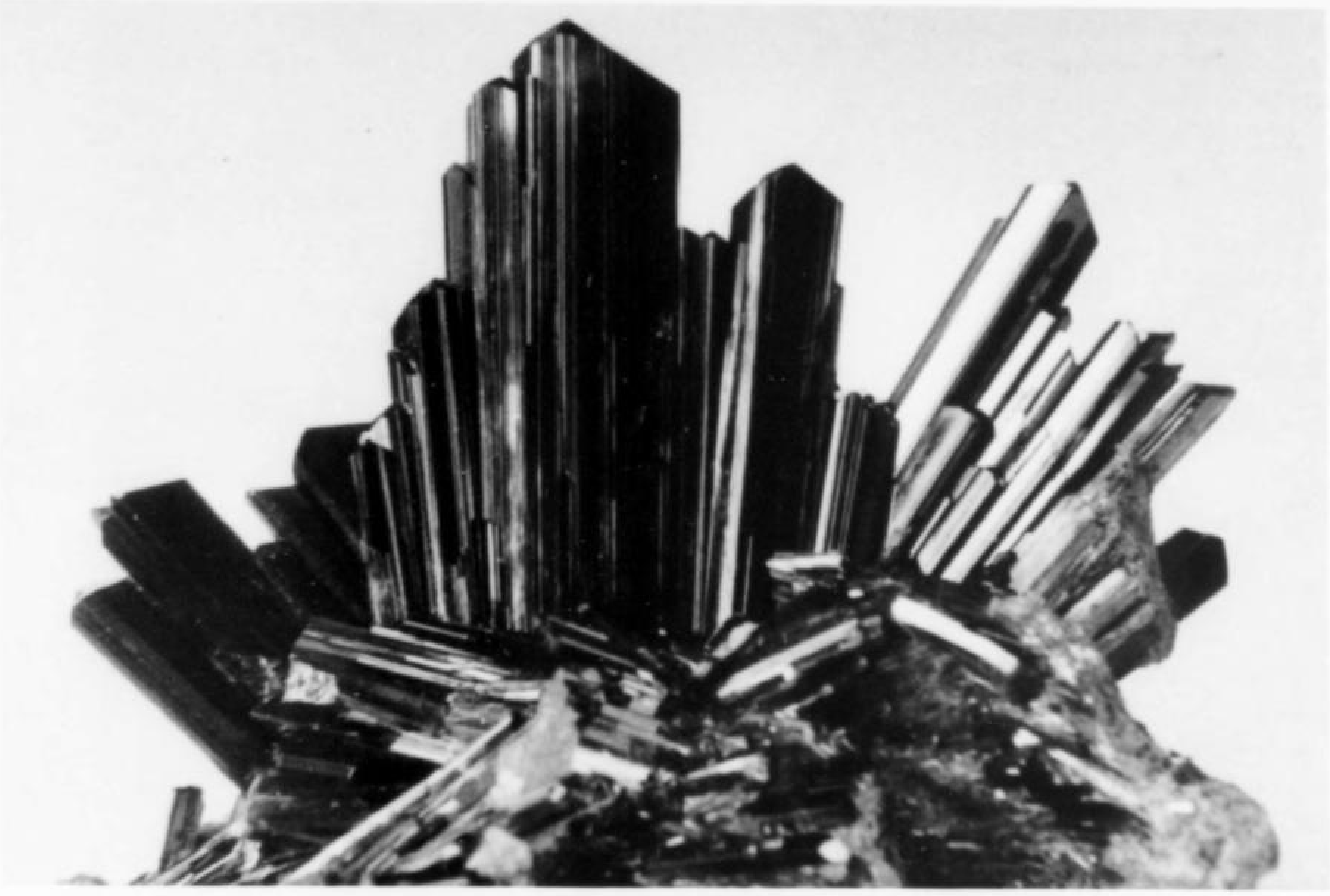


Figure 20. **Epidote crystals to 5 cm, found in 1871. Kontrus collection.**

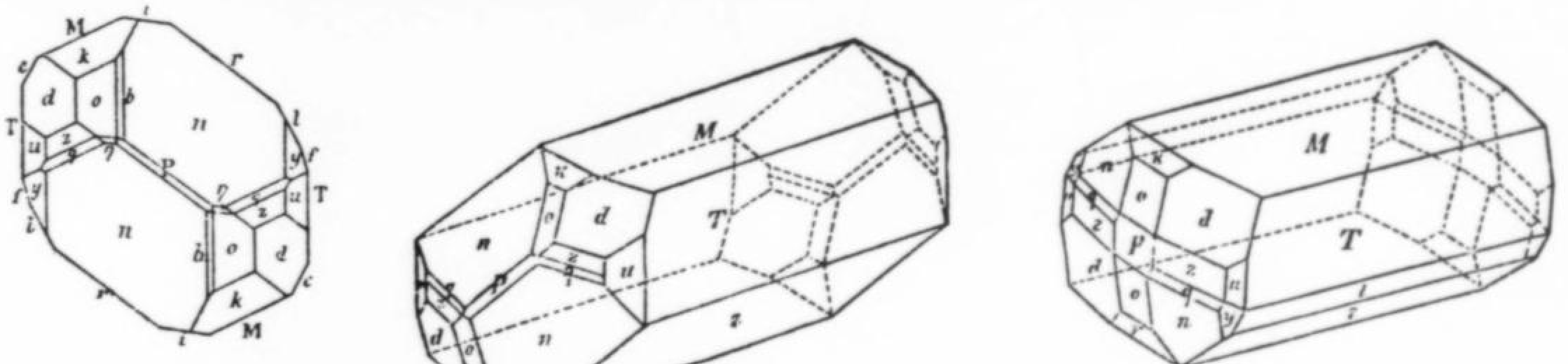


Figure 21. **Knappenwand epidote crystal drawings from Bücking (1878) and Kokscharow (1880).**

Two generations have been recognized, one being water-clear and idiomorphic, and the other milky and heavily included. Our analyses have shown 1.7 to 2.6% F and 0.07% Cl.

Galena PbS

A few millimeter-size crystal aggregates of galena have been found on epidote crystals. Very rare.

Molybdenite MoS_2

Very small, thin crystal plates of molybdenite to less than 1 mm in size have been found with scheelite in small clefts. Very rare.

Orthoclase $KAlSi_3O_8$

Orthoclase, as the clear variety adularia, is known as small, lustrous, white to transparent crystals to 1 millimeter in size. They form thin crusts on albite, epidote and calcite. Microcrystals perched on actinolite crystals make interesting micromounts. Due to the low potassium content of the country rock, orthoclase is much rarer than albite.

Quartz SiO_2

Colorless to milky quartz occurs mostly as coarse cavity fillings intergrown with chlorite, epidote and actinolite. Calcite is often associated as well. Water-clear well-formed crystals are encountered rarely, generally with chlorite and titanite and almost never with epidote crystals. The crystals, in some cases doubly terminated, may reach 10 cm in length and are commonly zoned with chlorite inclusions. Around the year 1900, some skeletal crystals to 20 cm were found with inclusions of byssolite.

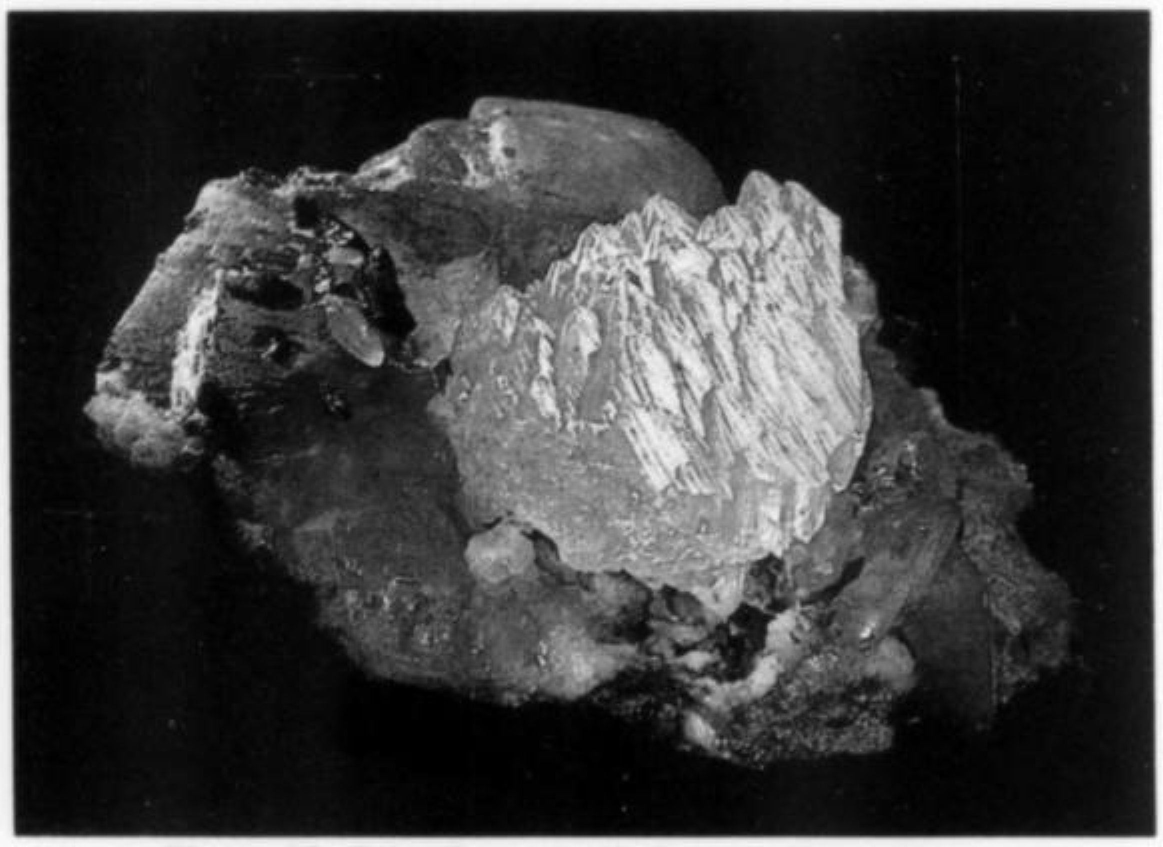


***Figure 22.* Scheelite crystal, 3 cm, with epidote and calcite. Natural History Museum of Vienna collection.**

Scheelite $CaWO_4$

Water-clear to milky white and yellow-brown crystal aggregates of scheelite have been found, mostly with corroded surfaces. These aggregates are usually under 1 cm in size. Crystals 3 to 5 cm in size are known in some old collections. Scheelite has only been found in certain areas of the tunnel. Crystals fluorescing yellow-green (molybdenum-bearing) and blue-white are known to occur.

Titanite $CaTiSiO_5$

Thin, tabular crystals of titanite having a pale yellow to yellow-green color have been found on rare occasions. Both twinned and untwinned crystals occur, mostly in clefts where epidote is not prominent. Crystals range up to 2.5 cm in size.

***Figure 23.* Titanite crystal, 1.5 cm, on quartz from cleft no. 26. Natural History Museum of Vienna collection. Photo by Rainer Bode.**

***Table 1.* Minerals found at Knappenwand.**

Rock-forming Minerals	Ore Minerals
Albite	Azurite
Amphibole	Bornite
Andradite	Cerussite
Biotite	Chalcopyrite
Calcite	Cyanotrichite
Clinochlore	Galena
Diopside	Glaucodot
Epidote	Ilmenite
Fluorapatite	Magnetite
Hastingsite	Malachite
Quartz	Marcasite
Titanite	Molybdenite
Tourmaline	Pyrite
Zircon	Pyrrhotite
	Scheelite
	Sphalerite

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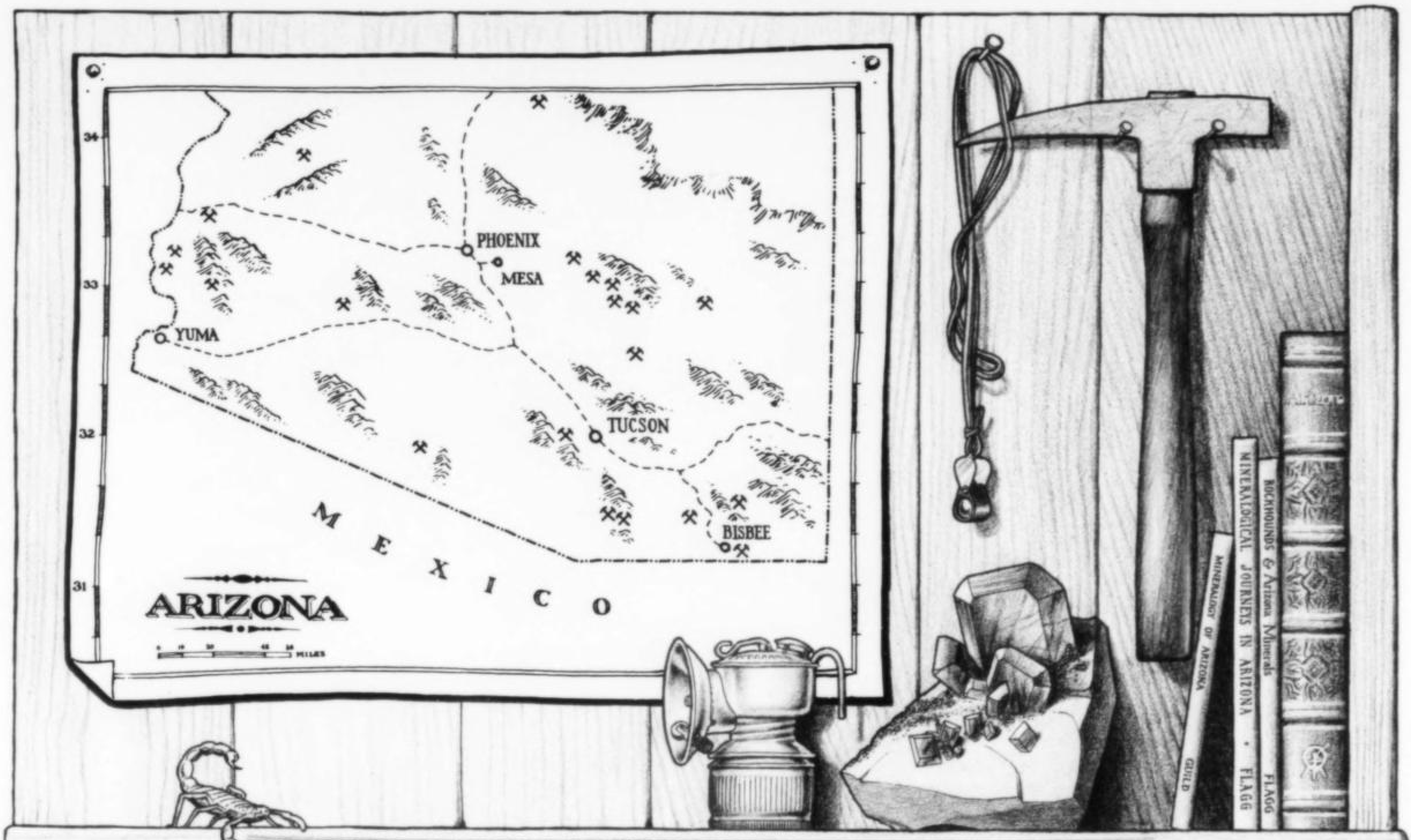

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New mineral occurrences from the LAURIUM SLAGS

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The slags which resulted from ancient mining and smelting of ore at Laurium, Attica, Greece, have produced many rare and exotic microminerals. Discoveries there continue to be made, and the list of known species has grown to more than 60.

INTRODUCTION

Since the lead oxychloride minerals laurionite, paralaurionite, fiedlerite and penfieldite were first described from Laurium[1] in the late nineteenth century (1887–1899), over 60 minerals from the Laurium slags have been reported (Table 2).

Laurium has long been noted as a prolific producer of lead and silver in the ancient world. The application of lead isotope analyses to copper and bronze artifacts by Gale and Stos-Gale (1982) suggests that Laurium was also an important bronze-age copper source in the Mediterranean. The major copper ore at Laurium was massive azurite and malachite, examples of which may still be collected at Kamariza.

Because of the relatively high lead-copper-silver content of the slags and the effect of sea water as an oxidizing agent, 34% of the reported slag minerals are lead, copper or lead-copper oxychloride compounds. Another 14% are lead arsenate-chloride compounds (Table 1). The chloride compounds, comprising the bulk of collectible Laurium slag minerals, are found in very few localities worldwide and in very limited quantities. Some of the slag minerals (georgiadesite, nealite, fiedlerite and the new mineral, thorikosite) are unique to Laurium.

The purpose of this article is to describe recently observed variances in habit and color for some Laurium minerals previously reported; to update the list of known Laurium slag minerals; to describe occurrences of some Laurium minerals recently characterized; and to describe some unidentified species.[2] The identities of the minerals described here have been determined by X-ray diffraction analysis or, in a few cases, by SEM energy-dispersive analysis. The crystals range in size from 0.1 mm to 3.0 mm. All of the slag minerals are of micromount size, requiring magnification of at least 10X for study.

NEW COLOR VARIATIONS

Aragonite $CaCO_3$

Aragonite occurs as short, arrowhead-shaped, acicular, bright orange crystals. It is normally colorless to white at Laurium.

Cerussite $PbCO_3$

Cerussite has been found as single, tabular, transparent, sherry-colored crystals; spear-shaped, sherry-colored, prismatic crystals in parallel growth; short, opaque, sherry-colored, rounded crystals forming stellate clusters; opaque, yellow, elongated and striated crystals forming V-twins; and twinned yellow-orange crystals with a tabular habit. Kohlberger (1976) describes red masses (colored by iron oxide) of cerussite as a supergene mineral. The normal color

---

[1] The names Laurium, Laurion and Lávrion are essentially interchangeable, although Laurium is the classical form and most applicable to the ancient mines themselves. The present-day town of Lávrion, formerly Ergasteria, was not founded until the nineteenth century when the mines were reopened.

[2] Kohlberger provides an excellent and detailed explanation of slag mineralization in "Minerals of the Laurium Mines, Attica, Greece," *Mineralogical Record,* May-June 1976. "Questionable Minerals," by Hugh Heron in the *South African Lapidary Magazine,* June 1981, provides a broad, in-depth perspective on exceptions (including Laurium minerals) to the principles governing the determination of the validity of mineral species.

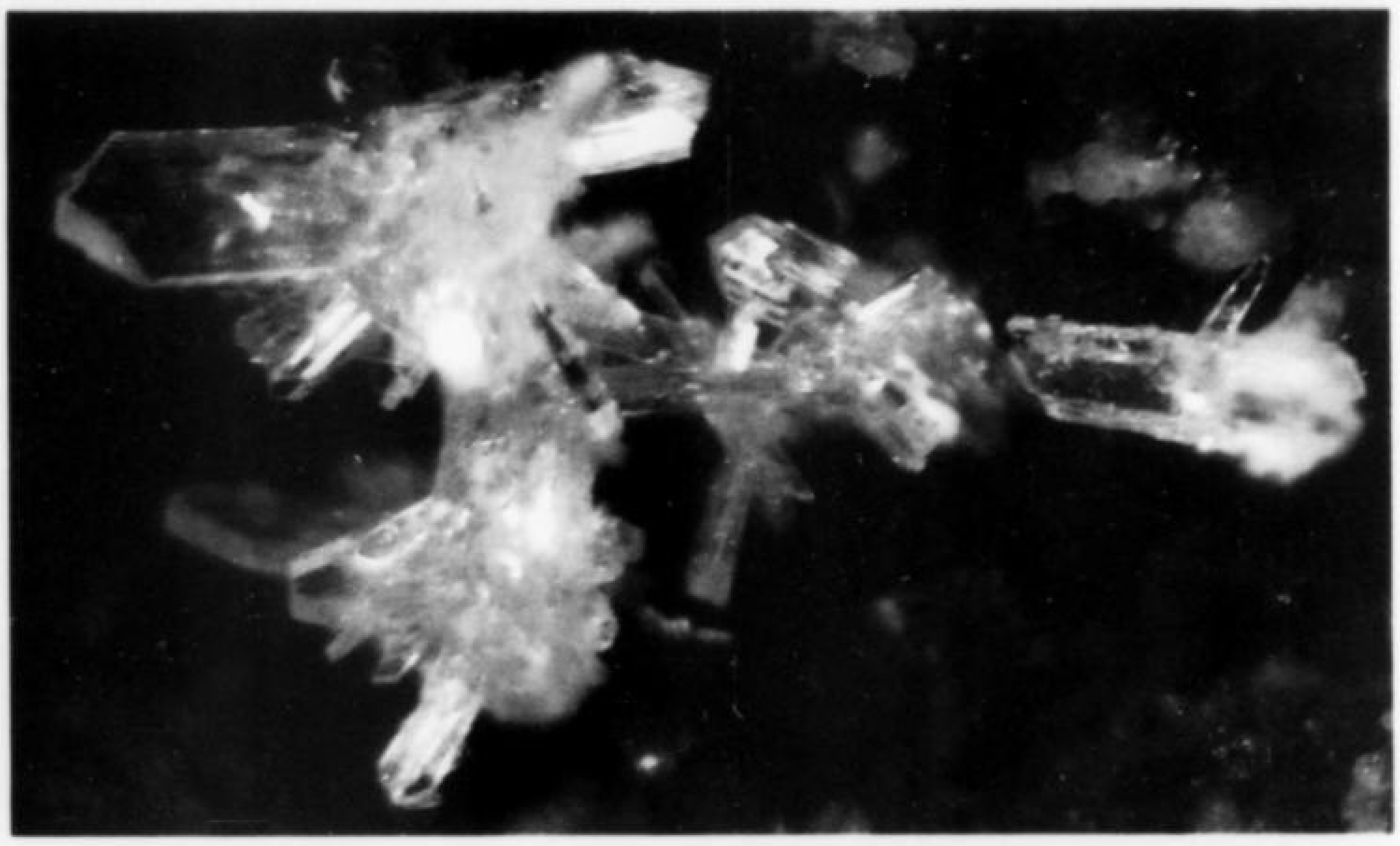


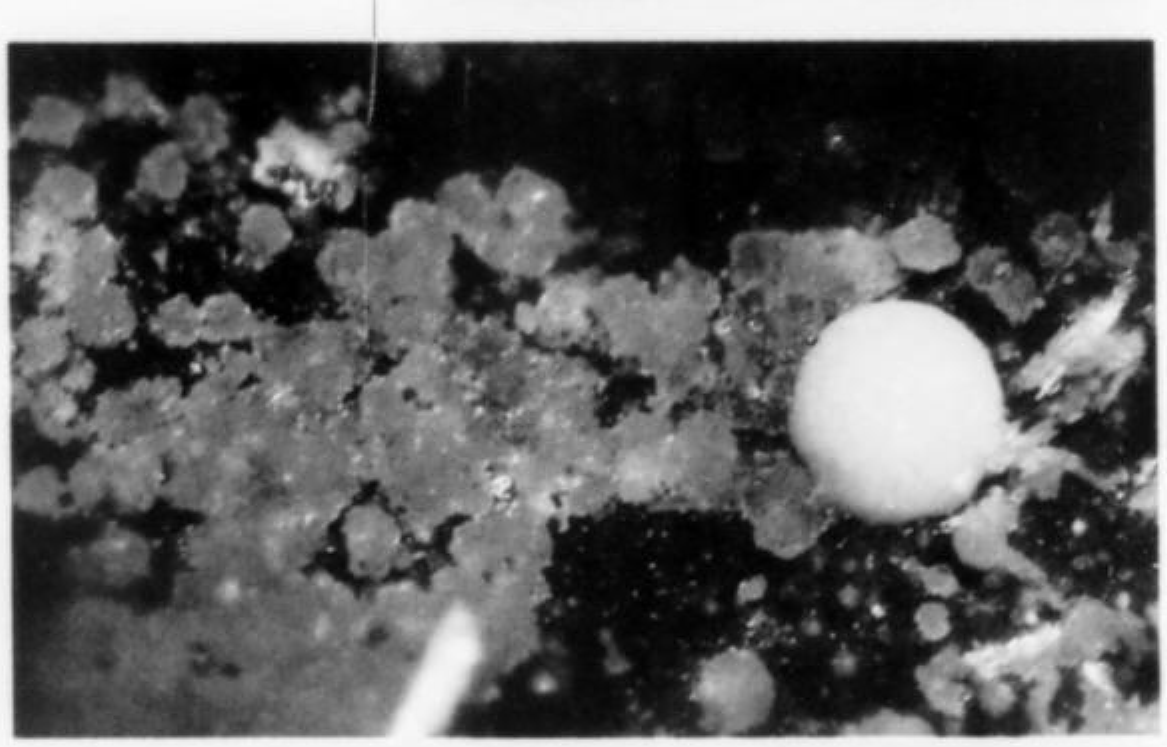
Figure 1. (Upper left) **Yellow thorikosite overgrowth on laurionite crystal, 0.4 mm. Collected by Piet Gelaude.**

Figure 2. (Upper right) **Nealite crystals to about 0.2 mm; Piet Gelaude specimen.**

Figure 3. (Left) **Yellow thorikosite overgrowth on paralaurionite, 1.1 mm, with cerussite.**

Figure 4. (Right) **Acicular mammothite to 0.3 mm on phosgenite.**

Figure 5. (Below left) **Diaboleite crystals to 0.5 mm; collected by Piet Gelaude.**



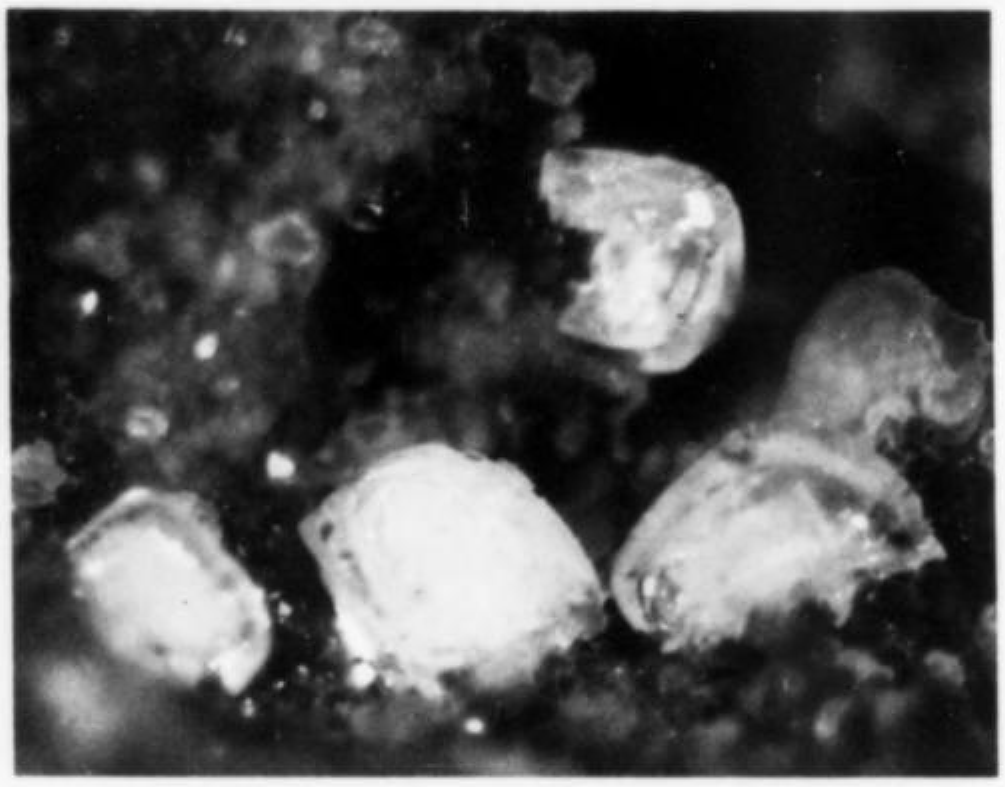


Figure 6. (Above right) **Bright green paratacamite with pale green sphere (0.15 mm) of an unidentified mineral. Collected by Piet Gelaude.**

Figure 7. (Left) **Thorikosite-like unknown, crystal group 0.6 mm.**

Figure 8. (Right) **Ludlockite-like unknown, group of sprays, 0.5 mm.**

Figure 9. **Location map.**

for Laurium cerussite ranges from colorless to milky to grey. Cerussite is second to aragonite in abundance among the slag minerals.

Ecdemite-Heliophyllite $Pb_6As_2O_7Cl_4$

Ecdemite-heliophyllite occurs as cream to gray, rounded platelets and rounded foliated masses with an adamantine luster. The normal color reported for both ecdemite and heliophyllite is yellow-green to yellow. Ecdemite and heliophyllite cannot be distinguished from one another by X-ray powder methods; they are usually found as associated intergrowths.

Hydrocerussite $Pb_3(CO_3)_2(OH)_2$

Hydrocerussite forms clear, sherry-colored, discoidal crystals in radiating clusters. The normal color range is colorless to white.

Laurionite $PbCl(OH)$

Laurionite has been observed as thick, tabular, transparent, sherry-colored single crystals with both pyramid and pinacoid terminations; also white, opaque (with a powdery appearing surface), elongated, prismatic crystals with pyramidal terminations. Laurionite is usually colorless to light gray.

Paralaurionite $PbCl(OH)$

Paralaurionite occurs as transparent, bright yellow, thin and tabular prismatic crystals. Most yellow paralaurionite crystals observed are twinned and are commonly associated with boleite. Paralaurionite is usually colorless to light gray.

NEW HABITS

Anglesite $PbSO_4$

Anglesite has been found as short, tapering, milky colored prismatic crystals with etched and rounded terminations which are a dull, opaque gray-white; also as colorless, thin, square, tabular crystals. Anglesite is usually found at Laurium as colorless, very sharply terminated prismatic crystals, and also, more rarely, as small, colorless, equant crystals.

Aragonite $CaCO_3$

Pseudohexagonal twins of aragonite in elongated, striated, transparent, prismatic, single crystals and in radiating groups of trans-

Figure 10. **Reconstructed ore washing tables at the Thorikos excavation, Laurium.**

Figure 11. **Replica of a mine marker found in the Aglia Trias Valley excavation. The original will be on exhibit in the Laurium Museum. The inscription, roughly translated, reads: "ASKLIPIAKON MINE, NOW OWNED BY SIMOS." The mine was named for Asklipios, god of health.**

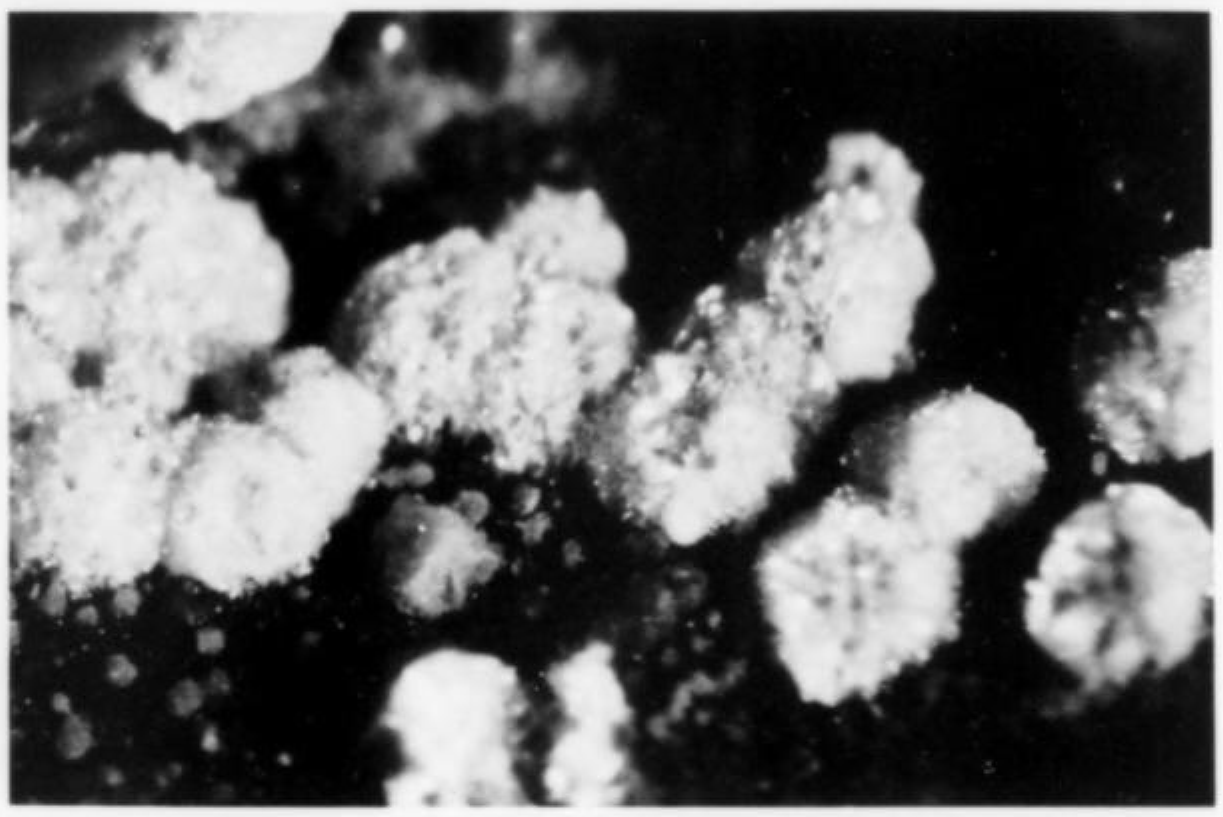


Figure 12. **Cream-colored tufts of ecdemite-heliophyllite. The field of view is about 3 mm across. (All specimens, except as noted, were collected at Laurium by Robert and Norma Jaxel, and were photographed by Norma Jaxel.)**

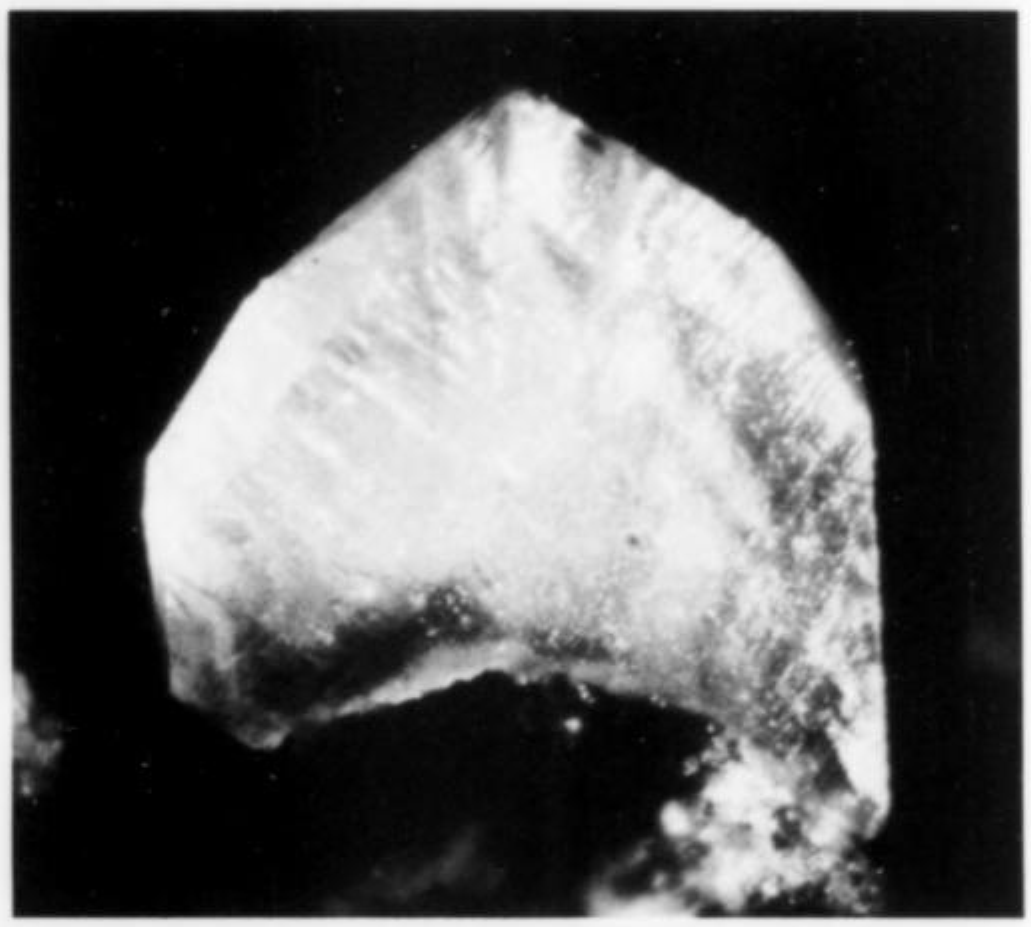


Figure 13. **Laurionite, pale sherry-colored crystal, 0.7 mm.**

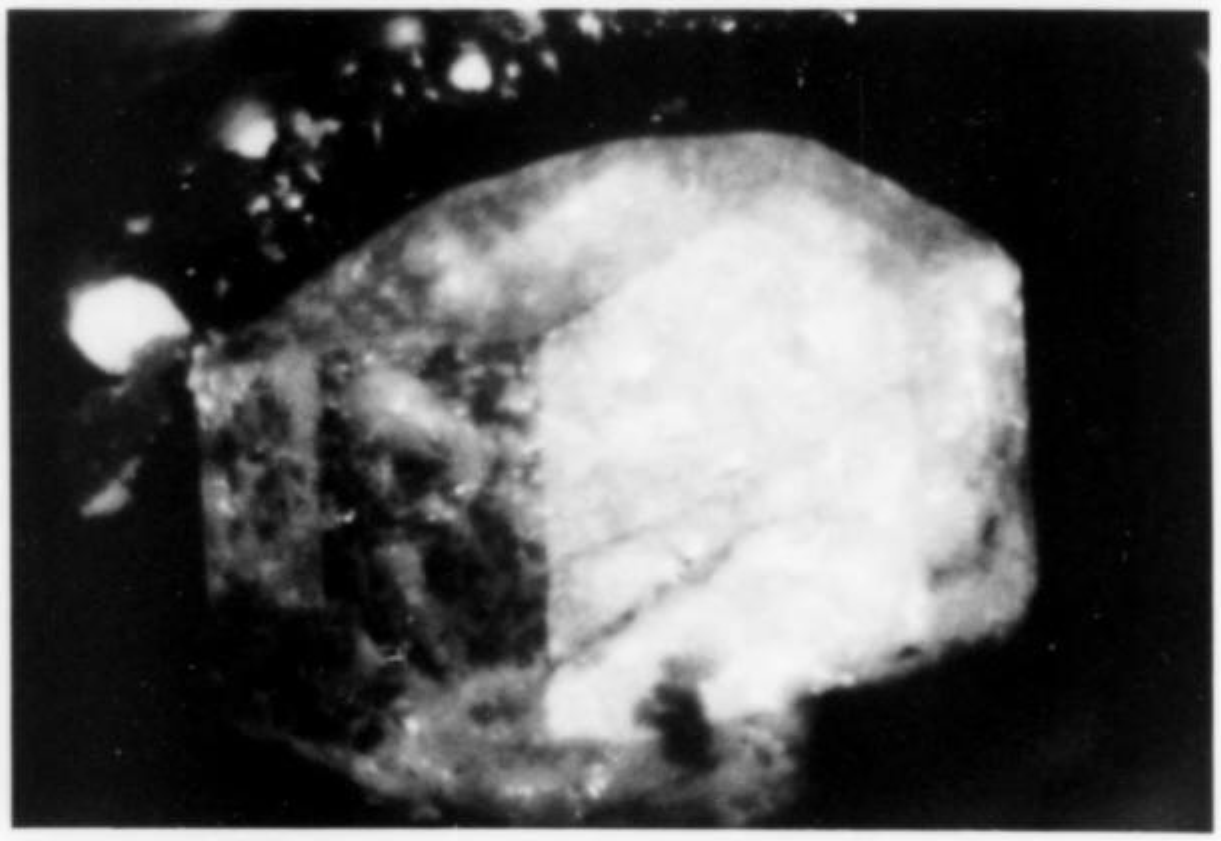


Figure 14. **Cotunnite, colorless transparent crystal, 0.5 mm.**

parent, short, stubby pseudohexagonal crystals have been collected. Also thin, prismatic crystals with high luster, with smaller crystals branching from the *c* axis at regular intervals. X-ray data show that these crystals have a slightly larger unit cell than normal aragonite, but that they are much closer to aragonite than cerussite. Based on observations of collected slag minerals, aragonite is the most common and abundant slag mineral and is usually found at Laurium as elongated, white, acicular, fibrous to stalactitic, divergent, radiating groups and sprays.

Calcite $CaCO_3$

White, isolated, blocky single crystals and aggregates of cream-colored to white, opaque calcite rhombs appearing very close to cubic in crystal habit have been seen. Calcite has previously been described from Laurium in rhombic and scalenohedral habit as both aggregates and single crystals. Calcite is the least common carbonate slag mineral.

Cotunnite $PbCl_2$

Cotunnite has been found as opaque, white to gray, single, dipyramidal, doubly terminated, equant crystals in both stubby and elongated habits. Also flattened, hoppered, distorted, equant, dipyramidal crystals. Cotunnite has previously been described from Laurium as prismatic crystals, in clusters or in parallel growth.

Diaboleite $Pb_2CuCl_2(OH)_4$

Transparent, light blue, thin columnar to acicular crystals of diaboleite have been found; also rather large (1 mm), blue, tetragonal shaped, columnar crystals tapering almost to a point at one end, commonly associated with mammothite. Some crystals are twinned and transversely striated. Most columnar diaboleite has a darker blue "cap" on the termination. Descriptions of diaboleite from Laurium and elsewhere depict a tabular habit with square outline.

Galena PbS

Flattened, elongated galena crystals with arborescent habit, very similar in appearance to arborescent silver or gold crystals, have been collected.

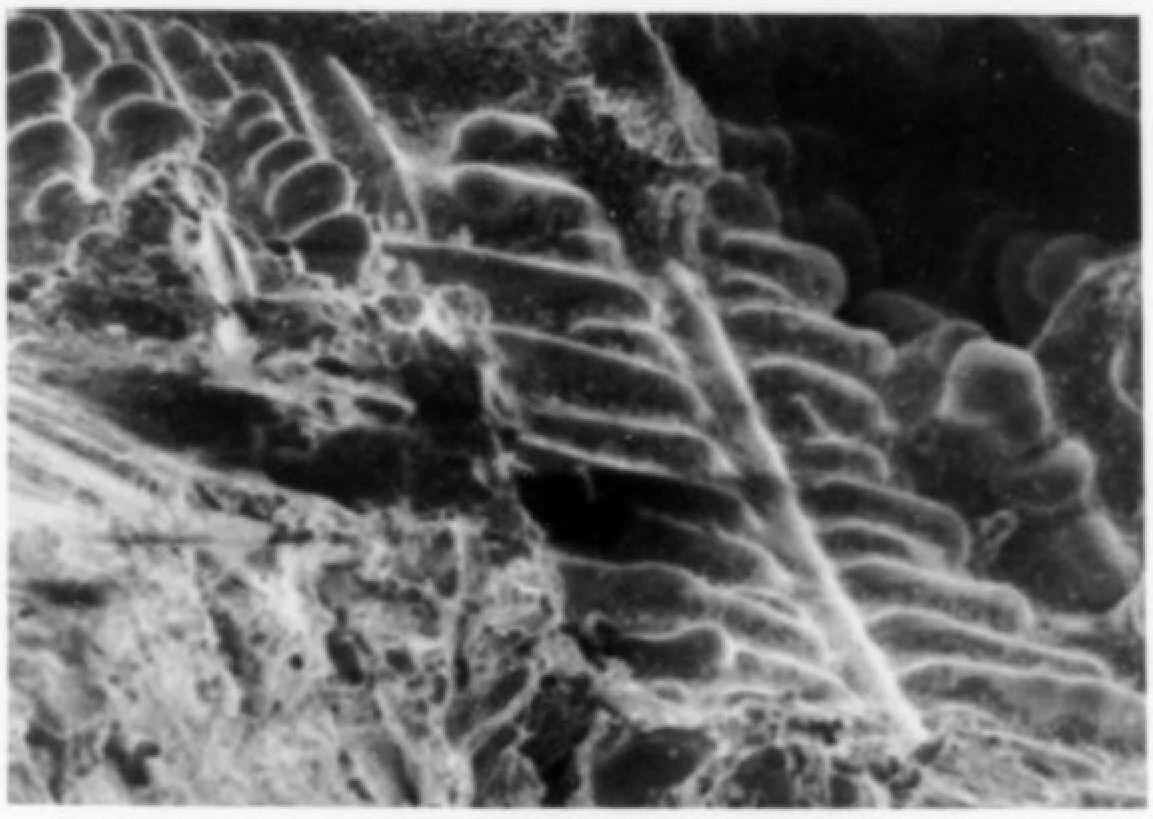


Figure 15. **Galena showing arborescent habit, about 0.8 mm across. SEM photo by W. Bohyn; Piet Gelaude specimen.**

Hydrocerussite $Pb_3(CO_3)_2(OH)_2$

Hexagonal hydrocerussite crystals with steep pyramidal faces topped with a pinacoid have been collected. Laurium hydrocerussite has previously been reported as extremely thin, hexagonal plates and thin clusters or rosettes of platelets.

Laurionite PbCl(OH)

Radiating groups of extremely thin, doubly terminated, colorless, prismatic laurionite crystals having both spear-shaped and sharp rounded terminations are known (some of the spear-shaped crystals have overgrowths of the rounded crystals); also bundles or sheaflike aggregates of these crystals which have a bow-tie appearance. Laurionite has previously been described as tabular, single and composite crystals.

Litharge PbO

Distinct, opaque, red rinds of litharge occur growing around balls of native lead in a slag matrix. Litharge has been previously reported as red-orange, earthy to scaly and massive, intergrown with massicot (which is dimorphous with litharge).

Nealite $Pb_4Fe(AsO_4)_2Cl_4$

Nealite has been found in fan-shaped aggregates and bow ties of yellow to red sheaf-like crystals; also tiny (0.3 to 1 mm), rose, yellow-orange, and red, needle-like crystals in thin, elongated, rod-shaped clusters composed of long and shorter needles, sometimes as a compact group. Crystals are mostly bright, sometimes dull; the color of the crystal groups ranges from rose to orange and red. Tiny white balls sometimes covering acicular nealite have not been identified. Nealite has been previously reported as prismatic or bladed crystals in radial or parallel growth.

Paratacamite $Cu_2(OH)_3Cl$

Small, opaque to translucent, bright blue-green balls and spherules of paratacamite have been collected. It has previously been described from Laurium as tiny, dark green, needle-like, intergrown spherical clusters; and as a very dark green aggregate overgrown on a mineral of the boleite group.

NEW OCCURRENCES

Amphibole Group

Amphibole occurs as blue-black, prismatic crystals. Amphibole species cannot be determined solely by X-ray techniques; this amphibole has not been chemically analyzed. It is an original slag constituent.

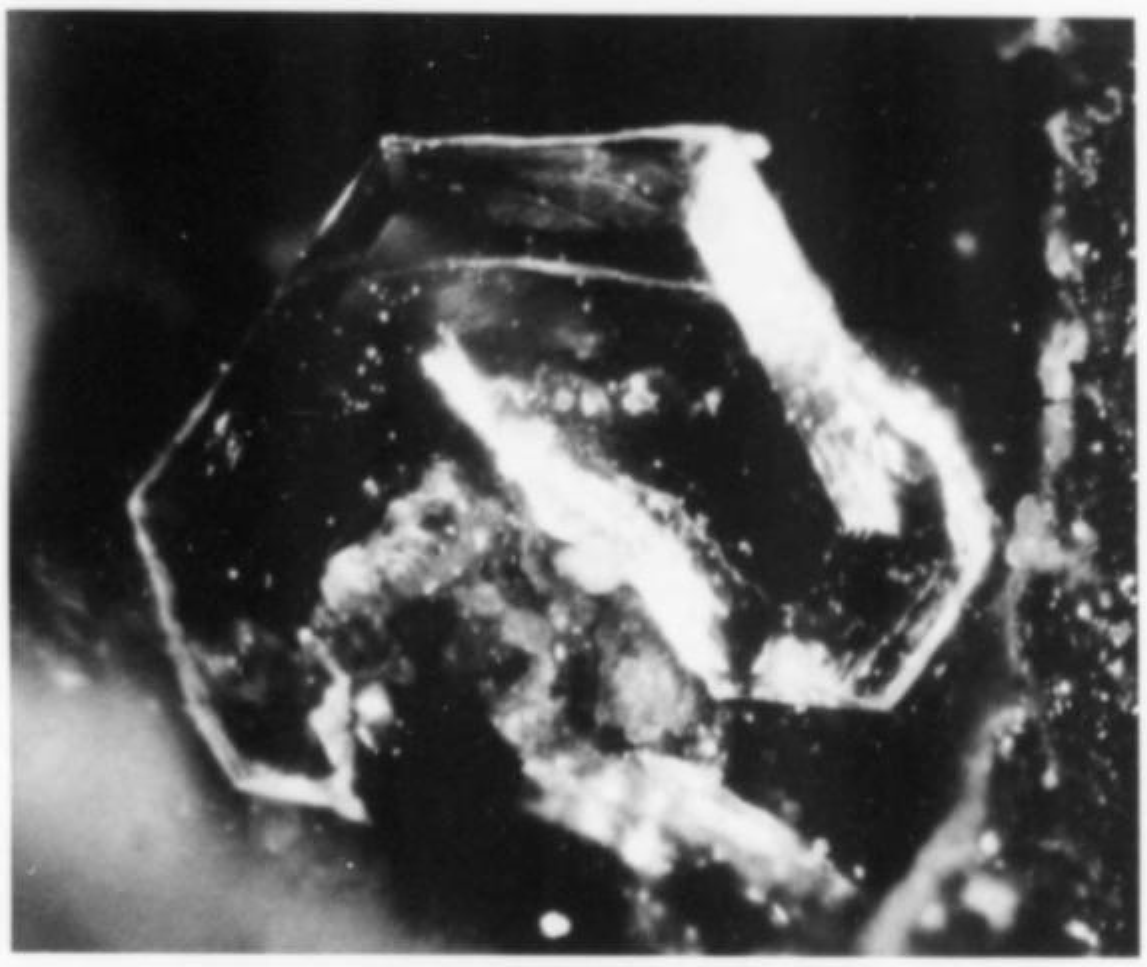


Figure 16. **Hydrocerussite, pyramidal crystal about 1.2 mm across.**

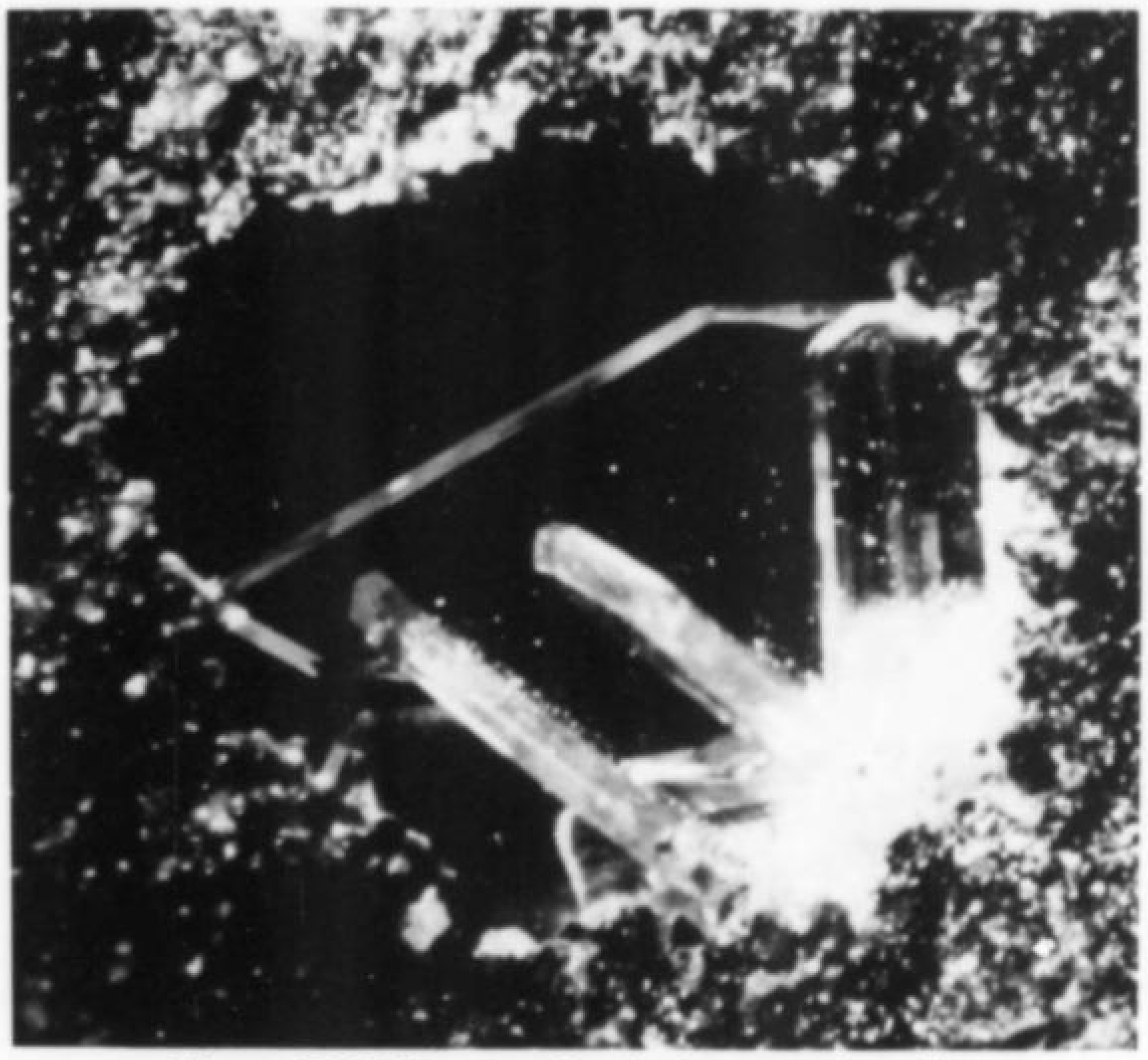


Figure 17. **Yellow paralaurionite crystals to 1.8 mm.**

Clinopyroxene Group

A probable member of the diopside-hedenbergite series has recently been found; it occurs as massive, glassy, yellow-green, and brownish green inclusions in slag associated with hematite. The clinopyroxene is an original, unaltered constituent of the slag.

Hematite Fe_2O_3

Hematite forms bright red, thin, massive coatings and thin plates with ragged edges in slag vugs. X-ray diffraction shows that the hematite is associated with halite (probably from sea water).

Mimetite $Pb_5(AsO_4)_3Cl$

Mimetite occurs as small, cream to tan balls of acicular crystals in a red, glassy, slag matrix associated with laurionite and massive massicot.

Symplesite $Fe_3(AsO_4)_2 \cdot 8H_2O$

Small, dark olive-green, compact, acicular aggregates of symplesite occur associated with undetermined red and red-yellow lead oxides (probably massicot-litharge).

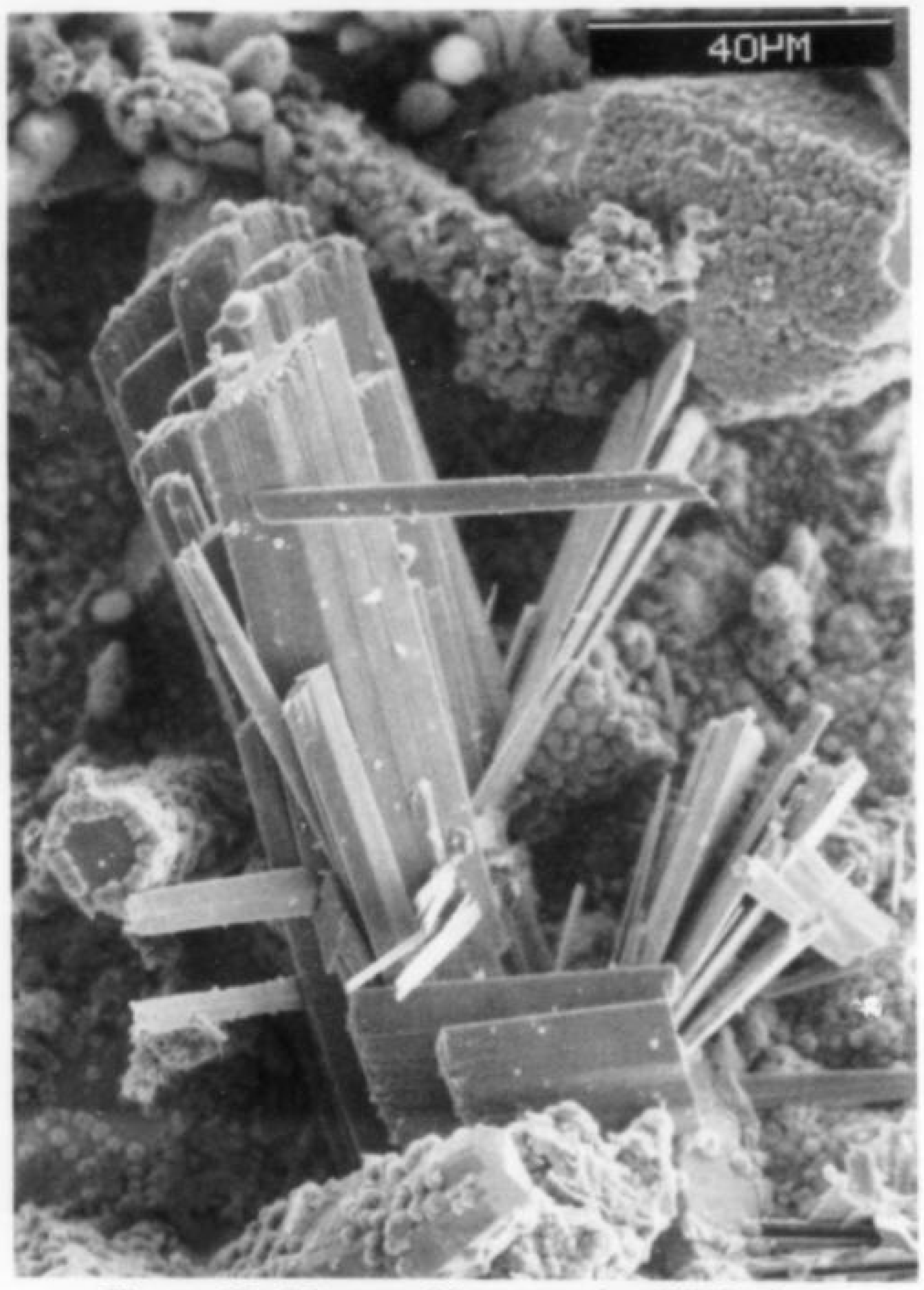


Figure 18. **Mammothite crystals; SEM photo courtesy of Pete J. Dunn.**

TWO NEW SPECIES

Mammothite $AlCu_4Pb_6Sb(SO_4)_2Cl_4(OH)_{18}$

Mammothite is a recently described blue, monoclinic mineral initially reported from both Laurium and the Mammoth mine, Tiger, Arizona (Peacor *et al.,* 1985). The majority of specimens seen from Laurium consist of light to medium blue druses of acicular crystals, in contrast to the more equant to tabular crystals from the Mammoth mine. Laurium mammothite is associated with (sometimes as overgrowths on) laurionite, paralaurionite, phosgenite, fiedlerite, penfieldite, boleite and diaboleite in slag vugs.

Thorikosite $(Pb_3Sb_{0.6}As_{0.4})(O_3OH)Cl_2$

Thorikosite is a newly described tetragonal species known only from Laurium (Dunn and Rouse, 1985). The formula has been verified by crystal structure analysis (Rouse and Dunn, 1985), and this has shown that thorikosite has a close relationship to many minerals from Långban, Sweden, all of which are also structurally related to certain synthetic bismuth oxyhalides.

Thorikosite forms pale to bright yellow, transparent, prismatic crystals with rounded and sometimes striated terminations; striations are diagonal across the termination. Associated minerals include aragonite, cerussite, ecdemite, hydrocerussite, an unknown mineral with sphalerite–fluorite-like structure, and unknown yellow discoids showing a thorikosite-like X-ray powder pattern.

Thorikosite is also found as bright to dull, thin, yellow-orange overgrowths on (sometimes intergrown with) laurionite and paralaurionite. Bright, yellow lollipop-like tips of thorikosite also form on paralaurionite crystals. We have noted that thorikosite has an affinity for laurionite and paralaurionite (more commonly) in the form of repeated overgrowths. A number of these overgrowths (and a few intergrowths) were confirmed using X-ray diffraction techniques. The affinity of thorikosite for these two minerals is perplexing, but clearly established, based on numerous observations and tests.

Thorikosite is named for the ancient Athenian mining town of Thorikos (5th century B.C.), which was an industrial complex for processing ore for lead and silver, located about 2 kilometers north of the modern town of Lávrion. The type specimen was found by one of us (RJ) in October 1980 on a beach about 7 to 8 kilometers south of Thorikos.

Because there are other Laurium minerals which could easily be confused with thorikosite, we include here a statement from Pete J. Dunn of the Smithsonian Institution.

> It should be noted that a number of compounds, as yet unstudied, yield X-ray powder diffraction data *very* similar to that of thorikosite (Dunn and Rouse, 1985). These samples, consisting of tiny aggregates of curved and/or tetragonal-like crystals have a predominantly yellow-orange color. Because of the uncommon solid solution relations between Pb, As and Sb in thorikosite, it cannot be stated with any degree of certainty that these minerals, shown to be related to thorikosite by X-ray powder data, are indeed thorikosite, or separate species. Much work remains to be done before these relationships are clear.

UNKNOWNS

Unknown Red-Orange Mineral

Beautiful red-orange spherules and balls of acicular crystals in brown-red glassy slag vugs occur associated with aragonite, laurionite, paralaurionite, cotunnite and unknown bright yellow balls with protruding acicular crystals which are probably mimetite by observation and association. The compact red spherules are deep-red, but the more acicular (less densely aggregated) crystals are a yellow-orange color. The crystals are dichroic with red and yellow pleochroic colors. This red mineral yields an X-ray powder pattern having strong similarities to ludlockite.

Unknown Foliated Mineral

Colorless to white, foliated, thin plates, in rough hexagonal outline with ragged edges, like bruised hydrocerussite in appearance, occur associated with aragonite, cerussite and an unknown yellow mineral. X-ray data resemble those of plumbonacrite and hydrocerussite.

Unknown White Cottony Material and Colorless Botryoids

White, amorphous, cottony masses have been found, some with rough cubic shape, and white, rounded cottony balls; also colorless to white, opaque, rounded botryoids similar in appearance to common opal. The opal-like mineral forms distorted rods with rounded terminations, like mushrooms, and small, rounded balls, joined to form curved rods like a string of pearls. Infrequently, the white amorphous material will form with and as a topping on the colorless rods so that the resulting crystals look like cotton-candy on a stick. Both of these minerals are poorly crystallized and fail to give sharp X-ray diffraction patterns, though the patterns do suggest a sphalerite–fluorite-like structure.

Unknown Red Platy Mineral

Deep red, radially structured spherules of platy, brittle, bladed crystals in slag matrix have been found. This mineral is still under study, but preliminary analyses suggest that it is a monoclinic Fe-Pb chloroarsenate. It occurs associated with a greenalite-like mineral.

Unknown Pseudohexagonal Mineral

A lead mineral has been found in colorless, doubly terminated, tapering crystals with hexagonal appearance, though it may not have true hexagonal symmetry. The crystal submitted for analysis proved too small to fully describe. It has one perfect cleavage, easily produced, and is very soft (2 Mohs). It contains only Pb and Ca

Table 1. **Frequency of distribution of minerals found in the slags***

	Number	Percent
Native Elements	2	3
Sulfides	3	5
Oxides, Hydroxides	9	14
Chlorides	22	34
Carbonates	9	14
Sulfates	5	8
Arsenates	9	14
Silicates	5	8
*Compiled from Table 2.	64	100

(among the elements with atomic number greater than 9). Preliminary analysis indicates Pb approximately 70 weight % and Ca approximately 1 to 2%. The strongest lines in the X-ray powder diffraction pattern are, in order of decreasing intensity, 3.32, 2.63, 2.07, 1.80, 4.15, and 3.10Å (Pete J. Dunn, personal communication, 1984).

Unknown Yellow Minerals

Flattened, bright yellow or yellow-orange tetragonal-shaped crystals of an unknown mineral have been found; also as rounded, discoidal, stellate aggregates of yellow crystals; also as bright yellow overgrowths on an adamite-like mineral which is as yet unidentified. Preliminary analysis suggests that these minerals may be related to thorikosite.

AN INVITATION TO FORM A LAURIUM SOCIETY

The authors would like to hear from other Laurium collectors on the topics generally covered in this report for the purpose of forming a loosely knit "Laurium Society" to maintain the slag mineral listing, publish significant mineral finds, and exchange information on Laurium. When one of us (RJ) visited Lávrion in May, 1984, he was informed that a new museum will open there in 1986 or 1987. The museum curator, Dr. Evagelos Kakavoyiannis, a scientist grounded in traditional archeology but also with a strong appreciation of the importance of industrial archeology, is also in charge of the excavations of the extensive ancient mining sites, industrial villages, ore processing facilities and workshops in the Aglia Trias Valley about 6 km from Lávrion.

Most of the ancient ruins are in a very good state of preservation and it is hoped that important archeological artifacts and sites will be uncovered which will provide more information on the ancient Laurium mines. An ancient mine marker discovered in recent years will be displayed in the museum. A copy of the mine marker is displayed close to the mine site where it was found. The museum will display many of the ancient artifacts found at the archeological sites and in the mines (mining lamps, tools, etc.) and an exhibition on the history of Laurium is in preparation. Two large ore washing tables have been reconstructed at the Thorikos excavations which are very close to the modern town of Lávrion. Of related interest, an important and exhaustive new book, *Le Laurium Antique Et La Technique Grecque De La Production De L'Argent,* by Constantine Conophagos, published by the Polytechnical University of Athens (April 1980), is available in French or Greek and makes worthwhile reading on the history of the mines and mining operations in the ancient Laurium area.

ACKNOWLEDGMENTS

The authors are especially indebted to Pete J. Dunn for performing the analytical tests which resulted in the identification of the Laurium minerals described here, for his support and encouragement which helped greatly in writing this article, and for supplying the SEM photo of mammothite. W. Bohyn of Ghent University Laboratorium voor Elektronmicroscopie supplied the SEM photo of galena. The late Neal Yedlin was for many years a basic source of information on the Laurium slag minerals and his enthusiasm in sharing knowledge of these minerals provided inspiration to all Laurium collectors. Roger Harker (now deceased) supplied maps to collecting sites, and information on an unknown mineral he collected at Laurium in 1978. Evagelos Kakavoyiannis was very generous in sharing his extensive knowledge of the ancient Laurium mining sites and related sources of information. Randolph Rothschild

Table 2. **Minerals found in the slags.**

	Reported Source		Reported Source
Native Elements		*Carbonates*	
Copper	3	Aragonite	2, 3, 4
Lead	2, 3	Tarnowitzite	4
Sulfides		Calcite	2, 3, 4
Covellite	4	Cerussite	2, 3, 4
Galena	3, 7	Hydrocerussite	1, 2, 3, 4, 5
Sphalerite	4	Leadhillite	3
Oxides, Hydroxides		Phosgenite	1, 3, 4, 5
Creedite	4	Smithsonite	4
Cuprite	3	Strontianite	3
Feroxyhyte	4	Susannite	3
Goethite	3, 5	*Sulfates*	
Hematite	2	Anglesite	1, 2, 3, 4
Litharge	2, 3	Connellite	3
Lepidocrocite	4	Gypsum	3
Massicot	3, 4	Lanarkite	3
Minium	3	Macphersonite	2
Chlorides		*Arsenates*	
Atacamite	1, 3, 4	Annabergite	3
Blixite	3, 4	Ecdemite	2, 3
Boleite	1, 3, 4	Georgiadesite	1, 2, 3, 4, 5
Botallackite	3	Heliophyllite	2, 3
Calumetite	3	Mimetite	2, 7
Cotunnite	2, 3	Nealite	1, 2, 3
Cumengite	1, 3, 4	Paulmooreite	4
Diaboleite	1, 2, 3, 4	Symplesite	2
Embolite	4	Unk. Iron Lead	
Fiedlerite	1, 3, 4, 5	Arsenate	
Fluorite	3, 4	(red spherules)	2
Halite	4	*Silicates*	
Laurionite	1, 2, 3, 4, 5	Chlorite	4
Mammothite	1, 2, 4	Diopside-	
Matlockite	1, 3, 4	Hedenbergite	
Mendipite	3, 5	(clinopyroxene)	2
Paralaurionite	1, 2, 3, 4, 5	Hemimorphite	4
Paratacamite	2, 3, 4	Quartz	4
Penfieldite	1, 3, 4, 5	Amphibole	2
Perite	6		
Pseudoboleite	3, 4		
Thorikosite	2		

1. *Mineralogical Record*: Kohlberger (1976), Yedlin (1973), Dunn and Rouse (1980), Peacor *et al.* (1985)
2. Pete J. Dunn, personal communications (1980–1984)
3. *Aufschluss*: Schnorrer-Köhler (1980, Schnorrer-Köhler *et al.* (1981, 1982)
4. *Lapis*: Grolic (1978), Hochleitner (1981a, 1981b), Rewitzer and Hochleitner (1982), Schnorrer-Köhler *et al.* (1985)
5. *Laurium*: Marinos and Petrascheck (1956)
6. Roger Harker, personal communication (1981)
7. W. Bohyn, SEM Analysis, Ghent University

read the draft manuscript and made suggestions for improvement. Norma Jaxel typed several drafts of the manuscript, provided many photomicrographs of each mineral for final selection, and reviewed the article many times for substance and accuracy of content. Finally, thanks are due to the ancient Athenians for serendipitously producing the slag environment where so many interesting minerals have formed.

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Senaite

from the Fazenda Guariba, Minas Gerais, Brazil

J. P. Cassedanne
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INTRODUCTION

Senaite, $Pb(Ti,Fe,Mn)_{22}O_{38}$, has long been known as an accessory mineral of diamond-bearing gravels from the Diamantina area, Minas Gerais, Brazil. The material was first reported by Damour (1856) as "fer titané tantalifère"; 40 years later it was formally described as a new species by Hussak and Prior (1896). The type specimens had been collected from waterworn gravels near Datas. It was subsequently reported (always from stream gravels) from neighboring occurrences at Imbiruçu, Santa Quitéria, Vargeas and Rio Cipó (Metelo, 1968); Riacho das Varas (Hussak and Prior, 1903); and at Curralinho where it is common at the lavra dos Miudos (Ferraz, 1929). It has also been reported in the Precambrian diamond-bearing conglomerates which have been recognized as a source of diamond-bearing gravels (Freise, 1930).

Discovery of senaite in the gold-bearing, platinum-bearing gravels near Serro (Cassedanne and Cassedanne, 1974a) prompted a search for the original outcrop of this mineral. Samples obtained from a Diamantina mineral dealer were the clue to tracking down the source. Description of this occurrence, the first *in situ* in Brazil (and probably in the world) is the purpose of this article.

Previous authors (referred to above) have maintained that senaite always occurs associated with anatase, ilmenite and rutile, either in gravels or in conglomerates. This led Metelo (1968) to postulate that senaite is an alteration product of titanium minerals.

LOCATION

The occurrence is located on the Fazenda[1] Guariba, which belongs to Alysio de Aparecida and is situated south of Presidente Kubitschek village. This village is about 150 km north-northeast of Belo Horizonte and 40 km south of Diamantina (coordinates x = 649.8 and y = 7934.8, Presidente Kubitschek map SE-23-Z-A-VI, 1/100,000 IBGE).

Access is by way of the paved Datas-Serro road, which branches off from BR 259 for a distance of 26.5 km, then on a good dirt road for 6 km to Presidente Kubitschek. The road to Pantina is then taken for 5 km, at which point one must leave the vehicle and proceed further on mule-back. The mule trail passes within a kilometer of some old quartz workings and concludes at an almost invisible foot-path. From there it is a 45-minute hike to cover the remainder of the 3 km separating the occurrence and the place where the vehicle was left.

GEOLOGY

The area is on a high plain composed of elongated domes and rugged mountains. The rocks are relatively free of plant life except for scattered grassy depressions and scarce patches of low forest. Strong erosion has dissected the area. Every valley has been worked and sieved in the search for placer diamonds.

Figure 1. **Location map.**

The rocks belong to the Espinhaço supergroup (Proterozoic, about 1,800 m.y. old). They consist mainly of quartzite with subordinate amounts of conglomerate, phyllite, schist and itabirite (a banded quartz hematite), plus some felsic and mafic metavolcanic rocks. A laterite level occurs near 1160 m elevation. For a regional description see Schobbenhaus *et al.* (1984).

The senaite outcrop lies 40 m below the highland in an irregular, subvertical shear zone running N70°W. The zone is 1 to 2.5 m in width, and is situated on the right bank of Riacho[2] Guariba, a

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[1] *Fazenda* = "farm."

[2] *Riacho* = "creek."

Figure 2. **The senaite exposure in 1982.**

tributary of the Rio Parauna. It intersects the southern part of an elongated hill where white quartzite crops out. The shear zone, covered by a thick eluvium of broken quartz crystals, is penetrated by a series of small pits near 1110 m elevation. These workings are distributed over an area of about 1 hectare.

The western portion of the shear zone (for about 50 m) has been stripped of debris by small irregular excavations. Massive milky quartz coated by translucent to transparent, chlorite-clouded quartz crystals were found there.

In the central portion a 6-meter cut about 3 m wide and deep follows the zone, which here is a stockwork of irregular quartz veins and veinlets. About 15 years ago this section was worked for transparent and chloritic quartz crystals for collectors. Small scattered cavities and fissures lacking a preferential direction are lined with quartz crystals from a more recent stage of deposition; here the senaite, anatase and rutile have been found in place, commonly accompanied by white clay, brown ocherous material and limonite.

To the east (for about 30 m) are many pits exploring for the shear zone, but only quartz has been found there.

Figure 3. **Senaite crystals in a vug in the shear zone.**

MINERALS

Anatase TiO_2

Anatase occurs as short or elongated tetragonal bipyramids 1 to 3 mm in size, bright or waxy in luster, transparent to translucent, and orange to pale brown in color. They are scattered on and in transparent, second-generation quartz crystals.

Kaolinite $Al_2Si_2O_5(OH)_4$

White patches, sometimes iron-stained, are common in voids in quartz crystals. X-ray analysis has shown this material to be relatively pure kaolinite.

Magnetite $Fe^{+2}Fe_2^{+3}O_4$

Small patches of magnetite occur scattered throughout the milky quartz masses in the shear zone.

Pyrite FeS_2

Very small crystals of pyrite have been found as inclusions in transparent quartz crystals.

Figure 4. **Black senaite crystals on quartz; 4.5 cm. All photos and specimens: J. P. Cassedanne.**

Figure 5. **Small, black senaite crystals, 2–3 mm, on quartz.**

Quartz SiO_2

Two stages or generations of quartz crystallization have been identified. The first consists of massive milky quartz crystals, and druses filling the shear zone; the second occurs as irregular crystals and druses lining cavities in first-generation quartz. Smoky quartz is rare.

First-generation quartz is saccharoidal in texture, milky to translucent and odorless when freshly broken. Coarse druses and large (to 20 cm) crystals once mined for piezoelectric quartz are part of the same generation. Some of these larger crystals are transparent and doubly terminated. Some contain bushy aggregates and planar phantoms of included chlorite. Golden yellow rutile needles, clay and limonite are also found as scattered inclusions.

Second-generation quartz followed a weak fracturing of the shear zone filling and is generally separated from first-generation quartz by a thin film of limonite or clay. It occurs as small, transparent to translucent, tabular and in some cases doubly terminated crystals commonly having included chlorite, clay and needles and plates of rutile.

Rutile TiO_2

Rutile occurs as acicular and tabular crystals and fibrous masses in quartz and as isolated, bright red rods. Radiating groups of needles in quartz are common, sometimes originating at a senaite crystal. Parallel groups of needles are known as well. Felted masses and reticulated sheets of needles coat some quartz crystals.

Rutile pseudomorphs after anatase occur as typical, short, tetragonal bipyramids to 5 mm, alone or in groups, sometimes lightly rounded and always having a corroded appearance. These consist of densely packed, orange-pink to golden yellow needles of rutile. Radiating growth is common, similar in appearance to malachite pseudomorphs after azurite crystals.

The rutile pseudomorphs predate the period of senaite crystallization. Such pseudomorphs have been reported from diamond-bearing gravels near the town of Diamantina (Cassedanne and Cassedanne, 1974b). Pseudomorphs and unaltered anatase occur scattered on first-generation quartz.

Senaite $Pb(Ti,Fe,Mn)_{22}O_{38}$

Senaite is black and waxy in appearance, with a sub-metallic luster. A brown alteration coating is present on some crystals. At least four habits have been found at the locality:

1. Pseudo-cubic rhombohedrons, millimeter-size, with small modifications and smooth faces.
2. Complexly twinned crystals resembling dolomite twins from Switzerland.
3. Platy crystals to 1 cm, commonly coated with acicular rutile.
4. Spongy, pitted and corroded crystals, perhaps the most abundant kind.

Crystals occur singly and in groups. They are generally easy to remove from the surfaces of quartz crystals, but are very brittle and are often found damaged.

Most senaite formed later than first-generation quartz, more or less contemporaneously with anatase and the beginning of second-generation quartz. Nevertheless, some senaite has been found included within first-generation quartz, and some overgrowing second-generation quartz and rutile.

Density of senaite varies from 4.2 to 5.3, depending on degree of alteration. Hardness (Mohs) is 6; no cleavage observed; streak is brownish black; non-magnetic; opaque to translucent dark green on thin chips. It crystallizes in the rhombohedral space group $R\bar{3}$, with lattice parameters $a = 9.172(1)$Å and $\alpha = 69.020(5)°$. The equivalent hexagonal parameters are $a = 10.393(2)$ and $c = 20.811(5)$Å (Grey and Lloyd, 1976). (See Hussak and Prior,

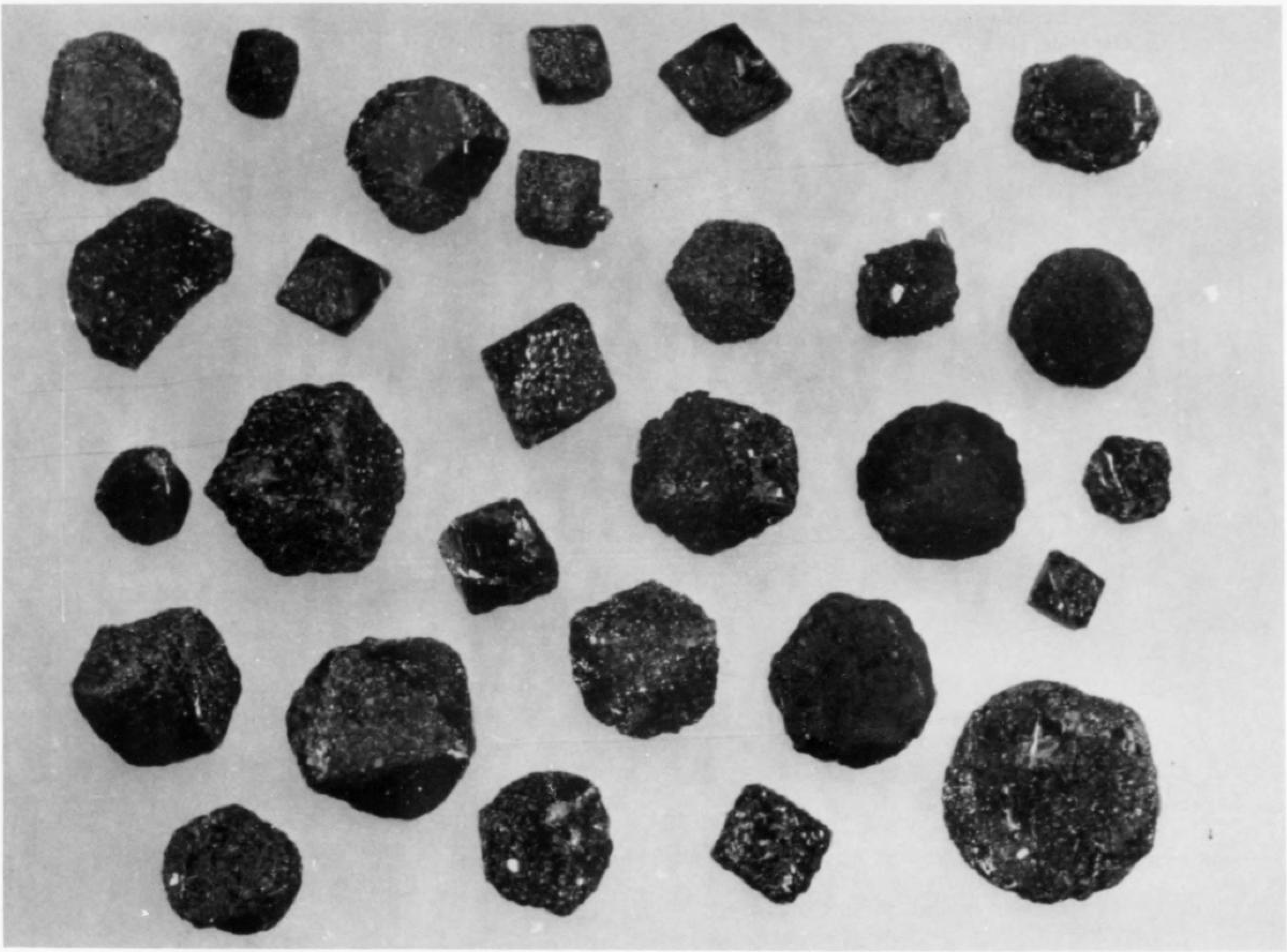

Figure 6. **Loose senaite crystals to 1 cm.**

Figure 7. **Skeletal rutile pseudomorph after anatase, 1.5 mm.**

1896; Metelo, 1968; and Grey *et al.,* 1976, for chemical analyses.)

A semi-quantitative X-ray fluorescence analysis on a crystal from Fazenda Guariba indicated Ti, Fe and Mn exceeding 10%; Pb, Y and Sr between 1% and 10%; Zr and Zn less than 1%; and traces of La, Cu, Gd, V, Nd and Th. The X-ray powder diffraction pattern matches well with JCPDS Card 20-1048.

The senaite X-ray pattern determined on near-surface samples is commonly blurred. Heating of samples reveals no metamictization despite the presence of thorium. Metelo (1968) suggested the presence of two polytypes: 9R (equalling that of Grey and Lloyd, 1976), and 7R (using the base dimension of Peacor, 1967).

The relationships between the crystal structures of senaite, crichtonite, davidite and magnetoplumbite were examined by Rouse and Peacor (1968) and Grey *et al.* (1976).

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Chalcophyllite and other rare hydroxy-sulfates from Maharahara, New Zealand

Allan J. Read
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Chalcophyllite, carbonate-cyanotrichite, connellite, posnjakite and langite are here reported from New Zealand for the first time, along with comments on the composition of chalcophyllite.

LOCATION

The Maharahara copper mine (Grid Reference NZMS 260, Sheet T23 540837) is located on the steep, bush-clad slopes of the Ruahine mountain range on the North Island of New Zealand. The mine is situated close to Copper Creek, a tributary of the Manga-atua stream on the eastern side of the Ruahine Range and is about 16 km from Woodville.

HISTORY

Although traces of copper were observed to be associated with the red rocks of the greywackes at several localities in the Ruahine Range, it was only at Maharahara that serious attempts were made to mine the metal. By 1915, three companies had worked the mine, though little had been learned about the deposit. When New Zealand Geological Survey geologists Hector and McKay visited the mine in 1891, access to the workings was dangerous or impossible due to rockfalls. Even after £30,000 had been expended in developing the property, Thomson (1915) considered that a further £10,000 would be necessary to test the property, with a high probability that the money would be lost.

In 1930, a further attempt was made to restart the mine (Lillie, 1953) and a drift of considerable length was made into completely barren ground. The same year, Maharahara Copper Mines Ltd. commissioned the Elbof Company to do a geophysical survey, but the indications were unfavorable and since that time no further work has been done at the mine.

A plan of the mine workings is reproduced here from Hector (1890). Three different outcrops were found but there was evidence of only one lode. The shaft was essentially an irregular excavation following the lode, which was found to pinch out at a depth of 19 meters. Two tunnels were driven which intersected the lode but no extensive orebody was located. In 1890, from the information available, Hector considered the lode to be discontinuous and to consist of a number of lenses. At present, all the workings have caved or been buried and are inaccessible.

GEOLOGY

The New Zealand geosynclinal rocks form the mountain chains of both islands of New Zealand. The Ruahine Range on the North Island forms part of this chain and consists predominantly of well-dissected Mesozoic sedimentary strata intersected and bordered by many faults. Its structure is that of a wedge-shaped horst in which the northern and southern extremities are intricately faulted with grabens in the north and overridden blocks in the south. The region is tectonically active and the many parallel faults show transcurrent movements in addition to normal and reverse faulting, and have led to large uplifts exposing the older rocks which form the Ruahine Range.

Throughout the rocks of the New Zealand geosyncline there are interbedded spilites. These crop out as red rocks with which are associated manganese and also copper deposits. The latter are characterized by sulfides almost to the exclusion of quartz and usually by only a trace of lead, zinc, nickel and the noble metals (Williams, 1974).

At Maharahara, the rocks dip at 60° NNE and consist of sheared, indurated sandstones interbedded with shales and a band of red and blue cherty sandstones containing some pyrite. Underlying this is the lode band and argillaceous sandstones, gray cherts, jasperoid slates, greenish sandstones, slates and shales containing pods of limestone (Hector, 1890). As noted by McKay (1888), two kinds of red rocks occur in the area. One is a light brown to red chert stained with iron oxide which may contain pyrite but is of no value in indicating mineralization. The other is a siliceous hematite with a purple hue considered by McKay to be the proper gangue of a true lode in the region.

Figure 1. **Location of Maharahara in the North Island of New Zealand.**

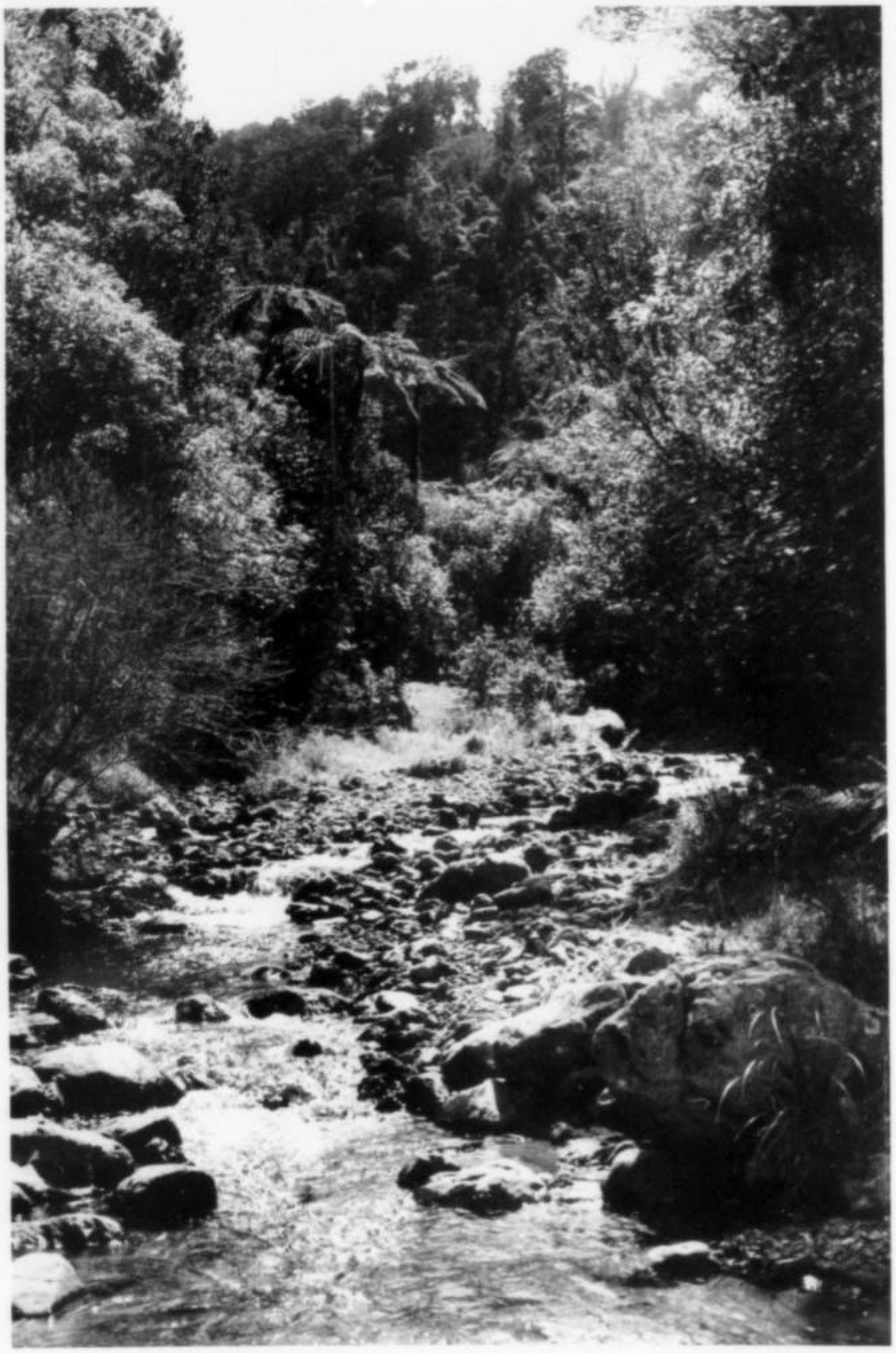
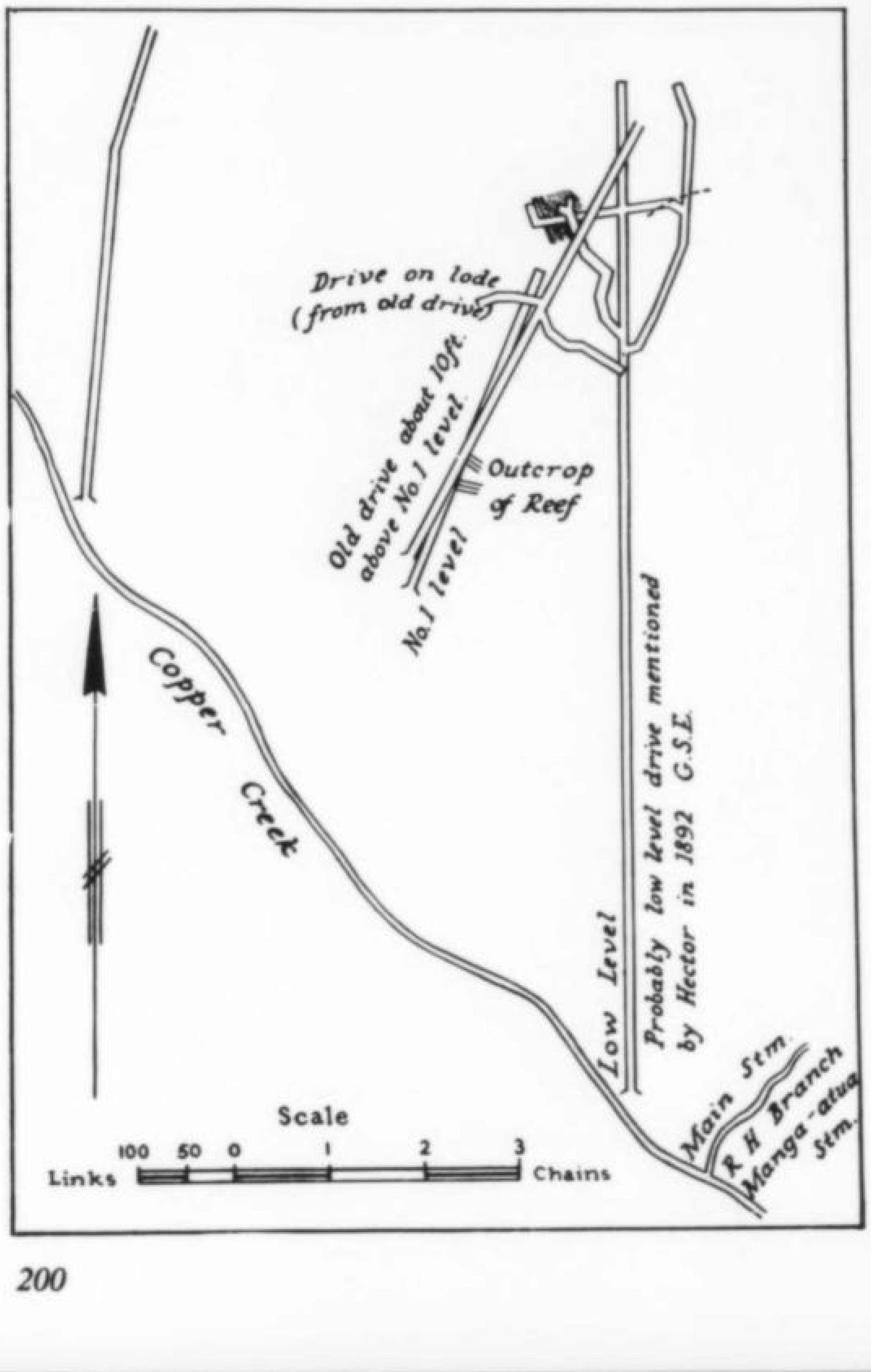


Figure 2. **View up Manga-atua Stream 10 minutes walk from the road end.**

Figure 3. **Plan of Maharahara Copper Mines showing workings as seen by Hector on his second visit.**



MINERALOGY

In the report on his visit to the mine in 1891, Hector (1892) noted that copper in the lower adit was present only as chalcopyrite and that secondary copper carbonates, silicates, oxides and native copper noted in the surface outcrops were absent, showing the lode to be beyond the effects of near-surface supergene alteration. In a recent study of copper and manganese mineralization at several localities throughout New Zealand, Roser (1984) has recognized the following primary minerals at Maharahara: pyrite, chalcopyrite, sphalerite, pyrrhotite and possibly bornite. Barite was also recorded. Secondary minerals recognized in iron-rich chert include cuprite, chalcocite, covellite, bornite, copper, malachite and chrysocolla.

This paper is the first to report the occurrence of chalcophyllite, carbonate-cyanotrichite, connellite, posnjakite and langite in New Zealand. The minerals were collected by the author from ore material which had been removed from the mine, dumped on the steep slopes above Copper Creek and allowed to fall to the creek bed. Although 50 tons of ore were reported to have been excavated (Hector, 1890), much of this material has been removed and considerable persistence is required if specimens of crystallized minerals are to be obtained.

Identification of the following minerals was made by X-ray diffraction using a Gandolfi camera with CuKα radiation.

Chalcophyllite $Cu_{18}Al_2(AsO_4)_4(SO_4)_3(OH)_{24}\cdot 36H_2O$

Chalcophyllite occurs at Maharahara as free-standing rhombohedral blades, as rosettes and as crusts of intergrown crystals. The crystals are commonly around 0.1 mm in length, range in color from pale turquoise-blue to a deep greenish blue and are generally transparent to translucent. The blades are commonly coated with unidentified material. Associated minerals include cuprite, connellite, brochantite, chrysocolla, langite and/or posnjakite. The refractive indices were found to be $n_o = 1.606$ and $n_E = 1.545$ (lower than the literature values of $n_o = 1.618$ and $n_E = 1.552$). The small difference may result from the different composition (see below) though the refractive indices of chalcophyllite vary markedly with water content (Palache *et al.,* 1951). Although chalcophyllite is uniaxial negative, a few blades did show some biaxial character.

As with many arsenates it is accepted that some phosphate may substitute for arsenate in chalcophyllite. Although the X-ray pattern for Maharahara material compared well with that of chalcophyllite, qualitative energy-dispersive X-ray analysis indicated that P»As and the possibility that the material was a new species warranted further investigation. Chalcophyllite blades were analyzed with a JEOL Superprobe 733, with an accelerating voltage of 15kV and a beam current in the range 0.8 to 1.2×10^{-8} A. Attempts to polish chalcophyllite ($H \approx 2$) were not successful and therefore individual blades were analyzed. Analyses were conducted varying the elemental sequence, the beam diameter and the beam current. The results for the elemental *ratios* may be satisfactorily interpreted but the water content (found by difference) varied, so that reliable information on the full molecular composition could not be determined. The water of crystallization is known to be only loosely held in the structure (Palache *et al.,* 1951) and the water content of the samples analyzed may have varied. However, the results have been used to investigate the ratio Cu:Al:P:As:S by normalizing the figures to 18 Cu atoms for comparison with the presently accepted formula. Three typical analyses with their corresponding atom contents based on 18 Cu atoms per formula unit are given in Table 1. Elements sought but not found include Mg, Fe, Zn, Ni and Co. The data from 9 analyses are averaged and included in column 4. The following points are to be noted:

Figure 4. **Pale blue-green chalcophyllite blades to 0.5 mm. All specimens from the author's collection.**

Figure 5. **Spray of blue connellite needles to 0.3 mm with deep red cuprite and blue-green chalcophyllite crystals on edge.**

Figure 6. **Deep greenish-blue crystals of langite on 0.5 mm with a characteristic twin.**

(a) The sulfur content is approximately constant (2.8 ± 0.4) per 18 Cu.

(b) The sum of $As + P + Si$ is constant (4.2 ± 0.2) per 18 Cu, even though the contents of arsenic (0.3–2.1), phosphorus (0.6–1.6) and silicon (0.8–3.0) vary.

(c) The sum $As + P + S + Si$ is constant (7.0 ± 0.3) per 18 Cu.

From a crystal structure determination of As-rich chalcophyllite from Cornwall, Sabelli (1980) concluded that As and S substitute in different sites with the sites filled by sulfur atoms being only 75% occupied, leading to the formula $Cu_9Al(AsO_4)_2(SO_4)_{1.5}(OH)_{12}\cdot 18H_2O$. Our analytical figures are consistent with this conclusion, suggesting As, P and Si substitute on one site and sulfur substitutes on a different site. On this basis, the formula should be written as

Figure 7. **Rosette of chalcophyllite coated with unidentified material. Qualitative energy dispersive analysis of the latter showed major Al and Si with minor Cu.**

Figure 8. **Scanning electron micrograph of blue-green chalcophyllite crystals to 0.05 mm showing rhombohedral symmetry and cleavage perpendicular to the *c* axis.**

$Cu_{18}Al_2[(As,P,Si)O_4]_4(SO_4)_3(OH)_{24}\cdot 36H_2O$. However, the precision of the analytical results does not exclude the possibility that As, P, S, Si substitute on both sites.

The presence of silicon in chalcophyllite may not always have been suspected, for in many of the earlier analyses SiO_2 was not determined (Palache *et al.*, 1951), though chalcophyllite from the Teniente mine, Rancagua, Chile, was reported to contain 1.33% SiO_2. In the present work, even when a crystal was cleaved perpendicular to the *c*-axis the analyses of the exposed surfaces showed that up to 5.5% SiO_2 was present.

The mutual substitution of PO_4 and AsO_4 occurs in a wide range of minerals and may lead to a complete range of compositions between end-members, e.g., the pyromorphite-mimetite series. The less well-known mutual substitutions of AsO_4 and SiO_4 and of PO_4 and SiO_4 have been discussed by Eitel (1975). For instance, arsenic substitutes for silicon in berzeliite (Blix and Wickman, 1958) and in ardennite (Semet and Moreau, 1965), and SiO_4 may substitute for PO_4 in apatites to around 50 atomic % (Lindberg and Ingram, 1964). In these cases, charge balance can be achieved by coupled cation substitution (see, e.g., Lindberg and Ingram, 1964) or loss of halogen or other anions (Wondratschek, 1963). For chalcophyllite, charge balance may be attained through loss of OH.

Table 1. **Microprobe analyses of chalcophyllite.**

CuO	58.6	55.3	59.7
Al_2O_3	4.3	4.2	5.0
SO_3	9.4	8.0	10.8
P_2O_5	1.8	4.5	2.8
As_2O_5	8.6	7.1	1.2
SiO_2	3.9	2.0	7.7
	86.6	81.1	87.2

Atomic contents based on 18 Cu atoms.

				Mean*	Idealized†
Cu	18.0	18.0	18.0	18.0	18.0
Al	2.1	2.1	2.4	2.3 ±0.2	2.0
S	2.9	2.6	3.2	2.8 ±0.4	3.0
P	0.6	1.6	0.9	1.1 ±0.3	
As	1.8	1.6	0.3	1.2 ±1.0	4.0
Si	1.6	0.9	3.0	1.9 ±1.1	

* Average of 9 analyses

† Based on $Cu_9Al(AsO_4)_2(SO_4)_{1.5}(OH)_{12}\cdot 18H_2O$ (Sabelli, 1980)

Finally, it should be mentioned that chalcophyllite may cleave and warp to an extent allowing access of solution to the interior of the crystal, thereby making possible alteration within the crystal. Considering that chalcophyllite alters to chrysocolla (Palache *et al.*, 1951), further work with well-crystallized chalcophyllites may clarify the role of Si in the structure.

Connellite $Cu_{19}Cl_4(SO_4)(OH)_{32}\cdot 3H_2O$

Connellite occurs occasionally as individual sprays but more commonly as radiating, azure-blue, acicular crystals to about 0.3 mm in length, on a core of massive cuprite. The associated minerals include cuprite, chalcophyllite, langite, brochantite and digenite. Connellite was identified by its X-ray pattern, and the presence of Cu, S and Cl were confirmed by energy-dispersive X-ray analysis.

Langite $Cu_4(SO_4)(OH)_6\cdot 2H_2O$

Langite occurs rarely as tiny, glassy, prismatic crystals to 0.5 mm which may show characteristic orthorhombic twinning, or as groups of radiating, intergrown crystals. Individual crystals within these groups may exceed 1 mm in length. The crystals are deep greenish blue in color, generally transparent to translucent, though some crystal groups showing surface alteration are opaque. The X-ray pattern of this latter material includes peaks characteristic of posnjakite. Langite is often associated with green brochantite and the two minerals may be intergrown. Brochantite is relatively common in oxidized ore and is usually massive or present as crusts of intergrown crystals.

Posnjakite $Cu_4(SO_4)(OH)_6\cdot 2H_2O$

Posnjakite is found rarely as poorly defined single crystals to around 0.2 mm and occurs more frequently as small crystal groups closely associated with chalcophyllite. Posnjakite and langite have been shown to have the same chemical composition (Ridkosil and Povondra, 1982) and may occur in mutual association with brochantite (Knight and Barstow, 1970).

Carbonate-cyanotrichite $Cu_4Al_2[(CO_3,SO_4)](OH)_{12} \cdot 2H_2O$

This mineral occurs as blue-green spherules to 0.4 mm in diameter, consisting of radiating laths, and also as laths loosely intergrown in delicate crusts. Spherules of carbonate-cyanotrichite may form on, alongside or may even engulf chalcophyllite blades. The color ranges from azure-blue to a pale blue-green. On occasion, spherules have azure-colored centers grading to a pale blue-green periphery; the color change seems to be associated with the density of packing of the crystals. Treatment with dilute HCl gives an effervescence indicating the presence of carbonate.

Identification as carbonate-cyanotrichite is based primarily on the agreement of the X-ray data with that reported for the type locality material. However, analyses were also conducted using a Cambridge Stereoscan 250 Mark II scanning electron microscope at an accelerating voltage of 20 kV, with an attached Link 860 Series 2 quantitative energy-dispersive analyzer. Analyses of two separate areas gave closely similar results with a mean value of Cu:Al:S:Si of 4:2.2:1.3:0.3. Although the Cu:Al ratio is in close agreement with the presently accepted formula, the S content is higher than expected for carbonate-cyanotrichite and small amounts of Si are present. The X-ray pattern included lines additional to those reported for type locality material; therefore, either another phase is present, or this is, perhaps, a new species closely related to carbonate-cyanotrichite.

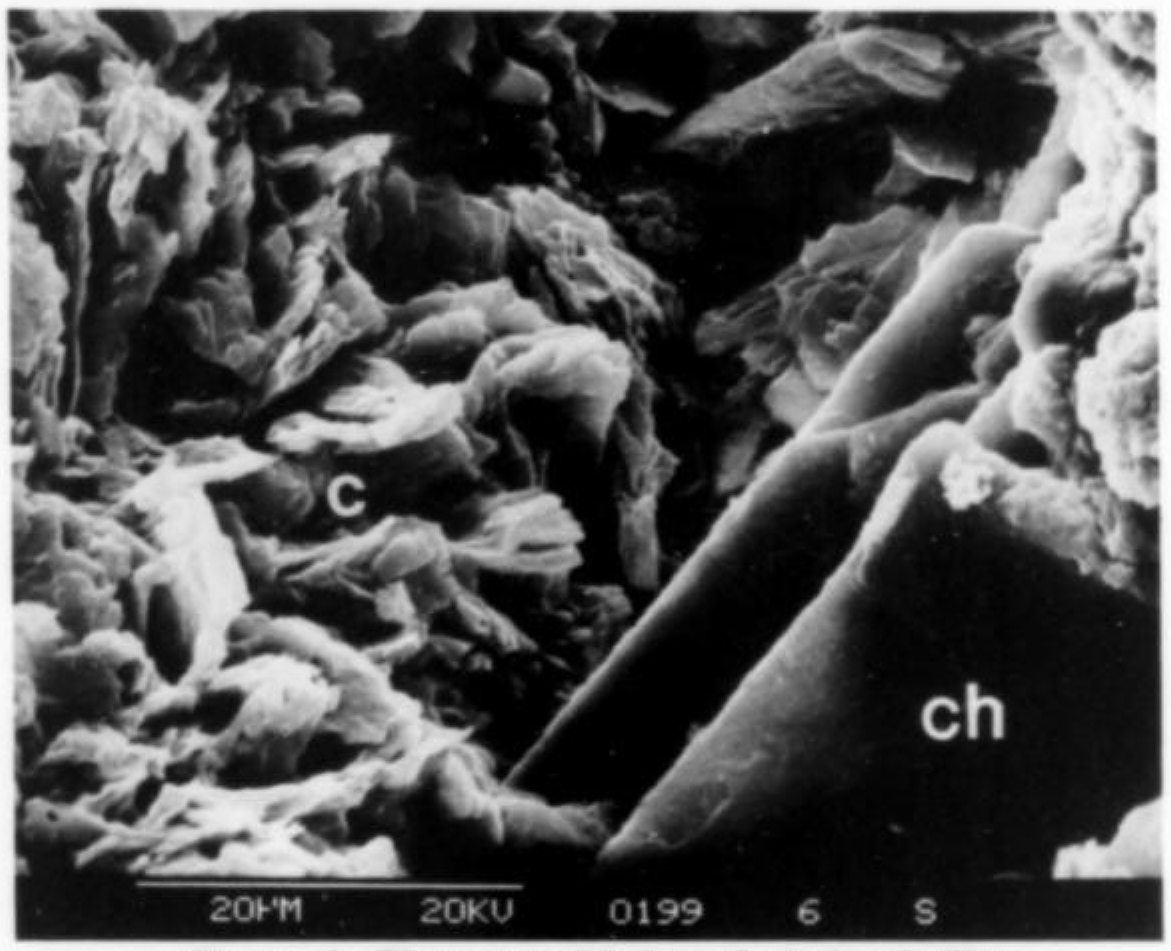


Figure 9. **Blue-green blades of chalcophyllite (ch) with pale blue-green carbonate cyanotrichite (c).**

PARAGENESIS

In 1976, Sporli and Bell described an occurrence of copper sulfides elsewhere in the Ruahine Mountains with rock sequences similar to those at Maharahara and considered the relationship of those sulfides to those of the massive volcanogenic type (e.g., Cyprus). The latter have many points of similarity (Constantinou and Govett, 1973) to actively forming seafloor sulfide deposits. Hydrothermal waters (T»350°C) pass through the sub-seafloor basalt layers mobilizing heavy metals and sulfur with precipitation of sulfides occurring in response to dilution of these solutions with cold seawater (Haymon and Kastner, 1981).

On the other hand, Jolly (1974) reported the mobilization of Cu and Zn during prehnite-pumpellyite facies metamorphism in the Keweenawan basalts. In this case, little reduced sulfur was available, and copper precipitated as the native element. The metamorphic grade of the rocks of the eastern Ruahine Range is not presently well established, though Sporli and Bell (1976) reported that from the observed mineralogy this appears to fall within the prehnite-pumpellyite-metagreywacke facies of Coombs (1960). Therefore temperatures may have been sufficiently high to mobilize copper during metamorphism, but the processes leading to the formation of the sulfide deposits and in particular, the compounds responsible for the transport of copper, at present remain speculative.

The secondary sulfates form in vein systems through ore containing copper sulfides and cuprite. Chalcophyllite, connellite, langite and brochantite often crystallize directly on the vein walls, whereas posnjakite more commonly forms on chalcophyllite and appears to crystallize at a later stage. On the other hand, carbonate-cyanotrichite forms alongside and occasionally engulfs blades of chalcophyllite. Brochantite, langite and posnjakite may form in mutual association (Knight and Barstow, 1970) and recently, Miskovsky (1975) has found from laboratory experiments that the crystallization of langite and posnjakite takes place over the pH range 5.7 to 6.6. Alwan and Williams (1979) analyzed mine waters from two mines in Cornwall, England, which were responsible for the formation of langite and malachite. The pH of these waters ranged from 6.0 to 7.5. Water in equilibrium with the atmosphere has a pH of around 5.8 and would readily dissolve cuprite, for the dissolution of cuprous oxide powder at pH = 5.8 in oxygenated solutions is extremely rapid (Read, unpublished data), producing cupric ions and increasing the pH by the sequential reactions:

$$Cu_2O + 2H^+ \rightarrow 2Cu^+ + H_2O$$
$$4Cu^+ + 4H^+ + O_2 \rightarrow 4Cu^{++} + 2H_2O$$

Similar but slower reactions occur with the sulfides. When the solubility product of a mineral is exceeded, crystallization may occur, releasing hydrogen ions for further reaction, e.g., for langite.

$$4Cu^{++} + SO_{4=} + 8H_2O \rightarrow Cu_4SO_4(OH)_6 \cdot 2H_2O + 6H^+$$

It has been suggested (Rickard, 1970) that the detailed mechanism of this reaction may involve intermediate compounds.

The observation that secondary minerals often form on a core of cuprite is consistent with these reactions changing the microenvironment (pH, Cu^{++} concentration) to exceed the solubility product of these minerals at the cuprite surface.

ACKNOWLEDGMENTS

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Notes from Italy

by Gianni Porcellini

Sicily is an island rich in history and scenic beauty. Roughly triangular in shape, it lies in the middle of the Mediterranean, just off the "toe" of the Italian peninsular "boot." The ancient Greeks called it *Magna Grecia* because it was the finest and richest in their empire. Ancient temples at Syracuse, Agrigento, Selinunte, Segesta and Taormina are among the best-preserved in all of the Mediterranean Basin.

A long succession of ancient peoples sought to make Sicily their own. Phoenicians, Cathaginians, Greeks, Romans, Normans, Arabs . . . all have left their legacy in monuments and history.

Natural beauty and sparkling clear sunlight are typical of the Mediterranean coastline. Sicily has a relatively arid climate and little grass cover but flowers bloom on gates and walls. Fields of citrus thrive along the coast, and the Etna volcano (highest in Europe) dominates the skyline with its black slopes and white plume of smoke.

So much for background; now to the minerals! At many Italian mineral shows over the years I have seen wonderful specimens of Sicilian sulfur in large crystals on white calcite. Specimens measuring 10 x 15 cm sell for about $10. Nice celestite in various habits and colors can sometimes be had for even less. Colorless to pale green aragonite specimens 10 x 10 cm with doubly terminated crystals 1–2 cm, really quite showy, were sold for $10–15. Colorless, short prismatic gypsum crystals with bitumen were priced at $4–6 for a specimen 6 x 8 cm. White coralloid aragonite ("flos ferri"), 3 x 4 cm, sold at around $2.

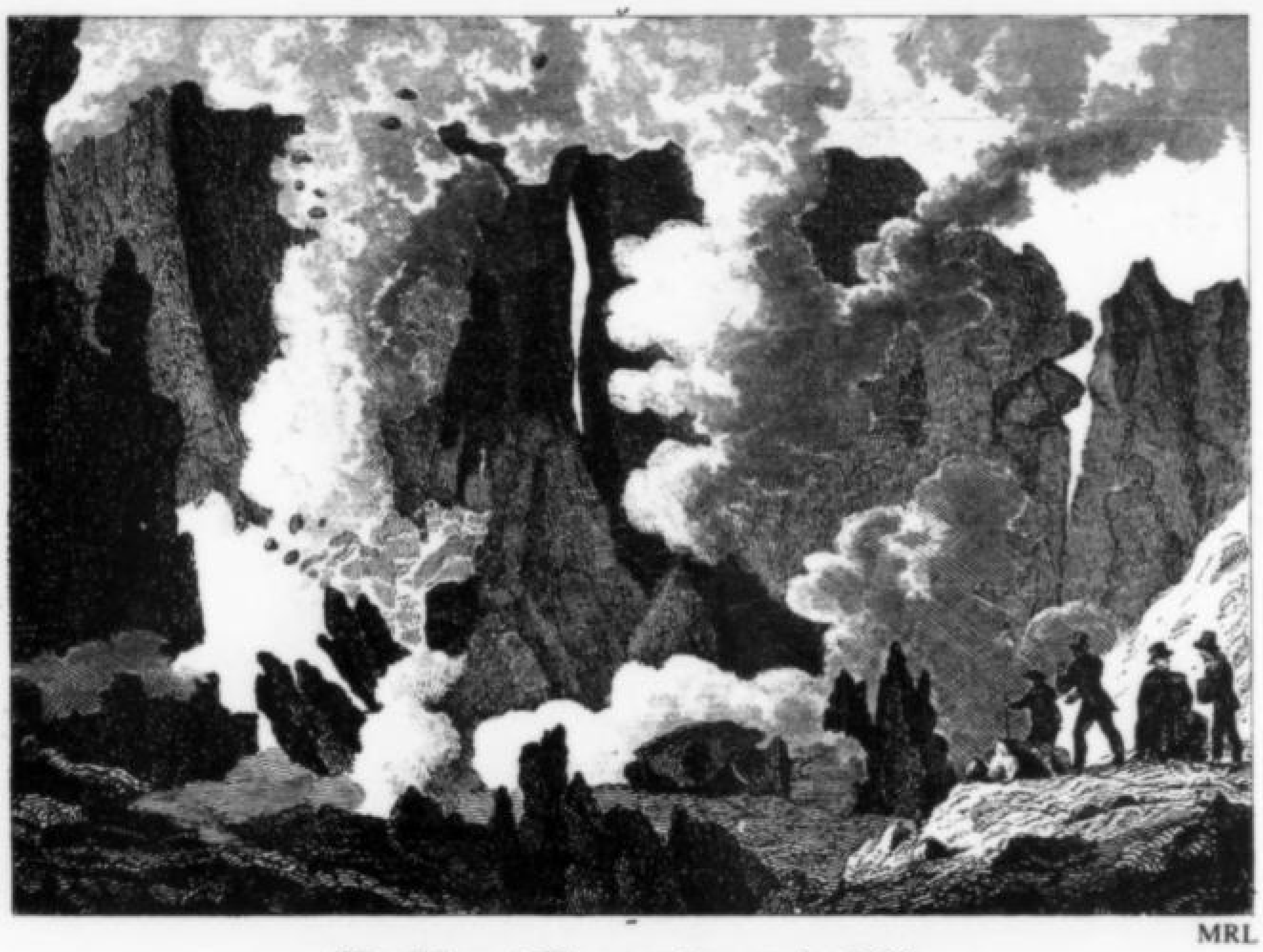
Having been sufficiently tantalized by these marvelous specimens I decided last May to spend my vacation there with my family. We traveled along the coastline because my wife and daughters wanted to swim and sun.

The most mineralogically interesting section of coast runs from Messina to Catania, the so-called "Lemon Coast." We camped in the shade of lemon trees and picked fresh lemons to eat. While the girls worked on their tans I explored the ancient lava flows extending from Etna down to the sea. Localities around Aci Trezza, Aci Castello, Timpa Santa Maria and Pelagonia are rich in zeolites. Exploring these occurrences in your swimsuit can be a pleasure, and when you get thirsty, cold lemonade can be purchased at stalls all along the coast. At mealtimes you can sit in a small restaurant overlooking the sea, eat superlative fresh-caught fish and sip a good vin rosé. Ah, the life of a mineral collector can be tough, can't it?

There is a small island called Lachea just off of Aci Trezza. This and other neighboring rocks are known as the Cyclopean Islands. The name comes from *The Odyssey*; here the giant cyclops Polyphemus, blinded by Odysseus, is said to have thrown enormous boulders at the hero's escaping ship, boulders which today appear as a scattering of little rocky islets. Local fishermen will row you out to the island for a dollar or two, and return to take you back when you're finished exploring. I recommend that you take water and a hat, because there is no drinking water or shade on the island. Three-fourths of Lachea belongs to the University of Catania, so collecting is restricted to the area where sedimentary rocks are in contact with basalt flows. Here can be found the best analcime in Italy, crystallized in a variety of habits. The colorless to white crystals, sometimes up to a centimeter or more in size, occur in small vugs in the basalt. Other minerals include albite (in white, platy, rhombic crystals of a variety called "cyclopite"), green acicular diopside, yellow striated crystals of grossular, black octahedral magnetite, yellow to brown mica, and opaque white scalenohedrons of calcite.

A few kilometers down the coast from Aci Trezza is Aci Castello, another prolific zeolite locality. An old castle overlooks the basalt flows. Specimens here are plentiful, but *good* ones are not common. Herschelite in fine, hexagonal platy crystals and groups occurs here with nice colorless phillipsite and white tufts of mesolite. Another nearby locality, Santa Maria la Timpa, is rich in white sprays of aragonite and phillipsite.

Not far inland rises Etna, a sight which must be seen! But don't plan to find heaps of good minerals up and down its dark flanks . . . all is just barren basalt. Arriving at Monti Rossi, one can park and purchase a ticket for a Jeep ride up to the most recent lava flow near the summit. Through the acrid fumes can be seen large cracks in the flow, giving a glimpse of red, molten rock beneath. Smoking fumaroles dot the hillside, their mouths surrounded by crusty deposits of red, yellow, green, white and orange sublimates. These consist of rare sulfates, chlorides, etc. which are unfortunately unstable, altering to white, earthy material when removed from the fumarolic environment. Compared to Vesuvius, Etna offers only sparse pickings for the mineralogist.



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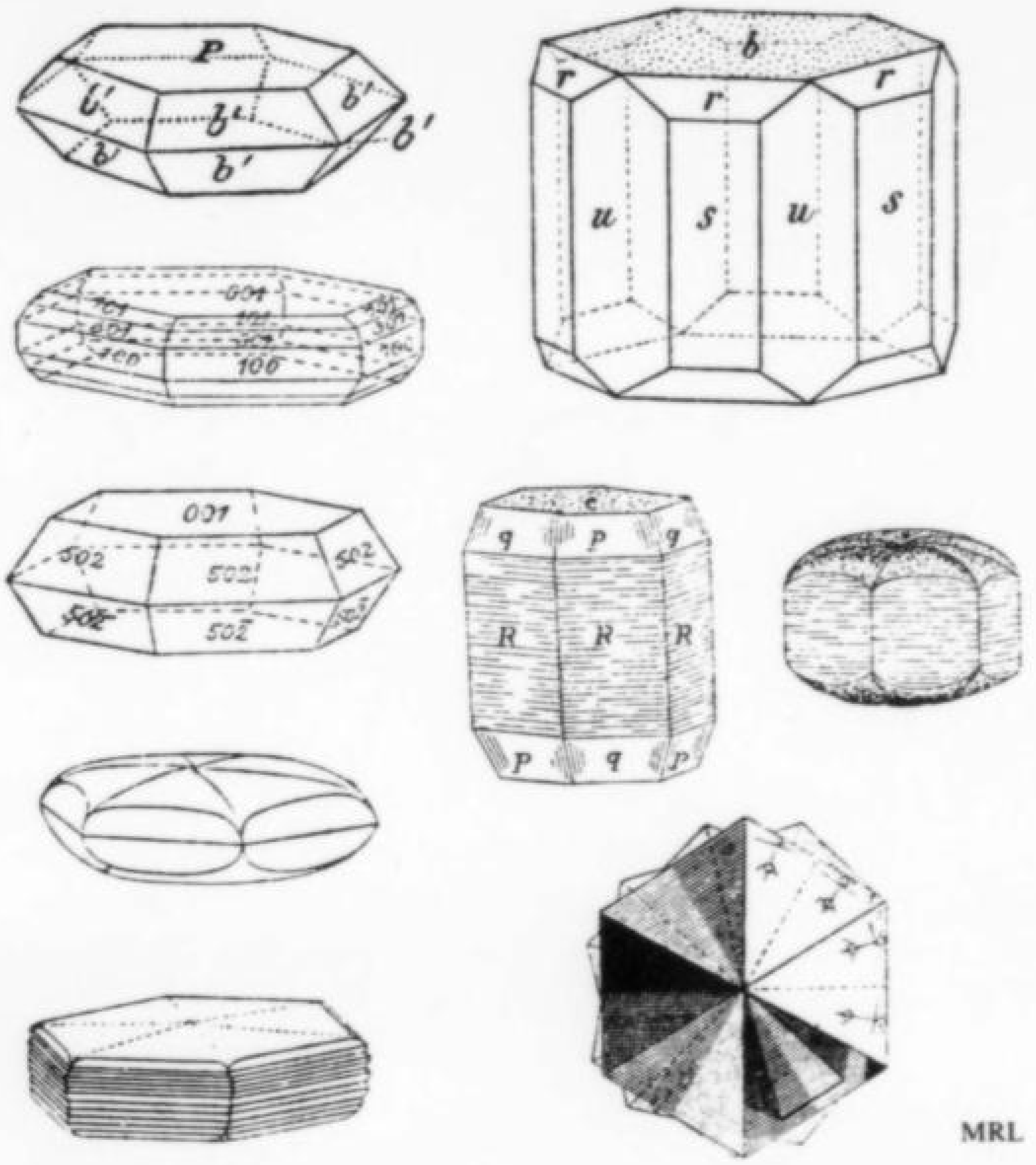
The Mount Etna crater, early 1800s.



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Herschelite crystals from Aci Castello (Goldschmidt, 1918).

MRL

Sulfur, Racalmuto (Brauns' *Das Mineralreich*, 1903).

Descending the south slope of Etna, one arrives at Biancavilla where it is possible to collect in a quarry in reddish basalt. Small vugs here have been found to contain nice hypersthene crystals, platy and brown to prismatic and yellow-brown. Also tridymite in small, colorless crystals, hematite in platy black crystals and a few rare crystals of enstatite.

Proceeding clock-wise around the coast we pass through Syracuse and on to Agrigento. Agrigento is famous among archeologists for its "Valley of the Temples," and among mineralogists for its sulfur mines. From Agrigento inland to Enna there are many sulfur mines (Racalmuto, for instance, should sound familiar); currently all are shut down for economic reasons. Large dumps and shafts can be seen along the hillsides, but it is impossible to find any good specimens there . . . the minerals break down too easily under surface conditions. Only at the Cozzodisi mine did I find a few nice, small crystals of sulfur and celestite; some commercial work had been done there just recently and I was lucky enough to find a small, fresh dump just a week old!

I spoke to a few old miners in the sulfur district, who still wait and hope for the mines to reopen. But years pass and nothing is done. Only the old photos remain as evidence of the hard-working young boys who spent their lives in these dangerous mines. I tried to ask them where the splendid specimens at mineral shows were coming from . . . the big sulfur crystals, aragonite, celestite and gypsum. No one would give me a precise answer. It seems you have to have contacts, be in good with the right people, in order to be offered the good specimens. Probably some of the miners saved away sizeable stocks of specimens when the mines were in operation. Or perhaps a few reckless individuals still sneak down into the old, abandoned workings. Who knows? In any case, the only sulfur specimens I actually saw for sale in Sicily were a few dirty and broken pieces priced at $5-10. One is much better off going to a good mineral show!

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What's New in Minerals?

by **Wendell E. Wilson**

TUCSON SHOW 1986

The Tucson Gem and Mineral Show and its many satellites comprise what has come to be the world's biggest mineral event, and this year it was even bigger. It keeps expanding, like The Blob, taking over additional motels and vacant lots surrounding the Tucson Community Center. For the visitor trying to see it all, logistics is a major problem; fortunately a number of publications have sprung up which can help to locate the dealers of most interest. Bob Jackson (*Jackson Mountain Press,* P.O. Box 2652, Renton WA 98056) puts out a booklet entitled *Tucson Independent Dealers Directory* (price: $1). It covers the Desert Inn, Doubletree, Holiday Inn Broadway (formerly the Marriott), Holidome, La Quinta, Quality Inn (formerly Holiday Inn South), Ramada, Santa Rita, Sheraton and Travelodge. Unfortunately it lacks maps and motel floor plans, and does not give addresses or other data for dealers who didn't pay the appropriate fee. But it does attempt to give at least the name and motel room of every satellite dealer in town. Perhaps the most thorough and widely distributed of the show catalogs is *Gems and Minerals Merchandizer* (555 Cajone Street, Suite B, Redlands, CA 92373), which devotes its entire January issue to Tucson. Maps, floor plans and informative ads are abundant. A subscription is free to bona fide dealers, and single copies are also free for the asking. The Desert Inn show (a focus for mineral collectors) has its own newspaper/catalog called *Gem Show News* (published by Shows of Integrity, Rt. 1, Box 161, Blue Ridge, TX 75004). It gives a detailed floor plan plus addresses for all dealers in the motel; copies are available at no charge. The Quality Inn and Holidome, though largely occupied by lapidary dealers, have a fine and detailed catalog which lists dealer specialties as well. This is available at no charge (to dealers with a resale number) from Bob Schabilion (*Gem and Lapidary Wholesalers Inc.,* P.O. Box 98, Flora, MS 39071). When the Tucson Show starts looming on your calendar next year, you might wish to order some of these catalogs.

For the mineral collector, most dealers of interest are found in the Desert Inn and the Travelodge. Serious collectors will nevertheless range farther afield to find those misplaced crystal dealers hiding out amongst the vendors of slab and gem. Sid Pieters, for example, a well-known Namibian (Southwest African) mineral dealer well worth visiting, was ensconced in the Ramada. Bruce Barlow (of recent Red Cloud mine fame) was in the Sheraton, along with book dealer Jack Garvin. Mario Vizcara's El Paso Rock Shop (importer of many fine Mexican specimens) is always in the Quality Inn. So it pays to nose around.

Before getting down to minerals I should mention that a very attractive show poster depicting a South African rhodochrosite is still available by mail from Carolyn Davis of Sanpete Publications (2751 West Monte Vista, Tucson, AZ 85745). The price is $13 postpaid. Posters from some past years are available too.

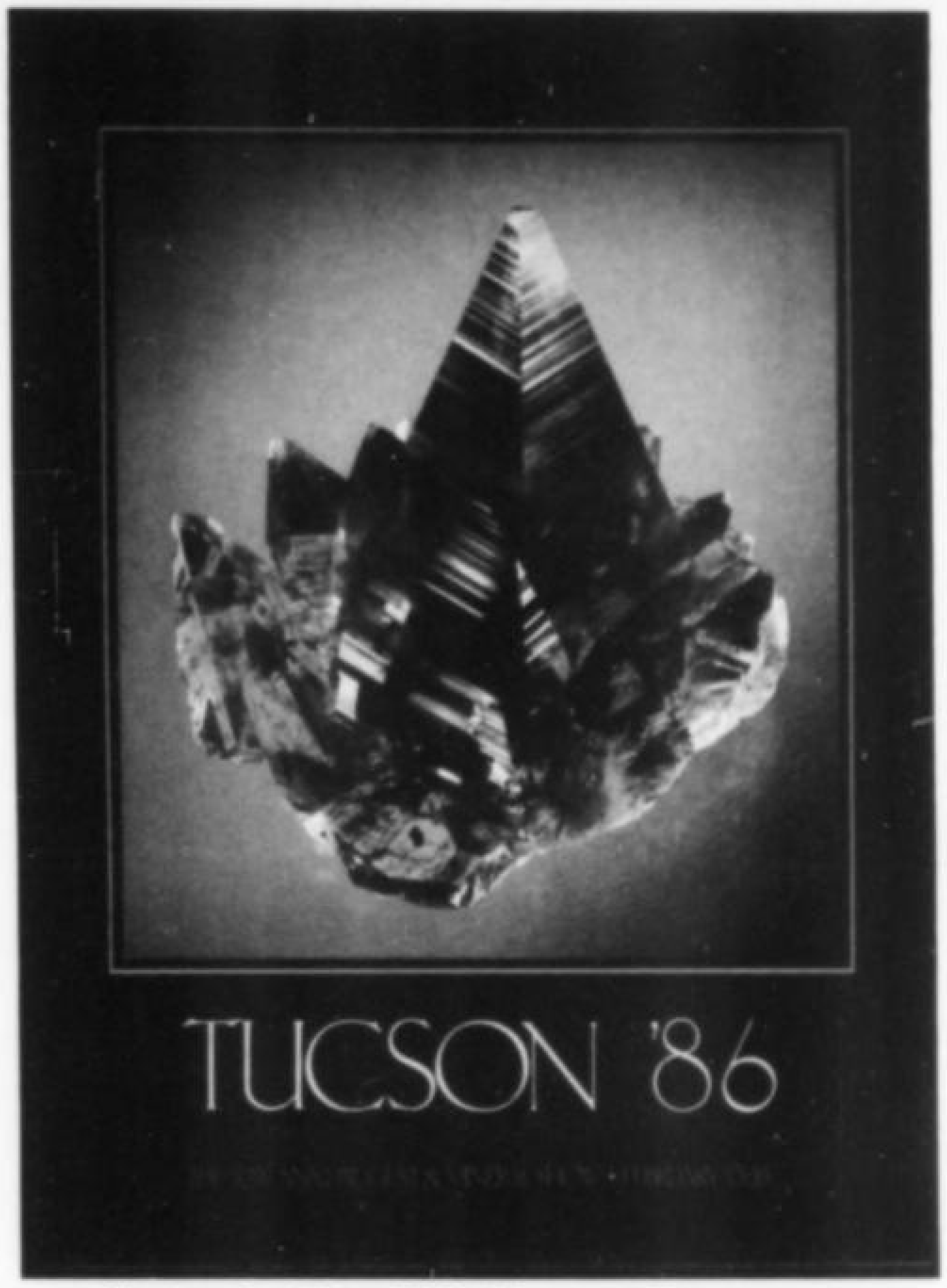

Figure 1. **The 1986 Tucson Show poster (available by mail order – see text).**

Now to the show. In general there was no major discovery that dominated the market this year. Sales were still very strong, however, especially on the first day of the main show. The mood among collectors was positive, and they spent their time shopping around for the old classics and discoveries of previous years. A number of dealers reported sales 30–40% above last year's.

Following are some items I made notes on, but only a small sampling of what was available.

- **Cobaltian Calcite from Zaire.** A little more of this material showed up, mostly through Gilbert Gauthier (see previous issue, p. 147–148). According to Gauthier, a recent analysis performed in France showed less than 1% CoO. Although some early authors use the term *cobaltocalcite* for cobaltian calcite, that term was used in the last edition of *Dana's System* to mean pure $CoCO_3$, a synonym for the now-preferred term *sphaerocobaltite.* Neither of these names should be used for the Zaire specimens. Having said that, I now have an excuse to run one more photo of this lovely material.

- **Nepal Tourmalines.** Just when you thought all hope was gone for obtaining a rare crystal of Nepalese tourmaline (see vol. 16, no. 5, p. 413–418), some new specimens have come to light, courtesy of *Mountain Minerals International.* Nearly 100 crystals, 2–3 cm, from both the Phakuwa and Hyakule mines, were available at their booth at the main show. These are pale in color, sometimes bicolored, with typical habit and, as usual, no matrix. In the same lot were some excellent specimens of purplish pink to rose corundum crystals, 2.5 to 5 cm, in and on matrix, from the Ganesh Range in Nepal.

- **Brazilian Anatase.** Ed Swoboda (672 North La Peer Dr., Los Angeles, CA 90069) does a fair amount of work in Brazil, and came up with a superb lot of large, bluish black anatase crystals on matrix from near Minas Novas, Minas Gerais. The largest crystal measures nearly 3 cm; most are 1 cm or so. The habit is typically bipyramidal; the matrix is smoky quartz. About 25 really good

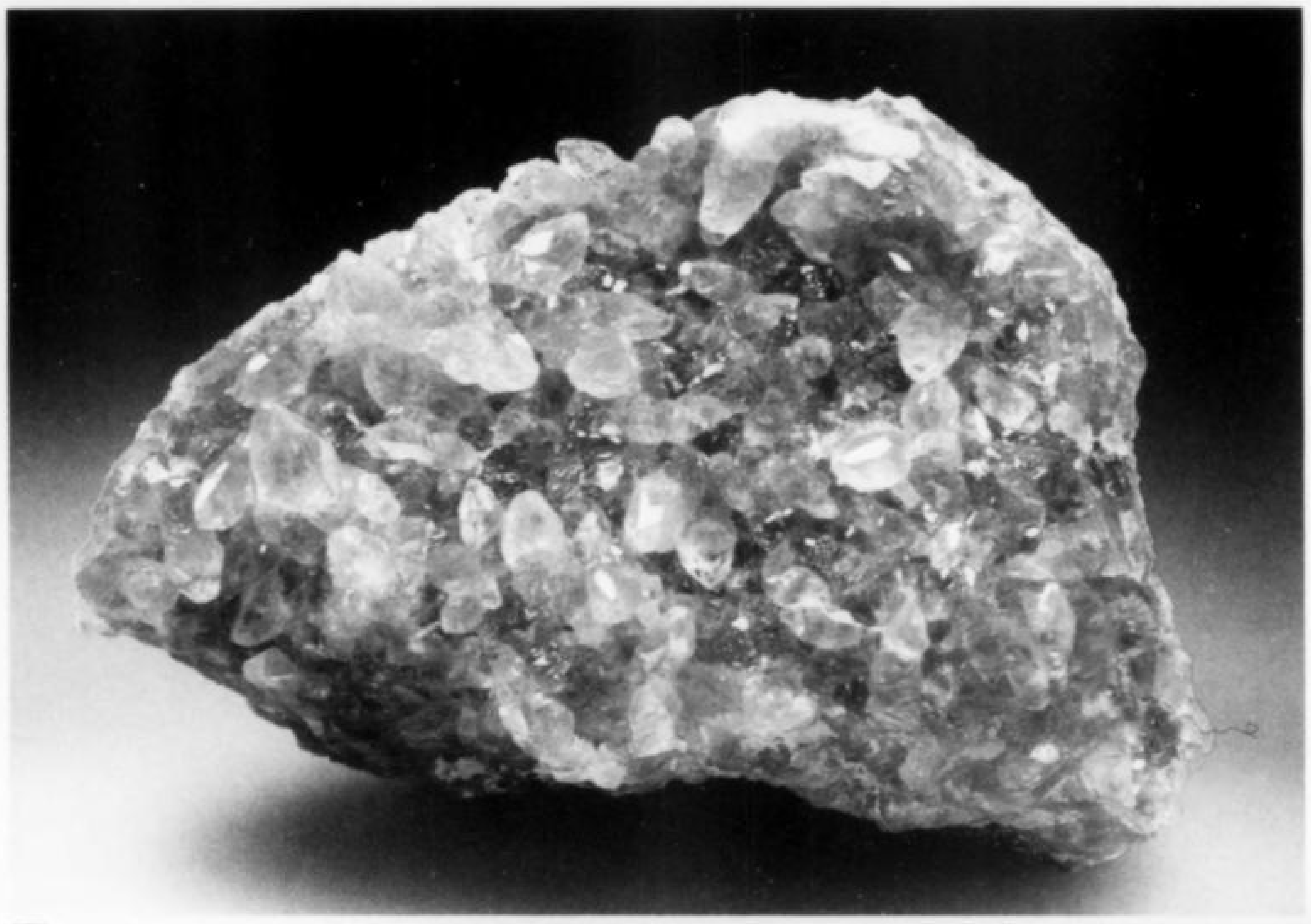

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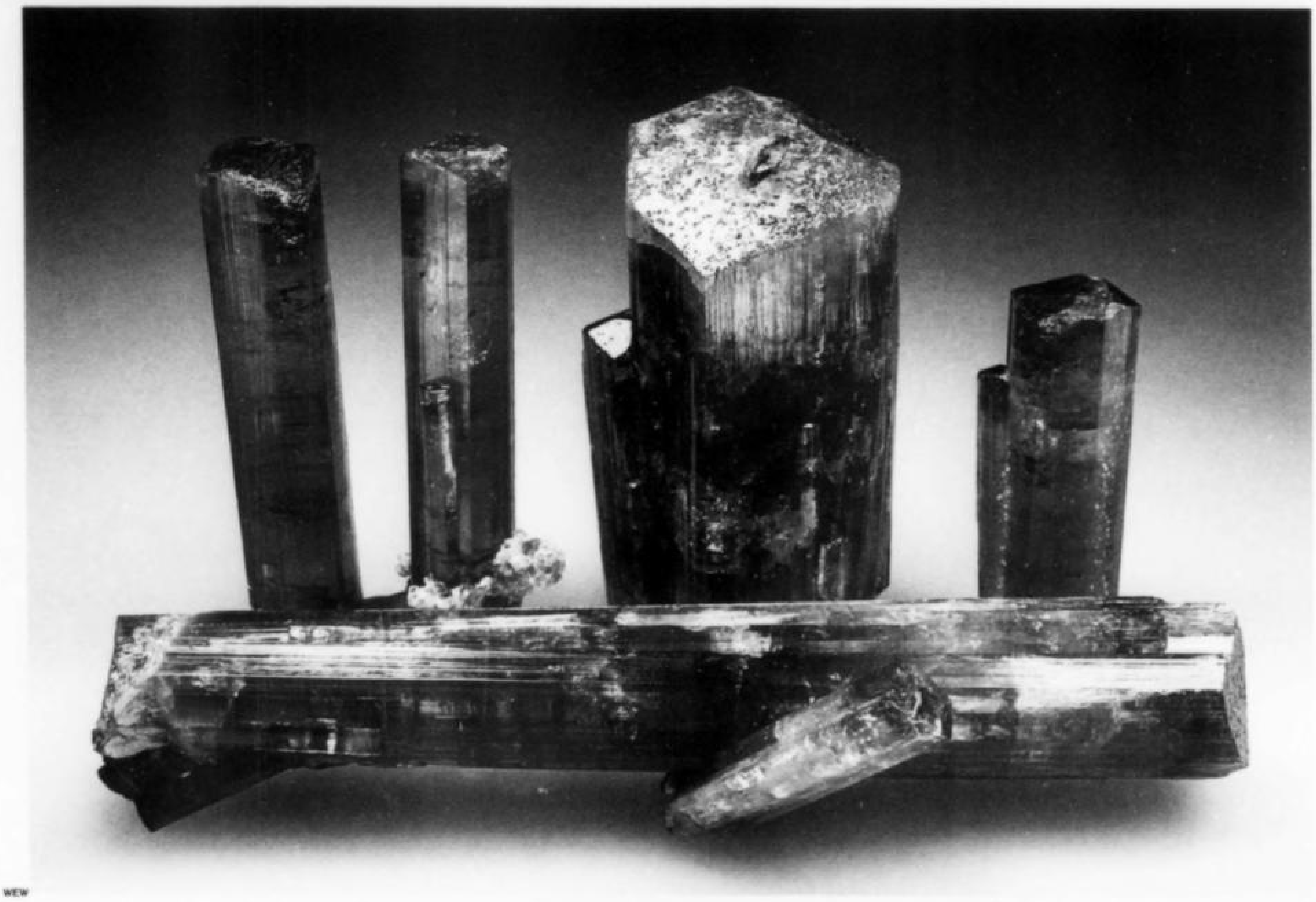
Figure 2. **Cobaltian calcite from Mupine, Shaba Province, Zaire. Herb Obodda specimen; 13 cm across.**

Figure 3. **Tourmaline crystals from Itinga, Minas Gerais, Brazil. Mike Ridding specimens; the crystal in the foreground measures 16 cm.**



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specimens and a couple of flats of mediocre material comprised the find.

• **Batopilas Silver.** John Whitmire (P.O. Box 4176, Yuma, AZ 85364) recently obtained a small pocket (22 kg) of silver in calcite from the New Nevada mine, Batopilas District, Mexico (see vol. 17, no. 1, p. 61–80). Following acid treatment to uncover the silver, about 20 flats of specimens resulted. These are more or less typical herringbone aggregates, but mixed in among them are specimens with a habit I haven't seen before. The habit consists of a flat plate (usually with a herringbone pattern of ridges on it); growing from this at 90° is a small forest of thin, parallel crystals roughly 1 cm long. The pieces look like silver Astro-turf or a silver bristle brush.

More Batopilas silver was available from Tony Otero (P.O. Box 437, Magdalena, NM 87825). Along with recently collected specimens he had some older (16–19 years) material of a very different granular-crystalline habit.

• **Brazilian Tourmaline.** Mike Ridding of *Silverhorn* had a new lot of tourmalines, obviously all from the same pocket, in his room at the Desert Inn. The locality is given only as Itinga, which is a town in Minas Gerais, not a mine, so presumably the source is some pegmatite in the surrounding area. The crystals are interesting because of their color (pink core near the base, green outer area and inner area higher up, and *orange* terminations). They are well formed, with nice terminal faces and relatively good clarity. Crystals reach about 16 cm maximum; some are narrow in habit and others are thicker, reaching 5–6 cm in thickness. According to Mike, the pocket yielded roughly 100 single crystals of varying sizes and 42 groups or combinations of tourmaline and lepidolite.

• **Washington Quartz/Tourmaline.** Bob Jackson (P.O. Box 2652, Renton, WA 98056, 206-255-6635) hit an extraordinary pocket of colorless quartz and fuzzy tourmaline at the Bald Hornet #3 claim, an old patented gold claim from around the turn of the century, near Mt. Teneriffe on a ridge near North Bend in King County, Washington. The pocket measured 1.2 x 2 x 2 meters, and yielded nearly a hundred pieces, from miniature to *large* cabinet size. Most of the quartz crystals are Japan-law twins up to 10 cm in size and very well formed. The tourmaline occurs as blackish green tufts of acicular crystals liberally spread among the quartz crystals. A few small, etched pyrite crystals and black sandy inclusions of stibnite in quartz complete the assemblage. These are very interesting and unusual specimens which quartz collectors and tourmaline collectors in particular will like.

Figure 4. **Ajoite in quartz crystals from the Messina mine, Transvaal, South Africa. Graeber and Himes specimens; the large crystal measures 3 cm.**

- **East German Minerals.** Newly collected specimens from East Germany rarely make it to the American market, but Ben De Wit had an excellent selection in his booth at the main show (hidden away with the equipment dealers in the arena). Clear crystals of picromerite to 3.5 cm, with halite, were available in cabinet-size specimens from the Rossleben area. Golden barite crystals to 6 or 7 cm (over 60 specimens including many cabinet pieces) came from a find at the Pöhla mine. He also had numerous thumbnail specimens of proustite, excellent quality, from Schlema in the Erzgebirge, attractive wire silver from Freiberg, and native bismuth crystals to 1 cm from Oberschlema in the Erzgebirge. Ben expects to be moving from the Netherlands to California soon.

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Figure 5. **Cuprian adamite from Tsumeb, Namibia. Marshall Sussman collection; the group is 3.2 cm across.**

- **Transvaal Ajoite.** Collectors with a long memory may remember the interesting specimens of papagoite in quartz crystals that came from the Messina copper mine in northern Transvaal, South Africa, many years ago. A similar find was made there just recently by Rob Smith (14 Ostend Rd., Klippoortjie, Germiston 1401, South Africa), except that the mineral included in the quartz crystals is turquoise-blue ajoite. Roughly 250 specimens comprised the find, mostly as crystals 5 to 7 cm but with some to 7 x 22 cm. Most specimens show only the two minerals, but epidote, chlorite, hematite, copper and shattuckite were also part of the assemblage.

- **Colorado Amethyst.** Mike Madsen (3201 Snowberry Court, Grand Junction, CO 81506) had many flats of amethyst on green fluorite from the Amethyst Queen claims, Mesa County, Colorado, near Copper City. The amethyst occurs as flat plates of crystal points overlying a flat layer of anhedral green fluorite 1–2 cm thick.

- **Czechoslovakian Aragonite.** Victor Yount had some remarkably large and fine crystals of aragonite from Podrecany, Czechoslovakia, about 30 specimens total. The crystals are partially gemmy, rather long (to about 18 cm), tapered, and colorless. The luster is bright, making these specimens among the best known for

Figure 6. **Amethyst group, 7 cm tall, from Vera Cruz, Mexico. Ken and Betty Roberts specimen.**

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Figure 7. **Colorless aragonite from Podrecany, Czechoslovakia. Victor Yount specimen.**

the species. Vic also had some of the best Moroccan vanadinite to come out in a long time; and here's a locality correction. Miners had always referred to the source as the Acif (pronounced "ah-seef") mine. Through recent discussions with the mine manager, Vic learned that the mines are simply designated by various combinations of letters, and that the one in question is actually the "ACF" mine. This sounds like "Acif" when the miners pronounce the three letters rapidly.

- **Colorado Barite.** The well known locality for blue barite at Stoneham, Weld County, Colorado, produced a large and excellent pocket of specimens in May of last year. Norm Bennett (5609 Pike Street, Golden, CO 80403) was one of the lucky collectors involved, and he had many specimens for sale in Keith Williams' room at the Travelodge. The crystals are flattened and rectangular, with good blue color and good luster. An article about this discovery is coming up in the next issue.

- **Colombian Quartz.** Gary Nagin (South American Minerals, Route 2, Box 1077, Ragweed Valley Rd., Royal, AR 71968) has been working a new deposit of quartz crystals at Alto de Cruzes, Santander, Colombia. The veins are exposed by bulldozer and then carefully mined with hand tools. Crystals are generally 7 to 10 cm in length, to a maximum of around 20 cm (8 inches). They are colorless and transparent, with excellent luster, and have been recovered in groups up to 60 cm across. Many groups are quite esthetic and make handsome cabinet pieces. Individual crystals tend to be slightly tapered and a bit longer in relation to width than most Arkansas quartz. A few rare Japan-law twins have also been found. Dozens of fine cabinet pieces and thousands of single crystals were available.

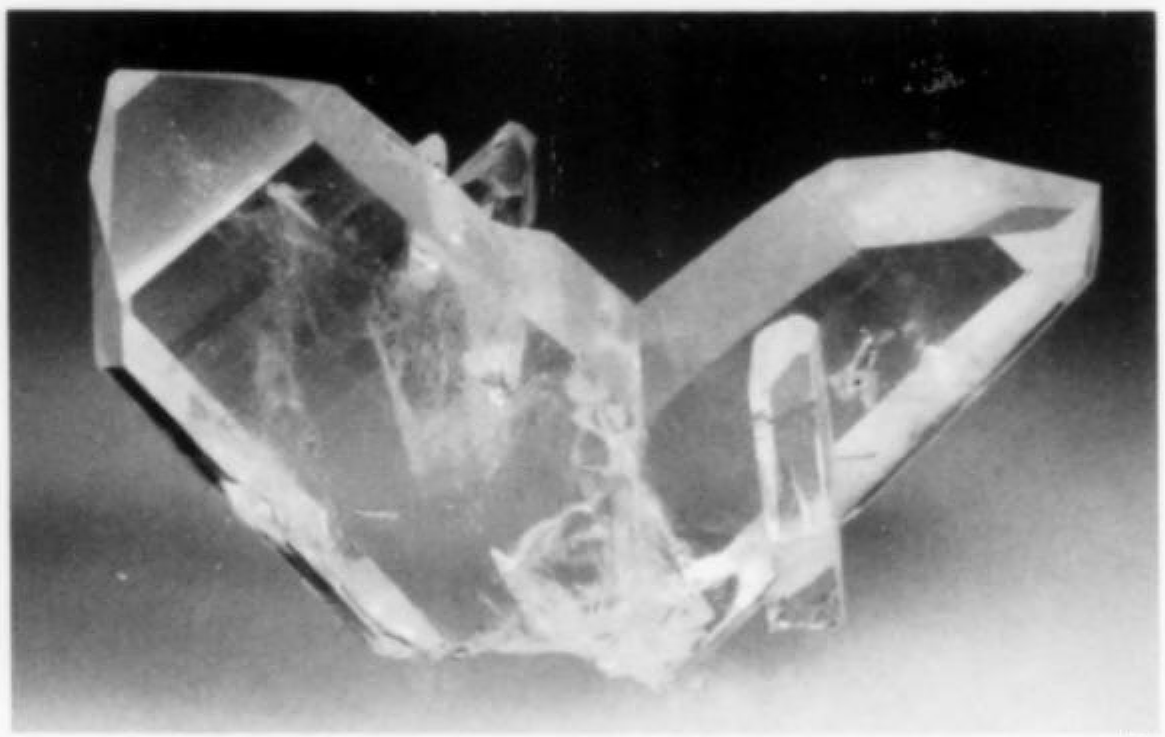

Figure 8. **Japan-law quartz twin, 7.4 cm across, from Alto de Cruzes, Santander, Colombia. Gary Nagin specimen.**

- **Rare Minerals.** Sharon Cisneros (*Mineralogical Research Co.*) had many things of interest to the species collector: a flat of white to pink botryoidal bulfonteinite from the N'Chwaning no. 2 mine in South Africa; black, 1-cm prisms of gaudefroyite in groups (same location); micro gold from the Lucky Break mine near Skamania, Washington; numerous rare uranium-bearing species from a new find at Mashamba, Shaba province, Zaire; some very nice, brown-red zircon crystals to 3 cm from the Lovozero Massif, Kola Peninsula, USSR; dark green, leafy vivianite from Kerch, Crimea, USSR; fine, yellow scheelite crystals to 5 mm, on matrix, from the Ortiz mine, Santa Fe County, New Mexico; and, for the Bisbee collector, many rich specimens of micromount-quality bromargyrite.

- **Etcetera.** Many more things were worth looking at than can be mentioned in detail here. Sid Pieters had some superb cuprian adamite from Tsumeb. Ken Gochenour had newly collected tourmalines from Riverside County, California. Pamour Mines offered some nice Canadian gold specimens. Ken and Betty Roberts had some of the highest quality, most esthetic Vera Cruz (Mexico) amethyst I've ever seen. Tom Palmer had more and larger black andradites from Mexico than ever before, including some remarkably fine cabinet pieces. Amethyst-lined lava tubes from Uruguay were available from many dealers. Don Zowader had some very fine and sharp Norwegian zircons. Bill Todzia exhibited some huge schorl groups from the Guadalupe mine, Sonora, Mexico. Jim Walker had what are probably the world's largest zunyite crystals (to 2 cm on an edge), on matrix, from a prospect pit near Quartzsite, Arizona . . . and they fluoresce *red.* Simon Harrison had some superb little gold specimens from a recently found British locality called Hope's Nose. And so on, and so on.

Displays

Tucson excells when it comes to exhibits . . . they alone are worth the price of admission. Space does not permit a detailed description of the more than 100 showcases, but here are a few of the high spots:

The Geoliterary Society had a nice, small case of books which included the extremely rare *Treatise on Mineralogy* by F. Mohs (1825); the three-volume set is owned by Curtis Schuh, much to the chagrin of the advanced book collectors I know, who are all missing it. (He says he plans to have the volumes buried with him when his time comes, so as to avoid having to decide who will get it.)

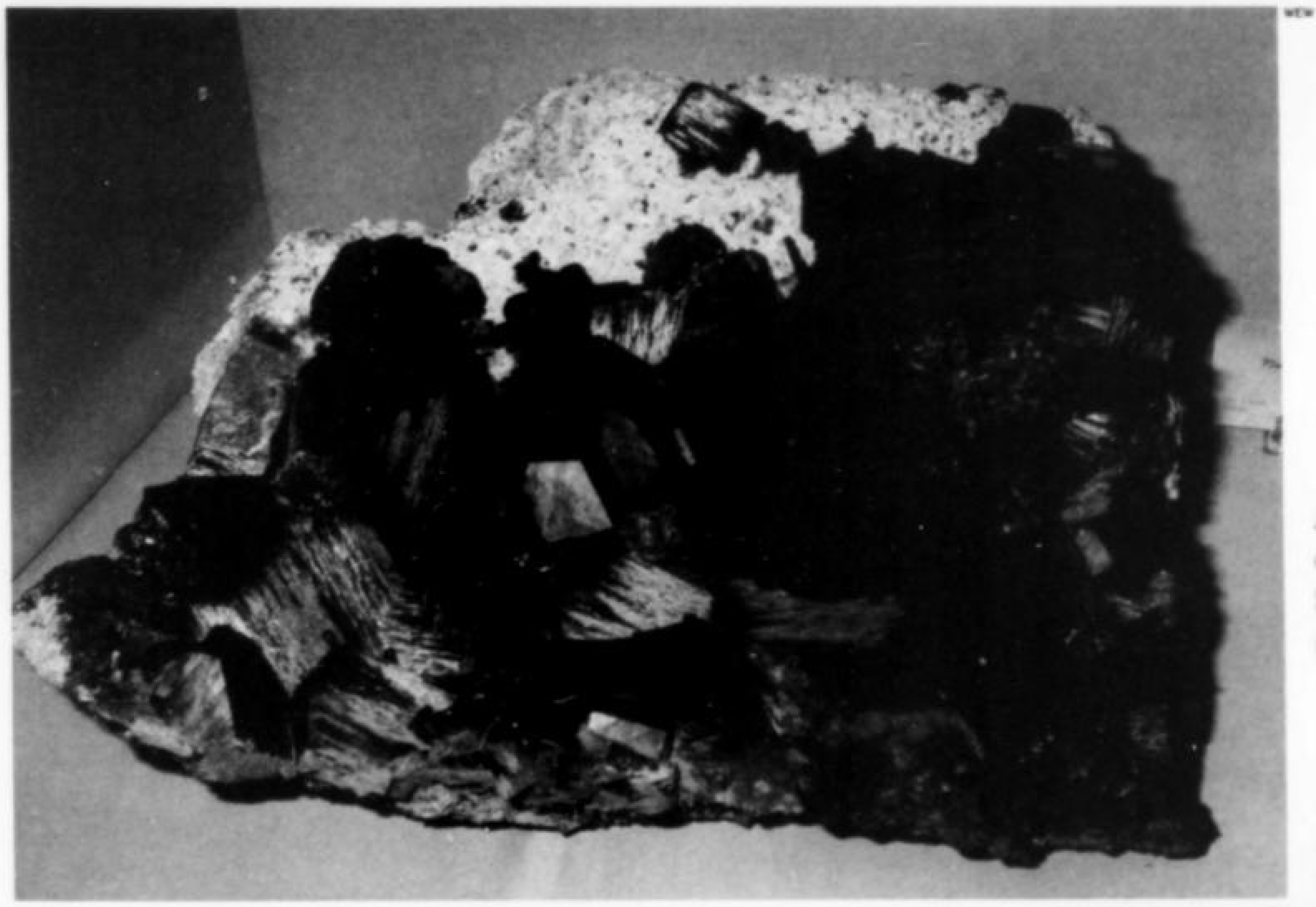

Figure 9. **Large (about 35 cm) group of schorl crystals on matrix from the Guadalupe mine, Santa Cruz, Sonora, Mexico. Bill Todzia specimen.**

Figure 10. **Spectators were always crowded around Peter Bancroft's four large cases of specimens illustrated in his book.**

The great museums worldwide were well represented: the American Museum of Natural History, the Arizona-Sonora Desert Museum, the California Academy of Science, the Cincinnati Museum of Natural History, the Cleveland Museum of Natural History, the Denver Museum of Natural History, the Harvard University Mineralogical Museum, the Milano Museum of Natural History, the Montana College of Minerals Sciences (Butte), the Natural History Museum of Los Angeles County, the New Mexico Bureau of Mines Mineral Museum, the Pinch Mineralogical Museum, the Portuguese Geological Museum, the Smithsonian Institution, the University of Arizona Mineral Museum, the University of California at Santa Barbara, and the University of Paris (the Sorbonne). What a list! I don't usually name them all in this column, but I thought it might be revealing this once, to show why Tucson is the world's leading mineral event. The four critical factors in any show are exhibits, dealers, speakers and efficient organization. Regarding exhibits, it would be hard to imagine a more impressive institutional line-up.

As to the other factors: the list of dealers at the main show is impressive enough, but when you count in the satellite shows, there is no event in the world to compare with it. The lecture series is limited by the number of hours in the day, but I can't think of another show (symposia aside) that has, over the years, garnered a better group of speakers. And when it comes to organization, the Tucson Gem and Mineral Society always seems to pull it off with efficiency and careful thought. Believe me, no one who has not worked on the staff of a big show knows the extent of effort involved.

Getting back to exhibits, one of the most popular and most impressive was a series of cases by Peter Bancroft. He borrowed dozens of specimens illustrated in his book *Gem and Crystal Treasures* and mounted them next to their photo. Many private collections were represented; it was a rare opportunity to see things that are usually unseeable. Pete is to be admired for the tremendous amount of work it took to assemble those four large cases, not to mention the astronomical liability risk he shouldered in order to bring these superb specimens into public view together.

Particularly enjoyable was the Pinch Mineralogical Museum case, because it was *packed* with exquisite goodies one rarely gets to see. This is now probably the finest private systematic collection in the country. But it is not destined to remain private for long. It is being sold to the Texas Memorial Museum on the University of Texas campus at Austin.

Betty Roberts' "family reunion" case this year contained smoky quartz gwindels (twisted crystals) from Switzerland. This exhibit made a nice companion to the case of Teodosi Venzin, which contained superb hematite crystals on quartz from Cavardiras, Switzerland.

There were many fine rhodochrosites on exhibit this year, since that was the species chosen by the Show Committee for special emphasis and competition. Private exhibits of other types were abundant as well. In all it was another good year to press one's nose against the glass.

Winners

Keith Proctor walked off with both the McDole and Lidstrom trophies this year, the latter recognizing his big tourmaline from the Itatiaia mine (shown on the cover of the *Mineralogical Record* for March-April 1981). Norm and Roz Pellman won the best miniature award for the species of the year (rhodochrosite) with their superb N'Chwaning mine specimen . . . the same specimen as pictured on

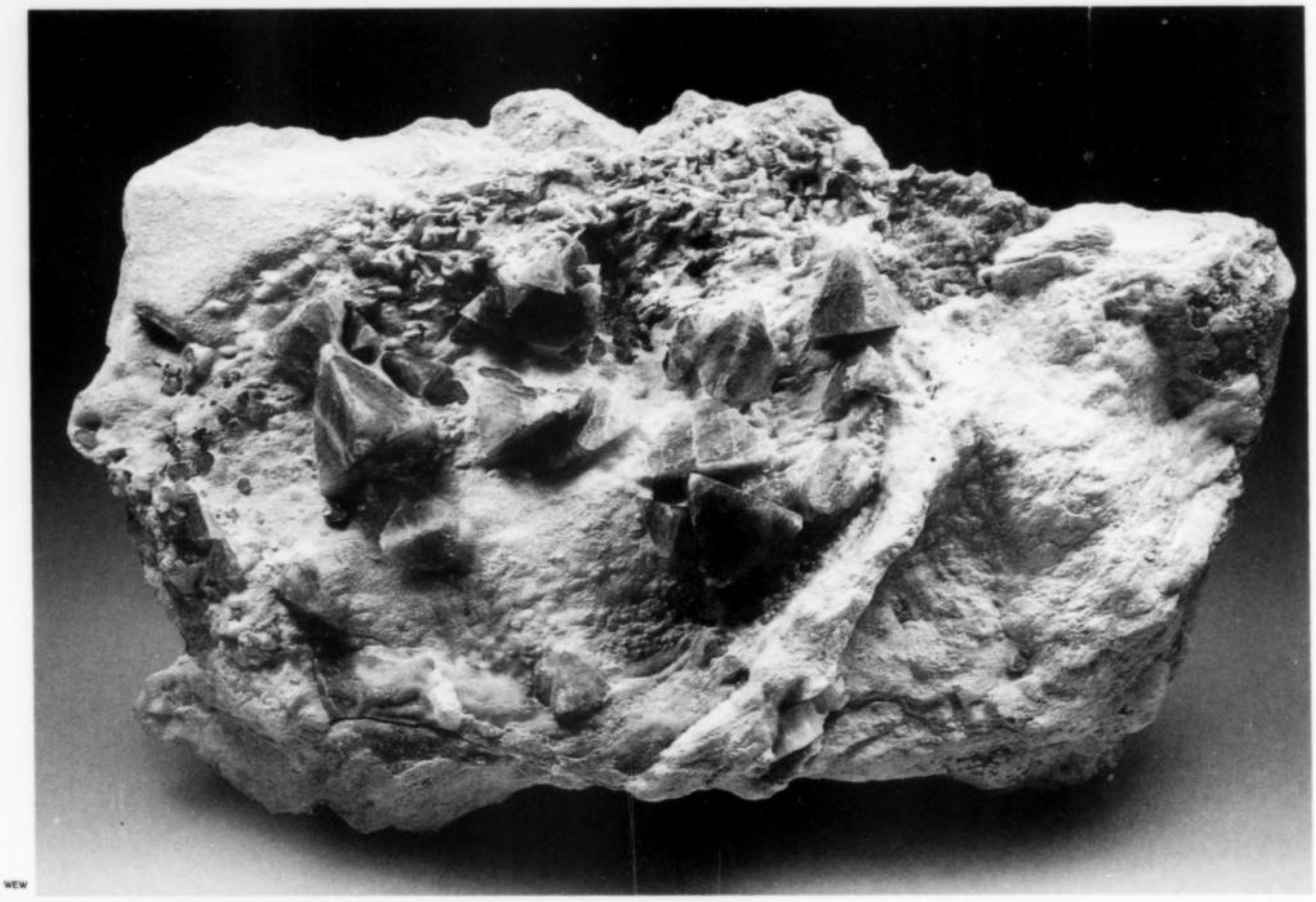

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Figure 11. **Zunyite crystals to 2 cm, on matrix, from near Quartzsite, Arizona. Jim Walker and Mary Fong/Walker specimen.**

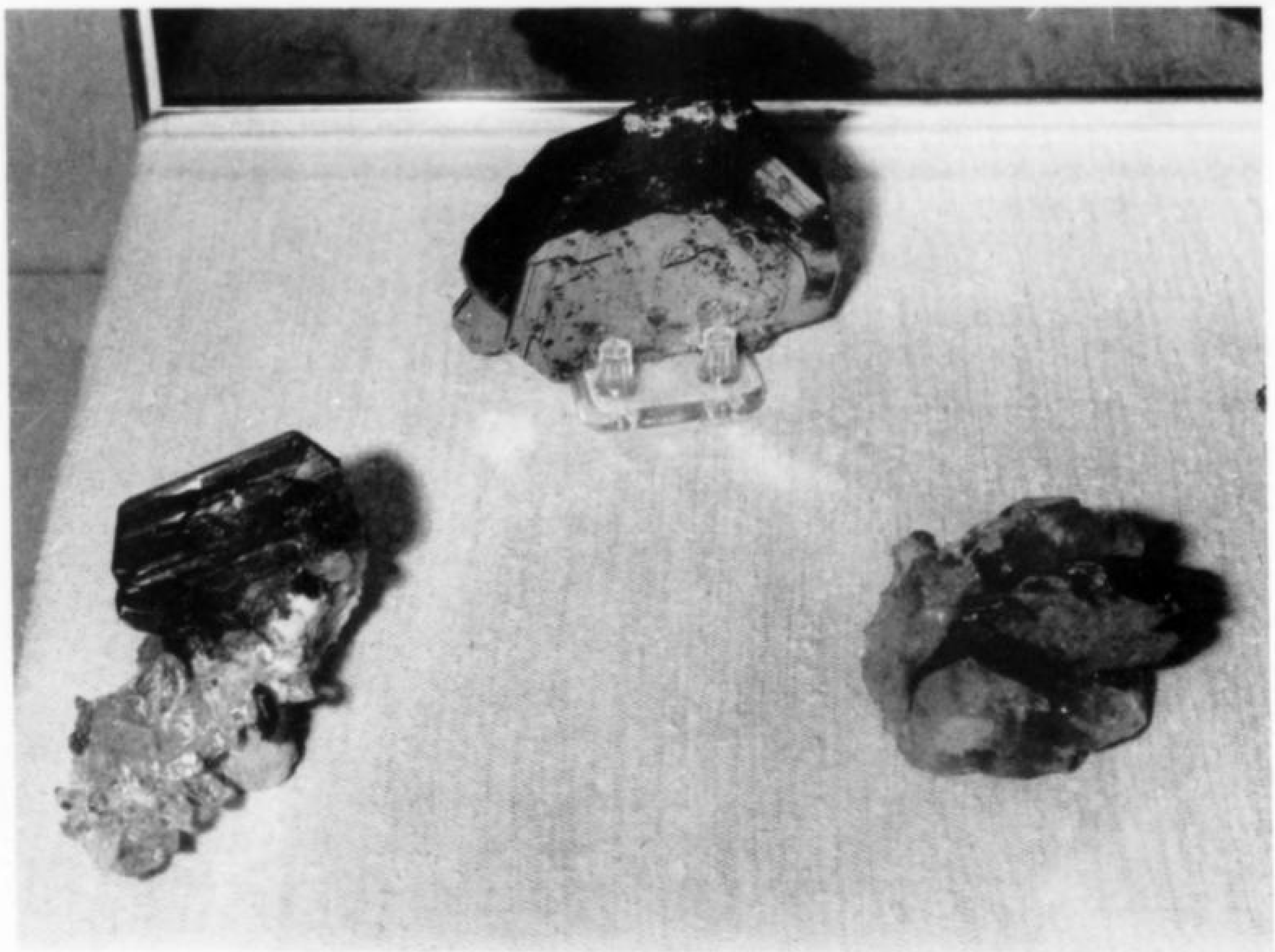

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Figure 12. **Teodosi Venzin's case included these Swiss hematite crystals.**

this year's show poster. Best small cabinet rhodochrosite went to another South African piece, "The Snail" (see vol. 9, p. 143, fig. 16), owned by Bill Larson.

First place winners in the tennis tournament were Pierro Gandiglio, Gale Thomssen, Ken Roberts, Ed David, Barbara Shelton, Wayne Leicht, Claus Hagemann, Victor Yount and Norm Bennett. (We have lots of categories, so we can have lots of winners!)

This year the annual Friends of Mineralogy Award for the best article of the year went to Brian England for his article on the Kingsgate mines in Australia. Martin Jensen's article on Majuba Hill, Nevada, came in a close second.

Thanks

The *Mineralogical Record* operates with a grand total of three (3) paid employees (myself, Circulation Manager Mary Lynn Michela, and Book Department Manager Gale Thomssen). It would clearly be impossible for us to manage the auction and man the subscription tables at the Tucson Show and other shows around the world without a great deal of help from our faithful staff of over 100 volunteers. It is in part due to their efforts that the magazine has remained healthy, and they deserve the thanks of every reader. Listed on the following page are those individuals who have done volunteer work for us during the last year.

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Thanks are also due the many show committees around the world who have agreed to provide the magazine with table space at no charge, and to the Tucson Gem and Mineral Society for allowing us the use of the lecture hall for our Saturday night program.

Of course our many donors deserve mention as well, and they are listed following this column.

I would like in particular to thank some people I've never formally thanked before: those among our subscribers who have for years quietly promoted the magazine by word of mouth. They show off copies to other collectors, pester friends and libraries to subscribe, urge new dealers to advertise, encourage potential authors to write, and lend moral support to our hard-working volunteers. An enthusiastic and supportive readership like that is a treasure indeed. Our thanks to you all.

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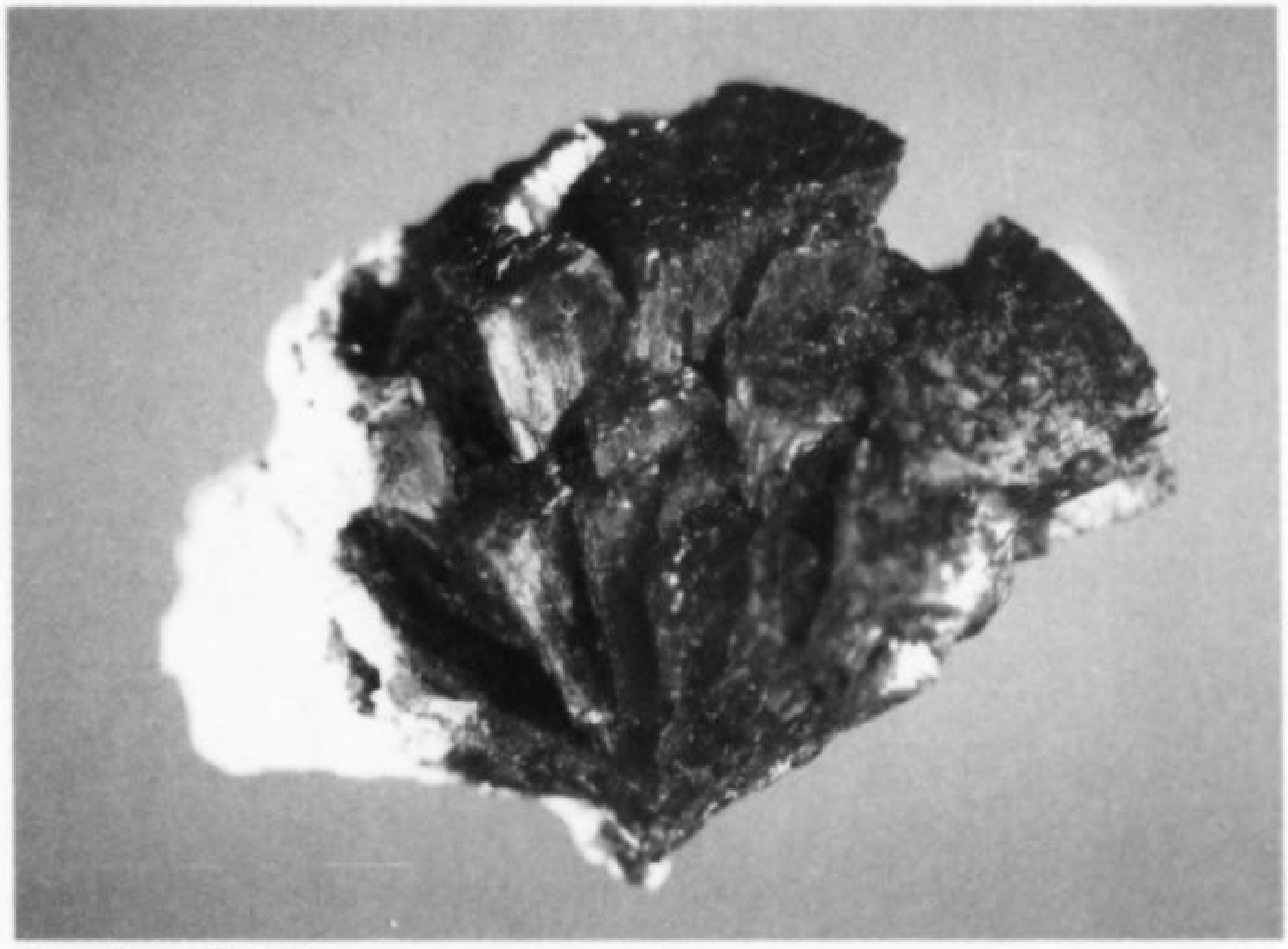

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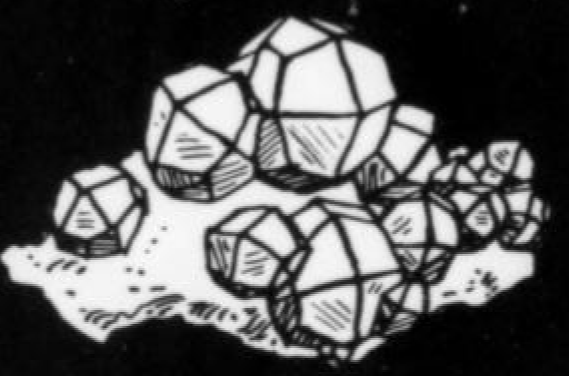

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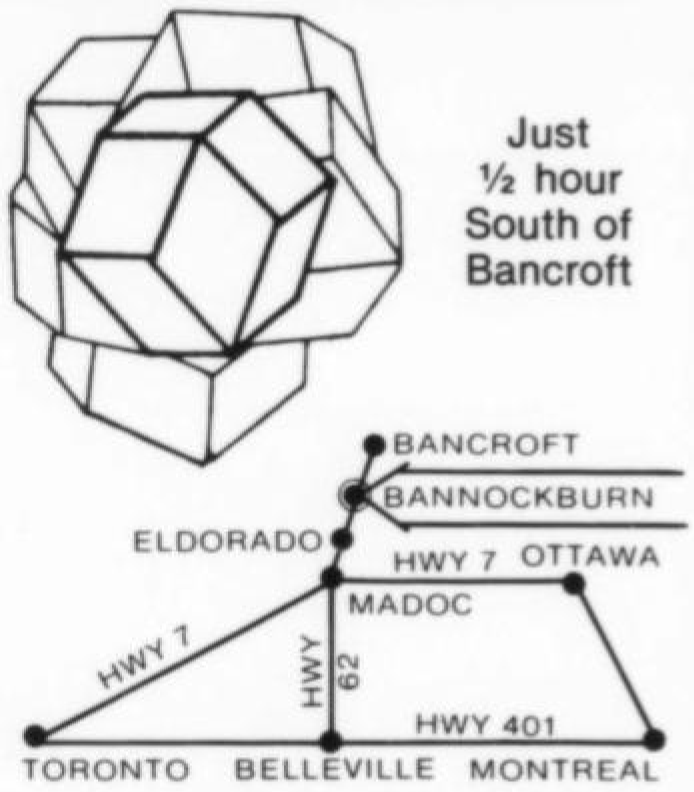

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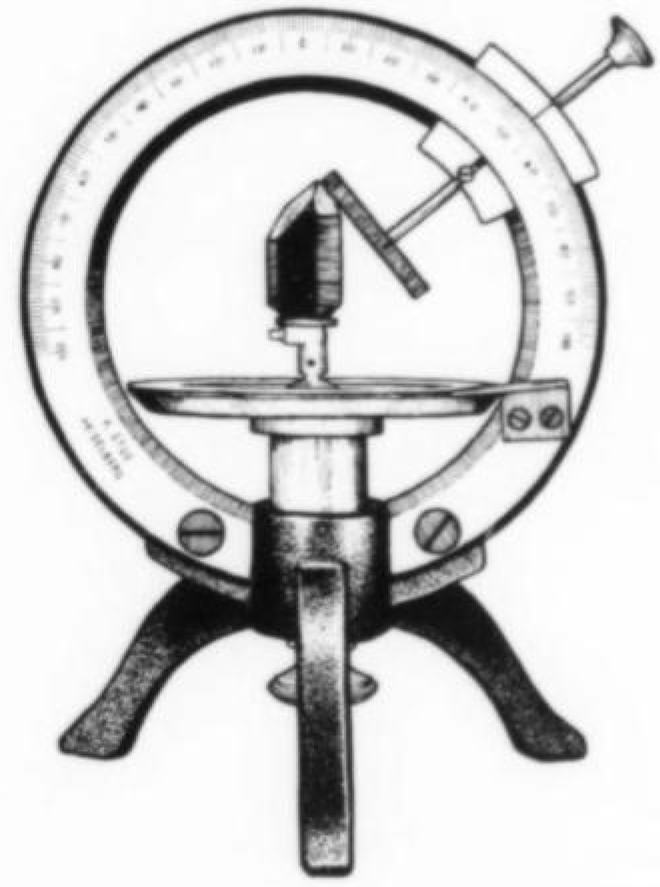

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I know all the readers of the *Mineralogical Record* will join me in saying thanks to these generous people who help to keep our magazine going year after year. W.E.W.

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Letters

AN OLD BATOPILAS COLLECTION

Regarding the article by Wilson and Panczner on the Batopilas silver district, Mexico (vol. 17, no. 1, p. 61–80), I thought you might be interested in seeing the enclosed copy of a collection sale catalog dated 1886. This was a collection built by A. Dohrmann of San Francisco. It was heavy in gold and silver and contained over 40 specimens from Batopilas. The present location of these specimens is, unfortunately, unknown.

[Some extracts selected by the Editor:]

Silver, native, Pastrana mine, Batopilas Dist.
- fine filaments forming thick tufts surrounded by octahedral pyrites. Exceedingly fine, Rare. 2 x 3¼ inches.
- Wire and filaments in cavities surrounded by small quartz crystals. Very fine. 1 9/16 x 3¼ inches.
- Wire associated with calcite crystals and stephanite. Very fine and choice. 3 x 3⅞ inches.
- Wire, curved with cinnabar [proustite?]. Beautiful, very rare, suitable for microscope work. ⅞ x 1 9/16 inches.

Silver, native, Trinidad mine, Batopilas Dist.
- Filaments and small shafts [crystals] on calcite. Very rich, very fine. 1¾ x 4 inches.
- Filaments and small shafts [crystals] in vein in limestone. Very fine and rich, rare. 1 9/16 x 2½ inches.

Native silver, Batopilas District
- In fluorite with garnets [?]. Interesting. 3½ x 6 inches.
- Radiating from a central point are fifteen lustrous shafts [crystals] (three of which are perfectly terminated), with branching crystals (i.e., herringbone, probably). Very beautiful and excessively rare; one of the gems of the collection. 3¾ x 3¾ inches.
- Thick plates covered with wire in fine filaments, in calcite. Very fine. 1⅞ x 3 inches.

Miargyrite, Batopilas District
- Crystalline, surrounded by calcite crystals. Very rare. 2 x 2½ inches.

Proustite with Pyrargyrite, Batopilas District
- Rich and very fine. 2½ x 3½ inches.
- Very fine. 1½ x 2½ inches.

Carl A. Francis
Harvard Mineralogical Museum

Very interesting. Although the identifications cannot be confirmed (unless someone reading this knows where the specimens ended up), fluorite, miargyrite, cinnabar and garnet would be new for the district. Considering the primitive identification techniques no doubt employed by Dohrmann, I would not be surprised if at least the "cinnabar" and "garnet" were something different. As to the mines, I am unaware of any surviving specimens from the Pastrana and Trinidad mines, so these catalog descriptions are valuable records indeed.

Ed.

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My congratulations on the Silver Issue – it is truly magnificent. May I also tender thanks on behalf of the readership of the *Mineralogical Record* and express our appreciation for the generosity of Randolph Rothschild and the other anonymous benefactors who have supported the production of this and other fine issues. I sincerely hope that the degree of satisfaction they get from their generous actions is commensurate with the degree of pleasure obtained by your readers.

J. R. Knight
Manchester, England

ERRATA

The article on Graves Mountain and its rutile (vol. 16, no. 6, p. 443–458) was magnificent! I noted a couple of minor errors in the caption to Figure 22: drawing E is a twin on (031), not (011); and the face labeled *e* on drawing B must be something else instead.

R. Peter Richards
Oberlin, OH

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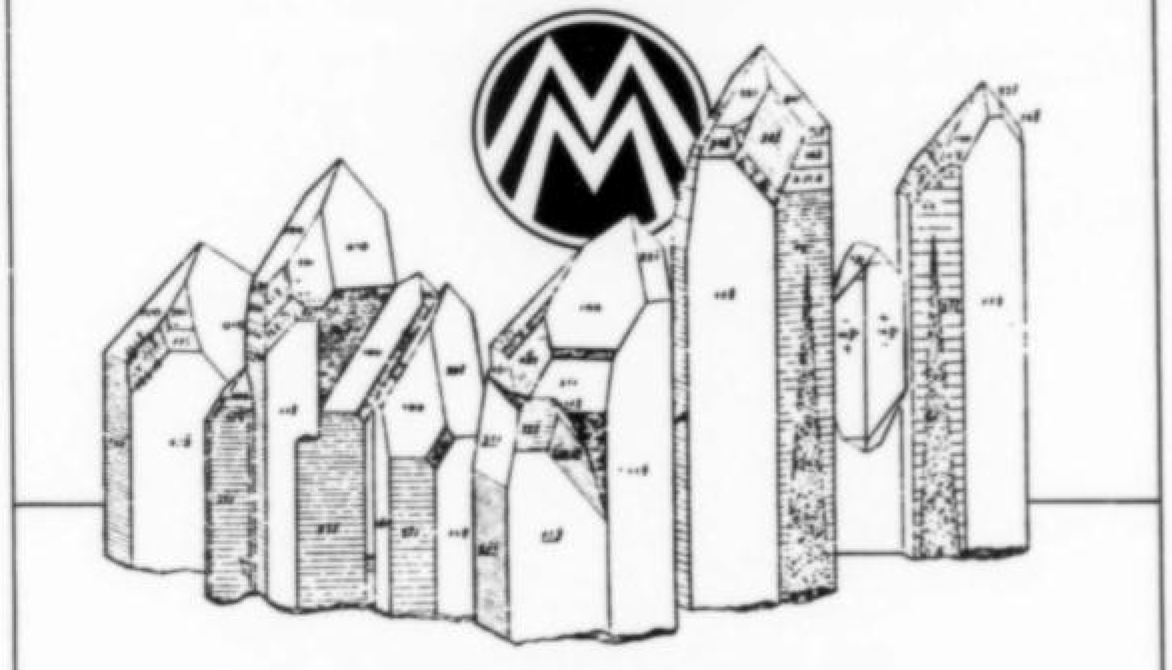

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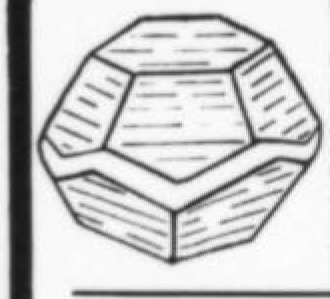

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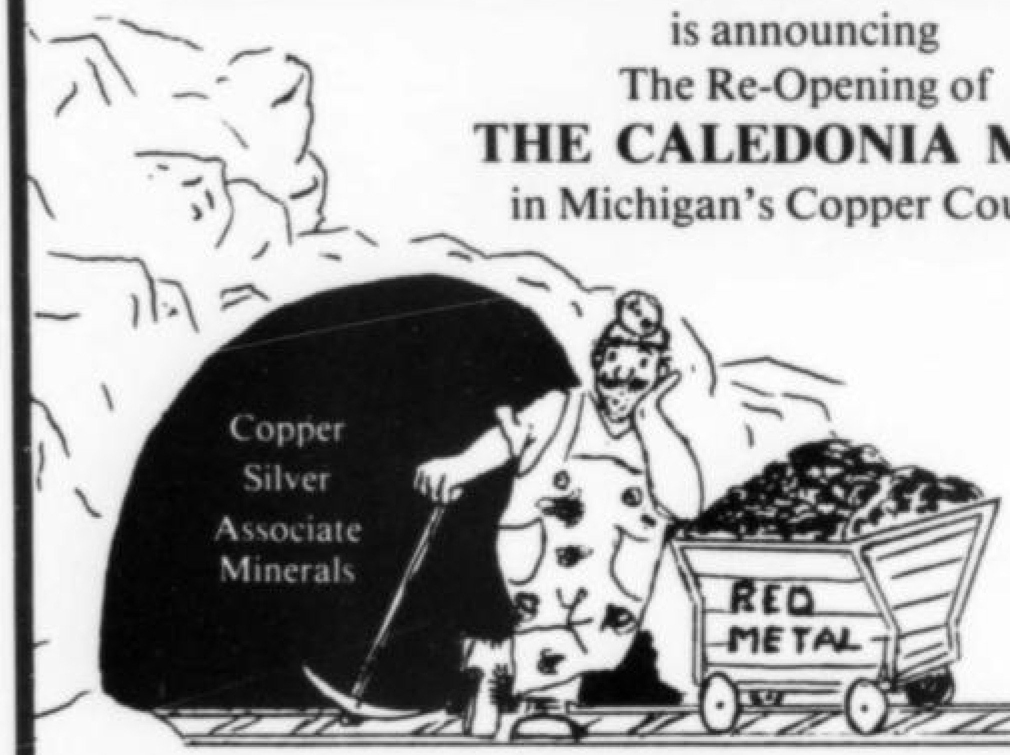

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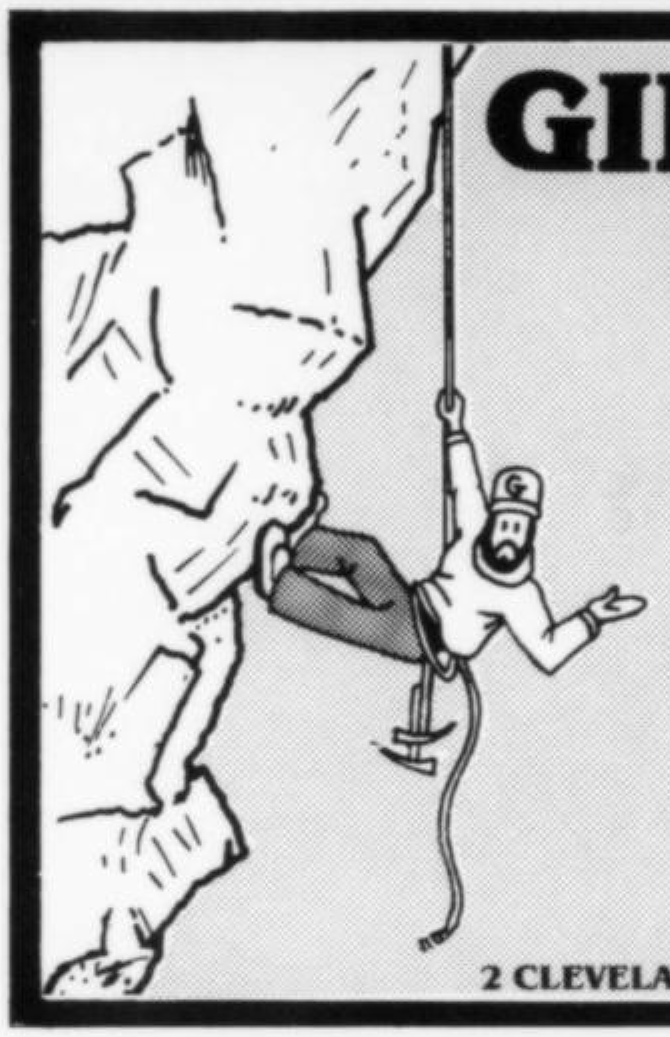

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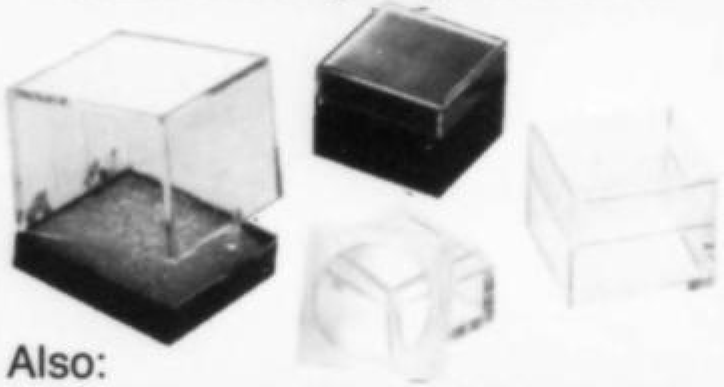

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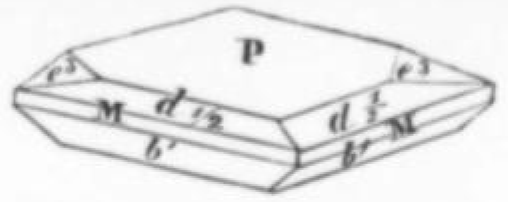

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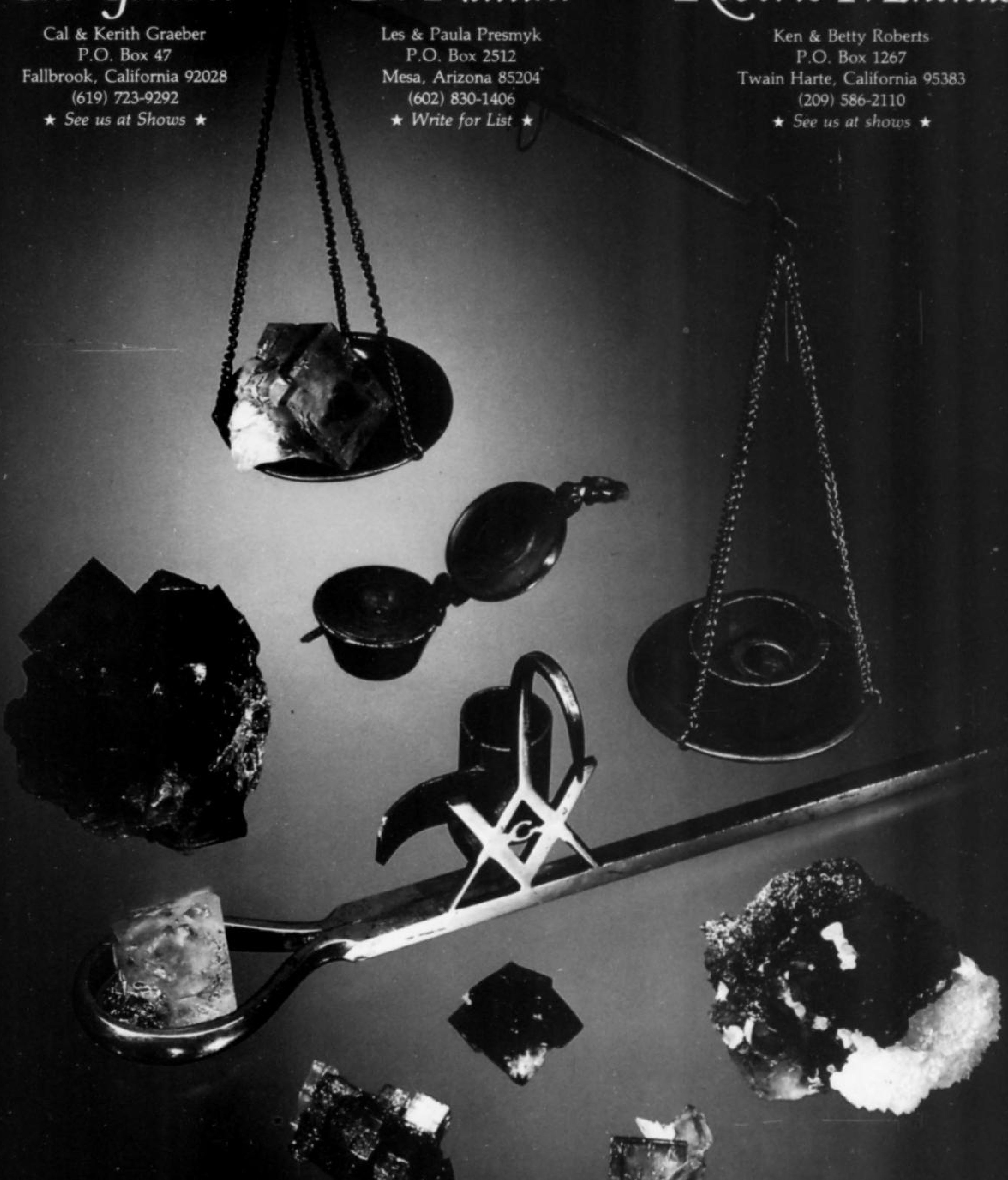

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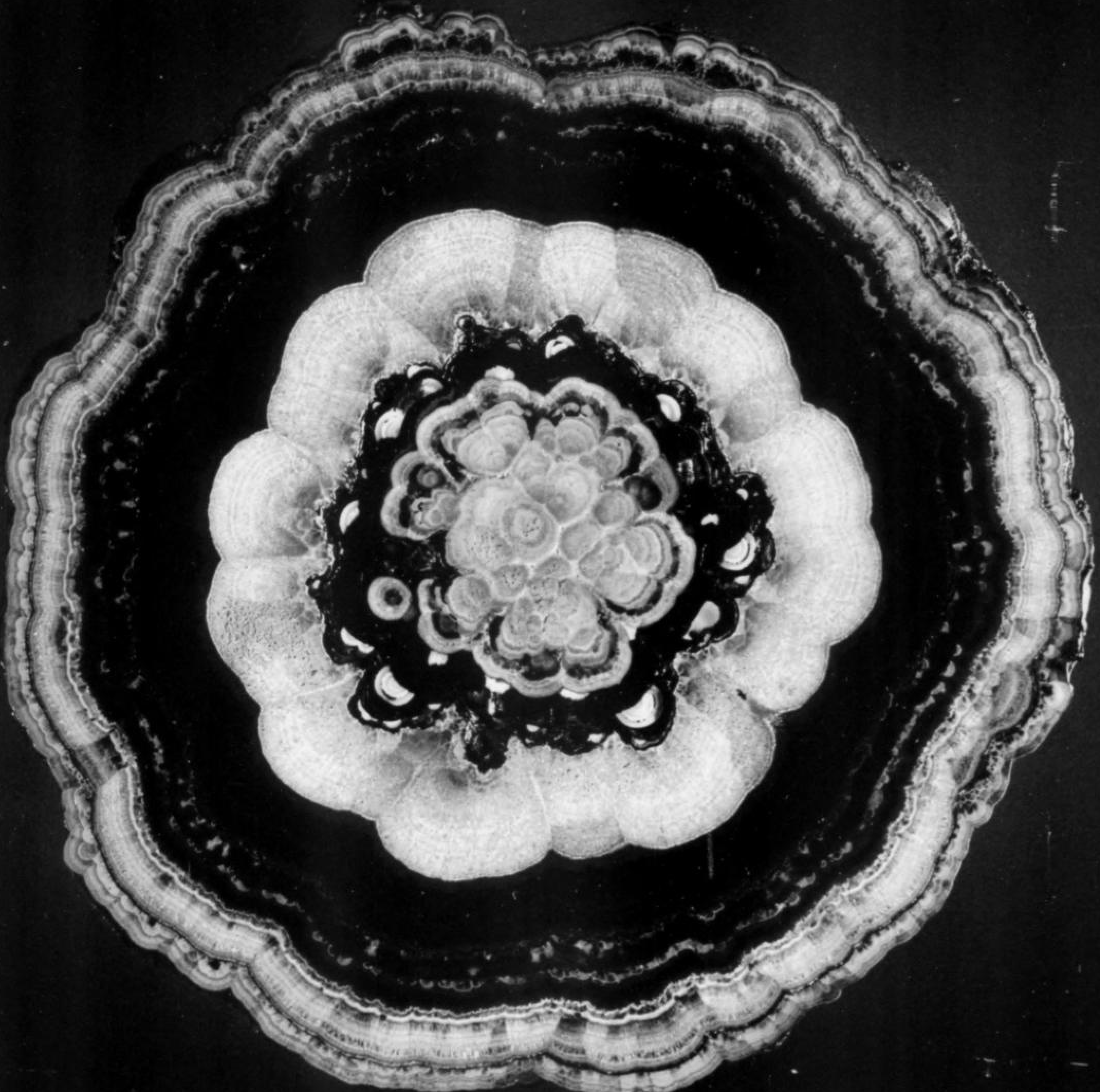

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